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**The velocity structure and turbulence at the center of the Orion
Nebula**

Castañeda, Hector Osvaldo, Ph.D.

Rice University, 1987

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300 N. Zeeb Rd.
Ann Arbor, MI 48106

RICE UNIVERSITY

THE VELOCITY STRUCTURE AND TURBULENCE
AT THE CENTER OF THE ORION NEBULA

by

HECTOR OSVALDO CASTAÑEDA

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IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

DOCTOR OF PHILOSOPHY

APPROVED, THESIS COMMITTEE:

C. R. O'Dell
Professor of Space Physics and Astronomy
Chairman

Reginald J. Dufour
Professor of Space Physics and Astronomy

F. Barry Dunning
Professor of Space Physics and Astronomy

Ruben D. Cohen
Assistant Professor of Mechanical
Engineering and Materials Science

HOUSTON, TEXAS

APRIL 1987

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by

Héctor Osvaldo Castañeda

Abstract

Using the Coudé Feed System of the Kitt Peak National Observatory at its highest possible dispersion and a CCD detector with wide dynamic range we were able to examine in detail the radial and turbulent velocities of the Orion Nebula at the seeing limit. We were able, for the first time, to resolve multiple components of the spectral lines and fit gaussian profiles to them.

Using four different observing runs, two circular areas 2' in diameter were observed, the first centered on θ^1 Orionis and the second centered on θ^2 Orionis. The velocity resolution of 1 km s^{-1} combined with the angular resolution of 2" allowed us to look in detail at line splitting as well as the location and measurement of high internal motions, about -50 km s^{-1} with respect to the bulk of ionized matter.

Because over 900 different positions were measured we were able to use modern statistical techniques for the analysis of turbulence, so that the dispersion relation and the structure function could be calculated and compared with predictions of the Kolmogorov theory.

The random motions showed correlation with spatial separation, as expected for turbulence; but, comparison with predictions of the classical theory for nebular turbulence showed poor agreement. If Kolmogorov theory applies, then the energy must be input at many scales.

Para Isabel, mi madre:

Mamá, miré a las estrellas y descubrí tu rostro.

*If you wish upon a star
Makes no difference who you are,
Anything your heart desires will
come...to...you.*

Acknowledgements

As I am the first student in the Department of Space Physics and Astronomy that can claim that I was almost killed (twice) in the line of duty, I want to thank the physicians and nurses that have made it possible for me to write these lines.

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Two people have given special contributions for the production of this thesis. First, Dr. John J. Hester had a crucial participation with the development of the software that was utilized for the reduction of the data. I thank him very much for his help and friendship. The second is my co-writer, Ms. Leisa Townsley. Thanks to her hard work and a massive application of the rules of English grammar my manuscript has been transformed into a terse piece of writing, for which she must be proud.

The core of my thesis constitutes the very high quality data that I was able to obtain

using the facilities of Kitt Peak National Observatory. I would like to express my recognition and appreciation to Daryl Willmarth and the other KPNO staff members for their help and first-class job.

My memory goes now to the people that I have known in Rice, Faculty, students, and staff. Their friendship is fondly acknowledged. In particular, I want to express my gratitude to everyone that helped me during the difficult times of 1984; all are remembered. Special recognition goes to my roommates Frank Toffoletto, Robert Hilmer, Ian Robertson, and Patrick Lyn; not only have they provided a close friendship during all these years, but they also probably saved me from premature death from a massive ingestion of frozen food.

Finally, a word to my family. I have been very lucky to have them always behind me. They provided the emotional support to go on in the good and bad moments. It is from their love that I have been able to finish my thesis.

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Introduction

"But we see now through a glass darkly, and the truth, before it is revealed to all, face to face, we see in fragments (alas, how illegible) in the error of the world, so we must spell out its faithful signals even when they seem obscure to us and as if amalgamated with a will wholly bent on evil."

Umberto Eco, *The Name of the Rose*

It has been near fifty years since Stromgren's classic paper gave a theoretical explanation to the observations of Herschel and others, showing that the so-called "diffuse nebulae" were areas of ionized hydrogen and helium, glowing under the radiation of bright O and B stars.

We can see how the history of our understanding of gaseous nebulae has shown, from its beginning, a close interplay between theory and observation. The discovery that the observed green lines were due to forbidden transitions of ionized oxygen opened the possibility for diagnosis of the physical conditions of the nebulae. Observations of the chemical abundances of helium and heavy elements in gaseous nebulae have had a profound effect on the models for the chemical evolution of galaxies.

Recently, a good deal of scientific research has been directed towards the understanding of the kinematics of HII regions. New techniques of observations give a glimpse of the velocity structure of nebulae at high spatial and velocity resolution. At the same time, a more sophisticated understanding of the dynamical evolution of gaseous nebulae and the ability to compute numerical models have made possible prediction and observation of new phenomena. As a result, astronomers have been forced to leave aside the simple models that described the evolution of gaseous nebulae, and recognize that they

are complex objects, interacting with their surroundings.

Radial velocity maps and the examination of line widths have suggested the presence of chaotic motions of an unknown nature. There is a strong belief that those motions could be represented by what is known as hydrodynamical turbulence. In consequence, some researchers have suggested that the fluctuations in velocity could be understood in the framework of the models of incompressible, isotropic, homogeneous turbulence, as predicted by the conventional models of Kolmogorov theory. The observational evidence, nevertheless, is not conclusive. There is an inhomogeneous set of data, in several cases very dependent on the type of observational technique used for gathering the information.

Nevertheless, the possible existence of turbulence is a very important physical prospect. New problems appear in this case, and one of the most demanding is the understanding of the presence of turbulent motions in the objects. Is turbulence actually present in gaseous nebulae? What is its source? Can it be explained by conventional models, or is a new approach needed? What is necessary is a systematic study of the velocity fields in selected nebulae, free of the observational problems that made the results of previous observations so inconclusive.

The present thesis attempts to answer some of those questions. The objectives have been, primarily, the characterization of the velocity structure at the center of the Orion Nebula (by building a unique set of high quality radial velocity measurements) and the study of turbulent motions in the nebula. The work has been part of a research program devoted to the study of kinematics of diffuse nebulae, conducted in collaboration with Dr. C. R. O'Dell.

The initial chapter is dedicated to presenting the basic theoretical tools necessary for understanding of the problem. In the first part we discuss the fundamentals of the physical

theory of gaseous nebulae and the kinematic observations that have led to the present assessment of the problem; in the second part we analyze the phenomenon of turbulence, with an emphasis on astrophysical situations. After it has become clear what are the problems at issue, we describe Orion, the gaseous nebula that is the subject of our research. We continue with a description of the astronomical observations and the data reduction. The last chapter is dedicated to the analysis and discussion of the vast wealth of data available, and to present the more important findings of this research. New questions are presented, and we suggest probable future lines of research.

After a first look at this work, the reader will appreciate that astronomy remains one of the few sciences where it is possible to conduct doctoral research almost single-handedly. The future apprentice astronomer participates in the different stages that form the scientific research: characterization of the problem, definition of the experimental procedures to test the theories, acquisition and reduction of the data, and analysis of the final data set. This forms a priceless impression and a unique contact with all the basic steps in the scientific method. I have tried to share some of that experience in writing this thesis.

Chapter 1

Gaseous Nebulae and Turbulence: An Overview

*"Why is it so dark, Moon Child? he asked
The beginning is always dark, my Bastian."*

Michael Ende, *The Neverending Story*

It is well known that in any research project, half the solution can be achieved if we are able to formulate the right question, identify the problem and find appropriate approaches to attain a solution. This somewhat lengthy chapter attempts to fulfill the previous objectives. The first part is devoted to the description of the type of astrophysical object that we are dealing with (gaseous nebulae), and its physical characteristics. In particular, the kinematical structure of HII regions is an area that has experienced great progress in the last two decades. The existence of random motions inside the nebulae has been recognized and attributed to the phenomena known as "turbulence". In the second part of the chapter we present a very summarized introduction to the concept of turbulence and the difficulties of its observation in gaseous nebulae. After the problem has been identified and the theoretical approaches for its study have been discussed, we present our research program, which constitutes the core of the present thesis.

1.1 Gaseous Nebulae

Gaseous nebulae constitute some of the more interesting objects observable in the night sky; of them, the Orion Nebula is of particularly striking beauty. Only with the advent of quantum mechanics was it possible to begin to understand the physical processes

operating in gaseous nebula and formulate realistic models for their understanding. At the present, the subject has grown to encompass multiple branches of physics. Any discussion would be incomplete without references to atomic physics, fluid dynamics, thermodynamics, plasma physics, etc; excellent sources of reference are the books by Osterbrock (1974), Spitzer (1978), Aller (1984) and Dyson and Williams (1980). Our aim is much more modest: to present the elementary principles required to understand gaseous nebulae. We follow with a discussion of the traditional models that explained the internal dynamics of gaseous nebulae and the comparison with observational evidence given for radial velocity maps of the nebulae. Because of the difference in angular resolution, optical observations reveal more complicated structures than radio studies, and in consequence there is more literature on that part of the wavelength range. Whereas more realistic models for the dynamical evolution of nebulae are now available, it is uncertain that the random velocities observed are due to turbulence. If that is the case, there could be important consequences in the subject of energetics and the dynamical evolution of HII regions.

1.1.1 The discovery of Gaseous Nebulae

HII regions are a distinctive type of object, part of the class of gaseous nebulae. As bright extended sources, HII regions have been observed from early times, but their exact nature remained a mystery until the development of spectroscopic techniques in the nineteenth century.

In 1864 the English astrophysicist William Huggins discovered that the spectra of the then called "diffused nebulae" consisted of bright emission lines, some of which were identified as characteristic of terrestrial elements like hydrogen and helium. Nevertheless, the brightest features, two lines in the green spectral region, noted as N1, $\lambda 5007 \text{ \AA}$, and

N2, $\lambda 4959 \text{ \AA}$, were not decisively identified, and were consequently attributed to a hypothetical element named "nebulium". A similar instance occurred with the discovery of bright yellow lines by the French astronomer Jules Janssen in the spectrum of the Sun, associated later with the element "helium".

Bowen (1928), with the use of quantum mechanics, identified the "nebulium lines" as emission lines from [OIII], oxygen doubly ionized; these are "forbidden" lines only observable in the low-density states that reign in the nebulae, where the metastable states excited by collisions with electrons have time to radiatively decay with the emission of forbidden lines.

The second crucial step in the understanding of HII regions was taken by Stromgren (1939), when he proved that a hot star will ionize completely any surrounding gas out to a sharply defined boundary, which may be small compared with the extent of the region. As a result, we observe in a medium of uniform density the formation of a sphere of ionized gas, the so called "Stromgren sphere", or, using the modern terminology, "HII region", with a radius given by

$$R_{\text{HII}} = \left[\frac{3 F}{4 \pi \beta n_o^2} \right]^{1/3} \quad [1-1]$$

(F = total number of ionizing photons s^{-1} produced by the star; n_o = hydrogen density of the medium; β = recombination coefficient).

An HII region is, in consequence, a volume of gas ionized by the ultraviolet radiation of one or several O or early B-type stars (Fig. 1.1). The ions and electrons collide

with each other, reaching a Maxwellian distribution where the temperature of the gas is around 10^4 K and densities range between 10 - 10^4 cm^{-3} . The primary constituent is hydrogen and the secondary is helium.

Traces of heavy elements are responsible for the forbidden line emission and for keeping the thermal balance of the nebula. Dust is mixed with the gas. To a good approximation, these objects are optically thin to the optical and the infrared radiation that comes from dust (Fazio 1978; Panagia 1978), whereas there is self-absorption in the radio range.

Fig. 1.1: Schematic diagram of a simple HII region (from Fazio 1978).

1.1.2 The dynamical evolution of a gaseous nebula

When a star reaches the main sequence and begins to radiate photons, a discontinuity is created between the HI-HII interface. Because the mean free path of the ionizing

radiation is around $0.05 n^{-1}$ pc (n is the hydrogen density), the interface between ionized and neutral gas can be treated as a discontinuity from the astronomical point of view. As the temperature of the ionized gas is a factor of 10^2 larger than the temperature of the surrounding neutral gas, and the density is approximately the same, the final result will be an expansion of the ionized gas region.

The classical picture of the evolution of HII regions may be summarized as follows (Spitzer 1968; Mathews and O'Dell 1969; Dyson and Williams 1980; Osterbrock 1974). A star is born at the center of a uniform cloud of infinite extension and constant density. As a result, there is a symmetric expansion of the gas. In the beginning of its evolutionary stage the ionizing radiation produces a spherical supersonic ionization front. This expands with a velocity decreasing with time, due to recombinations and the dilution of the ionizing radiation, until the ionization front reaches the Stromgren radius. At that moment, the pressure gradient within the ionization front evolves into a shock front, which moves ahead of the ionization front. This is the first stage of the expansion phase for the region. The shock front moves outward, followed by a shell of cool compressed neutral matter and by a subsonic ionization front; rarefaction waves move towards the star. These events continue until there is an equilibrium of pressure between the ionized and the neutral gas.

1.1.3 Observations on the kinematics of HII regions

Because the great majority of HII regions are extended objects with low surface brightness, the observation of the velocity structure is a difficult task.

Kinematic information for testing of theoretical models of evolution is available in the form of Doppler shifts and profiles of radio and optical recombination lines of various

elements, predominantly hydrogen, helium, carbon and forbidden lines of nitrogen, sulfur and oxygen. The sound velocity is $\approx 15 \text{ km sec}^{-1}$ ($T = 10^4 \text{ K}$), and the velocity dispersion is $10\text{-}15 \text{ km sec}^{-1}$; the expected flow is sub or near-sonic. Because the velocities are low, high order resolution spectroscopy ($\lambda/\Delta\lambda = R > 10^4$), with an adequate signal-to-noise ratio, is necessary in order to measure the Doppler shift in the spectral lines due to the velocity structure.

1.1.3.1 Observational techniques

The instruments employed for the decomposition of light into its constituent wavelengths are called spectroscopes. Two basic physical principles guide their construction (Kitchin 1984): differential refraction (prism-based spectroscopes) or interference (diffraction gratings or interferometers). Prism based spectroscopes were used in the beginning of the century for the first maps of velocities in gaseous nebulae (e.g. Campbell and Moore 1918). The advance in observational techniques, especially the development of high quality gratings and detectors of high quantum efficiency, have led to the predominance of the second type of instruments.

Fabry-Perot interferometers allow high wavelength resolution on low surface brightness objects and are useful when the primary objective is radial velocity field information (Vaughan 1967). Basically, these interferometers consist of two parallel, flat, partially reflecting surfaces where the light is incident at an angle θ ; the image is formed for those points where there is constructive interference. Changing the gap between the two surfaces allows the use of the Fabry-Perot as a scanning device, and so the possibility of obtaining a larger set of data is increased.

The use of direct photography of Fabry-Perot interference fringes as a method for

measuring Doppler shifts was first applied by Fabry and Buisson (1911), and further developed for astronomical purposes by Courtés (1960). Extensive use of this technique has been made by research groups in Marseille and Manchester (see, for example, Meaburn 1971; Goudis, Hippelein and Münch 1983; Smith and Weedman 1970; Dopita, Gibbons and Meaburn 1973). Further refinement of this technique has been made by the Canadian group lead by Jean-René Roy. The use of digitized photographic plates and high quantum efficiency detectors (Joncas and Roy 1984a) allowed them to obtain velocity maps for selected nebulae, with thousands of velocity points (Joncas and Roy 1984b; Joncas and Roy 1986).

Conventional slit spectroscopy is a laborious process, and only a handful of observations are available (e.g. Wilson et al. 1959; Miller 1968); the lack of observations is mainly due to the difficulty in reconciling the high resolution required with the loss of light in the slit. Recently, O'Dell et al. (1987) have obtained velocity maps of the inner regions of the Trifid and Lagoon nebulae with very high spatial and spectral resolution in the 5007 Å line of [OIII].

An improvement over the traditional method can be attained. Using an echelle grating, or echelon, it is possible to concentrate the light into many overlapping high-order spectra, with very high resolution. A second low dispersion grating, whose dispersion is perpendicular to that of the echelle then separates out each of the orders. A series of papers on the Rosette Nebula (Fountain, Gary and O'Dell 1979), M16 (Mufson et al. 1981), NGC 1499, NGC 7000, IC 1318B/C (Fountain, Gary and O'Dell 1983a) and S252 (Fountain, Gary and O'Dell 1983b) have shown the effects of stellar wind acceleration and "champagne flow" mechanisms (cf. section 1.1.4) on the evolution of gaseous nebulae. Detailed echelle observations are also available on M17 (Clayton et al. 1985) and the 30

Doradus nebula (Meaburn 1984).

1.1.3.2 Results

Whereas some cases of well organized flow have been observed (Hippelein and Münch 1981; Fountain, Gary and O'Dell 1983a), in general the mean Doppler shifts vary almost randomly, and do not show the expected velocity pattern of approach and recession over the surface of the nebula, from maximum radial velocity at the center to zero towards the edge. The spectral lines show a broadening larger than the thermal component, implying that the gas of the nebula is in a state of disordered motion along the line of sight, with velocities ranging from a few km s^{-1} to supersonic speeds. These lines often do not show Gaussian profiles. Instead they exhibit asymmetric humps and/or extended wings, which seldom match that expected from the classical expansion model (Meaburn, Lopez and Keir 1984). Some nebulae show high-velocity components, in some cases several times the velocity of sound, and regions where the splitting of line profiles is detected (Wilson et al. 1959; Meaburn 1977; Goudis, Hippelein and Münch 1983). Velocity gradients are observed between ions with different ionization potentials (Kaler 1967).

1.1.4 Present theories for the evolution of gaseous nebulae

The observational evidence obtained in the whole wavelength range (radio, near and far infrared, visible and ultraviolet) shows now that HII regions are complex objects, with the ionizing star often at the edge of or inside a parent molecular cloud and the ionized gas eating its way inside the cloud. This phenomenon was first recognized by Israel (1978), by comparison of HII region and CO cloud observations; he coined the term "blister model", to represent the similitude of the effect of the gas flowing away from a cavity filled with

ionized gas and dust to a "blister" on the skin of a molecular cloud.

The conventional theories for dynamical evolution have proven to be inadequate for the description of the observed velocity patterns, and more sophisticated models have been developed, taking into account the effect of stellar winds, supernova explosions, etc.

Perhaps the most realistic models for the study of the dynamical evolution of HII regions in an inhomogeneous medium are the so called "Champagne models" (Tenorio-Tagle 1982; Bodenheimer et al. 1979). The ionizing star is embedded in a neutral cloud of finite extent, with an intercloud medium around it (Fig. 1.2).

The initial stages of the evolution of an HII region created by an O star lying inside and near the edge of a dense neutral/molecular cloud (after Tenorio-Tagle 1979). ICM: intercloud medium; C: cloud. *Phase (a)*: Ultraviolet radiation emitted from an O star forms a dense spherical HII region near the edge of a dense neutral cloud. *Phase (b)*: The ionization front facing the edge of the cloud, encroaches into it and eventually breaks into the low density intercloud medium. *Phase (c)*: A strong shock produced by the pressure gradient moves into the ionized intercloud medium while a rarefaction wave (RW) moves toward the star.

Fig. 1.2: The "champagne" model (from Goudis 1982).

After the expanding HII region reaches the outermost limit of the cloud, the ram pressure confinement ceases, and the dense shell is ejected into the intercloud medium, followed by the freely expanding gas ("cork ejection"). The ionization front becomes supersonic after crossing the discontinuity. The champagne effect consists of a strong isothermal shock moving into the ionized intercloud medium, and a rarefaction wave travelling towards the star. The physical situation strongly resembles that of a shock tube, when the diaphragm is released (Lazareff 1983). The model is not restricted to a brief period of time; recent calculations of the length of the champagne flow phase (Yorke et al. 1983) show that this phase may be extended to more than 4×10^5 years.

The total mass ionized by an O star in the champagne process is much larger than what could have been ionized (for the same time period and cloud density) in a bounded HII region. Supersonic motions are generated in the champagne flow, but as the emissivity is proportional to the square of the density, this implies that supersonic motions may be hard to detect in the rarefied region (Joncas and Roy 1984b).

1.1.5 Summary

Although the new models explain the observed velocity structure as being the result of the expansion of the ionized gas into an inhomogeneous medium, the nature of the non-thermal component of the line width is far from clear.

After the effects of expansion, contraction and rotation have been taken into account in the radial velocity maps, there is a random velocity component, changing over scales of a few arc seconds, that can not be explained by these effects. This random component has been attributed to "turbulence"; this interpretation can be misleading, because it indirectly assumes that we know that the responsible process is turbulence, as defined in this

classical, fluid-dynamical sense. Two questions arise: do the observed random motions constitute clear evidence for the existence of turbulence and is this "turbulence" the same as that described by the conventional theories in fluid mechanics. We attempt to address these two questions in the second part of this chapter.

1.2 Turbulence

Turbulence remains one of the classic problems in fluid mechanics. Whereas a considerable amount of effort has been invested in its study, progress in its understanding has been hampered by the complexity of the phenomenon, given its intrinsic stochastic nature. This section attempts to give a very basic description of turbulence, mostly in the context of the analysis of our data. The reader interested in expanding this base should read the excellent references by Landau and Lifshitz (1959), Monin and Yaglon (1975), Leslie (1973), Tennekes and Lumley (1972), Panchev (1971), and in particular the compilation of classic papers by Friedlander and Topper (1961) and the recent review paper by Dickman (1985).

This section is conceptually divided into two parts. In the first is a discussion of turbulence, while in the second we discuss the theoretical bases for observation of turbulence in gaseous nebulae, and examine the observational problems and limitations associated with the testing of the theories.

1.2.1 Turbulence and Astrophysics

In classical fluid mechanics a flow changes from an orderly, laminar state to a chaotic, random state when a certain dimensionless coefficient, known as the Reynolds number, exceeds a critical value. That coefficient is defined as

$$R = \frac{u l}{\mu} \quad [1-5]$$

where μ = the kinematic viscosity of the fluid; u and l are typical velocity and length for the

flow. The Reynolds number measures the relative importance of inertial forces to frictional forces.

Astrophysical objects, given their linear dimensions, are characterized by large Reynolds numbers (Chandrasekhar 1949). The fact that turbulence could be a relevant process in astrophysics has encouraged the use of the theory in subjects ranging from cosmology and the formation of galaxies (von Weizacker 1951; Jones 1976) to star formation (Hunter and Fleck 1982), and the rotation of molecular clouds (Fleck and Clark 1981).

1.2.2 An intuitive representation of turbulence

Turbulence can be seen as random motions of a fluid, a collection of eddies forming and dissolving on a great variety of lengthscales. An "eddy", or "element of turbulence", is a volume element of the fluid having a common motion for an interval of time (von Weizacker 1951); the small eddies are inside the larger ones, which constitutes the so called "hierarchy of eddies".

An eddy is characterized by its size l , and its velocity v , relative to the neighboring eddies. For a mathematical formulation of this concept it is convenient to use a Fourier analysis of the velocity field. Instead of "eddy size", we then use the wavelength of a Fourier component or its reciprocal value, the wave number k , and instead of v we use the Fourier amplitude $F(k)$ corresponding to k . The average kinetic energy density of the eddies of size l can be represented by the following equation:

$$\frac{1}{2} v_k^2 = \int_k^{+\infty} F(k) dk \quad [1-3]$$

where $F(k)dk$ is the energy spectrum, with $k = 2\pi/\lambda$.

1.2.3 The study of turbulence

The basic assumption necessary for the study of turbulence is that the Navier-Stokes equations

$$\frac{\partial \underline{u}}{\partial t} + \underline{u} \cdot \nabla \underline{u} = -\nabla p + \mu \nabla^2 \underline{u} \quad [1-4]$$

$$\nabla \cdot \underline{u} = 0 \quad [1-5]$$

describe completely the evolution of the system under study.

From a historical point of view, research on turbulence has been characterized by the development of three different approaches (Chapman and Tobak 1985): (1) the statistical, to be described in the next section; (2) the structural, based on the recognition of structures (e.g. turbulent spots) in the flow; and (3) the deterministic movement, involving the use of modern theoretical approaches like bifurcation theory, fractals, strange attractors and renormalization group theory.

In this thesis, we have emphasized the interpretation of the observational data by the first approach.

1.2.4 The statistical approach

The observations of the flow's chaotic structure and the statistical theory of random perturbations lead to the statistical approach. The method, pioneered by Reynolds (1895),

consists essentially of the decomposition of the velocity field into a well-defined mean flow plus a randomly fluctuating component superposed (Tennekes and Lumley 1972); following this, the Navier-Stokes equations are time averaged, arriving at what are today called the Reynolds-averaged Navier-Stokes equations. The averages of products of the perturbation terms, defined as the Reynolds stresses, appear in the mean-flow equations.

The random motions are a manifestation of the statistical order in the flow, which allows the prediction of the behavior of the fluid. The analysis of the flow pattern is reduced to the calculation of the averages and correlations of different physical quantities like velocity, density, pressure, etc; the goal of the theory is to obtain analytical forms for those relations. The completion of this modeling requires the use of higher and higher moments (averages of products of perturbation quantities) in turn, leading to the problem of closure (Leslie 1973).

1.2.5 Isotropic and homogeneous turbulence

The inherent complexity of inhomogeneous turbulence necessitates the study of simplified cases. One special case in this theory is that of isotropic and homogeneous turbulence (Taylor 1935), where the velocity field is independent of direction and position.

1.2.5.1 The Kolmogorov spectrum

The Kolmogorov (1941,1942) model describes isotropic, homogeneous, fully-developed turbulence, in a regime where the energy spectrum of turbulence and the probability distribution for the relative velocities are determined only by ε (the rate of energy transfer) and μ (the kinematic viscosity). In the case of a sufficiently large Reynolds number, the spectrum becomes dependent only on ε . A simple dimensional

analysis defines the Kolmogorov spectrum by

$$F(k) \propto \varepsilon^{2/3} k^{-5/3} \quad [1-6]$$

where $\varepsilon = \varepsilon/\rho$ is the rate of energy transfer per unit mass per unit time.

The energy spectrum preserves its shape (in what is called "dissipationless energy cascade"), with the inertial forces transferring kinetic energy from larger to smaller turbulent elements. Using eq. [1-3], the average kinetic energy density of the eddies of size l is

$$\frac{1}{2} v_k^2 \propto k^{-2/3} \quad [1-7]$$

The Kolmogorov law states that the mean square of the velocity difference between two points separated by a distance r should be proportional to $r^{2/3}$. The Kolmogorov spectrum is only valid for a limited spatial range, known as the "inertial subrange", i.e. for scales $l_0 \ll r \ll L_0$. Scales comparable with L_0 , correspond to the size of the largest eddies, where the energy cascade begins; the energy spectrum on that case depends of the stirring mechanism and the character of the source is still evident. The Kolgomorov microscale, defined by $l_0 = (\mu^3/\varepsilon)^{1/4}$, is the lower limit of the scale of motion, at which point friction dissipates the energy flux ε into thermal energy.

1.2.5.2 The Structure Function

As stated previously, it is possible to calculate n-point correlation functions of

fluctuating physical quantities. In the case of velocities, we can define two-point velocity correlations; the first is the autocorrelation or autocovariance function

$$ACF_{ij}(s) = \langle v_i(r_1) v_j(r_2) \rangle \quad [1-8]$$

The second is the structure function,

$$B_{ij}(s) = \langle [v_i(r_1) - v_j(r_2)]^2 \rangle \quad [1-9]$$

where r_1 and r_2 denotes arbitrary positions inside the flow; v_i, v_j are components of the velocity field at that point; $\underline{s} = (r_1 - r_2)$, is the separation vector. Note that both functions are tensors.

If the random field is homogeneous and isotropic, the functions depend only on the absolute value of the separation between points. The autocovariance tensor at zero separation is proportional to the Reynolds stress tensor, whose trace is the turbulent energy density of the fluid (Tennekes and Lumley 1972). The structure function is more convenient for the study of turbulence, because it characterizes the velocity fluctuation correlations even in the presence of large-scale linear gradients (Scalo 1984; Dickman 1985). The function can be computed only if the turbulence is isotropic and homogeneous, with the fluid free of motion discontinuities (e.g. shocks fronts) and incompressible (Kaplan 1966).

From equation [1-3], the relation between the root mean squared velocity difference, $B(r)$, of mass points of separation r is

$$B(r) \propto (\epsilon r)^{2/3} \quad [1-10]$$

1.2.6 Observation of turbulence

1.2.6.1 Line Width approach

The width of the emission lines being in excess of the broadening due to thermal motions and natural width might be related to disordered or turbulent velocity fields. Assuming that a maxwellian distribution of velocities applies to both the thermal and turbulent components, the profile of an emission spectral line has a full width at half the maximum intensity (hereafter FWHM) given by (Lang 1980, p. 204):

$$\text{FWHM} = 2 \left[\ln 2 \left[\frac{2 k T_k}{M} \right] + W^2 \right]^{1/2} \quad [1-11]$$

M = atomic or molecular mass; T_k = kinetic temperature; W = most probable turbulent velocity; k = Boltzmann constant.

The first term represents the line broadening caused by the thermal motions of atoms or molecules in thermodynamic equilibrium and the second describes the broadening due to macroscopic motions of the gas. Deconvolution of the observed profile separates the non-thermal component of the line from the instrumental and the thermal contributions.

The limitations of this method to characterize the motions of the gas are: (a) the uncertainty in the thermal broadening due to a poor knowledge of the nebular temperature; and (b) lack of evidence for the extra broadening being the result of turbulence or the manifestation of other physical processes such as collapse of the gas, a large-scale gradient of the velocity dispersion, geometrical effects, etc (Scalo 1984; Leung 1978).

Studies of the relation of the non-thermal velocity dispersion (measured from the line

width) to the scale of motions have been done in molecular clouds and HII regions. In the classic work of Larson (1979, 1981), a correlation was found between the three-dimensional velocity dispersions (σ) in molecular clouds, determined from large- and small-scale variations and thermal motions, and the region size (L), represented by

$$\sigma (\text{km s}^{-1}) = 1.1 L(\text{pc})^{0.38} \quad 0.1 \leq L \leq 1000 \text{ pc}. \quad [1-12]$$

Larson was the first to interpret a correlation between the width of a molecular line and the linear dimensions of the region studied in terms of a turbulent velocity spectrum, suggesting incompressible Kolmogorov turbulence as one possible explanation. In a study by Myers (1983) on small clouds, a similar correlation was found, but with a steeper exponential dependence. Henriksen and Turner (1984) object to this interpretation, citing the effect of gravitational collapse in the value of the line width. Additional comparisons of the velocity width with cloud size have been made by Leung et al. (1982) and Stenholm (1984). CO velocity widths β appear to scale with the diameters D of the molecular clouds as $\beta \approx D^{1/2}$ (Fleck 1983).

Attempts to find a correlation between the turbulent component of the line width and the size of the region using Fabry-Perot spectroscopes on giant HII regions were presented by Terlevich and Melnick (1981). Gallagher and Hunter (1983) failed to find a correlation with an echelle spectrograph in dwarf Magellanic irregular HII regions. In a recent paper Roy, Arsenault and Joncas (1986) claimed to find a relationship between the linear diameters for a group of extragalactic HII regions and their turbulent line widths, suggesting hydrodynamic turbulence as the most probable mechanism to explain the correlation.

1.2.6.2 Structure function

Using the statistical theory of turbulence, the problem of the study of turbulence in gaseous nebulae is reduced to the study of the spatial structure of fluctuations in the mean radial velocity along the line of sight for a sampled region (Kaplan 1966; Kaplan and Pikelner 1970). The key to the problem is that we must reconstruct the structure function of a three-dimensional velocity field from observations of radial velocities across the surface of the nebula (i.e. our data is two-dimensional).

The analysis of the effect of the projection of a three dimensional correlation function over a two dimensional area was first carried out by von Hoerner (1951) and subsequently employed by Münch (1958) and Kaplan and Klimishin (1964). In this approach, each value of the radial velocity represents a mean velocity value, integrated along the line of sight, and as a result is an average over various elements of volume, which may move more or less independently from each other.

We can consider two geometrical models for the nebula. Model I is for an optically thin, plane parallel nebula of depth R . Model II is for an optically thick nebula, where R represents the distance at which the optical depth becomes one. The qualitative results are very similar in the two models (von Hoerner 1951; O'Dell and Castañeda 1987); consequently, we will discuss in some detail the behavior of the observed structure function in Model I.

The observed radial velocity measured from the profile of the emission line at a particular position α on the face of the nebula, u_α , is

$$u_\alpha = \frac{1}{R} \int_0^R w_{\alpha\tau} d\tau \quad [1-13]$$

where $w_{\alpha\tau}$ stands by the component of the velocity along the line of sight, for a depth τ .

As consequence, the difference in velocity between two lines of sight is (Fig. 1.3)

$$u_{\alpha\beta} = \frac{1}{R} \int_0^R (w_{\alpha\tau} - w_{\beta\tau}) d\tau \quad [1-14]$$

Fig. 1.3: Geometrical configuration for the calculation of Model I (from von Hoerner 1951).

The square of expression [1-14], statistically averaged over the data, is the value of the observed structure function; after a lengthy algebraic manipulation, we obtain that

$$u_{\alpha\beta}^2 = \frac{1}{R^2} \int_0^R \int_0^R \left[(w_{\alpha\tau} - w_{\beta t})^2 - (w_{\alpha\tau} - w_{\alpha t})^2 \right] d\tau dt \quad [1-15]$$

A general formulation of the problem is also possible. We can assume that the relationship between velocity difference and separation is

$$(w_1 - w_2)^2 = C^2 |r_1 - r_2|^n \quad [1-16]$$

The constant C is a scale factor, and the general index n defines the turbulence model. In the Kolmogorov case, $n = 2/3$.

If we substitute [1-16] in the equation [1-15], we obtain

$$u^2 = C^2 R^{-2} \int_0^R \int_0^R \left\{ \left[\Lambda^2 + (\tau - t)^2 \right]^{1/3} - |\tau - t|^{2/3} \right\} d\tau dt \quad [1-17]$$

Now a convenient change of variables, given by $x = [(\tau - t)/\Lambda]$, $y = (\tau/\Lambda)$, reduces the integral to

$$u^2 = B(\Lambda) = C^2 \Lambda^n 2l \int_0^{1/l} \left[(1 + x^2)^{n/2} - x^n \right] (1 - lx) dx \quad [1-18]$$

where $l = \Lambda/R$.

Fig. 1.4: The expected theoretical relation for the structure function (B) as it would vary with the ratio of separation distance to the depth of the nebulae (l) for two values of assumed index (n) in the relation $v^2 \approx r^n$. All data are normalized to $l = 1$, the maximum value of l that would apply to an optically thin nebula. Values of $l > 1$ would apply to nebulae that are flat cylinders or very optically thick (from O'Dell and Castañeda 1987).

The term following $C^2 \Lambda^n$ is a correction factor $F(l, n)$, which takes into consideration the integration of the velocity differences along all steps in both lines of sight. The observed structure function then can be calculated straightforwardly by numerical integration. Nevertheless, it is possible to calculate an analytical approximation

to the asymptotic behavior of the function. When $l \gg 1$, $F(l,n) \approx 1$, and the observed structure function reflects the true structure function. When $l \ll 1$, $F(l,n)$ depends on both l and n . Fig. 1.4 illustrates the solution of [1-16] for the adopted values n of $2/3$ (Kolmogorov's index) and $1/96$ (a computationally convenient value close to $n = 0$, which would be grey or neutral turbulence, where there is no dependence of velocity differences upon distance).

There is agreement between the observed and the real structure function only when $l \gg 1$ ($L \gg R$). For both models, this implies that the thickness of the nebula is much less than its extent in the pictorial plane, the dimension that can be considered to be representative of the depth of the object. In the case of Kolmogorov cascade, the prediction is a slope of $5/3$ for the structure function when the distance between two points is small compared with the dimension of the nebula.

The line half width at the $e^{-1/2}$ intensity point (Δ) is

$$\Delta^2 = R^{-2} \int_0^R \int_0^R (v_{\alpha\tau} - v_{\alpha t})^2 d\tau dt \quad [1-19]$$

when observed with a resolution size small compared with R .

For an optically thin nebula, the integral to be solved is

$$\Delta^2 = C^2 \Lambda^2 2l \left[\int_0^{1/l} x^n dx - l \int_0^{1/l} x^{(n+1)} dx \right] \quad [1-20]$$

The solution of the integral is

$$\Delta^2 = 2 C^2 R^{2/3} \frac{1}{n^2 + 3n + 2} \quad [1-21]$$

For the case $n = 2/3$, the spectral line is broadened by the factor

$$\Delta^2 = \frac{9}{20} C^2 R^{2/3} \quad [1-22]$$

1.2.6.3 Comparison of the theory with observations

Studies concerning the determination of the structure function in gaseous nebulae are few, because this approach requires an appreciable number of observations employing an emission line to which the nebula is optically thin to avoid the problems of extinction, and with accurate velocity resolution and low system noise. Early attempts to compute the structure function of HII regions were made by Von Hoerner (1951) and Münch (1958) for the Orion Nebula, and are discussed in detail in Chapter 2. Louise and Monnet (1970) used the radial velocities obtained by Courtes (1960) to calculate the structure function for M 8, finding $B(\Lambda) \approx \Lambda^{2/3}$, but the lack of error analysis and the quality of the data raise questions about the results. Recent measurements were made by Joncas and Roy, on S142 (Joncas and Roy 1984ab, Roy and Joncas 1985) and M17 (Joncas and Roy 1986), using a Fabry-Perot interferometer at a good velocity resolution (20 km s^{-1}) and velocity accuracy ($2\text{-}3 \text{ km s}^{-1}$) and at $3''$ angular resolution. Their observations suggest three different regimes for $B(\Lambda)$. At small Λ , the function levels off; at intermediate scales, the function

can be represented as $\Lambda^{1/2}$, a steeper slope than expected by Kolmogorov; for larger scales, on the order of the angular size the nebula, the function shows a decorrelation. O'Dell (1986) has studied radial velocity maps in H_α at low spatial resolution and intermediate spectral resolution for NGC1499, NGC7000 and S252, concluding that the slope of the structure function is of the order of 0.18, 0.30 and 0.45 respectively, much lower than Kolmogorov's predicted values. O'Dell and Castañeda (1987) have examined the velocity maps obtained by O'Dell, Townsley and Castañeda (1987) on the Trifid and Lagoon nebulae; whereas there is a dependence of the random velocities upon scales, there is no a single power law for the observed structure functions that fits the observations

Improvements in the sensitivity of millimeter-wave receivers has made possible the application of statistical methods to molecular clouds, as enough positions can be measured in reasonable amounts of time (Dickman 1985). Kleiner and Dickman have made use of the autocorrelation function (eq. [1-8]), obtaining the power spectrum of their data using Fast Fourier transforms (Kleiner and Dickman 1984, 1985; Dickman and Kleiner 1985). The method has also been applied to a detailed radial velocity map of the molecular cloud ρ Ophiucus by Scalo (1984), although at low spatial resolution. Statistical studies have also be made by Stenholm (1984) and Baker (1973, 1976).

1.3 Summary and Conclusions

The combination of observational data from Fabry-Perot and Echelle systems, and the more sophisticated numerical models that describe the evolution of the nebula, show that the gross velocity structure of HII regions is extremely complex, with the observations indicating mass motions that can be attributed to a chaotic component.

Nevertheless, the kinematic picture is far from complete. One problem is the nature of the velocity structure at fine scale. Most of the data provide radial velocity maps at the price of information about the shape of the line profile (as in Fabry-Perot Interferometry) or with insufficient spatial resolution for detecting the fine structure of the velocity. It is not clear, for example, whether or not the spectral line observed can be described by several lines superposed, each with a distinctive radial velocity.

If the non-thermal component of line width is due to turbulence, a question immediately arises regarding the scale of the phenomenon. If we were able to obtain the structure function for different nebulae we could compare the results and decide if the same physical processes apply in different objects. If that would be the case, it would imply a "universal" structure function, either described by a conventional theory (e.g. Kolmogorov's law) or by a different model, taking into account effects as compressibility, intermittence, etc. If the dominant role of turbulent energy in gaseous nebulae is confirmed, then we must reassess the basic energy balance mechanisms in HII regions.

1.4 Observational program

What is needed is a new set of observational data, free of the reduction problems that plague most of the other sets of observational data, and at much better spatial and spectral resolution. With the technique of slit spectroscopy the problems of the deconvolution of

the instrumental profile are reduced to a minimum. The observational evidence indicates that we must expect to see turbulence in scales of a few arc seconds, and because of the relatively low velocities involved, we need to work both at the seeing limit and at high velocity resolution.

To answer the questions formulated in the preceedings paragraphs, our research program attempts the characterization of the velocity structure in the nearby bright nebula NGC 1976 (the Orion Nebula) and the development of a realistic model to explain the turbulence. The Orion Nebula is a small object compared with other gaseous nebulae (Kennicutt 1984). The proximity of Orion to the Earth, around 500 pc, and its location in the sky give the nebula the highest optical surface brightness of any HII region. Consequently, it provides us with an excellent opportunity to study and understand the physical phenomena present in gaseous nebulae.

This thesis is essentially a repeat the previous work of Wilson, Münch, Flather and Coffen (1959) on the Orion Nebula, observing a bright line of a heavy element to obtain a map of radial velocities, line widths, intensities and fluxes, with enough measurements so that it is possible to use statistical techniques for the study of turbulence. With the availability of new linear detectors with a large dynamic range, high quantum efficiency and linearity it is possible to detect multiple components in the emission nebular lines. As a result, more accurate studies of the velocity field are possible, and better models for the nebula can be formulated. The new observations would allow the determination of the adequacy of present theories of turbulence in HII regions.

Chapter 2

The Orion Nebula

"God must have wanted us to understand HII regions, or He wouldn't allowed us to view the exciting stars of a young, high density, high emission measure, dusty HII region."

B. Zuckerman (1975)

As stated previously, the Orion Nebula is one of the most extensively studied astronomical objects. Scientific journals rarely publish few issues without a new paper on M42 being presented. Complete books have been dedicated to the vast amount of observational information and theoretical models available (e.g. Goudis 1982; Glassgold et al. 1982). Scientific reputations have been built and quite a few future astronomers have started on the road to the stars looking at Orion. This wealth of information, in some ways, works as a disadvantage, because we must select the good from the bad data, which is sometimes not an easy task. We could see M42 as a puzzle; each new observation helps to unravel it, but a realistic model will be possible only when we are able to unify and interpret the multiple pieces of data, which sometimes seem to contradict each other. What we present in this chapter is a very abbreviated view of the current understanding of Orion. The observational evidence seems to justify the idea that the nebula is undergoing a champagne flow. In the last part, the kinematical information is subjected to scrutiny, to conclude that a reevaluation of the models in light of the current data is necessary.

2.1 Historical background

For the ancient Chinese, the celestial sphere was divided into four different sections, each section representing a different animal (Staal 1984). In turn, each animal was subdivided into seven houses or mansions. In the section of the White Tiger of Autumn (Pen-Hou), the seventh house (the head), was entitled Tsan, the supreme commander. The sword, Fa, which contains what we call the Orion Nebula, was to the Chinese a battle axe, which was used to predict the fate of the armies in battles. Western civilization has associated the myths of the ancient Greeks with the stars. For them, Orion was a hunter, the son of the sea god Poseidon (Raymo 1985):

"After many adventures, Orion voyaged to the island of Chios, where he fell in love with Merope, the daughter of King Oenopion. The king agreed that Orion should wed his daughter but insisted that the giant should prove his worth by accomplishing a series of difficult tasks. As Orion completed each assignment, the king imposed another, each more demanding than the one that went before. At last Orion began to suspect that Oenopion had no intention of giving up his daughter and that the tasks would have no end. He decided to be done with it; he would carry Merope away by force. But the giant's plan was discovered by the king. Oenopion had Orion seized, blinded, and cast upon the strand by the water's edge to wander the Earth in darkness"

Shortly after the invention of the telescope by Lippershey in Holland around 1608, the Orion Nebula was discovered by Nicolas Peirsesc in France, in 1611 (Ashbrook 1984). However, Christiaan Huygens in 1656 was the first to make a drawing of the nebula, published in his 1659 book about Saturn. One hundred years later, Charles Messier included Orion in his list of comet like objects, classifying it as M42. The

beginning of the scientific study of Orion can be traced to John Herschel in the 1820's. To detect evolutionary changes of the nebula, he undertook the task of making very careful drawings of the object at different epochs. The era of the human eye as the sole source of information about M42 ended on September 30, 1880. A wealthy amateur astronomer from New York, Henry Draper, took the first good photograph of a gaseous nebula, Orion, with a 57-minute exposure using the 11 inch Clark Refractor (Gingerich 1982). This event marked the beginning of modern observational and theoretical studies of the Orion region.

2.2 Description

2.2.1 General Features

We understand the Orion complex to be a group of molecular clouds, HII regions, dark clouds and reflection nebulae which covers much of the constellation, extending over an area of about $10^0 \times 10^0$ (Fig. 2.1). Prominent members are the molecular clouds Orion A and Orion B, the Horsehead Nebula, the Barnard Loop and the Orion Nebula (Goudis 1982).

Visible at radio wavelengths, the molecular clouds are systems of interstellar gas and dust, of around 10^5 solar masses, essentially made of neutral hydrogen with trace elements such as carbon, oxygen and nitrogen, and dust grains. Observations of molecular bands, in particular that of CO, show that the densest part of the molecular cloud is behind the Orion Nebula. When we look in the infrared, we detect a cluster, apparently a group of protostars forming inside the cloud. In the 3-10 micrometer range, the brightest infrared source is the Becklin-Neugebauer (BN) region (Becklin and Neugebauer 1967), believed to be a hot star, probably early B-spectral type, which is losing mass and which is

embedded in dust. At 12 arc sec south of BN is the Kleinmann-Low (KL) region (Kleinman and Low 1967), containing H_2O and OH "point" sources, apparently the product of circumstellar dust that reradiates the UV radiation of a newborn star.

The Orion Nebula is the most optically visible member of the complex, and it is located in front of the Orion Molecular Cloud A.

Fig. 2.1: The Orion complex: carbon monoxide features (from Henbest and Marten 1983).

2.2.2 The Orion Nebula

Like any other HII region, Orion is a mix of ionized gas and dust. The source of ionization is the Trapezium, a group of four stars separated from each other by about 10 arc seconds. The Trapezium is noted as θ^1 Orionis; the brightest star is θ^1 Ori C. Three arc minutes to the south-east there are two stars named θ^2 Orionis A and B (Fig. 2.2). The feature known as "the bar" is probably an ionization front expanding from the Trapezium.

The spectrum of Orion is composed of a strong continuum due to scattered light from the Trapezium stars plus atomic sources, with intense emission lines superposed. The dust particles, around 1% of the mass of the nebula, absorb the Lyman continuum photons from the ionized hydrogen, with reemission in the infrared. They also scatter the stellar light directly; the continuum spectrum of Orion in the visible is dominated by dust scattered stellar light, the atomic component only being responsible for 20-30% of the observed continuum (O'Dell and Hubbard 1965). The temperature of the gas in the nebula is $\approx 7 \cdot 10^3$ - 10^4 degrees Kelvin, typical for an HII region. Radio continuum measurements show that the ionized gas has a spherically symmetric distribution; the density falls exponentially from the center, with a root mean square electron density of 10^4 cm^{-3} . However, observations of forbidden lines of [SII] and [OII] give local density values of 10^5 cm^{-3} at the center of the nebula. The difference can be explained if only part of the volume of the nebula is occupied by ionized matter, in the form of condensations (Osterbrook and Flather 1959). An estimation of the volume occupied is given by the filling factor a , the ratio of the root mean square electron density to the local density, that for Orion is of the order of 0.03-0.05 (Dopita et al. 1974). These results are compatible with observations of intensity and density variations over the core of M42 (Elliot and Meaburn 1973).

Schematic representation of the most important optical features of the Orion nebulae (M42, M43) as appear in the light of many emission lines. A narrow band [S II] $\lambda\lambda$ 6717, 6731 Å photograph of Orion (M42, M43), taken by T. R. Gull at the Kitt Peak National Observatory is also shown for comparison (after Balick *et al.*, 1974).

Fig. 2.2.: The Orion Nebula (from Goudis 1982).

The nature of the clumpy structure of the gas is revealed by photographic evidence. That shows intensity variations over the surface of the nebula, which are attributed to the existence of condensations of ionized matter within the nebula. They are described with names such as ionized stellar size condensations (Laques and Vidal 1979), partially ionized globules (Dopita et al. 1974) and ionized knots. The exact nature of these condensations remains not clear, but some are certainly Herbig-Haro objects (Canto et al. 1980; Münch 1977).

2.3 Models

Combining the observational data from the many available studies leads to the standard models of the Orion Nebula, described in the papers of Zuckerman (1973), Balick et al. (1974) and Dopita et al. (1974), for example. In those models, the Orion Nebula lies in front of the molecular cloud (Fig. 2.3). The nebula is density bounded on its front side and radiation bounded on its back side. The carbon recombination lines originate in the HII-HI molecular interface layer behind the Trapezium. In this layer the gas suffers acceleration due to the large density gradient, moving away from the molecular cloud and towards the observer.

The lines due to low degrees of ionization are formed in a region near the ionization front, moving relatively slowly compared to the lines of high degrees of ionization which arise in the flow closer to us, i.e. closer to the star. The mean distance between the Trapezium stars and the front edge of the molecular cloud is around 0.3 parsecs, with the stars moving into the cloud with a relative velocity of $+3 \text{ km s}^{-1}$ and the partially ionized interface layer also moving at the same speed. The ionized gas flows away from the cloud with a relative velocity of -10 km s^{-1} .

Fig. 2.3: Model of the Orion Nebula by Zuckerman (from Goudis 1982).

The champagne model reproduces this physical situation and interprets the data from the kinematic structure. The Orion Nebula is identified as a protrusion of the front edge of the dense molecular cloud associated with the KL nebula. In this configuration, the ionization front from the Trapezium stars, after being formed at the edge of the molecular cloud, expands up to the cloud boundary. There a rapid flow is generated and, driven by the difference in gas pressure, it bursts out into the low density surrounding medium. Because the gas in the ionized core is continuously replenished, the apparent discrepancy in age between the Trapezium stars and the HII region is resolved. The observed [OII] being redshifted with respect to [OIII] (Wilson et al. 1959; Wurm and Perinotto 1965) and the [FeII] redshifted with respect to [OII] (Kaler 1967) can be explained as the effect of the rarefaction wave produced after the ionization of the discontinuity cloud- intercloud

medium has gone past the stars. This results in the outward motion of the formerly inward-moving gas (Bodenheimer et al. 1979). The fact that [OIII] and [OII], when viewed along the same line of sight, have different relative intensities and velocities, implies different physical conditions (e.g. ionization, temperature and density) in the two distinctive emitting volumes. Arguments against the Champagne model for Orion have been raised by Peimbert (1982), based on observations of the pressure gradient and data from stellar absorption lines (Franco and Savage 1982). But a particular configuration of stars and gas could explain the observations (Yorke et al. 1984). Nevertheless, the model cannot account for the weak high velocity components in excess of 50 km s^{-1} observed in the nebula.

2.4 Kinematic structure and turbulence

2.4.1 Velocity maps

There have been several studies of the radial velocities of the gas in the Orion Nebula, in optical (Fischel and Feibelman 1973; Smith and Weedman 1970) and radio (Pankonin et al. 1979) wavelengths. The classic paper of the kinematics of Orion was written by Wilson, Münch, Flather and Coffeen (1959). Over 100 hours of observing time using the 5 meter telescope at the Palomar Observatory produced over 40,000 velocity data points of Orion, in three different wavelengths ([OIII] λ 5007, [OII] λ 3727 and $\text{H}_\gamma\lambda$ 4340). They used a multislit spectrograph that allowed them to obtain spectrograms of different areas of the nebula simultaneously. No clear pattern in the radial velocity was observed; in fact, there were regions where lines appeared split. The nebular lines showed a non-thermal component, with a root mean quadratic turbulent velocity of 12 km s^{-1} for [OIII] λ 5007 (c.f. sec. 2.5).

2.4.2 Turbulence

The first attempt to interpret the motions observed in Orion as turbulence was made by Sebastian von Hoerner (1951), employing the ideas of von Weizacker regarding the influence of turbulence in astrophysical processes. Von Hoerner was able to compare the predictions of the Kolmogorov (1941) theory with data of Campbell and Moore (1918); accurate velocities were obtained for 85 points over the nebula, with a probable error of around 1 km s^{-1} . Because the smallest average angular separation was 6.75 arcseconds, velocity fluctuations could not be well determined below this scale. He concluded that the data approximately satisfied the relation $B(\lambda) = \lambda^{2/3}$ (Fig. 2.4), implying that the effective depth of the nebula is only 10 percent of its linear dimensions, if the structure function is a manifestation of the Kolmogorov law.

Fig. 2.4: Structure functions for the velocity field in the Orion Nebula from data of von Hoerner (open circles) and Münch (solid circles) (from Münch 1958).

His conclusions were challenged by Münch (1958), using the data of Wilson et al.. Münch concluded that the Kolmogorov law was not applicable to Orion, because the observed $2/3$ slope of the structure function at small distances (Fig. 2.4) would indicate an optical depth smaller than the value postulated by von Hoerner. However, both of these results were inconsistent with the optical depth obtained from the observed line width of the $[\text{OIII}]\lambda 5007$ line. Münch attributed the failure of Kolmogorov theory to the presence of compressibility. This phenomenon was evident from regions on the face of the nebula that exhibit spectral line splitting (Fig. 2.5). These split lines correspond to velocity differences of up to twice the thermal velocity between emitting elements in the line of sight.

The literature contains similar studies, but the quality of the data does not allow a meaningful comparison. Courtès (1955) attempted a similar program, using a Fabry-Perot etalon spectrograph and measuring H_α emission lines. A study of the correlation of surface brightness, an indication of turbulent fluctuations in density, was carried out by Pikelner and Shain (1954).

The line splitting and the generation of turbulence can be explained in the model of Dyson (1968a,b). The model assumes that dense condensations, or globules of neutral gas exist within the ionized gas. Dyson studied the nature of the interactions between the streams of ionized gas, coming from two identical globules (size around 10^{16} cm, roughly stellar mass, distance between globules < 0.15 pc) of neutral material, expanding into their lower-density surroundings. From these interactions he predicted the shapes of the emission lines characteristics of these regions. This could explain splitting over distances of a few tens of arc seconds, but it is not sufficient when one considers splitting over

distances of several arc minutes (Deharveng 1973).

Fig. 2.5: Radial velocities measured in [OII] and [OIII] in the Orion Nebula along an E-W line 25" S of θ^1 Ori C. Solid circles indicate points at which line is measured single; open circles indicate points at which line is measured double. The length measured on each separate spectral plate is indicated by an arrow (from Münch 1958).

2.5 Summary

A critical perusal of the available data shows some problems with the work of Wilson et al., which is traditionally used as a starting point for discussion of the kinematics

of Orion. The velocity data were obtained using photographic techniques that determined radial velocities using the peaks of the line profiles. This association does not take into account the shape of the line or the existence of multiple velocity components; line fitting profiles not being obtained. Because the velocity data is used for the calculation of the structure function, this calls into question any conclusions based on the function. More importantly, the Münch paper does not give a correction to the numerical values of the structure function for the effect of mass flow across Orion. A selection problem appears in the determination of the turbulent velocity component from the line widths, because the authors decided to concentrate on the areas where the lines appeared sharpest. They made this decision in order to avoid measurement of areas where they had partial overlapping of the lines, due to the use of a multislit, and then assumed that the lines were gaussian in shape.

It is clear then that a new set of kinematic data is necessary for the determination of a realistic model of the nebula.

Chapter 3

The Observations

*"It is a capital mistake to theorize
before one has data."*

Sir Arthur Conan Doyle,
The Adventures of Sherlock Holmes

Whereas actual astronomical observations is a relatively straightforward process, only interrupted by the vagaries of the weather and the reliability of scientific instruments (which impose a continual test on the mental stability of the observer), the process that leads to this observational stage is complex. A careful analysis of the objectives of the project must be made. The requirements of the observational program impose severe constraints on the type of observation undertaken and consequently constrain the study of the object. Then follows an evaluation of the possible instruments to be used, with multiple considerations given, from the technical feasibility of the observations to the subjective possibility of obtaining observing time for the desired instrument. All this process rarely generates more than a page in a scientific journal, but its importance cannot be underestimated. Since this is a thesis, we have the advantage of being able to go more into detail about this part of our research.

3.1 Selection of the spectral line

The information we expected to obtain from the nebular line consisted of velocity, peak intensity, line width and flux. The possible presence of multiple velocity components, separated by a few km s^{-1} , is more easily discernible in narrow emission lines; it was thus

necessary to observe thermally narrow lines, which are also associated with heavy ions. Using the smaller correction for thermal motion, which is sensitive to the temperature estimate for the nebula (that may not be accurate), minimizes the error in the determination of the non-thermal velocity component of the line width.

We decided to use the very bright [OIII] λ 5007 Å, a forbidden line of oxygen. Also known as N1, it corresponds to the transition $2p^1\ ^1D - 2p^2\ ^3P$, and is prominent in planetary and diffuse nebulae. The [OIII] zone occurs in the nebula where photons of energy between 35 and 55 eV are abundant. The nebula must be considered optically thin to the line, like all the forbidden lines, unless there is absorption by dust. Notwithstanding its relatively low abundance, between $1.4\text{--}3.0\text{--}10^{-4}\ n_e$ (Simpson 1975; Melnick et al. 1979), the λ 5007 line is one of the brightest lines in the spectrum of Orion (comparable with H_α); this proved to be very useful for the discovery of high velocity features, which are intrinsically faint.

3.2 Selection of the instrument

The important characteristics of the instrument to be employed were spatial resolution and velocity resolution. We expected to observe velocity fluctuations on the order of a fraction of the sound speed in the gas, in the high resolution range ($\lambda/\Delta\lambda \approx 10^5$) over areas of the nebula on the order of a few arc sec, the size of the seeing disk ($\approx 2''$).

A Coudé spectrograph gives us the advantages of high spectral resolution and spatial coverage. Additionally, slit spectroscopy is free of peculiar problems related to the instrumental deconvolution that affect Fabry-Perot techniques and, in consequence, is ideal for our study.

High dispersion grating spectrometers are much too large to hang on the telescope

itself. We define linear dispersion $d\lambda/dx$, in Angstroms per mm, as

$$\frac{d\lambda}{dx} = \frac{1}{f_{\text{cam}}} \frac{1}{(d\beta/d\lambda)} \quad [3-1]$$

where f_{cam} = the camera focal length, and $d\beta/d\lambda$ is the angular dispersion given by the grating, and given by

$$\frac{d\beta}{d\lambda} = \frac{n}{d \cos\beta} \quad [3-2]$$

(n = diffraction order analyzed; d = ruling spacing of the diffraction grating; β = diffraction angle). We want $d\lambda/dx$ small as determined by our scientific requirements. For a fixed ratio of ruling spacing (d/n) we only have the focal distance of the camera, f_{cam} , as a free parameter, so the camera focal length is then made as large as possible with the restriction that the size of the optical beam not exceed the size of the grating (Gray 1976). The resolution desired then determines the size of the spectrograph. Because of the large resulting size, a high resolution spectrograph is constructed at the Coud focus, so that it does not move during the night.

The speed is determined from the nature and number of optical elements in the telescope, the type of light detector and its quantum efficiency, and the nature of the source. In the case of an extended source, whose angular size is larger than the size of the slit, a simple dimensional analysis shows that the speed is determined by the surface brightness of the object, not by the total flux; and the speed is inversely proportional to the

square power of the focal ratio of the telescope and the spectrograph camera. As the speed is then independent of the diameter of the telescope, increasing the size of the telescope does not shorten the time required for observations.

3.3 Coudé Spectrograph

The instrument we decided to use was the Coudé Feed Spectrograph at Kitt Peak National Observatory (KPNO). The spectrograph, originally designed to be used in combination with the 2.1 m telescope, is now used most of the time with an auxiliary feed system. Due to the fact that the focal ratio of the two systems (2.1 m/auxiliary feed system), both can reach the same spectral resolution, with little difference in speed for extended sources.

It is useful to describe the Coudé Spectrograph as composed of three different elements: the light collector (telescope), the light analyzer, and the light detector.

3.3.1 Light Collector

The light collector in this case is part of a new type of telescope, which is possible thanks to fundamental advances in design and computers.

The Coudé Feed Spectrograph at KPNO employing the auxiliary feed system, is composed of a 1.5 m altitude-azimuth mounted flat mirror, moved under computer control, that feeds the light to a 0.9 m off-axis, paraboloidal mirror. The light is deflected to a 0.15 m flat mirror that feeds the light ray, which is then along the polar axis, to the Coudé room (Fig. 3.1). The scale of the image at the entrance slit is $7''.2 \text{ mm}^{-1}$.

COUDÉ FEED TELESCOPE

Fig. 3.1: The Coudé Feed Spectrograph at Kitt Peak National Observatory.

3.3.2 Light analyzer

Different configurations of the spectrograph are possible, depending on the observational program. Four different cameras are available for the spectrograph, as are different types of images detectors.

As stated in eq. [3-1], it is important to use camera focal length as large as possible; Camera 6 is the camera with the longest focal length (3.7 m) and thus gives us the highest spectral resolution. Two collimators are available, but the large collimator is only useful with grating B due to the large beam size (cf. sec. 3.2). Grating D, of size 204 x 208 mm has a double diamond ruling with the highest ratio of grooves mm^{-1} . The blaze at first order is 8000 Å. Two blocking filters were used, GG400 and CuSO₄.

The use of the maximum slit length (dekker #1 = 25 mm) allowed us to cover the largest possible area of the nebula with each integration. Working for maximum resolution, the slit width was selected to project to two pixels (60 μm) at the CCD detector. From

$$w \approx p \frac{f_{\text{coll}}}{f_{\text{cam}}} \quad [3-3]$$

(w = width of the slit; p = image of the slit; f_{coll} and f_{cam} = focal length of the collimator and the camera) we found $w \approx 0.1 \text{ mm}$.

3.3.3 Light detector

In 1946, the astronomer and part-time science-fiction writer Robert S. Richardson described the recovery of Halley's comet, using a 300 inch (!) telescope (Clarke 1966):

"A wave of emotion welled up within me such as I had never experienced before in my whole life. A sudden realization of the transientness of human existence and the eternity of space and time. I returned the plate to Blakeslee with trembling hands. "It's back again," I whispered.

He smiled faintly. "Yes, back again. Halley's comet -back again after three-quarters of a century."

Blakeslee, having finished his second cup of coffee, lighted his old briar pipe and subsided into the battered armchair that faces the library windows to the south. the discovery plate of Halley's comet was in the drying cabine from where it would soon be transferred to the measuring machine upstairs. In the meantime, with the comet safely trapped, we could afford to relax in the luxurious contemplation of two years'work brought to a triumphant conclusion."

This is not only bad literature, but the wrong scientific prediction. More than anything, it speaks of the great advances made in the subject of light detection in the last decades. The photographic plate has been complemented by photomultiplier tubes, image tubes, electronic cameras, television cameras, diode arrays, etc. The latest fundamental advance has been the introduction of two-dimensional solid state detectors known as charge coupled devices (CCD). A CCD is a light-sensitive semiconductor that stores charges in picture elements (pixels) proportional to the amount of light falling on them; they are read electronically. Made commercially available recently, they come within a small factor of being perfect detectors, and are suitable for astronomical applications. The devices provide high quantum efficiency, a large dynamic range, good linear resolution and spatial coverage in a stigmatic system (Latham 1982).

The key factor in our observational program has been the availability of a CCD

detector to be used with the Coudé Feed.

The RCA-CCD detector No. 2 was used; the quantum efficiency at $\lambda 6500 \text{ \AA}$ is 65%, with a dynamic range of 10^4 . The format is 512×320 pixels, size $30 \text{ }\mu\text{m}$, with a useful sensitivity over the wavelength region $3400\text{-}9000 \text{ \AA}$.

The CCD control system consists of an interface chassis, the CCD controller and a LSI 11/23 computer. Associated with the 11/23 computer are a Winchester 80 MB disk for data storage and a Grinnell unit for video display of the data. The CCD computer system is connected via a link to the telescope control computer. This link is used to transfer information regarding the circumstances of an observation (e.g. coordinates of the object, celestial time, status of the CCD, etc). The software is composed of a multi-tasking Forth system resident in the LSI 11/23 that allows the observer to manipulate and display previously obtained pictures while the current integration is in progress. Our particular software package operates in the "long slit" mode.

3.4 Observing run

3.4.1 Preplanning

The first stage of the observational preplanning consisted of the selection of the optimal observing dates. Orion is a winter object, so the best period for observations was November-February, with optimum observing times centered at early December. No particular constraints existed, save the technical limitations of the instrument.

In the second stage we selected the area to be studied and the guide stars. For the central part of the nebula, the Trapezium stars (θ^1 Orionis) were used for guiding, whereas for the area south of the bar we employed θ^2 Orionis A. We concluded that a good velocity map across the nebula would require about 30 observations (two each on 15 different

orientations for the slit).

3.4.2 Mountain routine

In the beginning of the observing run, the mountain night assistants set up the grating and camera and assisted with any problems that arose. After the CCD was installed, the assistants proceeded to insure proper settings of the detector. Using the narrow slit and the Thorium/Argon comparison line, the final focus was set to the point where the line appeared symmetric and the line width minimum (approximately 2 pixels using grating D).

A typical observation proceeded as follows. After opening the telescope, the coordinates of the object were fed into the main computer that controls the flat mirror; at the end of the computer controlled setting a finder telescope which provides a field of view of four minutes of arc in diameter, could be used for localization of the object. The telescope was guided by locating the stars at the center of the slit, which could be observed via a TV camera attached to the entrance of the spectrograph. A hand paddle provided the fine guiding for tracking during the observation. Two types of guiding were used, one where two stars were employed as reference and the second where only one star intersected the slit and a position angle was selected with the help of the image rotator (position angles are measured from the direction of the celestial north pole). The guidestars were placed as near to the center of the entrance slit as possible.

Due to the fact that the spectrograph is aligned over the polar axis of the telescope, the field of view rotates during of the observation. This effect is corrected with the same optical field rotator attached to the slit entrance. Because of the altitude-azimuth mounting of the Coudé auxiliary system, the standard drive rate could not be used and a particular

correction must be calculated. For a given object, the relation between the true position angle (PA_{true}) and the orientation of the slit (the image rotator position) is

$$\text{OBS} = PA_{\text{true}} - \text{CORR} \quad [3-4]$$

$$\text{CORR} = \alpha + \frac{A}{2} + 154^\circ \quad [3-5]$$

α and A are constants that depend on the hour angle, the declination of the object, and the latitude of the observatory.

CORR was calculated for the possible values of hour angle. As the object was tracked, the value of OBS was adjusted as the field slowly rotated. The image rotator could be manually adjusted during the exposure, and the position angle was maintained constant with a precision of $\pm 1''$.

Integration times were two hours, unless problems such as software or hardware malfunction, bad weather, or the fact that the telescope reached the limits of operation in right ascension ($\approx \pm 3.5$ hours), forced us to stop the observation. At the end of the integration, the spectra were transferred to disk, and written immediately to a raw data tape, to prevent damage to the original picture.

Comparison spectra were obtained nightly using a thorium-argon lamp, mounted to the right of the slit head, and selected by an adjustable prism. In that way, the configuration of the instrument stayed the same, and only the light source changed. The comparison spectra served three purposes: to determine the instrumental profile, the slit curvature, and to establish a wavelength standard for each raster so that the wavelength scale might be determined. On the first two observing runs, the comparison spectra were

taken at the beginning and at the end of the night. A preliminary analysis found a slight drift in the position of the peak of the comparison lines, probably because of boil-off of liquid nitrogen coolant in the CCD head dewar during the night. As a consequence, in the last two observing runs the comparison spectra were taken before and after each integration, to minimize the error introduced by this shift.

Thirty-six two dimensional spectra were obtained after four observing runs on the period 1983-1985. Fig. 3.2 illustrates the area covered by the observations.

Fig. 3.2: Diagram of the observed area in the Orion Nebula.

Tables 1 and 2 gives the date of observations, position angle, and exposure time. The seeing disk was 2"-3" during most observations. A typical two hour exposure onto the CCD detector gave typical line peak signal-to-noise ratios of up to 500 for the area around the Trapezium.

3.4.3 Picture processing

The image processing of the raw spectrum image consists of two steps, necessary for removing unwanted signals generated in the CCD and to correct for the lack of uniformity in the device. (Thorne 1986; Mackay 1986).

The first step is the bias subtraction, to eliminate the output generated by the detector in the absence of illumination (known in the trade as "dark current"). The bias image was constructed by averaging ten frames with zero-integration time, obtained at the beginning of the night, and then proceeding to do a pixel-by-pixel subtraction of that image from the object spectra. The CCD picture contains 32 columns of "overscan" in addition to the image, and the bias level can be measured from the overscan region; since any secular variation in the bias level is removed using the bias overscan, it is unnecessary to obtain bias frames during or at the end of the night.

The second step, the flat field correction, serves to compensate for pixel-to-pixel variations in sensitivity in the CCD, as well as non-uniformities in detector illumination. This is a simple division operation with a constant scale factor to preserve the original count rates. The detector is exposed to a quartz lamp, which is used to provide a spatially-uniform continuum source illumination for calibration; five frames with 30 seconds integration time each were taken, averaged, normalized, and the result divided into all bias corrected frames.

After picture processing, the frames are ready to be saved on tape, for further reduction at Rice. The data formats of the tape that we have used is the FITS (Flexible Image Transport System) format, and camera format, which is used at KPNO on most of the digital television-type detector systems.

Table 1: Record of observations for the θ^1 Orionis region.

Position angle	Date (UT)	Integration time (hours)	Start (UT)	End (HA)
Orion A to B	8 Feb 1984	2.5	5:24	4:04W
	19 Jan 1985	2.0	1:49	1:15E
Orion A to C	14 Nov 1983	1.9	6:43	0:50E
	15 Nov 1983	1.8	9:29	1:35W
	6 Feb 1984	2.0	4:10	2:12W
Orion A to D	14 Nov 1983	2.0	11:05	3:38W
	7 Feb 1984	2.0	5:48	3:55W
Orion B to C	14 Nov 1983	1.7	9:18	1:36W
	15 Nov 1983	2.0	11:03	3:36W
	8 Feb 1984	2.5	2:50	1:31W
Orion B to D	15 Nov 1983	2.0	5:36	1:48E
	9 Feb 1984	3.0	2:19	1:33W
	5 Nov 1984	2.0	9:30	1:30W
Orion C to D	14 Nov 1983	1.3	5:15	2:49E
	15 Nov 1983	1.3	7:39	0:15E
	7 Feb 1984	3.0	2:33	1:39W
Orion Apa180	21 Jan 1985	1.5	7:48	4:31W
	22 Jan 1985	2.0	3:08	0:14W
Orion Apa240	6 Nov 1984	2.0	9:07	1:12W
	7 Nov 1984	1.8	7:11	0:52E
Orion Apa330	6 Nov 1984	1.5	11:12	2:45W
	20 Jan 1985	1.5	1:25	2:04E
Orion Bpa270	20 Jan 1985	1.4	8:00	4:25W
	22 Jan 1985	1.5	1:18	2:06E
Orion Bpa330	9 Nov 1984	2.0	7:01	0:43E
	19 Jan 1985	1.5	6:34	2:59W
Orion Cpa180	20 Jan 1985	2.0	3:22	0:19W
Orion Cpa270	20 Jan 1985	2.0	5:40	2:39W

Table 1: Record of observations for the θ^1 Orionis region (cont.).

<u>Position angle</u>	<u>Date (UT)</u>	<u>Integration time (hours)</u>	<u>Start (UT)</u>	<u>End (HA)</u>
Orion Dpa180	7 Nov 1985	1.9	10:35	2:37W
	19 Jan 1985	2.0	4:13	1:07W
Orion Dpa225	9 Nov 1984	1.8	9:20	1:20W
	21 Jan 1985	1.5	1:20	2:08E

Table 2: Record of observations for the θ^2 Orionis region.

Position angle	Date (UT)	Integration time (hours)	Start (UT)	End (HA)
Orion 2Apa180	19 Jan 1985	1.0	8:56	4:47W
	22 Jan 1985	0.9	5:27	0:30W
Orion 2Apa225	21 Jan 1985	2.0	5:27	2:31W
Orion 2Apa270	21 Jan 1985	2.0	3:08	0:12W

Chapter 4

Data reduction

*"Through me you pass into the city of woe:
Through me you pass into eternal pain:
Through me among the people lost for aye.
Justice the founder of my fabric moved:
To rear me was the task of Power divine,
Supremest Wisdom, and primeval Love.
Before me things create were none, save things
Eternal, and eternal I endure.
All hope abandon, ye who enter here."*

Dante Alighieri: *The Divine Comedy*

The data processing at Rice involved two phases: data extraction, and generation of derived data. The raw data, composed of two-dimensional spectra processed in the observatory, needed to be transformed into a series of one dimensional spectra, from which the kinematic information was determined from the values of the line width and line wavelengths (hence radial velocities). The line profiles were investigated for multiplicity of components, with the use of appropriate software developed in our Department.

4.1 The Rice University Picture Processing System

The data reduction was accomplished using the Rice University Picture Processing System (RUPPS). The Picture Processing System is based on a PDP-11/55 computer system that runs the multiuser, multitasking Unix operating system (Talbot 1980). A 4013 Tektronix terminal enables the user to interactively plot and fit gaussian profiles to emission lines. A GENISCO color video display terminal with a 512 x 512 pixels format, each with 8 bits of color or grey scale encoding, permits the display and analysis of the

spectrum pictures. Spectra profiles can be displayed on the terminal or plotted via a Printronix 300 lpm printer/plotter.

The programs for the reduction of the two-dimensional pictures were written in the C language. The software manipulated Camera or FITS format files, reduced two-dimensional pictures to multiple one-dimensional spectra, and fitted gaussian profiles to the spectra.

4.2 Preliminary reduction

A general two-dimensional picture, in Camera or FITS format, of size 320 rows (spatial direction) x 512 columns (dispersion direction), was transformed into two files compatible with the operating system. The first contained the two-dimensional picture; the second contained the header information, which consisted of the relevant parameters of the observation.

Several steps were needed before we were able to produce one-dimensional spectra from the original picture. First, it was necessary to select a spatial point to use as the zero-point for the extraction of one-dimensional spectra. That was accomplished by extracting five different spectra at different positions along the spatial direction, and measuring the position of the peak of the stellar continuum in each case. The average position of the peak was used as the position of the star; in the case of two guide stars, the value used was that of the brightest star. That particular column was used as reference for the extraction of one-dimensional spectra. By this means we had a common reference point for spectra obtained at different nights. The two-dimensional pictures were then divided into a series of one-dimensional spectra, each containing intervals of two arcseconds (five rows) corresponding to the best seeing, measured from the zero point.

The ordinate of the one-dimensional output spectra (the intensity of the signal) represents the data values averaged over five adjacent rows.

4.3 Study of the instrumental response

4.3.1 Fundamentals

Inherent to any spectroscopic observation is the problem of determining the instrumental response; the recorded line profile is the result of the processing of the true nebular line by the particular instrument used in the observation.

Let us assume that we have a light source producing an infinitely narrow spectral line, which can be described as a delta function. The spectrum that is measured for the delta function is the "instrumental profile", henceforth $r(\lambda)$. A general spectrum, $F(\lambda)$, can be view as composed of a series of delta functions, with heights modulated by $F(\lambda)$. The observed spectrum, $D(\lambda)$, is the convolution of the instrumental profile with the true flux spectrum. We write then (Gray 1976, p. 269)

$$D(\lambda) = \int_{-\infty}^{+\infty} r(\lambda - \lambda_o) F(\lambda_o) d\lambda_o \quad [4-1]$$

4.3.2 The Coudé Spectrograph instrumental response

The program that performs the line fitting assumes that the instrumental response is a gaussian. As a result, the emission lines are fit to gaussian profiles (because the convolution of two gaussians is a third gaussian). Unfortunately, the intrumental response of the spectrograph was pseudo-gaussian, as a result of the imperfect alignment in focus.

The fitting of the comparison lines by gaussian profiles showed that the lines had an asymmetric profile for the lower wavelengths.

Given the fact that the observed profile of the [OIII] line is the convolution of the instrumental response with the true nebular line, it is necessary to obtain an empirical function that describes the instrumental response of the spectrograph. The convolution of that function with a gaussian, the profile of the nebular line, delivers the form of the final function, which will be fit to the observed profile.

The original comparison line can be assumed to be a narrow spectral line, which mathematically may be described as a δ function. The profile of the comparison line that is measured is called the δ function response.

The form of the instrumental response to a delta function centered at $\lambda = \lambda_0$, could be approximated, empirically, as a combination of an exponential and a gaussian function (Fig. 4.1). The function can be written as

$$\begin{aligned} r(\lambda) &= \alpha N e^{a(\lambda - \lambda_0)} & \lambda \leq (\lambda - \epsilon) \\ r(\lambda) &= N e^{-b^2(\lambda - \lambda_0)^2} & \lambda > (\lambda - \epsilon) \end{aligned} \quad [4-2]$$

where N is the normalization constant, defined by

$$\int_{-\infty}^{+\infty} r(\lambda) d\lambda = \int_{-\infty}^{-\epsilon} N \alpha e^{a\lambda} d\lambda + \int_{-\epsilon}^{+\infty} N e^{-b^2\lambda^2} d\lambda \quad [4-3]$$

Fig. 4.1: The observed instrumental profile.

so

$$N = \left[\frac{\alpha e^{-\epsilon a}}{a} + \frac{1}{b} \int_{-b\epsilon}^{+\infty} e^{-u^2} du \right] \quad [4-4]$$

The constant a is the slope of the exponential, ϵ is the value at which the instrumental response function has one-half of its peak intensity, α a scale factor, and b is a factor of the gaussian, related to the full width at half maximum by

$$B = \frac{1}{\sqrt{2} \sigma} \quad \text{and} \quad \text{FWHM} = 2.3556 \cdot \sigma_{n\epsilon b} \quad [4-5]$$

If we assume that the nebular line is a gaussian, defined by

$$F(\lambda) = \frac{A_{\text{neb}} B e^{-B^2 (\lambda - \lambda_c)^2}}{\sqrt{\pi}} \quad [4-6]$$

the problem of obtaining the necessary fitting function reduces to computing the convolution of the gaussian with our particular instrumental response.

The convolution of a gaussian profile with the exponential part of the instrumental response is

$$D_1(\lambda) = \frac{N \alpha A_{\text{neb}} B}{\sqrt{\pi}} \int_{(\lambda + \epsilon)}^{+\infty} e^{a(\lambda - \lambda_o)} e^{-B^2 (\lambda - \lambda_c)^2} d\lambda_o \quad [4-7]$$

or

$$D_1(\lambda) = \frac{N \alpha A_{\text{neb}} B}{\sqrt{\pi}} e^{(a/2B)} \left[\sqrt{\pi} \operatorname{erfc}(Bx + (a/2B)) \right] e^{a(\lambda - \lambda_c)} \quad [4-8]$$

where $x = (\lambda - \lambda_c + \epsilon)$, and erfc = complementary error function.

The convolution with the gaussian part of the instrumental response is

$$D_2(\lambda) = \frac{N A_{\text{neb}} B e^{-C_1}}{\sqrt{\pi (B^2 + b^2)}} \int_{-\infty}^{C_2} e^{-u^2} du \quad [4-9]$$

where

$$C_1 = \frac{[b B (\lambda - \lambda_c)]^2}{(b^2 + B^2)} \quad [4-10]$$

and

$$C_2 = (\lambda - \lambda_c + \epsilon) \sqrt{B^2 + b^2} - \frac{b^2 (\lambda - \lambda_c)}{\sqrt{B^2 + b^2}} \quad [4-11]$$

The convolution operation gives the form of the function used for line fitting, which is

$$D(\lambda) = D_1(\lambda) + D_2(\lambda) \quad [4-12]$$

For each observing run, the thorium and argon lines used as references were fit with a gaussian profile. The mean value of the instrumental FWHM for each observing run was calculated and the coefficient b computed via eq. [4-5]. For each line, the points that did not agree with the Gaussian profile were plotted as log Intensity (counts) vs. log position (pixels). Assuming that these values were represented by an exponential function, we could compute a least-square fit to a line, the slope of which is the parameter a . The mean value of the slope for the observing run was taken as the value of the constant $\underline{a}$. From the value of FWHM it is possible to calculate ϵ as $\epsilon = (\text{FWHM}/2)$.

After the instrumental responses for each observing run were obtained, the fitting routine was modified, introducing the function to be used for fitting as represented by the

equation [4-12]. Four different programs, one for each observing run, were used for the analysis.

The characteristic mean full width at half maximum intensity was 3.98 km s^{-1} (equivalent to 2.29 pixels).

4.4 Line fitting

The core of the reduction process is the program that performs the line fitting, called specred, a multipurpose software package for the analysis of emission spectral lines, developed at Rice University by Dr. John J. Hester. Its primary function is to simulate the emission line profile by a summation of a number of Gaussians of different heights, widths and radial velocities (i.e. line centers). The algorithm utilized requires an initial guess of the above function parameters, and employs a linearization of the fitting function, combined with a gradient search of parameter space (see Bevington 1969, p. 204, for a description of the procedure).

The function used for the calculations is the integral over a pixel width of a sum of one or several gaussians. That number is a more accurate representation of the value returned by a CCD detector at a given pixel: the integration of the incident energy over a given wavelength interval. As stated previously, the program was modified so the function to be fit was the convolution of the instrumental profile for the particular observing run of the spectrum with the true nebular line.

Over 2300 spectra were individually analyzed. Each nebular profile was examined for multiple components and an initial guess of peak intensity, line center and width of line was given for each line. The minimum possible number of nebular lines that was compatible with an optimum fitting of the profile (that could be discerned by visual

inspection) were used. A linear baseline was selected in all the fittings. All the points within 50% of the peak intensity of the line were given extra weight. The iteration was truncated when the derived chi squared function changed less than 0.1% between successive iterations. An unsatisfactory fit was obtained when the number of spectral lines guessed was erroneous or, in some cases, when the line profile showed an ambiguous shape. The plot of the final fit was examined visually and in the case that it was found to be unsatisfactory, a new fit was arranged with an additional line.

Excellent reproducibility, in both the line profiles, as tested by redundant observations made in different years, and in the fits of line wavelength, width, and relative intensity were found. We estimated the dispersion in the averaging of the data as less than 1 km s^{-1} .

4.5 Conversion of the data

After a fitting run, the parameters determined for each spectral line were: peak intensity and flux, in Analog Digital Units (ADU's), and line center and FWHM (after correction for the instrumental broadening), in units of pixels. It was then necessary to convert the line center and FWHM from pixel to wavelength units, and in turn, to heliocentric velocity in units of km s^{-1} . From the thorium/argon comparison spectra, the relationship between pixel number and wavelength was established, using the two more intense lines, $\lambda 5002.097 \text{ \AA}$ (Thorium) and $\lambda 5009.334 \text{ \AA}$ (Argon) for calibration. The velocity was obtained from the Doppler shift equation, using the value for the wavelength of [OIII] of $\lambda 5006.86 \text{ \AA}$. The measurement of the position of the peak of the comparison lines along the spatial axis would expose any shift in the wavelength calibration due to an imperfect alignment of the CCD detector (the lines could shift but would always be

parallel) or optical distortion (in which case the lines would appear skewed). A quantitative determination of these effects was obtained by curve fitting of the comparison spectra, which was repeated every 50 pixels along the spatial direction of the raster to detect any shift in the center. Linear least-squares fits of the line center indicated that for each raster the slopes were identical to each other within an error less than 10^{-4} pixels. The slit curvature was less than one pixel over the direction perpendicular to the dispersion. In the following discussion, we denote as Y (rows) and X (columns) the pixel coordinates in the spatial and spectral directions of the detector.

If we call

$$Y_{th/ar}(x) = A_{th/ar} \times X + B_{th/ar} \quad [4-13]$$

($Y_{th/ar}$ is the position of the thorium/argon center line at row number X; A and B are constants obtained by least squares fitting, and Y_{N1} the position (in pixels) of the observed [OIII] line N1), then the wavelength of the observed N1 line, is

$$N1(\text{\AA}) = 5002.097 \text{\AA} + \left\{ \frac{[(Y_{N1} - Y_{th}) \times 7.237 \text{\AA}]}{(Y_{ar} - Y_{th})} \right\} \quad [4-14]$$

whereas the FWHM (in pixels), has an equivalence in Angstroms given by

$$FWHM(\text{\AA}) = \frac{[FWHM(\text{pix}) \times 7.237 \text{\AA}]}{(Y_{ar} - Y_{th})} \quad [4-15]$$

The equivalent velocity in km s^{-1} at that particular point can be obtained using the Doppler equation. The velocity scale was determined to be 1.74 km s^{-1} per pixel.

As stated in the Chapter 3, at the beginning the comparison spectra were taken at the beginning and the end of each observing night. It was found that the lines of the comparison spectra were showing a slight drift in position (less than half a pixel during the night). It was decided then to obtain comparison spectra before and after each particular observation. The values of A and B are, then, the average of the two comparison spectra associated with a nebular spectra. Nevertheless, a study of the velocity values in the Trapezium stars did not uncover systematic differences in values obtained from different observing runs, within the observational error. Mean values of the radial velocities at the position of the stars at different times of the year were consistent within their error (around 0.3 km s^{-1}).

4.6 Velocity corrections

Before we could compare results from different observing runs, it was necessary to introduce two corrections into the velocity data to convert the values to heliocentric velocities. The first takes into account the Doppler shifting of the radial velocity due to the motion of the earth around the Sun. The radial velocity correction is (Lang 1980, p. 535)

$$V_{\text{re}} = V \cos\beta \sin(\lambda_s - \lambda) + V \epsilon \sin(\gamma - \lambda) \cos\beta \quad [4-16]$$

where λ , β are the ecliptic coordinates of the celestial object; λ_s is the longitude of the Sun at the epoch for which λ and β are determined; ϵ is the longitude of the Sun at perigee; γ the eccentricity of the Earth's orbit and V the velocity of the Earth around the Sun. The

values of λ and λ_s are obtained from the equations

$$\lambda = 281^\circ 13' 15'' + 6189.03'' T + 1.63'' T^2 + 0.012'' T^3 \quad [4-17]$$

$$\lambda_s = 279^\circ.097 + 0^\circ.985647 d \quad [4-18]$$

(T = number of tropical centuries since 1900; d = Julian Date - 2445334.5.

The second correction is for the effect of the earth's rotation during the time of the observation. It is given by (Lang 1980, p. 535)

$$V_{\text{rot}} = V_e \sin(h) \cos\delta \cos\phi \quad [4-19]$$

Here V_e is the equatorial rotational velocity of the Earth (0.465 km s^{-1}), h is the hour angle of the object, δ is its declination, and ϕ is the geocentric latitude of the observatory.

The information necessary for the calculation of these two corrections was available in the logs of the observing runs.

The heliocentric radial velocities can be converted to local standard of rest velocities by subtracting 18.1 km s^{-1} .

4.7 Data set form

Given a particular spectrum, we need to associate the computed values of intensity, flux, velocity and FWHM with a particular position on the face of Orion. The procedure is straightforward.

The angular scale along the projection of the entrance slit was determined to be

($0''.408 \pm 0''.003$) per pixel by measurement of stars in the Trapezium. By keeping two guide stars on the slit, a double stellar spectrum was obtained. The separation of such double spectra was measured, and the values compared with the published angular separations (Aitken 1932), to obtain the angular scale (O'Dell and Ball 1985).

Once the previous information is available, it is a simple geometrical calculation to obtain the position of the spectrum given the distance (in pixels) of the center of the spectrum to the brighter star in the raster, and the corresponding position angle.

The spectra that corresponded to the same position on the face of the nebula were compared, and the averaged values for intensity, velocity, FWHM and flux were obtained. Over one thousand positions were examined; that final data set constituted the backbone of our thesis research. The next chapter is dedicated to the analysis and discussion of the observations.

Chapter 5

Analysis and Discussion

*"And maybe what's good
gets a little bit better.
And maybe what's bad
gets gone."*

From the title song of the film *Norma Rae*

In this final chapter we attempt to present an analysis and discussion of the observational data that we have obtained in the course of our research program. Because of the complex nature of the data, we have decided to present our results into two sections, the first dedicated to the θ^1 Orionis region (the Trapezium stars), and the second to the θ^2 Orionis area. While the primary objective of our research was the study of turbulence in the Orion Nebula, the velocity data has been used to analyze subjects such as the kinematical models for the nebula and the presence of high velocity components in restricted areas of Orion.

In the first section of the chapter, evidence for the existence of three velocity components in the nebular profile of the $[\text{OIII}]\lambda 5007$ line at the center of the Orion Nebula is presented. We discuss our results in relation to the available observational data, and present a model to explain the velocity structure as the interaction of a "champagne" flow with a stellar wind bubble and secondary streams from inhomogeneities in the nebula. The existence of turbulence in M42 is analyzed by three different approaches: structure function, line width, and dispersion analysis. New observations of weak, high-velocity components and line splitting are shown. The present work gives strong evidence for structured fine scale motion, i.e., that there is a correlation between random velocities and

distance across the face of the nebula.

The second part of the chapter is dedicated to discussing the velocity structure and turbulence of the area around θ^2 Orionis A. We suggest that it is a region isolated from the Trapezium area. High-velocity emission from condensations in the area are reported.

We conclude with a brief summary of our results. As always happens in scientific research, new questions and problems are raised. We suggest some future programs that could help in clarifying some of the issues that remain unsolved.

5.1 The θ^1 Orionis Region

5.1.1 Structure of the nebular line

Not a single profile in the core of Orion could be fitted by one gaussian line. Whereas a few positions required two, a typical profile required a three-line fitting; one very broad and of low peak intensity together with two strong, narrow lines of variable ratio of intensity. A few cases of very low intensity, high negative velocity were found. Previous studies gave an indication of asymmetry of $[\text{OIII}]\lambda 5007$ in Orion, (Wilson et al. 1959; Smith and Weedman 1970) and multiple components in the line profile (Meaburn 1984), but no attempt at a systematic study had been done until the present one.

Typical cases are shown in Figures 5.1 to 5.6: a very intense line, a lower intensity line and a broad component (Fig. 5.1); two principal components with approximately the same intensity (Fig. 5.2); line splitting (Fig. 5.3); two-gaussian fittings (Fig. 5.4); a complex structure with 4 components (Fig. 5.5); a high velocity component blue-shifted with respect to the principal line (Fig. 5.6).

Fig. 5.1: Typical three-components line: 26.8" E, 5.1" N from θ^1 Ori C.

Fig. 5.2: Three-components line: 42" E, 10.7" S from θ^1 Ori C.

Fig. 5.3: Example of line splitting: 29.2" W, 22.5" S from θ^1 Ori C.

Fig. 5.4: Two-gaussian fitting: 39.6" W, 35.7" N from θ^1 Ori C.

Fig. 5.5: Four component line: 33.6" W, 29.4" S from θ^1 Ori C.

Fig. 5.6: Example of a weak high velocity component blue-shifted with respect to the principal line: 17.9" W, 9.8" S from θ^1 Ori C.

5.1.2 Study of nebular components

5.1.2.1 Continuity

For each position angle, the individual components of the line profile were plotted from highest to lowest peak intensity, as a function of their distance from the reference star. Examples are given for the two most intense lines on the spectra Orion A to D (Fig. 5.7), B to C (Fig. 5.8) and A to C (Fig. 5.9).

A peculiar behaviour is observed from the examination of the plots of velocity vs. position. In some positions the two more intense components show discontinuities in the velocity, i.e. positions $r = 12''$ and $0''$ in Orion A to D, and $r = -16''$, $-8''$ and $4''$ in Orion B to C, when observed individually. This apparent discontinuity is the result of the intensity change of the components over the surface of the nebula. Any kinematic study must first disentangle the physical components of the flow, and identify their continuity.

Beginning at the center of a particular position angle (position of the brightest star), we scanned along the slit, identifying the continuity of each component. The guidelines used were line width, velocity and intensity of the line, in that particular order; based on the fact that if the components represent different elements of the flow, the FWHM (related to the depth of the emission layer) is the more representative element in the nebular line for identification of physical continuity.

Compilation and depiction of the data as plots of heliocentric velocities along the slit image revealed that the separate line components were actually three principal velocity systems, which we have called A, B, and C. Component A was in general more intense than Component B, whereas Component C had the lowest peak intensity with the broadest line width.

Fig. 5.7: Plot of separate component heliocentric velocity along the length of the entrance slit. Filled and open circles represent the two more intense components in decreasing order of peak intensity. The Trapezium stars $\theta^1 A$ and D were used for guiding.

Fig. 5.8: The same that figure 5.7. The Trapezium stars θ^1 B and C were used for guiding.

Fig. 5.9: The same that figure 5.7. The Trapezium stars θ^1 A and C were used for guiding.

5.1.2.2 Self-consistency

The solution was checked for self-consistency. At a given intersection region observed by two or more different position angles, the values of velocity for each component given from the different sets of data must agree. In addition, if we compare the velocity plots of two-dimensional spectra at close spatial separation, the behaviour of the plots for each component must be similar. The two-dimensional spectra noted as Orion A to B, A to D, B to C, B to D and C to D were studied over the Trapezium area for consistency. Following that, the remaining nine spectra were compared with the previous solution, and the definitive values for Components A, B and C at the positions of the Trapezium stars were obtained. Then, we examined the remaining intersection positions between spectra with different position angles, beginning from the inner zone, and moving to the outside of the Trapezium. In each position where a discrepancy between the velocity values of the same component was detected, the three-component solution for each spectrum involved was reanalyzed and the appropriate correction determined. After each correction the complete set of intersection points was checked again for contradictions.

The same process was repeated until a self-consistent data set was determined. The data, which constitute the basic information utilized in the analysis, is recorded in Appendix I; this Appendix contains the velocity data for the different components for the fifteen position angles studied.

The final set of data for components A and B does not include an area north of the Trapezium, due to the lack of enough information to decide between two possible solutions for both components. Whereas the data has its own intrinsic value, we decided not to use it in the following discussion. For that particular area, in Appendix II we show the values for the two more intense components. Component C are easy to identify, and are indicated in

the table. A complete solution for the three velocity systems is illustrated in Fig. 5.10.

Fig. 5.10: The three systems in M42 are illustrated in this plot of separate components heliocentric velocity along the length of the entrance slit. Filled circles, open circles and filled squares represent the line components in decreasing order of peak intensity. The dashed lines connect system A, the dotted lines system B, and the remainder of the data points belong to system C. The Trapezium stars θ^1 A and D were used for guiding (from Castañeda and O'Dell 1987).

5.1.2.3 Flow analysis

The observations having provided a map of the velocities and FWHM for each of the velocity systems, the question then becomes one of how to use this map to characterize and understand any turbulence in the Orion Nebula. What we want to do is to meaningfully provide measures of the random velocities, separate from flow due to large-scale motions arising from evolution of the nebula as a whole.

The study of the mass flow across the face of the nebula is essential. The calculation of the structure function for the analysis of turbulence must remove any large scale motions due to mass flow; otherwise, artificial correlations will be established in the velocity field. Furthermore, the flow models could give an indication about the validity of dynamic models for the nebula.

Two-dimensional velocity maps for the three components (Fig. 5.11 to 5.13), each point representing the mean velocity with its error in an area of $10'' \times 10''$, were prepared for the analysis of the flow structure. The maps show a structure that is not apparent from the study of the velocity data of Wilson et al. (Fischel and Feibelman 1973).

It is important to remind the reader in the following discussion that the lower the absolute values of the radial velocities, the higher the velocity of the gas moving in the direction of the observer and, at the same time, the higher the velocity of the gas moving away from the molecular cloud.

Fig. 5.12: Two-dimensional map for the component B. Each point represents the mean velocity with its error (in parenthesis) in an area of $10'' \times 10''$.

Fig. 5.13: Two-dimensional map for the component C. Each point represents the mean velocity with its error (in parenthesis) in an area of 10" x 10".

5.1.2.3.1 Flow analysis for Component A

This component of the velocity field shows a definite structure (Fig. 5.11), in which the radial velocity decreases from the values at the Trapezium to the outer region. The maximum value is about 7" north-east of θ^1 Orionis C ($x = -5''$; $y = +5''$). The data set includes 805 points, with mean velocity of $(18.71 \pm 0.13) \text{ km s}^{-1}$, standard deviation of 3.68 km s^{-1} . The velocities are blueshifted with respect to the molecular cloud. The radial velocity mass flow can be represented by a system of elliptical isovelocities, centered on the position of the velocity maximum, and with the symmetry axis over the north-south axis.

We conjecture that Component A may represent the interaction of the main section of the gas flow coming from the molecular cloud with the stellar wind from one or several Trapezium stars, as described by the Pankonin et al. (1979) model (Fig. 5.14). The maximum near the Trapezium probably is the effect of the obstruction of the ionized gas coming in the direction of the observer by the stellar wind of the star.

A strong argument in favor of the stellar bubble model is the evidence for stellar wind over θ^1 Orionis C, with terminal velocity of 1650 km sec^{-1} (Snow and Morton 1976), which could also provide a source for the discrete emission of X-rays, located at the Trapezium by the Einstein Observatory (Bianchi 1982). The star θ^1 Orionis D also shows stellar winds.

The proposed model also provides an interesting explanation to a particular feature of the velocity field. An examination of the velocity plots along the slit seems to indicate an area $\approx 30''\text{-}40''$ in length, centered around the Trapezium, where components A and B show a definite split structure (Fig. 5.15).

Fig. 5.14: Model of the core of the Orion Nebula (after Pankonin et al. 1979).

Ultraviolet radiation emitted from the star θ^1 Ori C creates a cup shaped cavity of ionized gas. Marked in the right hand scale are the velocities (with respect to the local standard of rest) of the neutral / molecular gas (V_n), of the carbon recombination lines (CII), of the Trapezium stars (V_s) and of the ionized hydrogen at the inner and outer part of the cavity (V_{HII} and V_{io} respectively) (From Goudis 1982).

Fig. 5.15: The area close to the Trapezium is illustrated in this plot of separate components of heliocentric velocity along the length of the entrance slit for three different position angles. Filled circles and open circles represent the more intense components in decreasing order of intensity. The dashed lines connect system A and the dotted lines system B.

This is probably what we are looking at: the high velocity (deceleration) close to θ^1 Ori C, the result of the gas blocked by the stellar wind in the area towards the molecular cloud; then the velocity decreases (accelerating) to both sides, as it moves around the cup formed by the interaction of the main flow with the stellar wind. The gas is forced to squeeze out at higher velocities around the edge of the cup (Harwitt 1982). For component B, we see the opposite: the flow just behind the cup has the maximum velocity, with the velocity increasing (decelerating) to both sides. A simple analogy to the process is the classic fluid mechanics problem of the interaction between a plane parallel flow with a point source. Given an upper limit for the mass loss rate $\leq 10^{-7} M_{\odot} \text{ yr}^{-1}$, Franco and Savage (1982) estimated the radius of the bubble as $R_b \leq 10^{17} \text{ cm}$ or $\approx 17''$ at the Orion distance, compatible with our ideas.

5.1.2.3.2 Flow analysis for Component B

This element of the velocity field seems to represent a different physical part of the flow. The number of points in the data set is 711; the mean velocity is $(12.44 \pm 0.17) \text{ km s}^{-1}$, standard deviation of 4.44 km s^{-1} . The velocity gradient was represented by a linear function, the velocity values decreasing from the north-east to the south-west. Notice the area around θ^1 A, where the velocities are strongly blueshifted with respect to the surroundings. This feature, which can be observed in Fig. 5.7 and 5.9, was discovered in all the spectra that included θ^1 Ori A. A reason for the observation is not obvious, but it merits further consideration.

5.1.2.3.3 Flow analysis for Component C

For Component C the mean velocity was $(22.49 \pm 0.19) \text{ km s}^{-1}$, with a standard

deviation 5.86 km s^{-1} . The data set is comprised of 925 points. Here the velocity field does not show a clear pattern and, as a consequence, an empirical flow model was not calculated. Component C is difficult to interpret. We discard its association with the expanding shell in the Orion-Eridanus region (Reynolds and Ogden 1979), due to the lack of agreement with the kinematic data.

5.1.2.3.4 General discussion

Establishing the existence of the three-velocity systems in the inner part of M 42 is an important result of this investigation, because it argues in support of the complex, face-on type model first advanced by Zuckerman (1973). Our present understanding of the dynamics of the Orion Nebula suggests that the presence of multiple components in the nebular profile is due to contributions to the $[\text{OIII}]\lambda 5007$ line of different flows and different regions along the line of sight. The situation is similar to that described by Balick et al. (1974), with secondary flows coming, for example, from condensations of neutral gas interacting with the primary stream of ionized gas from the molecular cloud. The discontinuities in velocities probably indicate changes in the physical region that are giving rise to portions of each velocity system.

The biggest objection to this interpretation comes from numerical simulations using the "champagne" model. Provided adequate geometry, the existence of components could be simulated by the integration of the projected velocity over the line of sight, along a long path where the physical conditions of the flow, for example density and velocity, change (Yorke et al. 1983, 1984). The limited range of spatial scales examined by this model makes its testing difficult until additional observational evidence (e.g., comparison with observations of other nebular lines) is available.

The maps show that Components A and B, and to a lesser extent Component C, are blueshifted with respect to the Molecular Cloud and the Trapezium stars, which is an indication of a flow coming in the direction of the observer. In the models discussed in Sec. 2.3, M 42 was described as a front-illuminated ionization boundary with the gas coming off at a heliocentric velocity of $+28 \text{ km s}^{-1}$ while the foreground illuminating stars are at 29 km s^{-1} . The predominant HII emission is at $+16 \text{ km s}^{-1}$, this smaller velocity being due to a net expansion of 12 km s^{-1} toward the observer, who is looking in through an open window which allows optical observation of both the nebula and free expansion. In this model our component A would be located between the region of dominant HII emission and the ionization front, while component B would be closer to the observer than even the averaged HII emission. System C is more problematic. Its velocity would place it the closest to the ionization front and the large FWHM would argue for its being a region of high density and large radial velocity change, which would be consistent with location immediately in front of the ionization front.

5.1.3 Study of the turbulence

Three methods for the study of turbulence were employed. First, we used the structure function. Then, we calculated the non-thermal component of the velocity field from the FWHM. Finally, we examined the dispersion of velocities in relation to sample size.

5.1.3.1 The structure function

The structure function was selected for the statistical study of the turbulence in the velocity field. Several characteristics make statistical analysis attractive (cf. section 1.3). Its

two-point correlation makes possible the use of many more data points in the calculation of the velocity properties at a given distance. Considering such, it is inherently more sensitive to the exact nature of the turbulent process (O'Dell et al. 1987). Its large absolute value makes it less sensitive to instrumental dispersion corrections. The restriction of the study to a small area at the center of Orion, provides us with a turbulent velocity field that is, as far as possible, homogeneous and isotropic, and without detectable flow discontinuities. The large set of data assures that there is no bias problem in the calculation.

From the statistical point of view, the data sample is a portion of the total population of radial velocities that can be measured, but because the set is relatively large, this structure function is a good estimator of the true structure function.

5.1.3.1.1 Instrumental dispersion

The value of the instrumental dispersion for each component depends on the random errors accumulated in the process of acquisition and reduction of the data: instrumental error, numerical error in the results of the fits, corrections in the velocity, comparison and averaging of different spectra, etc. The mean quadratic dispersion of the difference in velocities on the common intersection points for different position angles for each component can be taken as an accurate representation of the instrumental dispersion. Comparison of exposures at 51 points of intersection of two or more slits shows that the dispersion of radial velocities is: $\sigma_A^2 = (0.29 \pm 0.10) \text{ km}^2 \text{ sec}^{-2}$; $\sigma_B^2 = (0.65 \pm 0.18) \text{ km}^2 \text{ sec}^{-2}$; $\sigma_C^2 = (4.92 \pm 1.42) \text{ km}^2 \text{ sec}^{-2}$.

5.1.3.1.2 Calculation of the Structure Function

The procedure for the calculation of the structure function was straightforward. For

components A and B the systematic motions were subtracted from the observed radial velocities. The results of these corrections were radial velocities varying from point to point only by the uncertainties in the measurements and the random motions. The structure function was computed by selecting all the possible combinations of pairs of points within a given sample size, $(\Lambda - \Delta) \leq \Lambda \leq (\Lambda + \Delta)$, Λ being the angular separation for the velocities, and then obtaining the mean quadratic velocity difference. The bin size selected was 2" ($\Delta = 1''$), so that the statistical sample formed from the data set is quite large. The structure function was then corrected for instrumental dispersion (O'Dell 1986) by

$$B_{\text{true}}(\Lambda) = B_{\text{obs}} - \sigma_{\text{inst. disp}}^2 \quad [5-1]$$

The structure functions given in Table 3 and Figures 5.16 to 5.19 were derived from the data corrected for large-scale motion and have been corrected for instrumental dispersion.

5.1.3.1.3 General discussion

The derived $B(\Lambda)$ is quite different from the earlier studies of von Hoerner (1951) and Münch (1958) (Fig. 2.8). The behavior of the structure function is very similar for each velocity system but each system shows an appreciable difference in the absolute value of the structure function (Fig. 5.19). There is a definite correlation between velocity and distance for at least Components A and B, and to a less degree for component C, indicating the presence of statistical regularities. Nevertheless, the structure function does not show the simple behavior predicted by the straightforward approach of the Kolgomorov model.

Fig. 5.16: Observed structure function for component A.

Fig. 5.17: Observed structure function for component B.

Fig. 5.18: Observed structure function for component C.

Fig. 5.19: The observed structure function is shown as a function of separation distance. Filled circles, open circles and filled squares represent velocity systems A, B, and C, respectively.

The structure function shows variations from the expected smooth slope far beyond the probable errors of the determinations and does not fit the simple models over the entire range. This argues that the energy source driving the turbulence is input at several scales.

Münch (private communication) has pointed out that scattering of the emission lines by dust in the nebula would diminish the correlation of velocities with distance and the resultant values of $B(\lambda)$, this being the most important effect of the dust. Such a case has not been modeled, but it seems that the thin slab model would have to apply before these effects would be important.

It is very unlikely that the source of disagreements with the theory lies in the plane parallel model of von Hoerner. The basic mathematical model is correct, and the application to the core of the Orion Nebula should make this simplified approach accurate.

The application of the simple approach described in sec. 1.2.6.2 with a $2/3$ power law for $B(\lambda)$ does seem not possible. The order of magnitude of the slopes at smaller distances would indicate that each velocity system is a thin slab, either physically or optically. It seems very unlikely that all three velocity systems would happen to be thin slabs seen face on, so this interpretation is unlikely. The interpretation of a thin slab being due to a large optical depth could only be used to explain the most distant component, otherwise the other velocity systems would be obscured. Since it is unlikely to have a combination of the front two systems being thin slabs of the correct orientation aligned in front of an optically thick system, the correct interpretation must lie elsewhere. Furthermore, the simple model predicts an increase in the value of the structure function, and when the distance between points is larger compared with the depth of the nebula, the slope of the function is $= 2/3$. Since the structure function seems to flatten at large distances, this is another argument against the simple thin slab model.

The same remarks apply if we keep the turbulent field isotropic and homogeneous, but change the exponent of the correlation function to a general coefficient. It seems that more complex models are necessary to explain the observations, but the problem is that if we increase the number of free parameters that are necessary to fit the data, this could render ambiguous the interpretation of the results.

If we conclude that there is not a simple model that can be used for the description of the observed $B(\Lambda)$, we must ask ourselves what is the physical reason. In the conventional theory, energy is injected "on the top" of the linear scale, and transferred without dissipation to the Kolmogorov microscale, where it is dissipated into thermal energy. If the system injects or dissipates energy at intermediate scales, the form of $B(\Lambda)$ will be altered.

The most attractive interpretation is that the small slope of the observed structure function is due to the input scale of the turbulence being small as compared with the larger separation distances and that the irregularities of the slope are due to input at several sizes. Unfortunately, this interpretation does not allow a test of just how closely the power index of $2/3$ ever applies.

One basic assumption of the above models is that the turbulence arises from the largest eddy size, even in the thin slab model, and is present at all the smaller sizes. No consideration is given to the introduction of a scale for decorrelation of the velocity field. Kaplan and Pikelner (1970) have considered the case where the turbulence is introduced at a size smaller than the maximum size of the nebula and show that the expected behavior of $B(\Lambda)$ is the same as before, except that $l(\Lambda/R)$ is now scaled to the dimension at which the turbulent energy is introduced. Such a model would allow an observed $B(\Lambda)$ which is much flatter than the power index n , and could even have structure in $B(\Lambda)$ by having the turbulence introduced at several scale sizes. The correlation function can be represented as

(Kaplan and Pilkerner 1970)

$$(v_1 - v_2)^2 = \frac{(\epsilon L)^{2/3}}{[1 + (L/r)^{2/3}]} \quad [5-2]$$

were $r = |r_1 - r_2|$, and ϵ is the rate of transfer of energy. The factor L characterizes the scale for input of energy and the scale of correlation. $B(r) = (\epsilon r)^{2/3}$ for $r \ll L$ (Kolgomorov's Law), and $B(r) = (\epsilon L)^{2/3}$ for $r \gg L$ (decorrelation). In a general case, we can consider L as a fraction of R , the depth of the integration. The structure function has a form

$$B(\Lambda) = C^2 l^n \int_0^{1/l} \left\{ \frac{1}{[l^n + k^n (1+x^2)^{-n/2}]} - \frac{1}{[l^n + k^n x^{-n}]} \right\} (1-lx) dx \quad [5-3]$$

where $k = L/R$.

This approach addresses the problem of the scale of correlation. It seems probable that the value must be related to the size of the larger eddies. A natural lengthscale is provided by the size R of the layer. We have tested two different models, $k=1$, and $k=0.1$. Both provide flatter curves compared with the straightforward power models, but the results become dependent on the free parameter L . Again, a simple model is not enough to explain the shape of the functions.

5.1.3.1.4 Behavior of the structure function at small distances

At small distances, the same systematic trend for the three components holds. For

distances $\Lambda \leq 15''$, the structure function shows a definite correlation between velocity dispersion and distance; a linear least squares fit for the structure function represented as a power law of the type $B(\Lambda) = M \times \Lambda^n$, gives for component A the value of the exponent as $n = (0.861 \pm 0.052)$, r (correlation coefficient) = 0.991. For scales $\leq 11''$ the behavior for component B is similar; the least-square fit gives $n = (1.013 \pm 0.080)$, $r = 0.998$. For component C, a linear least-square fit for $\Lambda \leq 11''$ gives $n = (0.750 \pm 0.111)$, $r = 0.968$. That section is the most sensitive to subtraction of the correction for instrumental dispersion, but since this correction was only about 9-22% of the uncorrected structure function, this uncertainty is unlikely to have much effect on the final $B(\Lambda)$. The smallest separations plotted correspond to mean angular separations of only 3 seconds of arc. Our data was reduced in units of two seconds of arc since the seeing was frequently of this size; but never better and often worse. No observations were made in conditions worse than four seconds of arc. The poorest seeing would make adjacent fields artificially appear to have similar velocities, thus suppressing the derived value of $B(\Lambda)$. This may account for the drop in the structure function at the smallest separation in each velocity field, but should not affect any other points.

The analysis of the three different structure functions hints that there is a "plateau" for the structure function in the zone of $10''$ - $20''$. It can be argued that the value 0.025-0.05 pc ($10''$ - $20''$) is a characteristic physical length of the system, but it is not clear what to associate that length. Furniss et al. (1983) found $D = 0.028$ pc as the depth necessary to produce the intensity observed in the $52\mu\text{m}$ and $88\mu\text{m}$ [OIII] infrared lines (relatively unaffected by extinction), in a 1.65 arc minutes field of view centered on the Trapezium. The result is model dependent on the density and the chemical abundance in Orion along the line of sight. It could be that the characteristic length is a sheet of material,

perpendicular to the line of sight, responsible for the emission.

5.1.3.1.5 Behavior of the structure function at intermediate distances

In the case of component A, for the distances $15'' \leq \Lambda \leq 35''$, apparently there is decorrelation in the structure function. For $35'' \leq \Lambda \leq 100''$, the function becomes correlated again and, for the same function described previously, the power coefficient is $n = (0.501 \pm 0.023)$, $r = 0.993$.

For component B, at $\Lambda > 11''$ the structure function clearly shows decorrelation; statistical correlation is only observed at a small scale, on the order of tens of arc sec. It can be argued that the structure function must decorrelate at some point, the length corresponding to the size of the largest turbulent eddies. The behaviour of $B(\Lambda)$ could be understood in that case as indicating that the maximum correlation length for that component of the flow is very small. It could happen that component B is a form of secondary flow, lacking the statistical relationship that is observed for a flow coming from a unique source, as for example, we would expect for component A in our model.

In the case of component C, for largest distances the structural function does not show a well-defined behaviour.

5.1.3.1.6 Behavior of the structure function at large distances

The downward hook in the structure function values seen at the larger separations is the same type of feature seen in the studies of the entire faces of several nebulae (Roy and Joncas 1985; Joncas and Roy 1986; O'Dell 1986), where the hook could be accounted for by the conditions of turbulence changing at the boundaries of the nebulae. However, this explanation is not possible here, because it would require our fortuitously having sampled

exactly over the frontal size of the regions forming velocity systems A and B. Edge effects (J.-R. Roy, private communication) must be ruled out in the case of Orion, because we are only studying a small fraction of the nebula. Moreover, we see the small hook in the $B(\Lambda)$ determined for NGC 6514 and NGC 6523, where the area sampled was only a small fraction of the frontal area (O'Dell, Townsley, and Castañeda 1987). The dependence upon the sample number was tested with the Orion data by taking successively smaller partial samples. In this case we saw the hook remain, but rapidly disappear within the scatter of the derived $B(\Lambda)$ values, indicating that the reliability of the $B(\Lambda)$ results diminishes rapidly at the outer edge of the sample, where the number of maximum separation entries diminishes more rapidly. In the case of a statistical effect, we should expect a simple scattering of the data points, without a systematic downward characteristic. In a private communication, John Scalo has suggested that the hook could represent a sampling effect where the largest separations are located on the same eddy, having the same velocity, which would cause the structure function to drop towards zero.

5.1.3.1.7 Validity of the Kolmogorov model of turbulence

The mathematical calculation of the structure function requires a series of physical assumptions associated with the particular theory of turbulence. In the case of the Kolmogorov model, the basic hypotheses are: (a) incompressible flow, (b) an isotropic and homogeneous velocity field, (c) fully developed turbulence (steady-state), (d) with a gaussian distribution of velocities. In the case that any of the assumptions would prove inadequate, the application of the Kolmogorov theory would become questionable. We examine each of the hypothesis in greater depth in the following sections.

5.1.3.1.7.1 Incompressibility hypothesis

From the measurement of the line width we can have an estimate of the correctness of the assumption of compressibility. As discussed in sec. 1.2.6.1, the non-thermal component of the FWHM gives an indication of the order of magnitude of turbulence. The values obtained (sec. 5.1.3.2.1) seem to indicate that, at least in components A and B, the non-thermal component is smaller than the sound velocity, so there is a good chance that the flow could be incompressible. For component C the opposite applies, but the difficulty of disentangling flow effects from true random motions does not allow us to reach firm conclusion about compressibility.

The problem of the application of the theory of incompressible and homogeneous turbulence to a compressible medium with density fluctuations and self-gravity has been considered. Lightill (1955) estimated that, for small Mach numbers, turbulence in a compressible medium would generate quadrupole acoustic waves and thereby increase the energy dissipation somewhat, but it may be that small density fluctuations have little effect on turbulent flows (Bradshaw 1977).

The effect of shock dissipation is to steepen the velocity vs. separation correlation (Kaplan 1966; Larson 1981), while the injection of turbulent energy at smaller scales of motion would act to soften this relationship (Fleck 1983). The Kolmogorov model seems then inappropriate for the compressible general interstellar medium, which is typically characterized by supersonic velocity amplitudes and by energy exchanges over an enormous range of length scales (Fleck 1983); in a supersonic regime part of the kinetic energy is immediately dissipated into thermal energy in the form of shock waves. Nevertheless, there are not "a priori" objections for the application of this model in gaseous nebulae. It is useful to note that there is an indication of the validity of the Kolmogorov

model in atmospheric turbulence, an obvious case of a gas that is not perfectly incompressible.

5.1.3.1.7.2 Continuity of the flow

Our study characterizes the velocity field in a very restricted area of Orion; flow corrections have been introduced to the data. Examination of the velocity maps does not indicate discontinuities in the flow, so it seems that the assumption of isotropy and homogeneity is valid.

5.1.3.1.7.3 Steady-state condition

The importance of this condition must be emphasized. It must be remembered that the Kolmogorov spectrum corresponds to a stationary case, where an equilibrium between energy input and dissipation has been reached. If that stage has not been reached, the spectrum of turbulence will be different than that described above. The nebula appears to be in a state of continuous flow, with the material flowing from the molecular cloud being continuously replenished, so it is reasonable to assume that a certain type of stationary flow has been reached. The steady-state or "fully developed" turbulence condition will depend on the comparison of two timescales: the age of the nebula and the typical time for development of a turbulent field. The canonical age of the nebula can be taken as 10^5 years. The timescale for the development of turbulence will be on the order of that of the physical process that acts as source of energy. In consequence, a check for the validity of this hypothesis will depend to the development of a realistic model for the source of turbulence.

5.3.1.7.4 Gaussian distribution of velocities

A gaussian velocity distribution is assumed in the Kolmogorov theory. As discussed in Chapt. 2, the velocity field in the nebula is the sum of a systematic plus a random component. The integrated value of velocity, after correction for mass flow, reflects the turbulent motion.

If that component is a Gaussian stationary random function, then the integrated value is a random variable with a Gaussian distribution (Kampe de Fariet 1955). It follows that the radial velocity histograms must show a gaussian distribution. An analysis of the histograms for the three components after flow corrections (Fig. 5.20 a to c) shows skewness for component C. Components A and B may be considered to have, at first approximation, a gaussian distribution of velocities.

Provided that the simple power law could be used as a representation for the correlation of velocities, what could cause a change in the numerical value of the exponent? A reason may be the fact that turbulence is intermittent. A conceptual problem recognized early in the Kolmogorov theory was that the energy dissipation rate per unit mass must be a random function of the spatial coordinates and time. The energy associated with small scale structures is distributed very unevenly in space, being confined to a smaller and smaller fraction of the available space as the eddy size decreases (Monin and Yaglon 1975, sec. 25); this phenomenon is called intermittence. The theory was originally developed by Oboukhov (1962), suggesting that ϵ would have a log-normal distribution, given by (Leslie 1973)

$$\epsilon = \epsilon_0 e^{\left[\eta - (\beta/2) \right]} \quad [5-4]$$

where η is a normal or Gaussian variable satisfying $\langle \eta \rangle = 0$; $\langle \eta^2 \rangle = \beta$.

Fig. 5.20a

Fig. 5.20b

Fig. 5.20c

Fig. 5.20: Histogram of radial velocities for Components A (5.20a), B (5.20b), and C (5.20c).

The phenomenon of intermittency is related to the Mandelbrot fractal model of turbulence, where the fractal dimension D is a measure of the extent to which the regions in which dissipation is concentrated fill space (Paladin and Vulpiani 1986).

An attempt to modify the theory by Frisch et al. (1978), with what they call the beta-model, has been extended to astrophysical objects (molecular clouds), which are regarded as rather small turbulent structures (Ferrini et al. 1982). The different theoretical approaches to the problem result in a higher value for the exponent in the power spectrum of turbulence, just the opposite to what the observations suggest from the simple model.

5.1.3.1.8 Source of turbulence

After we have established the existence of statistical correlation for the velocities in Orion, we must address the problem of the source for the turbulence. Turbulence is a phenomenon intrinsically dissipative. The energy dissipation rate per unit mass (ϵ), regardless of the particular form of the spectral law characterizing turbulence (von Weizacker 1951), is of the order of (Landau and Lifschitz 1959)

$$\epsilon = - \frac{\mu v_l}{l} \quad [5-5]$$

(μ = viscosity; l and v_l = size and velocity of the larger eddies).

The dissipative nature of the phenomenon requires a mechanism continuously supplying the energy fed to the cascade, or the turbulence would decay into thermal energy. Different sources have been proposed, depending of the type of astrophysical situation: differential galactic rotation (Fleck 1981; von Weizacker 1951); T-Tauri winds

(Norman and Silk 1980); gravitational energy (Scalo and Pumphrey 1982; Ferrini et al. 1983) or Kelvin-Helmholtz instabilities (Roy and Joncas 1985).

In the particular case of Orion, the physical model represents a continuous flow of material from the molecular cloud to the HII region. Two possibilities for the source of turbulence may be considered: either (a) the turbulence is generated by a physical process in action in the flow or (b) the neutral gas in the molecular cloud is in an original state of turbulence. It seems apparent that it would be very difficult for a flow to remain laminar as is represented in the champagne models (see, for example, Fig. 2 in Tenorio-Tagle 1982), and not develop instabilities. Roy and Joncas (1985) have suggested the possibility of the development of Kelvin-Helmholtz instabilities in the champagne flow, leading to vorticity and to a turbulent cascade process. Also, as discussed in sec. 4.4, the interactions of flows coming from globules of neutral gas inside the nebula could create a turbulent field.

Because the ionized gas leaves a surface beyond the ionizing stars, it is obvious to ask ourselves if the molecular gas is in an initial state of turbulence. Harwitt (1982) estimates that the molecular cloud is turbulent in its interior and quiet on the surface, but no quantitative estimation of the turbulence is given. A possible test of this hypothesis is to observe an emission line with low ionization, which must originate close to the ionization front; consequently, the lines have a negligible flow velocity with respect to the front and the neutral material, and the line profile must reflect the kinematic state of that area. A single observation by Münch and Taylor (1974) in $[\text{OI}]\lambda 6300$ indicates a FWHM for the line (visually estimated from their data) of approximately 14 km s^{-1} , after correction for instrumental line width. More recent Fabry-Perot observations of Münch and Hippelein (1982) in $[\text{CI}]\lambda 9850$ indicate a FWHM of 6.1 km s^{-1} . This value can serve as an indication of the kinematical state of the gas if we can estimate the temperature of the gas; for $T =$

100-1000 K, the non-thermal component is around $6.1\text{-}5.8 \text{ km s}^{-1}$, which would lead us to conclude that the value is close to the computed value of FWHM for components A and B, and that in consequence the gas has an intrinsic turbulent state that extends to the champagne flow.

5.1.3.2 Turbulent width

5.1.3.2.1 Computing the values for FWHM

For each nebular line, we computed the value of FWHM for the turbulent component of the emission line. Given the scale of our observations (at the angular limit of resolution), the turbulent motions represent the random motions along the line of sight and not mass flows over the surface of the nebula. The calculation required an assessment of the nebular temperature. We assume that the profiles have thermal widths corresponding to a temperature of 9175 K, determined by Peimbert (1967) from the ratio of $[\text{OIII}]\lambda 4363/\lambda 5007$. The thermal line width derived from equation [1-11] is $\text{FWHM} = 5.35 t^{1/2}$ for oxygen, where t is the electron temperature in units of 10^4 Kelvin degrees, or $\text{FWHM (thermal)} = 5.12 \text{ km s}^{-1}$ for the adopted temperature.

Component A showed a mean FWHM value of $(10.02 \pm 0.10) \text{ km s}^{-1}$. Component B showed a FWHM of $(9.48 \pm 0.12) \text{ km s}^{-1}$, whereas component C had a mean width of $(31.26 \pm 0.21) \text{ km s}^{-1}$. The FWHM's corrected mass motion are then (8.42 ± 0.12) , (7.66 ± 0.15) , and $(30.82 \pm 0.21) \text{ km s}^{-1}$, for components A, B, and C respectively. This remaining width must be the addition of turbulence along the line of sight and the large-scale motions. Unlike the case of the structure function, it is difficult to isolate the latter and make the corresponding correction in FWHM.

The values for the turbulent component are smaller than those previously cited in the

literature. Wilson et al. (1959), with an angular resolution comparable with our work, obtained for the mean square velocity of mass motion in one component, for $[\text{OIII}]\lambda 5007 \text{ \AA}$, values from 5.0 to 7.7 km s^{-1} , equivalent to most probable turbulent velocities of 7.1 to 10.9 km s^{-1} (10% accuracy), with Smith and Weedman (1970) reporting a mean value for the most probable turbulence as 7.6 km s^{-1} , with an angular resolution varying from $7''$ to $12''$.

The difference in values can be easily attributed to the fact that most of the lines are not single gaussians. A line profile similar to that of Fig. 5.2 could be confused with a single gaussian function and result in a larger value for the line width. For the total set of data (992 positions) only 5% could be represented as almost a pure gaussian profile (Fig. 5.4). For those lines, the mean value of FWHM is $(9.39 \pm 0.20) \text{ km s}^{-1}$, in agreement with the mean values of Components A and B.

5.1.3.2.2 Discussion

Any interpretation of the previous results must take into account the presence of the systematic mass motions detected in our two-dimensional velocity maps. To separate the effect of macroscopic velocities from turbulence, we have minimized instrumental problems (with high signal-to-noise ratio, and maximum spatial and velocity resolution) and studied the single components of the velocity field. It is more difficult to assess problems such as different physical conditions for line formation along the line of sight. What is more relevant, the mass motions detected probably are broadening the line profile, making it difficult to estimate the real contribution of the turbulence component (Leung 1978). It is possible to remove mass flow from the radial velocity field over the surface of the nebula, but this does not mean that we have removed the effects inside the nebula.

Unfortunately, the uncertainties in the correction for large scale motions preclude a rigorous interpretation of the line widths. In the case of velocity systems A and B, the systematic velocities varied over 10 km s^{-1} . If a significant fraction of these velocities were also found along the lines of sight, then this would mask the turbulent components. System C showed no obvious large scale motions, with an upper limit of about 15 km s^{-1} , so that FWHM may be useful for future discussions.

The model of von Hoerner predicts the broadening of the line-of-sight emission line by turbulence along the line of sight distance (R), which can be either the physical or the optical depth (Fig. 1.3). The line width increases proportional to the square root of the power law that describes the velocity correlation. It is not clear what the effects of scattering by dust would be on the value of the line width, but we expect that it would broaden the line, giving higher values than those expected for simply the line of sight turbulence. If the scale size for the input of turbulence is smaller than R , then the FWHM will be correspondingly smaller. Independent of the turbulence model, we will expect that the FWHM will increase with depth.

It seems natural to study the variation of line width with position. This was done by taking averages at concentric samples of bin size 10 arc sec, from the coordinate center. Component A shows a systematic decrease in the value, from 11.97 km s^{-1} at the center to 8.69 km s^{-1} at the sample limit (80 arcsec from the Trapezium). Component B does not show a clear behaviour; the central area has a mean FWHM of 10.08 km s^{-1} , but then the line width decreases and then increases to 12.87 km s^{-1} , while the dispersion of values is appreciable at the sample limit. The same behavior is observed for component C, but with larger values for the line width.

The lack of an appropriate model for the effect of mass motions on line width

precludes us from making any final statement about the meaning of those results. Nevertheless, we can comment on what would happen if the problem were negligible. For a spherically symmetric nebula, one would expect the line width to decrease near the edge of the nebula, as the line-of-sight path through the nebula decreases. In our case we are only observing in a limited area, comparatively small compared with the whole of Orion, so this effect should be small. By the same consideration we preclude that a change of electron temperature will explain a systematic variation in FWHM. In the context of the model that we postulate for the three components the most probable explanation for the change of line width is the effect of integration over variable depths. The results would indicate that component A consist of a sheet of material of depth decreasing with distance from the center, whereas the material is more evenly distributed for the other two components.

5.1.3.3 Dispersion analysis

There is another analysis possible, which consists of the determination of the dispersion of velocities as a function of a sample size over the nebula. Changing the dimensions of the sample will change the volume it encompasses but not its depth, so a dispersion vs. sample size relation will reflect a correlation between size and velocity fluctuations (Roy and Joncas 1985). Turbulence theory predicts that the dispersion should increase with increasing size.

In the present set of data, the sample of velocities is good near the Trapezium stars but poor at larger distances. For this reason, we took non-overlapping samples of adjacent spectra of size s along the slit and calculated the dispersion of each sample. Then, the most probable turbulent velocity in one component - W - was calculated by multiplying the dispersion by $(2/3)^{1/2}$ (O'Dell 1986). The mean value of W for all samples of that size was

then taken and the dispersion of that mean value determined (O'Dell et al. 1987). The final values were corrected for instrumental dispersion (eq. [5-1]). These instrumental corrections were comparatively large for the smallest sample sizes where the dispersions were small. As a result, the shape of the dispersion-size relation is predominantly determined by the accuracy of these corrections. The dispersion relations are illustrated in Fig. 5.21 and given in Table 4.

Least squares lines were calculated for the power law $W = a D^n$, D the size of the sample, excluding the lower and higher points; the first because it was more sensitive to the instrumental dispersion correction, and the second to account for the smaller sample of data. The values of the n exponent were (0.136 ± 0.030) , (0.337 ± 0.064) , (0.395 ± 0.059) for components A, B, and C respectively.

A meaningful discussion of the dispersion data awaits a theoretical solution for the change of dispersion with respect to the sample size, such as von Hoerner's discussion of the structure function. Neither a specific ($n=2/3$) or general formulation of the solution for the most probable three-dimensional turbulent velocity (w) has been made; however, a general consideration must apply (O'Dell and Castañeda 1987), i.e., the differences in line-of-sight velocities will be less than those corresponding to the separation Λ , only approaching those velocities as l becomes very large. This would lead us to expect a dependence rising more rapidly than $\Lambda^{n/2}$ for l small and proportional to $\Lambda^{n/2}$ for $l \gg 1$.

Fig. 5.21: The most probable one dimensional turbulent velocity (W) is shown as a function of sample size (D) for the θ^1 Orionis region. Filled circles, open circles and filled triangles represent velocity systems A, B, and C respectively.

5.1.3.4 Special features of the velocity field

5.1.3.4.1 High velocity components

There is an appreciable body of information about the presence of high velocity components in Orion in the range $\approx -50 / -100 \text{ km sec}^{-1}$ (Schcheglov 1968; Meaburn 1971, 1986; Dopita et al. 1973; Traub et al. 1974). Due to the fact that the observations were obtained via Fabry-Perot techniques, they lacked the angular resolution necessary to make an identification with nebular features.

Five positions (Table 5) on the core of Orion, illustrated in Fig. 5.22, show a high velocity, very faint line blue-shifted with respect to the principal line (see Fig. 5.6). Most

of the positions seem to have a few arcsec size, and mean velocity of $(-29.40 \pm 1.57) \text{ km s}^{-1}$, with intensities 2-3 % of the principal line. The positions 3-4-5 are close to the ionized condensation founded by Lee (1969), 43.5" from θ^1 Orionis A in position angle 195° ; this condensation showing a velocity of -36.4 km s^{-1} for $[\text{OIII}]\lambda 4363$; based on the hypothesis that the violet feature observed in his spectra was $[\text{OIII}]\lambda 3727$, Lee estimated a lower density limit of 10^4 cm^{-3} .

The positions do not correspond to any peculiar feature previously detected. They are not any of the 10 small ionized knots in the core of Orion with many of the characteristics Herbig-Haro objects (Canto et al. 1980; Axon and Taylon 1984; Meaburn 1986), Herbig-Haro objects that also show high velocity components (Canto et al. 1980) or any of the six, quasi-stellar condensations discovered by Laques and Vidal (1979) near the Trapezium.

The nature of the features remains unanswered. The problem is not lack of models; possible explanations include free expansion from the dense molecular cloud into a "vacuum" and gas and dust accelerated by radiation pressure. Small but dense neutral globules completely covered by ionization fronts (Partial Ionized Globules -PIG's-), flowing away into their lower density surroundings, embedded in the gas, with sizes $< 0.01 \text{ pc}$ (Dopita et al. 1974) could explain the observations, but only observations in other wavelengths (e.g., $[\text{SII}]$, $[\text{OII}]$ or $[\text{NII}]$ data) would allow comparisons to check the model. We did not detect an equivalent red-shifted component of the velocity. A possibility (Axon and Taylor 1984) is that the source is within the molecular cloud, so the gas traveling away from the observer is substantially obscured as it buries itself in the cloud.

We think that the proximity of the features 3 to 5 is not accidental. Maybe they are the manifestation of the presence of an "elephant trunk" from a perturbation of the interface

between HII-HI, which disintegrated into several "blobs" or globules of dense HI (Vidal 1982) and that have become partially ionized globules, or they denote a continuous sheet of material with supersonic velocity, something that has not been studied in theoretical models. The next step is obviously observations of spectra in intermediate position angles.

Fig. 5.22: Positions where high-velocity blue shifted components were observed (compare with Table 5).

5.1.3.4.2 Splitting of the lines

We define a split line as a line that shows a double maximum in the nebular profile (Fig. 5.3). Only around 2 % of the observed positions showed this characteristic; the mean value for the separation of the components was $(10.52 \pm 0.40) \text{ km s}^{-1}$. No splitting of the

order reported by Wilson et. al. (1959) was recorded, but the mean difference in velocity between the two principal components is similar to the values recorded by Devarheng (1973) on $[\text{NII}]\lambda 6584$ using a different extensive area of Orion, near the $[\text{NII}]$ ridges in the outer region.

We can explain our observations as a consequence of the two principal components reaching approximately the same intensity and separated in a way that the line becomes split. The sequence in Figure 5.23 illustrates a transition from single to double line, due to a change in the relative intensity of the two components. The line splitting (Fig 5.3) was used by Münch (1958) as an argument to claim that the flow was compressible; the appearance of double lines was interpreted as the existence of discontinuities in the flow, produced by shock waves. Whereas this could be the case, our model seems more plausible.

Fig. 5.23a: 1.1" E, 12.5" N from θ^1 Ori C.

Fig. 5.23b: 2.9" E, 11.5" N from θ^1 Ori C.

Fig. 5.23c: 4.7" E, 10.5" N from θ^1 Ori C.

Fig. 5.23a to c: Transition from single to split line.

5.2 The θ^2 Orionis Region

5.2.1 Structure of the nebular line

The spectra of the θ^2 Orionis region show a complex structure similar to the Trapezium area, with three distinct velocity components describing each line, again identified as components A, B, and C. Nevertheless, the analysis is more difficult because the peak intensity of the lines is a factor 3 lower with respect to the weakest areas of the θ^1 Ori region, with typical signal-to-noise ratio of 30. Examples of the lines observed are shown in Figures 5.24 to 5.27: a three components line, with a very intense line, a lower intensity component and a broad component (Fig. 5.24); line splitting (Fig. 5.25); a high velocity component blue-shifted with respect to the principal line (Fig. 5.26-5.27).

Only three position angles were observed. The two spectra associated with PA180 rendered results that were incompatible; we could not identify whether the problem came from the election of the position angle or from the comparatively low exposure time (less than one hour). We decided to use them for the dispersion analysis but not for the calculation of the structure function or the study of the line width. The procedure for analysis of turbulence was analogous to section 5.1.3.

The problems described above, fundamentally the limited sample of velocities and the lower quality of the data, make the following results only a tentative indication of the possible characteristics for the velocity field. Only a systematic investigation in this area of the nebula (similar to that achieved for the Trapezium region) could yield more reliable information.

Fig. 5.24: A three-components line: 8.2" E from θ^2 Ori A.

Fig. 5.25: Example of line splitting: 31.4" E, 31.4" N from θ^2 Ori A.

Fig. 5.26: Example of a weak high velocity component blue-shifted with respect to the principal line: 10.1" W, 10.1" S from θ^2 Ori A.

Fig. 5.27: Example of a weak high velocity component blue-shifted with respect to the principal line: 16.3" W from θ^2 Ori A.

5.2.2 The velocity structure

The velocity structure seems to be different than that of the trapezium area. No apparent flow could be detected; the velocities seem to be uniform over the surface of the nebula; the flow seems to be much more quiescent. Again, three different velocity systems were identified. Note that in Fig. 28 components A and B show the same behavior. For position angle (PA) 270, a clear transition can be seen in the shape of the line along the slit, moving in the direction of the bar. The $[\text{OIII}]\lambda 5007$ line becomes much more intense and splits, the effect obviously of the ionization front running from θ^1 Ori. The bar, in effect, seems to divide two different velocity structures; at PA 270, for distances larger than ≈ 40 arc seconds West with respect to θ^2 Orionis A, the line intensity, form, and order of magnitude is similar to the Trapezium region.

Using the velocity data employed for the calculation of the structure function (cf. section 5.2.3) we calculated the mean values of velocity for each component. The results are mean velocities of (13.90 ± 0.15) , (2.91 ± 0.18) , and (21.90 ± 0.82) km s^{-1} for components A, B, and C respectively. The data seem to indicate that the area around θ^2 corresponds to a quiescent object, and not a champagne flow situation. The same type of quiet flow is observed in $[\text{SII}]\lambda 6716$, south of θ^2 Orionis A, with a mean velocity of around 20 km s^{-1} (Walsh 1982). The observations substantiate the idea that there is an HII region around θ^2 Ori, disconnected from the main flow, with the star a foreground and not a background object relative to the Trapezium (see Peimbert 1982 for a summary of the arguments). Fig. 5.29 illustrates that model.

Fig. 5.29: A schematic representation of the regions close to θ^1 and θ^2 Orionis (from Peimbert 1982).

5.2.3 Analysis of turbulence

To insured that we worked with a set of data genuinely representative of the region, the area near the bar was excluded from the analysis of turbulence. Also, we selected an area where component B was well defined. We have indicated in Appendix III the velocities that were used for the calculation of the structure function; the same values were utilized for the discussion of the turbulent line width.

5.2.3.1 Instrumental dispersion

The instrumental dispersion was obtained by looking at velocity values of each component for the central five spectra (around θ^2 Ori). Two instrumental dispersions were calculated, the first for the structure function (using only PA 225/270), and the second for the dispersion analysis (adding the two rasters for PA 180). Since for this particular area we only have one set of data for determining the instrumental dispersion in each velocity system, we are not able to estimate the accuracy of our dispersion correction.

In the case of the structure function, for component A the dispersion of velocities was 0.57 km s^{-1} , for component B it was 0.66 km s^{-1} , whereas for the less intense system (C) the dispersion was 1.48 km s^{-1} .

5.2.3.2 Structure function

Examination of the data did not show the existence of any large scale motion that arises from systematic gas flow; as a consequence, no corrections to the velocity data were necessary. The structure function was computed for the three components in a way analogous to that described in section 5.1.3.1.2. Because the data set is small, the computation is susceptible to bias error; the function can only be considered as an estimation of the true structure function. The number of points for each component was 102 (Comp. A), 66 (Comp. B), and 91 (Comp. C).

The final results are indicated in Table 6 and Fig. 5.30 to 5.33. Components A and B show a very similar behaviour. $B(\lambda)$ for component C is very irregular, with the points showing a large dispersion; it being very sensitive to the baseline of the fitting and, in consequence, very difficult to determine with confidence with a low signal-to-noise. Notwithstanding the limited number of points observed, the structure functions show a definite correlation between velocity and distance.

Fig. 5.30: Observed structure function for component A.

Fig. 5.31: Observed structure function for component B.

Fig. 5.32: Observed structure function for component C.

Fig. 5.33: The observed structure function is shown as a function of separation distance. Filled circles, open circles and filled squares represent velocity systems A, B, and C, respectively.

5.2.3.3 Turbulent FWHM

Employing the same group of velocities, we calculated the mean FWHM for the different components. An electron temperature of 9100 K, determined from the $H_\alpha/[NII]$ ratio (Dopita et al. 1973), was assumed for the calculation of the thermal component; from equation [1-11], the value of FWHM (thermal) is 5.10 km s^{-1} . Component A showed a mean FWHM of $(13.41 \pm 0.51) \text{ km s}^{-1}$, component B a value of $(6.66 \pm 0.32) \text{ km s}^{-1}$, whereas component C had a mean of $(28.55 \pm 0.91) \text{ km s}^{-1}$. The FWHM's corrected mass motion are then $(12.09 \pm 0.58) \text{ km s}^{-1}$, $(5.67 \pm 0.40) \text{ km s}^{-1}$, and $(28.05 \pm 0.92) \text{ km s}^{-1}$. We can see that component B is significantly narrower than A; in addition, a number of positions (around 30%) showed a B component with a width smaller than the thermal value; this could reflect variations of temperatures in the flow.

5.2.3.4 Dispersion analysis

The dispersion analysis was carried out in a way analogous to that for the Trapezium area. The data set measured for PA 180 was included in the calculation, but given a weight half that given to the data for PA 225/270. The weighted instrumental dispersion for component A was 0.57 km s^{-1} , for component B it was 0.64 km s^{-1} , whereas for the system C the dispersion was 1.86 km s^{-1} . Along the same line as section 5.1.3.3, least squares lines were calculated for the power law $W = a D^n$, D the size of the sample, excluding the lower and higher points. The values of the n exponent were (0.538 ± 0.089) , (0.787 ± 0.110) , (0.372 ± 0.124) for components A, B, and C respectively. The dispersion relations are illustrated in Fig. 5.34 and given in Table 7.

Fig. 5.34: The most probable one dimensional turbulent velocity (W) is shown as a function of sample size (D) for the θ^2 Orionis region. Filled circles, open circles and filled triangles represent velocity systems A, B, and C respectively.

5.2.4 Another characteristics of the velocity field

5.2.4.1 High velocity components

The existence of condensations ("knots") in the region near θ^2 Orionis is well known (Münch and Wilson 1962; Laques and Vidal 1979). Radial velocities of three of these features, known as knots A, B, and C, have been measured by Taylor and Münch (1978) in $H\alpha$ and $[NII]$ (Fig. 5.35). In all the cases components blue shifted with respect to the surrounding nebular material were found. Our data allowed us to observe one of those condensations, noted as knot A.

Fig. 5.35: A sketch of the θ^2 Ori region showing the position of knots A, B, C and D. The area of the bright bar is stippled (from Walsh 1982).

High-velocity components were detected over two position angles, PA 270 and PA225. The northern part of the knot was barely observed, with a signal-to-noise ratio ≈ 2 . Table 8 indicates the values observed. It is interesting to note that we did not detect knot C, which could be expected from the geometry to be observed at PA 225 (see Fig. 5.35); maybe the emission from [OIII] is very weak in this region.

The nature of these condensations is not clear. Taylor and Münch (1978) proposed that these high-velocity features arise from emission of shocked gas as a stellar wind-driven bubble around θ^1 Ori encounters mild density inhomogeneities. Several difficulties are encountered with the model which have lead to alternative theories (see

Walsh 1982, and references herein). Our results could allow testing of different models when the velocity values are compared with results from emission lines for different elements.

5.2.4.2 The ionization front

Photography of the core of Orion in different wavelengths allows us to trace the structure of the ionization and to detect ionization fronts. Evidence from Elliot and Meaburn (1974) suggests that the source of the bright bar near θ^2 Ori is an ionization front produced by θ^1 Orionis, eating into a mass of neutral material. The bar stretches from ($\alpha = 5^h 33^m 03^s$; $\delta = -5^\circ 25' 36''$) to ($\alpha = 5^h 32^m 51^s$; $\delta = -5^\circ 27' 30''$); the projected distance from the bar to θ^2 is 0.04 pc.

As stated before, the examination of the spectra corresponding to PA 270 reveals clearly the presence of the bar, as an intermediate stage from the θ^2 to the θ^1 regime of velocities. The emission line is clearly split from a distance of 38 to 51 arc seconds west of θ^2 Ori A (Fig. 5.36), but it is difficult to fit several components to it, which probably means that the motions of the gas cannot be pictured simply as several components of gas, as follows from the existence of a shock.

Fig. 5.36a: 36" W from θ^2 Ori A.

Fig. 5.36b: 40.9" W from θ^2 Ori A.

Fig. 5.36c: 51" W from θ^2 Ori A.

Fig. 5.36a to c: The change of the line profile over the bar.

5.3 Final Remarks

5.3.1 Turbulence

The results presented in this thesis argue for the presence of turbulence, but they are in disagreement with the standard theory (Kolmogorov's 2/3 law) and the most simple models, indicating the injection of energy at different scales of motion. If this is the case, then the most natural assumption is that the input at the smallest scale arises from free expansion around small knots which are only incompletely ionized and shedding material to the general HII region at high velocities. The larger scale inputs are equally uncertain, possibly being instabilities or flow around naturally occurring obstacles.

The implications of the new observations are far reaching, because their confirmation and more precise understanding could have important implications for the subject of energetics and dynamical evolution of gaseous nebulae.

5.3.2 Future lines of research

The obvious continuation of this research is the observation of the velocity field using a different emission line. The study of kinematics requires the observation of spectral lines that also have narrow thermal width, so that the deconvolution of multiple components is possible. An obvious choice is the [OII] λ 3727 doublet. An advantage of the use of this emission line is that the ratio of the [OII] λ 3729/3726 individual lines is an indicator of the local density. This information is extremely important because the gas is not symmetrically distributed: there are globules, ionization fronts and dense shocked shells. Unlike the previous studies where the single [OIII] λ 5007 line was used, two very important observational data, velocity and density, could be obtained from the same

observation. Correlations between density fluctuations and behaviour of the multiple components of the line profile for different states of ionization will be then possible.

A very important question from the theoretical point of view is the use of statistical methods for the study of turbulence. There is some doubt about the ability to discriminate between turbulence and pseudo-correlation of the velocity field (Scalo, private communication). Our work indicates that only a limited sample for the complete set of velocity data is enough to make predictions about the nature of the flow.

The observations suggest that it may be inappropriate to consider the correlations of turbulent velocity dispersions, from emission line widths, on the scale of the size of the object as indicative of Kolmogorov turbulence. This is particularly important when considering molecular clouds and giant HII regions. It is obvious that more careful studies are needed to determine what types of physical phenomena are producing the observed relationship.

The intrinsically dissipative nature of turbulence requires a continuing source of energy. Theoretical possibilities must be explored, as Kelvin-Helmholtz instabilities, stellar winds, generation of instabilities via shock waves, etc. We lack quantitative and qualitative models, that will predict, for example, the rate of injection of energy in the media. These models can obviously be extended to the interstellar medium. The scale of turbulence is another unknown quantity. Only new observations and their interpretation can determine the existence of correlation/decorrelation of velocities at scales comparable with the size of the nebulae. Finally, there are no theoretical studies about the effect of a turbulence velocity field in the evolution of gaseous nebulae.

The study of turbulence in Astrophysics, and in particular gaseous nebulae, seems a very timely subject. The improvement in observational techniques will make it relatively

simple to obtain velocity maps of objects with low surface brightness, and the use of powerful supercomputers will allow the construction of more realistic models for the numerical simulation of astrophysical flows in state of turbulent motion. Given the fact that this classical problem of fluid mechanics has been with us for a century, we can expect to have enough problems to study for the next decade.

Table 3: Structure functions for the θ^1 Area.

Δ	Component A		Component B		Component C	
	B(Δ)	ΔB	B(Δ)	ΔB	B(Δ)	ΔB
3.0	2.16	0.14	6.47	0.53	17.64	1.33
5.0	3.91	0.16	10.88	0.51	33.22	1.48
7.0	5.18	0.15	17.44	0.64	38.55	1.37
9.0	6.33	0.15	20.81	0.60	43.92	1.28
11.0	7.42	0.15	22.81	0.60	48.12	1.23
13.0	8.26	0.15	22.95	0.57	49.38	1.18
15.0	8.60	0.16	22.12	0.53	50.48	1.17
17.0	8.31	0.15	23.56	0.54	54.63	1.17
19.0	8.85	0.15	23.59	0.54	58.26	1.18
21.0	9.53	0.16	22.96	0.51	60.18	1.15
23.0	9.96	0.16	22.92	0.45	61.77	1.14
25.0	10.11	0.16	23.40	0.45	61.68	1.12
27.0	9.85	0.16	23.36	0.47	59.78	1.09
29.0	9.68	0.15	23.46	0.47	58.28	1.03
31.0	9.50	0.15	25.30	0.49	57.75	1.01
33.0	9.34	0.15	25.53	0.48	59.34	1.02
35.0	9.66	0.16	25.13	0.46	61.89	1.04
37.0	9.89	0.17	25.17	0.46	64.33	1.06
39.0	10.43	0.18	25.00	0.45	66.43	1.06
41.0	10.68	0.18	24.66	0.44	68.78	1.07
43.0	11.04	0.18	24.19	0.44	69.12	1.06
45.0	11.09	0.18	24.90	0.46	70.25	1.07
47.0	11.30	0.18	25.32	0.46	72.05	1.10
49.0	11.32	0.18	25.25	0.46	72.63	1.13
51.0	11.66	0.19	24.63	0.46	72.35	1.13
53.0	11.97	0.19	23.95	0.46	70.68	1.12
55.0	12.61	0.21	22.92	0.45	70.56	1.34
57.0	12.65	0.21	22.80	0.45	70.03	1.15
59.0	12.45	0.21	22.59	0.45	71.08	1.19
61.0	12.72	0.22	23.02	0.46	69.21	1.17
63.0	13.17	0.23	22.91	0.47	68.17	1.20
65.0	13.31	0.24	22.80	0.48	67.58	1.20
67.0	13.70	0.25	22.76	0.50	67.34	1.23
69.0	13.82	0.27	22.40	0.51	69.21	1.29
71.0	13.81	0.27	22.31	0.53	69.84	1.33
73.0	13.77	0.28	20.96	0.52	71.13	1.39
75.0	13.72	0.29	20.76	0.53	69.31	1.41
77.0	14.08	0.31	21.19	0.55	69.15	1.49
79.0	14.33	0.34	22.01	0.58	68.79	1.56
81.0	14.35	0.36	22.09	0.62	66.52	1.58
83.0	14.87	0.41	22.14	0.65	65.35	1.61
85.0	14.82	0.43	22.80	0.72	64.79	1.68
87.0	15.27	0.46	22.82	0.76	62.69	1.73

Table 3: Structure functions for the θ^1 Area (cont.).

Λ	Component A		Component B		Component C	
	B(Λ)	ΔB	B(Λ)	ΔB	B(Λ)	ΔB
89.0	15.94	0.51	22.82	0.79	60.89	1.78
91.0	15.55	0.52	22.30	0.80	59.82	1.82
93.0	15.60	0.55	21.69	0.83	58.07	1.87
95.0	16.19	0.61	20.69	0.85	60.85	2.00
97.0	15.67	0.63	19.69	0.88	62.52	2.14
99.0	16.41	0.73	18.96	0.93	63.37	2.35
101.0	15.27	0.73	17.33	0.87	60.97	2.32
103.0	15.56	0.77	16.85	0.88	61.25	2.41
105.0	15.23	0.79	16.73	0.94	59.16	2.52
107.0	14.79	0.79	15.69	0.93	58.20	2.69
109.0	13.99	0.77	14.87	0.93	55.88	2.75
111.0	13.70	0.76	14.55	0.93	55.29	2.85
113.0	13.34	0.77	14.16	0.96	57.27	3.21
115.0	13.05	0.81	14.22	1.03	58.75	3.49
117.0	12.73	0.84	14.50	1.12	55.74	3.65
119.0	12.72	0.88	13.96	1.16	58.29	3.90
121.0	13.56	1.00	14.22	1.26	56.15	4.05
123.0	14.01	1.10	13.73	1.33	58.67	4.57
125.0	14.02	1.22	13.62	1.39	61.03	5.13
127.0	14.30	1.33	12.35	1.31	66.16	5.88
129.0	14.37	1.50	11.54	1.34	62.73	6.74
131.0	15.08	1.76	10.61	1.30	68.75	7.63
133.0	14.49	2.00	9.88	1.26	61.20	7.96
135.0	14.31	2.44	9.66	1.36	65.19	9.06
137.0	13.91	2.71	8.66	1.44	55.46	8.90
139.0	13.16	3.24	7.18	1.24	59.99	12.80
141.0	13.37	4.46	7.63	1.60	51.77	13.45
143.0	14.74	5.67	7.19	1.91	20.72	6.99
145.0	11.83	5.34	5.49	2.56	25.01	13.65
147.0	8.53	5.08	2.75	1.84	12.71	5.53
149.0	7.93	6.10	1.20	1.71	42.38	43.62
151.0	2.27	0.69				

Λ in units of arcseconds; B(Λ) and ΔB in units of $\text{km}^2 \text{s}^{-2}$.

Table 4: Dispersion analysis for the θ^1 Orionis region.

Sample Size (D)	Component A		Component B		Component C	
	W	ΔW	W	ΔW	W	ΔW
8.	0.74	0.01	0.89	0.08	0.82	0.15
16.	1.29	0.07	1.40	0.12	1.89	0.19
30.	1.31	0.08	2.13	0.22	2.88	0.26
40.	1.41	0.09	2.13	0.24	3.12	0.27
60.	1.43	0.12	2.25	0.36	3.78	0.27
80.	1.65	0.12	2.81	0.39	3.84	0.36
100.	1.60	0.17	2.62	0.42	3.92	0.37
120.	1.37	0.18	2.12	0.47	3.97	0.39

D in units of arcseconds; W and ΔW in units of km s^{-1} .

Table 5: High velocity components for the θ^1 area.

Position	Spectra	Velocity	FWHM	Position	
				x	y
1	AtoB	-25.34	19.60	20.58	-8.65
		-29.30	22.82	21.67	-10.38
2	CtoD	-23.31	15.64	17.89	-9.82
		-24.44	20.18	19.68	-10.80
		-30.42	17.86	21.47	-11.79
3	Apa180	-39.14	32.43	9.78	-32.16
		-36.14	33.16	9.78	-30.12
4	Cpa180	-28.33	17.29	0.00	-34.70
		-28.61	22.48	0.00	-32.66
5	Dpa180	-29.02	18.63	-11.81	-36.38

Velocity and FWHM in units of km s^{-1} ; position in units of arcseconds.
Positions measured with respect to θ^1 Orionis C (West and North are positive).

Table 6: Structure functions for the θ^2 Area.

Λ	Component A		Component B		Component C	
	B(Λ)	ΔB	B(Λ)	ΔB	B(Λ)	ΔB
3.5	0.93	0.22	0.80	0.27	36.65	6.40
7.5	1.15	0.17	1.16	0.30	53.81	7.51
12.5	1.79	0.17	1.68	0.29	95.69	9.21
17.5	2.56	0.22	2.80	0.41	127.08	10.58
22.5	4.21	0.35	4.60	0.58	96.33	6.96
27.5	4.27	0.39	4.26	0.65	66.20	6.26
32.5	4.08	0.32	4.26	0.53	87.51	6.64
37.5	3.80	0.34	4.55	0.57	144.56	10.03
42.5	4.14	0.38	3.80	0.39	159.89	8.88
47.5	4.54	0.42	3.93	0.48	165.59	9.91
52.5	4.61	0.51	6.55	1.01	144.92	10.58
57.5	5.27	0.51	6.24	0.73	113.18	9.05
62.5	5.15	0.47	6.32	0.56	93.58	9.85
67.5	5.78	0.51	7.70	0.75	99.79	12.82
72.5	5.97	0.68			128.00	17.49
77.5	6.85	0.87			145.34	17.98
82.5	7.08	1.27			131.77	19.42
87.5	8.78	1.50			119.69	15.94
92.5	8.23	1.71			133.78	19.68
97.5	8.50	1.85			196.35	27.61
102.5	8.69	1.06			273.44	28.91
107.5	8.37	1.19			313.01	34.21
112.5	9.69	1.06			420.44	28.97
117.5	9.68	1.48			390.87	36.64
122.5	12.51	1.43			371.18	28.53

Λ in units of arcseconds; B(Λ) and ΔB in units of $\text{km}^2 \text{s}^{-2}$.

Table 7: Dispersion analysis for the θ^2 Orionis region.

Sample Size (D)	Component A		Component B		Component C	
	W	ΔW	W	ΔW	W	ΔW
8.	0.00	0.04	0.25	0.11	1.67	0.29
12.	0.23	0.04	0.29	0.07	2.26	0.31
16.	0.33	0.05	0.36	0.08	2.94	0.33
24.	0.50	0.05	0.45	0.10	2.87	0.46
32.	0.61	0.06	0.70	0.10	3.50	0.71
40.	0.68	0.07	0.59	0.14	3.72	0.23
60.	0.67	0.06	1.12	0.05		
70.	0.70	0.10	1.06	0.08		
100.	1.12	0.23				
120.	1.52	---				

D in units of arcseconds; W and ΔW in units of km s^{-1} .

Table 8: High velocity components for the θ^2 area.

Position	Spectra	Velocity	FWHM	Position	
				x	y
1	PA 180	-47.61	12.07	18.37	0.00
		-49.03	10.26	16.33	0.00
		-47.35	8.89	14.29	0.00
2	PA 225	-46.58	10.63	12.99	-12.99
		-38.14	29.54	10.10	-10.10

Velocity and FWHM in units of km s^{-1} ; position in units of arcseconds.
Positions measured with respect to θ^2 Orionis A (West and North are positive).

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Appendix I

The θ^1 Orionis region: The system of velocity components for fifteen different position angles

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Velocity and FWHM in km s^{-1} ; peak intensity in units of A.D.U; position in units of arcseconds.

Positions measured with respect to θ^1 Orionis C (West and North are positive).

TABLE I-1: VELOCITY COMPONENTS FOR THE SPECTRA ORION A TO B

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
-10.76	41.56	14.11	10.43	1613.4	10.48	7.30	913.0	21.63	36.56	123.5	---	---	---
-9.68	39.83	14.66	10.80	1727.3	9.43	6.91	856.5	24.03	35.86	116.6	---	---	---
-8.60	38.10	15.60	11.85	1652.3	10.14	7.20	842.0	25.75	35.18	111.7	---	---	---
-7.52	36.36	13.70	10.07	1946.9	21.86	8.66	703.1	25.37	38.27	132.3	---	---	---
-6.44	34.63	14.92	10.58	2059.1	23.17	6.77	661.8	22.42	36.97	180.8	---	---	---
-5.36	32.90	17.07	12.47	1756.9	---	---	---	24.22	41.32	93.5	---	---	---
-4.28	31.17	18.30	10.63	2196.8	11.16	11.57	713.4	31.15	29.24	124.8	---	---	---
-3.20	29.44	17.79	9.84	2062.8	9.57	8.33	683.1	27.32	34.86	145.9	---	---	---
-2.11	27.71	16.93	10.91	1925.9	8.39	8.59	499.4	35.76	23.39	114.9	---	---	---
-1.03	25.98	16.36	11.97	1611.1	7.57	7.58	283.8	37.68	21.78	100.0	---	---	---
0.05	24.24	16.91	11.67	341.1	15.95	13.03	1302.0	38.31	20.09	99.1	---	---	---
1.13	22.51	20.47	7.15	605.3	13.89	11.09	1612.4	25.67	36.67	141.6	---	---	---
2.21	20.78	19.62	7.56	1223.1	12.52	8.99	1565.9	22.71	36.35	181.5	---	---	---
3.29	19.05	20.13	7.57	1245.8	13.07	9.81	1569.8	22.16	32.59	221.0	---	---	---
4.37	17.32	20.98	6.54	876.2	15.59	12.42	1666.4	22.69	34.80	214.7	---	---	---
5.45	15.59	20.37	8.47	1460.4	15.54	12.26	1310.6	21.37	36.48	230.4	---	---	---
6.53	13.86	19.80	9.44	2370.3	13.18	14.78	653.9	23.89	41.23	148.7	---	---	---
7.61	12.13	19.94	10.43	2389.7	11.08	15.87	643.0	22.57	41.09	139.8	---	---	---
8.69	10.40	19.22	12.30	2318.4	7.38	11.64	668.4	24.32	35.55	195.9	---	---	---
9.78	8.66	17.62	13.07	2404.5	6.69	9.38	677.8	25.86	33.78	143.4	---	---	---
10.86	6.93	17.09	12.31	2651.8	8.74	10.85	794.6	27.54	31.87	153.1	---	---	---
11.94	5.20	17.98	10.89	2260.6	12.57	11.69	2282.3	24.54	35.74	235.1	---	---	---
13.02	3.47	16.95	11.17	2934.1	11.34	8.28	1232.3	22.56	42.03	218.6	---	---	---
14.10	1.74	17.71	10.00	2998.2	11.47	7.61	1640.1	20.63	37.35	261.1	---	---	---
15.18	0.01	16.74	12.52	3289.6	10.85	4.31	484.1	19.18	43.69	252.5	---	---	---
16.26	-1.72	15.41	10.91	2848.1	22.20	10.52	1162.3	17.59	41.46	270.3	---	---	---
17.34	-3.45	14.67	9.58	3325.7	22.05	11.19	1201.3	16.86	39.30	277.9	---	---	---
18.42	-5.19	13.91	9.05	3725.6	22.98	9.43	1041.3	19.10	37.75	248.4	---	---	---
19.50	-6.92	13.18	8.69	3297.4	23.10	9.51	720.1	20.02	28.38	288.4	---	---	---
20.59	-8.65	12.19	7.98	798.0	---	---	---	---	---	---	-25.34	19.60	64.1
21.67	-10.38	11.39	8.23	2312.3	---	---	---	26.87	27.57	111.0	-29.30	22.82	49.4
22.75	-12.11	11.42	10.54	3397.2	4.76	7.18	371.9	20.36	26.55	261.5	---	---	---
23.83	-13.84	12.99	10.06	3705.4	5.31	8.22	1584.7	24.58	33.51	191.2	---	---	---
24.91	-15.57	14.32	9.69	3825.7	5.36	8.52	2378.1	29.78	26.64	191.1	---	---	---
25.99	-17.30	14.55	10.99	3035.4	5.21	8.51	2288.6	31.38	22.90	198.9	---	---	---
27.07	-19.04	14.83	11.26	2142.3	5.70	8.91	1964.7	31.30	23.21	235.3	---	---	---
28.15	-20.77	14.90	11.58	1671.5	5.96	8.96	1515.7	32.61	21.71	240.8	---	---	---
29.23	-22.50	16.01	10.99	1454.0	5.82	9.06	1333.3	33.73	21.03	222.3	---	---	---
30.31	-24.23	18.22	10.78	1341.9	5.79	10.17	1340.9	36.45	17.63	184.7	---	---	---
31.39	-25.96	19.51	10.77	1474.0	5.40	11.20	1449.1	38.24	16.05	182.4	---	---	---
32.48	-27.69	20.62	11.11	1221.8	7.77	11.47	1339.6	38.30	18.26	197.8	1.66	6.20	823.8
33.56	-29.42	8.09	11.82	1635.0	1.80	5.87	999.3	39.15	17.43	206.1	20.87	13.38	705.7
34.64	-31.15	8.22	11.25	1355.9	2.18	6.28	1068.7	37.42	20.56	178.0	14.85	17.82	606.9
35.72	-32.89	9.34	13.63	1477.0	2.91	6.78	893.0	27.21	33.15	187.1	---	---	---
36.80	-34.62	9.12	14.39	1067.7	3.23	6.47	535.4	29.60	31.26	119.7	---	---	---
37.88	-36.35	10.35	15.83	780.6	3.65	7.10	501.5	32.58	26.32	96.0	---	---	---
38.96	-38.08	11.28	16.20	878.1	3.56	6.71	370.6	34.54	23.48	82.8	---	---	---
40.04	-39.81	11.64	13.85	985.4	3.85	8.56	405.5	29.32	29.09	89.1	---	---	---
41.12	-41.54	14.10	8.96	810.1	5.60	9.55	918.6	24.00	34.86	106.6	---	---	---
42.20	-43.27	13.89	9.10	932.8	4.82	9.38	786.4	27.04	33.99	87.8	---	---	---
43.29	-45.00	12.77	10.39	1017.3	2.97	8.11	522.3	28.47	30.88	83.0	---	---	---

TABLE I-2: VELOCITY COMPONENTS FOR THE SPECTRA ORION A TO C

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
21.38	18.95	12.79	7.53	2773.2	6.14	8.42	1075.1	28.59	27.43	156.1	19.47	10.74	913.9
19.86	17.60	13.44	8.01	2226.8	4.76	6.77	809.0	37.73	16.92	149.5	15.20	16.82	1507.4
18.33	16.24	13.69	10.70	3049.9	3.69	6.36	837.4	22.00	32.89	349.1	---	---	---
16.80	14.89	14.05	11.00	2687.6	3.73	7.55	842.8	26.76	32.35	272.4	---	---	---
15.27	13.54	14.71	11.12	2343.1	4.31	8.86	826.0	27.61	31.17	276.3	---	---	---
13.75	12.18	15.41	12.35	2038.3	3.89	8.27	682.3	25.65	30.70	300.3	---	---	---
12.22	10.93	16.58	12.96	1915.6	4.12	8.41	659.2	23.23	29.95	318.0	17.26	12.52	2182.5
10.59	9.48	17.55	13.28	2136.6	5.12	8.93	676.0	25.11	32.69	181.0	---	---	---
9.16	8.12	18.74	11.97	2179.9	9.40	12.19	908.1	28.58	28.88	136.3	---	---	---
7.64	6.77	21.11	10.84	1240.6	13.93	13.13	1649.4	25.28	33.00	165.8	---	---	---
6.11	5.41	22.72	11.45	1270.4	13.67	11.43	1764.8	24.96	38.19	166.8	---	---	---
4.58	4.06	22.85	12.37	1519.2	12.41	10.54	1308.3	25.34	38.29	176.7	---	---	---
3.06	2.71	23.57	12.41	1733.1	11.38	10.06	1050.1	26.82	38.95	172.5	---	---	---
1.53	1.35	23.99	12.01	1821.3	11.14	9.65	870.2	26.82	35.32	188.7	---	---	---
0.00	0.00	23.66	11.22	1816.9	10.95	9.54	786.3	26.02	35.21	185.5	---	---	---
-1.53	-1.35	22.93	11.18	1761.2	11.95	9.97	900.4	29.86	37.80	115.5	---	---	---
-3.06	-2.71	21.77	12.37	1608.9	12.20	9.26	1098.8	30.48	45.76	125.3	---	---	---
-4.58	-4.06	22.21	12.57	1362.3	12.86	10.10	1500.3	35.00	40.90	154.4	---	---	---
-6.11	-5.41	22.52	14.42	1245.3	13.26	10.96	1377.0	40.18	36.52	127.7	---	---	---
-7.64	-6.77	23.86	15.91	927.8	14.97	12.93	1210.9	42.42	28.12	64.9	---	---	---
-9.16	-8.12	19.31	12.39	1463.6	10.72	4.83	406.2	25.68	37.50	171.2	30.90	7.22	366.6
-10.69	-9.48	19.85	8.74	1398.9	11.96	6.23	527.6	23.88	32.24	243.0	31.03	8.15	397.6
-12.22	-10.83	19.65	7.66	1282.8	12.51	5.57	385.0	23.23	27.43	347.6	31.99	7.39	327.2
-13.75	-12.18	19.66	8.81	1220.9	11.84	3.55	194.5	22.59	27.21	265.9	31.60	9.18	310.5
-15.27	-13.54	19.63	8.64	989.9	---	---	---	21.85	25.31	244.0	---	---	---
-16.80	-14.89	23.51	13.78	848.6	18.52	6.38	502.6	21.57	30.19	158.9	---	---	---
-18.33	-16.24	25.41	7.62	831.0	18.29	7.30	890.4	20.54	27.72	233.9	---	---	---
-19.86	-17.60	24.79	8.02	933.7	17.78	6.18	789.6	21.02	27.95	257.8	---	---	---
-21.38	-18.95	24.06	7.97	1059.9	17.10	6.24	759.2	20.02	26.67	219.0	---	---	---
-22.91	-20.31	22.78	9.22	1189.4	16.41	5.65	534.8	19.05	25.39	183.9	---	---	---
-24.44	-21.66	22.38	9.59	1314.6	15.95	4.95	505.6	18.66	23.89	194.2	---	---	---
-25.97	-23.01	22.72	9.10	1418.6	15.93	5.68	691.0	18.98	23.82	222.0	---	---	---
-27.49	-24.37	22.33	9.50	1568.8	16.17	6.23	746.4	18.92	23.88	233.4	---	---	---
-29.02	-25.72	20.55	10.85	1976.4	16.52	4.66	351.8	19.30	27.20	167.2	---	---	---
-30.55	-27.07	20.61	11.45	1647.6	17.95	6.48	1035.4	19.19	26.71	184.2	---	---	---
-32.08	-28.43	20.29	12.17	1415.2	17.76	6.40	1263.6	19.58	28.09	167.4	---	---	---
-33.60	-29.78	24.16	10.58	635.1	17.65	8.57	2093.5	19.10	26.27	229.9	---	---	---
-35.13	-31.14	23.48	13.82	797.3	16.94	9.31	1767.4	16.82	34.04	118.8	---	---	---
-36.66	-32.49	23.46	14.82	728.9	16.59	9.72	1430.5	17.09	37.33	110.7	---	---	---
-38.19	-33.84	19.38	8.64	1209.4	13.87	7.04	1290.1	17.48	32.01	213.8	25.99	11.77	464.8
-39.71	-35.20	19.33	12.92	1110.5	13.25	6.13	812.3	19.31	28.96	291.0	---	---	---
-41.24	-36.55	20.94	9.64	1075.9	12.42	6.10	1420.7	16.27	28.43	344.1	---	---	---
-42.77	-37.90	21.97	10.19	927.2	12.39	6.15	1282.0	15.30	27.83	333.2	---	---	---
-44.30	-39.26	23.84	9.95	784.9	12.54	5.41	1041.6	15.20	24.58	484.8	---	---	---

TABLE I-3: VELOCITY COMPONENTS FOR THE SPECTRA ORION A TO D

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
-69.44	0.90	20.72	7.86	461.6	14.50	4.92	518.1	18.36	21.77	248.6	---	---	---
-67.41	1.10	20.26	9.58	623.6	14.64	3.49	440.8	14.24	16.05	200.4	31.73	20.05	37.8
-65.38	1.29	20.78	7.78	578.5	15.03	5.12	586.1	15.57	19.40	220.0	35.96	21.02	28.8
-63.35	1.49	20.26	7.86	609.5	14.82	5.32	606.0	16.78	23.13	212.0	---	---	---
-61.32	1.69	20.97	6.56	629.1	15.65	4.57	483.7	17.83	21.41	206.8	---	---	---
-59.29	1.89	18.39	9.72	938.6	---	---	---	17.15	30.12	101.7	---	---	---
-57.26	2.09	18.38	8.97	983.5	---	---	---	16.84	26.29	132.2	---	---	---
-55.22	2.29	19.29	7.48	934.7	14.67	3.99	329.5	17.36	23.17	165.9	---	---	---
-53.19	2.49	20.23	7.57	693.2	16.26	6.31	607.6	17.68	24.84	142.8	---	---	---
-51.16	2.69	19.99	8.15	723.2	16.33	5.87	616.3	17.79	24.26	157.2	---	---	---
-49.13	2.89	20.55	8.19	591.1	17.03	6.23	816.9	17.64	23.69	151.4	---	---	---
-47.10	3.09	20.37	7.89	540.1	17.44	6.67	884.2	17.99	24.13	153.3	---	---	---
-45.07	3.29	20.43	8.53	401.5	18.02	7.28	1107.5	17.68	25.27	137.6	---	---	---
-43.04	3.49	18.60	8.01	1572.9	---	---	---	19.35	24.00	160.5	---	---	---
-41.01	3.68	17.82	6.70	1470.3	21.53	7.48	688.5	17.76	24.95	158.4	---	---	---
-38.97	3.88	18.97	8.02	1913.6	---	---	---	20.97	18.50	271.5	---	---	---
-36.94	4.08	19.51	17.21	880.5	17.14	6.98	640.2	18.50	25.57	158.8	---	---	---
-34.91	4.28	21.73	6.40	1971.1	16.70	6.52	1522.5	18.54	25.15	172.1	---	---	---
-32.88	4.48	21.95	7.63	2055.3	15.44	6.50	898.9	19.14	24.88	187.9	---	---	---
-30.85	4.68	22.59	7.41	1919.5	15.73	7.34	1044.7	19.50	26.64	168.7	---	---	---
-28.82	4.88	21.79	8.40	2063.5	14.60	6.62	854.2	19.59	27.47	168.8	---	---	---
-26.79	5.08	21.34	8.42	2239.0	14.38	5.98	892.0	20.10	25.61	218.2	---	---	---
-24.76	5.28	20.76	8.48	2429.1	14.18	5.97	905.9	20.44	25.85	221.4	---	---	---
-22.72	5.48	19.64	8.92	2652.1	13.28	4.99	629.1	20.26	27.10	193.9	---	---	---
-20.69	5.68	18.37	10.01	2932.2	---	---	---	21.93	34.21	134.7	---	---	---
-18.66	5.88	18.03	9.85	3129.4	---	---	---	21.69	24.55	254.2	---	---	---
-16.63	6.07	18.14	9.57	2946.2	---	---	---	21.46	24.91	268.1	---	---	---
-14.60	6.27	18.48	10.22	2618.0	---	---	---	20.97	24.57	298.3	---	---	---
-12.57	6.47	19.69	10.03	2285.4	12.40	5.02	427.6	21.05	24.51	367.4	---	---	---
-10.54	6.67	21.21	9.65	2192.8	13.06	7.24	658.4	21.64	25.37	362.2	---	---	---
-8.51	6.87	22.59	9.44	2299.5	13.72	8.59	947.3	22.74	29.19	266.4	---	---	---
-6.47	7.07	23.86	8.44	2238.9	14.90	10.69	1353.0	25.82	34.18	222.5	---	---	---
-4.44	7.27	24.45	7.72	2125.5	15.49	11.55	1685.1	28.00	38.07	263.8	---	---	---
-2.41	7.47	24.83	7.21	1822.1	16.24	12.10	1941.0	28.35	38.22	270.8	---	---	---
-0.38	7.67	24.89	7.48	1590.4	16.57	12.10	2067.3	25.87	38.82	254.6	---	---	---
1.65	7.87	24.74	7.92	1461.4	16.46	12.01	2142.4	24.12	37.86	259.4	---	---	---
3.68	8.07	23.72	8.35	1570.1	16.30	10.75	2017.1	21.92	34.81	304.4	---	---	---
5.71	8.27	23.77	7.35	1101.5	16.08	12.37	2064.5	20.98	32.72	296.2	---	---	---
7.74	8.46	21.09	9.99	915.0	15.54	15.80	1822.5	26.55	35.79	151.4	---	---	---
9.78	8.66	17.19	13.58	2043.4	5.69	8.09	480.4	21.66	33.92	178.6	---	---	---
11.81	8.86	16.44	13.25	2634.4	5.01	8.44	627.3	24.44	34.18	203.1	---	---	---
13.84	9.06	15.70	11.85	2955.8	5.08	7.64	815.4	22.32	32.18	293.0	---	---	---
15.87	9.26	15.18	10.24	3495.9	5.76	8.17	1050.3	21.56	32.13	308.2	---	---	---
17.90	9.46	15.49	8.68	3089.1	8.29	9.72	1404.7	21.91	32.27	226.8	---	---	---
19.93	9.66	14.70	8.45	5372.0	7.60	8.31	1858.9	19.58	31.11	387.5	---	---	---
21.96	9.86	13.74	10.17	4979.2	---	---	---	15.18	35.80	267.8	---	---	---
23.99	10.06	13.72	9.98	5153.7	---	---	---	15.49	39.28	222.8	---	---	---
26.03	10.26	13.62	9.80	5027.1	---	---	---	15.28	43.80	178.0	---	---	---
28.06	10.46	13.61	9.14	5012.3	---	---	---	16.55	36.66	223.7	---	---	---
30.09	10.66	13.86	8.29	5144.1	---	---	---	16.67	29.84	286.7	---	---	---
32.12	10.85	14.13	7.43	5582.9	---	---	---	16.69	21.25	501.0	---	---	---
34.15	11.05	14.21	7.10	6118.9	---	---	---	17.15	17.03	690.9	---	---	---
36.18	11.25	14.13	6.55	6714.6	---	---	---	16.35	14.32	1163.2	---	---	---
38.21	11.45	14.16	6.99	7563.3	---	---	---	17.87	21.53	552.8	---	---	---
40.24	11.65	14.49	9.56	3292.9	13.98	5.71	4806.4	20.31	34.82	280.9	---	---	---
42.28	11.85	14.46	9.71	3675.7	13.86	5.44	4156.3	18.90	35.07	321.9	---	---	---
44.31	12.05	14.28	9.60	4232.3	13.32	4.64	3114.7	17.14	33.46	405.0	---	---	---
46.34	12.25	14.25	10.34	3065.7	13.29	5.21	3930.2	15.86	32.22	443.2	---	---	---
48.37	12.45	14.09	10.56	2490.3	13.32	5.73	3809.6	14.78	30.27	486.6	---	---	---
50.40	12.65	13.85	9.69	3269.8	13.20	5.46	2617.9	13.94	28.67	547.4	---	---	---
52.43	12.85	13.40	8.04	4867.9	---	---	---	13.74	25.67	709.2	---	---	---
54.46	13.05	13.21	8.19	4482.3	---	---	---	14.63	29.45	561.5	---	---	---
56.49	13.24	13.30	9.46	3103.2	12.57	4.71	1440.4	15.90	37.80	347.6	---	---	---
58.53	13.44	14.77	8.39	1838.4	12.38	6.11	2290.0	15.92	38.29	315.1	---	---	---

TABLE I-4: VELOCITY COMPONENTS FOR THE SPECTRA ORION B TO C

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
9.68	31.19	15.20	11.84	1534.0	---	---	---	26.08	42.13	100.7	---	---	---
9.07	29.24	17.39	10.95	1219.4	10.62	10.87	764.9	29.13	38.14	97.9	17.78	10.56	940.5
9.47	27.29	18.91	9.56	1030.7	12.67	12.08	1382.2	26.13	39.64	142.5	---	---	---
7.86	25.34	18.45	9.97	1118.4	12.38	12.53	1100.4	26.70	38.84	135.2	---	---	---
7.26	23.39	19.30	8.80	609.7	14.60	15.04	1564.9	36.81	24.12	123.5	---	---	---
6.65	21.44	19.33	10.25	686.3	14.33	15.13	1495.0	36.37	20.67	136.8	---	---	---
6.05	19.49	20.46	8.03	556.3	14.63	13.40	1581.0	22.81	37.39	188.1	---	---	---
5.44	17.54	20.53	8.45	884.4	15.01	12.84	1558.8	21.10	37.24	219.0	---	---	---
4.84	15.59	21.06	7.17	998.2	16.20	12.17	1762.8	19.55	35.58	271.6	---	---	---
4.23	13.65	21.90	5.45	872.3	17.46	11.83	2162.4	19.20	34.05	291.8	---	---	---
3.63	11.70	23.42	5.27	627.1	17.99	12.21	2535.8	19.66	34.73	271.5	---	---	---
3.02	9.75	24.22	5.63	965.1	17.56	12.27	2592.0	21.55	35.56	273.8	---	---	---
2.42	7.80	24.60	7.88	1399.3	16.46	12.33	2406.9	24.35	40.13	252.4	---	---	---
1.81	5.85	23.99	19.69	1457.8	14.32	10.46	1860.2	24.26	40.94	268.4	---	---	---
1.21	3.90	24.56	9.99	2009.4	13.50	10.85	1439.0	24.45	35.39	276.0	---	---	---
0.61	1.95	24.28	10.82	2083.6	11.81	10.63	1054.5	26.59	32.49	242.0	---	---	---
0.00	0.00	23.70	11.48	2037.1	11.03	9.79	908.1	28.33	33.77	164.5	---	---	---
-0.61	-1.95	22.76	12.81	1875.0	10.98	9.29	858.6	33.78	33.26	96.2	---	---	---
-1.21	-3.90	21.45	14.78	1565.9	11.15	9.24	937.3	35.10	36.80	77.5	---	---	---
-1.81	-5.85	21.04	17.01	1300.2	11.52	9.62	1213.2	---	---	---	---	---	---
-2.42	-7.80	21.29	16.76	1225.6	12.12	10.15	1475.2	34.57	25.58	110.1	---	---	---
-3.02	-9.75	22.28	17.24	1153.6	13.07	10.97	1278.9	39.28	24.23	59.9	---	---	---
-3.63	-11.70	24.00	15.39	1283.9	14.42	10.88	1598.7	34.05	25.93	106.4	---	---	---
-4.23	-13.65	22.13	15.14	1467.2	14.43	8.26	1218.2	24.92	32.31	202.0	---	---	---
-4.84	-15.59	21.93	12.68	1434.8	15.30	8.14	1350.0	23.93	31.40	237.3	---	---	---
-5.44	-17.54	19.60	11.26	1896.8	14.70	7.43	747.5	22.62	26.49	335.7	---	---	---
-6.05	-19.49	18.52	13.50	1335.6	16.80	9.33	1253.9	22.53	33.39	148.1	---	---	---
-6.65	-21.44	17.22	10.05	2488.4	---	---	---	19.61	21.03	574.0	---	---	---
-7.26	-23.39	16.93	10.26	2950.5	---	---	---	18.02	24.35	278.5	---	---	---
-7.86	-25.34	16.60	10.50	3143.8	---	---	---	18.85	38.05	136.0	---	---	---
-8.47	-27.29	16.37	10.66	3010.4	---	---	---	20.08	36.44	118.3	---	---	---
-9.07	-29.24	16.17	10.27	2814.5	---	---	---	17.89	31.98	173.4	---	---	---
-9.68	-31.19	15.69	8.95	2496.1	---	---	---	16.13	21.67	434.6	---	---	---
-10.28	-33.14	15.57	8.60	2243.5	---	---	---	14.66	20.23	488.1	---	---	---
-10.89	-35.09	16.50	8.41	1832.5	12.28	12.51	636.3	21.08	33.42	123.6	---	---	---
-11.49	-37.04	18.24	6.73	901.7	14.54	10.34	1506.5	18.98	36.55	148.5	---	---	---
-12.10	-38.99	18.80	6.02	1289.8	14.36	10.23	1438.5	20.13	37.37	155.7	---	---	---
-12.70	-40.94	18.54	7.12	2179.9	11.82	7.41	966.0	19.50	33.78	200.6	---	---	---
-13.31	-42.88	19.02	7.39	2246.8	11.64	6.71	1041.2	18.74	36.69	200.9	---	---	---
-13.91	-44.83	19.58	7.18	2084.5	11.75	7.65	1086.6	19.21	36.02	214.9	---	---	---
-14.52	-46.78	19.68	7.00	1983.1	10.94	7.22	1144.8	18.27	35.87	225.5	---	---	---
-15.12	-48.73	18.99	7.88	1549.6	9.75	5.79	1098.7	---	---	---	---	---	---
-15.72	-50.68	18.52	7.53	1429.8	9.75	5.72	1206.3	20.93	35.42	188.4	---	---	---
-16.32	-52.63	18.37	8.65	1338.9	9.61	5.92	1290.7	27.57	31.58	133.9	7.08	17.12	355.7
-16.94	-54.58	18.03	7.92	1329.1	9.62	6.02	1414.7	21.03	39.82	165.4	5.64	14.00	396.8

TABLE I-5: VELOCITY COMPONENTS FOR THE SPECTRA ORION B TO D

Position		Component A			Component B			Component C			Component D		
x	y	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity
20.13	24.64	12.65	7.90	3395.4	4.18	6.29	348.7	---	---	---	21.65	14.13	1576.1
18.36	23.63	12.84	8.68	2450.5	4.19	5.50	253.0	20.56	36.22	145.9	22.91	9.88	1035.6
16.58	22.62	13.52	10.06	2814.8	3.09	5.27	334.2	20.91	35.86	209.2	23.95	9.24	1156.5
14.81	21.61	14.94	10.49	2360.0	4.78	8.43	367.8	23.85	35.61	190.5	24.00	8.65	680.4
13.03	20.61	16.20	12.10	2570.2	4.80	9.58	427.0	23.86	32.03	306.5	---	---	---
11.26	19.60	16.64	12.09	2629.4	4.87	9.07	498.9	30.15	30.46	209.8	---	---	---
9.48	18.59	16.90	12.77	2313.1	5.10	10.02	396.0	35.80	21.32	156.8	---	---	---
7.71	17.58	---	---	---	---	---	---	36.32	17.99	146.8	---	---	---
5.94	16.57	20.08	8.55	1177.9	15.31	13.25	1584.0	21.28	37.26	237.8	---	---	---
4.16	15.56	21.10	6.77	969.2	16.11	12.29	1963.0	22.33	34.64	244.4	---	---	---
2.39	14.55	21.79	7.31	961.3	16.41	12.02	2111.0	23.70	35.84	210.0	---	---	---
0.61	13.54	23.52	5.78	797.8	17.24	12.47	2563.2	24.63	35.72	194.3	---	---	---
-1.16	12.54	24.47	5.28	1355.8	16.67	12.37	2747.5	27.99	30.64	222.7	---	---	---
-2.94	11.53	24.36	6.68	2090.7	15.67	10.78	2561.2	26.32	32.45	219.4	---	---	---
-4.71	10.52	24.24	8.96	2297.2	15.63	10.62	2147.1	24.91	30.26	244.4	---	---	---
-6.48	9.51	23.36	7.85	2322.7	15.01	9.93	1397.2	21.83	23.65	517.8	---	---	---
-8.26	8.50	22.47	7.94	2309.3	16.41	13.21	848.7	19.17	18.53	782.2	---	---	---
-10.03	7.49	21.98	7.92	2364.5	14.42	9.11	977.6	21.46	23.42	511.0	---	---	---
-11.81	6.48	21.10	8.69	2377.7	13.80	7.75	892.4	21.60	26.29	332.8	---	---	---
-13.58	5.47	19.47	9.94	2577.5	12.97	6.02	499.9	21.70	27.47	258.9	---	---	---
-15.36	4.47	23.11	17.22	470.1	17.50	10.00	2949.3	---	---	---	---	---	---
-17.13	3.46	23.12	14.05	642.6	17.16	9.31	3027.7	---	---	---	---	---	---
-18.90	2.45	22.50	12.93	830.1	17.27	9.15	2538.6	---	---	---	---	---	---
-20.68	1.44	20.60	16.45	1288.5	15.90	7.32	1192.0	20.91	29.38	155.1	---	---	---
-22.45	0.43	22.27	10.03	1637.3	15.53	7.00	1131.8	19.08	31.34	139.6	---	---	---
-24.23	-0.58	23.04	9.69	1546.2	15.33	7.09	1134.6	18.27	29.82	136.0	---	---	---
-26.00	-1.59	22.39	11.39	1700.9	14.56	6.24	749.4	17.74	30.73	122.7	---	---	---
-27.78	-2.60	21.37	12.77	1725.1	13.73	3.65	359.1	15.96	32.41	91.1	---	---	---
-29.55	-3.60	21.60	12.54	1719.3	14.20	4.17	366.6	13.67	32.54	99.0	---	---	---
-31.32	-4.61	21.27	11.59	1799.6	14.09	3.58	297.8	18.14	31.40	113.2	---	---	---
-33.10	-5.62	21.90	9.34	1939.6	15.53	5.72	503.3	19.00	25.58	164.0	---	---	---
-34.87	-6.63	21.76	9.30	2146.8	15.67	3.89	296.0	19.22	24.78	162.1	---	---	---
-36.65	-7.64	21.66	10.51	1988.0	---	---	---	19.54	34.50	73.6	---	---	---
-38.42	-8.65	26.01	7.47	787.4	20.17	8.04	1389.0	19.70	28.25	135.4	---	---	---
-40.20	-9.66	25.34	8.59	982.1	19.46	6.92	1014.0	19.42	27.16	153.1	---	---	---
-41.97	-10.67	25.64	8.79	958.6	19.44	7.11	972.7	19.77	26.83	174.7	---	---	---
-43.74	-11.67	26.61	8.33	859.1	19.90	8.00	993.7	19.82	28.68	162.8	---	---	---
-45.52	-12.68	27.03	7.87	800.4	20.07	8.70	927.3	19.49	29.26	160.1	---	---	---
-47.29	-13.69	27.18	7.57	889.7	20.24	9.18	824.0	19.83	29.06	171.7	---	---	---
-49.07	-14.70	27.57	5.85	505.6	22.00	11.00	831.1	19.40	28.10	172.9	---	---	---
-50.84	-15.71	26.28	6.95	691.5	21.46	10.70	599.7	18.96	26.47	200.5	---	---	---
-52.62	-16.72	25.27	7.42	966.7	20.10	10.36	372.7	18.67	25.35	217.1	---	---	---
-54.39	-17.73	23.72	8.25	1086.2	15.89	9.83	218.8	17.97	29.12	142.7	---	---	---
-56.16	-18.74	23.26	8.67	982.0	16.91	10.47	283.5	17.31	29.39	145.8	---	---	---
-57.94	-19.74	22.29	10.40	1048.5	15.24	13.86	299.5	38.20	21.32	38.3	0.37	9.10	73.0
-59.71	-20.75	22.26	10.89	987.6	14.32	7.82	291.9	34.37	24.78	43.6	3.27	13.27	105.1
-61.49	-21.76	23.29	9.63	726.3	16.10	8.90	467.2	23.10	41.14	50.8	1.72	10.05	99.9
-63.26	-22.77	25.00	8.09	569.5	17.19	10.37	827.6	18.93	45.49	64.2	1.86	10.11	107.1
-65.04	-23.78	23.42	9.03	601.7	16.40	7.39	787.4	14.61	28.72	262.0	---	---	---
-66.81	-24.79	25.42	6.26	443.1	17.36	7.76	1230.2	14.37	29.92	260.8	---	---	---
-68.58	-25.80	23.94	8.82	473.5	16.96	6.49	1218.6	12.34	30.49	270.6	---	---	---
-70.36	-26.81	21.98	12.87	663.5	16.65	6.16	933.4	---	---	---	4.08	15.13	299.5
-72.13	-27.81	22.76	11.74	595.7	16.52	7.53	820.6	---	---	---	5.56	13.67	410.9
-73.91	-28.82	---	---	---	17.94	14.82	982.5	17.30	46.46	45.1	4.83	9.60	330.1

TABLE I-6: VELOCITY COMPONENTS FOR THE SPECTRA ORION C TO D

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
-69.77	38.31	17.68	7.84	578.1	16.98	19.86	206.3	33.57	44.60	5.6	---	---	---
-67.98	37.33	18.20	7.09	512.6	16.56	19.44	212.2	---	---	---	39.50	4.14	27.8
-66.19	36.35	18.84	7.65	328.3	16.36	18.57	219.8	---	---	---	---	---	---
-64.41	35.36	19.30	7.08	329.5	15.63	16.78	202.7	25.02	42.78	20.4	---	---	---
-62.62	34.38	19.89	6.03	286.8	15.77	16.68	214.4	22.53	31.82	28.9	---	---	---
-60.83	33.40	19.58	7.76	223.6	13.98	15.62	140.0	22.31	34.47	20.2	---	---	---
-59.04	32.42	19.92	8.95	201.4	13.87	14.35	133.8	19.74	36.85	24.4	---	---	---
-57.25	31.43	21.72	7.41	210.5	15.84	14.12	223.9	19.39	38.71	33.6	---	---	---
-55.46	30.45	22.21	4.95	140.3	16.45	14.56	154.0	---	---	---	16.13	20.22	157.1
-53.67	29.47	21.88	5.01	141.4	15.36	19.84	111.2	---	---	---	16.09	6.94	97.3
-51.88	28.49	21.47	8.49	293.1	15.33	14.31	241.9	21.78	47.04	24.7	---	---	---
-50.09	27.50	19.44	8.92	165.9	13.15	14.76	103.1	24.36	44.49	11.8	---	---	---
-48.30	26.52	20.03	8.36	303.4	13.82	14.26	176.6	20.98	39.34	26.5	---	---	---
-46.52	25.54	19.63	8.85	298.3	13.23	14.83	151.1	---	---	---	31.30	16.69	22.8
-44.73	24.56	19.73	7.96	363.1	14.34	12.72	203.2	16.59	34.15	55.7	---	---	---
-42.94	23.58	19.61	8.13	296.4	15.04	13.61	198.4	18.65	38.21	45.4	---	---	---
-41.15	22.59	20.07	8.63	312.4	14.91	13.43	226.0	19.68	35.21	38.6	---	---	---
-39.36	21.61	21.26	6.90	235.6	16.35	11.72	318.5	17.49	28.11	81.5	---	---	---
-37.57	20.63	21.16	6.78	219.7	16.64	10.35	301.0	16.75	22.84	93.4	---	---	---
-35.78	19.65	22.26	7.73	748.0	16.66	8.21	733.3	18.14	23.41	227.1	---	---	---
-33.99	18.66	21.09	8.60	1105.6	15.77	7.43	815.7	18.18	24.25	189.0	---	---	---
-32.20	17.68	22.33	8.17	1095.2	16.31	7.53	1669.6	19.27	28.49	178.9	---	---	---
-30.41	16.70	22.25	7.06	949.2	16.54	7.34	17012.2	18.92	25.99	189.4	---	---	---
-28.63	15.72	22.34	6.19	997.4	16.46	7.41	2187.3	18.73	25.08	201.5	---	---	---
-26.84	14.73	22.05	6.43	774.1	16.04	7.92	1916.6	18.36	27.61	136.3	---	---	---
-25.05	13.75	21.78	7.51	1814.3	16.07	7.99	2732.6	20.61	31.37	165.6	---	---	---
-23.26	12.77	22.26	6.85	1577.9	16.33	7.42	2848.2	19.89	29.56	201.9	---	---	---
-21.47	11.79	23.39	6.52	770.9	17.50	8.62	3068.9	20.31	31.48	187.3	---	---	---
-19.68	10.81	18.07	9.63	2789.4	---	---	---	20.71	29.75	170.7	---	---	---
-17.89	9.82	18.09	9.20	2636.1	---	---	---	18.74	25.90	277.9	---	---	---
-16.10	8.84	18.82	8.48	1683.4	16.97	12.32	868.7	22.34	32.15	127.6	---	---	---
-14.31	7.86	19.54	8.74	1285.0	15.11	11.39	650.8	22.32	31.51	116.8	---	---	---
-12.52	6.88	20.67	8.65	2164.6	13.26	7.47	698.2	20.87	26.38	282.2	---	---	---
-10.73	5.89	21.21	9.97	1985.3	12.56	7.18	602.0	21.25	26.97	315.1	---	---	---
-8.95	4.91	22.85	9.36	1939.6	14.24	9.25	862.0	22.34	29.18	227.1	---	---	---
-7.16	3.93	23.74	8.61	1764.3	14.98	10.98	1030.5	24.25	32.47	205.2	---	---	---
-5.37	2.95	23.26	9.07	1853.8	13.65	10.21	952.5	23.43	32.45	186.5	---	---	---
-3.58	1.96	23.78	8.06	1888.9	13.49	11.90	976.8	25.31	30.58	194.3	---	---	---
-1.79	0.98	23.87	9.33	1904.6	12.34	12.27	910.7	29.76	29.80	151.9	---	---	---
0.00	0.00	23.71	11.11	1783.3	10.97	10.74	794.6	29.96	32.53	157.2	---	---	---
1.79	-0.98	23.25	13.32	1578.0	10.08	9.14	631.2	27.76	39.84	149.3	---	---	---
3.58	-1.96	22.23	15.50	1389.1	9.30	8.21	461.9	27.51	40.64	147.8	---	---	---
5.37	-2.95	21.61	15.78	1291.6	9.74	8.80	502.7	26.63	41.81	174.0	---	---	---
7.16	-3.93	23.14	12.02	1287.1	11.87	11.28	1077.7	28.36	37.35	200.9	---	---	---
8.95	-4.91	21.85	12.61	1632.0	11.69	11.31	1351.7	29.36	37.18	204.5	---	---	---
10.73	-5.89	19.02	13.81	2317.6	9.70	9.93	914.0	27.86	38.86	181.8	---	---	---
12.52	-6.88	17.13	14.98	2356.7	11.44	12.21	832.3	30.08	36.95	137.2	---	---	---
14.31	-7.86	17.02	15.85	1483.1	13.27	11.38	2189.4	25.23	40.68	160.2	---	---	---
16.10	-8.84	18.54	14.65	575.5	11.92	11.43	2175.2	22.07	46.05	120.7	---	---	---
17.89	-9.82	16.77	15.83	926.4	11.71	9.42	2953.9	21.81	40.83	179.4	-23.31	15.64	64.7
19.68	-10.81	13.45	17.13	961.7	11.04	8.27	2520.4	26.19	29.98	146.9	-24.44	20.18	65.2
21.47	-11.79	---	---	---	11.05	9.77	3455.7	---	---	---	-30.42	17.86	50.9
23.26	-12.77	---	---	---	10.63	12.05	3476.4	17.87	42.34	195.5	---	---	---
25.05	-13.75	12.04	10.09	3746.1	4.18	8.38	1447.4	23.68	32.42	199.1	---	---	---
26.84	-14.73	13.04	9.73	3566.5	4.73	9.19	2013.8	27.61	26.90	209.5	---	---	---
28.63	-15.72	12.87	9.94	3183.6	4.05	8.86	1986.0	26.62	28.12	242.9	---	---	---
30.41	-16.70	12.77	10.68	2715.2	3.76	8.82	1577.9	27.33	27.69	255.1	---	---	---
32.20	-17.68	13.42	10.93	2114.8	4.62	9.63	1422.2	29.76	25.30	263.8	---	---	---
33.99	-18.66	14.21	11.86	1872.4	4.89	9.91	1285.3	33.55	20.26	246.0	---	---	---
35.78	-19.65	15.11	12.35	1419.6	4.11	9.57	982.0	34.92	18.06	176.3	14.95	12.26	1583.2
37.57	-20.63	17.63	10.97	1524.2	5.27	11.35	1168.4	---	---	---	35.40	18.65	179.6
39.36	-21.61	18.21	11.12	1500.9	5.31	11.94	989.6	---	---	---	36.81	15.82	170.9
41.15	-22.59	17.13	11.43	1467.9	4.65	11.13	873.8	---	---	---	36.08	19.35	170.3
42.94	-23.58	16.31	12.63	1150.8	3.79	10.70	686.4	---	---	---	37.11	17.57	144.4
44.73	-24.56	17.25	12.21	943.7	5.25	12.45	660.0	18.01	51.46	54.6	37.32	17.40	127.9
46.52	-25.54	16.22	16.03	938.9	3.29	10.24	491.7	---	---	---	17.01	14.69	1026.1
48.30	-26.52	12.63	13.13	708.6	1.84	7.15	421.1	20.21	41.69	158.1	21.60	7.23	339.5
50.09	-27.50	14.08	12.99	814.9	2.27	8.12	501.5	19.04	42.03	185.4	23.05	5.23	376.0

TABLE I-7: VELOCITY COMPONENTS FOR THE SPECTRA CRION A POSITION ANGLE 180°

Position		Component A			Component B			Component C			Component D		
x	y	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Inten.
9.78	-54.61	9.81	13.27	1761.3	---	---	---	20.62	30.65	256.6	---	---	---
9.78	-52.57	9.96	14.00	2021.3	---	---	---	---	---	---	---	---	---
9.78	-50.52	14.01	16.39	1457.8	5.92	10.14	781.4	---	---	---	---	---	---
9.78	-48.48	14.38	16.68	1620.0	4.40	7.95	775.2	---	---	---	---	---	---
9.78	-46.44	15.77	14.65	1355.5	4.98	8.52	1071.1	22.64	41.28	101.7	---	---	---
9.78	-44.40	15.88	14.91	1102.2	5.55	8.40	1036.0	21.26	37.42	142.2	---	---	---
9.78	-42.36	14.52	16.40	1073.0	5.42	8.07	431.8	22.41	36.90	150.1	---	---	---
9.78	-40.32	15.85	15.34	1092.5	5.88	12.53	252.1	---	---	---	---	---	---
9.78	-38.28	17.65	13.67	815.9	11.04	16.46	525.0	---	---	---	---	---	---
9.78	-36.24	18.09	12.75	1229.3	7.95	13.06	425.1	---	---	---	---	---	---
9.78	-34.20	19.04	8.35	905.9	---	---	---	---	---	---	---	---	---
9.78	-32.16	18.62	9.99	1448.5	6.60	9.71	324.2	22.60	38.39	240.1	-39.14	32.43	70.0
9.78	-30.12	18.47	8.59	870.0	---	---	---	---	---	---	-36.14	33.66	73.1
9.78	-28.07	17.07	10.92	1508.1	7.55	10.72	527.0	27.99	35.45	149.8	---	---	---
9.78	-26.03	15.97	11.78	1818.3	7.18	10.72	459.7	33.29	24.84	113.6	---	---	---
9.78	-23.99	14.22	14.72	1421.3	15.56	9.29	988.3	35.76	21.19	88.6	---	---	---
9.78	-21.95	14.51	7.11	299.9	15.17	12.13	2401.0	22.00	39.21	123.6	---	---	---
9.78	-19.91	22.74	6.47	476.8	15.02	10.66	2581.1	20.45	33.54	182.2	---	---	---
9.78	-17.87	20.91	8.49	1327.9	13.62	9.48	2112.7	21.17	32.81	205.1	---	---	---
9.78	-15.83	19.74	9.34	1814.6	12.00	8.28	1794.7	21.46	32.81	229.1	---	---	---
9.78	-13.79	20.06	5.40	1741.5	11.69	9.38	2042.3	21.64	33.02	251.4	---	---	---
9.78	-11.75	19.74	8.84	1762.7	11.01	10.39	2148.4	22.63	34.69	218.5	---	---	---
9.78	-9.70	18.06	11.81	2252.9	9.17	9.31	1428.6	23.63	38.97	171.4	---	---	---
9.78	-7.66	17.86	13.48	2343.5	8.10	7.83	802.6	25.79	41.89	152.6	---	---	---
9.78	-5.62	19.40	14.84	2080.5	9.40	9.64	742.6	---	---	---	---	---	---
9.78	-3.58	22.44	11.13	1397.6	12.44	11.13	1295.5	28.42	38.06	237.5	---	---	---
9.78	-1.54	22.53	11.88	1388.2	12.29	11.36	1371.8	39.22	21.21	201.7	---	---	---
9.78	0.50	20.65	11.67	1099.1	12.35	9.81	1363.4	25.68	39.32	246.9	---	---	---
9.78	2.54	20.93	10.93	932.2	12.79	10.03	1824.4	25.14	38.31	222.7	---	---	---
9.78	4.56	21.58	10.78	636.4	13.78	11.89	2004.0	25.84	36.99	165.6	---	---	---
9.78	6.62	16.91	12.91	1951.8	8.19	11.23	508.8	26.72	32.59	133.5	---	---	---
9.78	8.66	17.16	14.01	1862.3	5.14	9.30	451.4	35.25	22.49	86.8	---	---	---
9.78	10.91	18.78	12.89	1651.2	5.69	11.32	484.2	---	---	---	---	---	---
9.78	12.75	19.61	11.07	1698.1	8.98	16.94	563.1	---	---	---	---	---	---
9.78	14.79	19.24	10.84	1708.0	9.99	16.91	550.3	---	---	---	---	---	---
9.78	16.83	17.65	12.16	2015.4	6.29	12.65	406.9	---	---	---	---	---	---
9.78	18.87	16.68	14.04	1464.2	---	---	---	---	---	---	---	---	---
9.78	20.91	16.71	12.93	1150.3	---	---	---	35.48	21.59	102.8	---	---	---
9.78	22.95	15.86	13.52	1244.6	---	---	---	---	---	---	---	---	---
9.78	24.99	15.84	13.81	1458.6	8.01	21.48	73.4	36.80	25.61	77.7	---	---	---
9.78	27.03	15.48	13.38	1291.5	---	---	---	---	---	---	---	---	---
9.78	29.07	14.74	13.20	1220.7	---	---	---	24.07	41.49	95.7	---	---	---
9.78	31.12	15.62	12.33	1102.6	9.73	13.97	319.1	32.65	32.44	71.6	---	---	---
9.78	33.16	14.28	11.79	1485.7	5.89	5.71	173.2	22.31	38.93	111.8	---	---	---
9.78	35.20	13.14	13.19	1622.2	14.18	5.32	357.1	23.91	31.45	111.9	---	---	---

TABLE I-8: VELOCITY COMPONENTS FOR THE SPECTRA ORION A POSITION ANGLE 240°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
-50.32	43.36	16.48	6.32	247.2	13.73	12.77	240.0	17.86	34.35	39.1	---	---	---
-48.55	42.34	15.44	7.39	292.9	13.78	16.86	190.5	27.61	25.00	17.6	---	---	---
-46.79	41.32	15.36	7.36	273.8	13.73	15.76	209.1	---	---	---	---	---	---
-45.02	40.30	15.13	8.84	381.3	---	---	---	18.51	27.53	53.8	---	---	---
-43.25	39.28	15.18	8.70	228.4	13.43	16.11	147.0	26.16	40.56	20.9	---	---	---
-41.48	38.26	15.27	9.81	183.7	13.49	15.59	168.7	23.25	33.02	25.1	---	---	---
-39.72	37.24	17.47	10.13	241.4	11.56	12.66	126.6	22.42	29.90	30.1	---	---	---
-37.95	36.22	19.20	7.26	128.0	15.98	14.42	231.4	23.34	41.13	20.4	---	---	---
-36.18	35.20	18.60	7.95	259.6	15.17	15.11	258.8	24.61	36.22	28.2	---	---	---
-34.41	34.18	18.92	8.43	497.7	12.20	10.77	176.1	19.40	27.00	75.4	---	---	---
-32.65	33.16	18.45	7.62	621.8	11.58	8.89	208.2	17.78	23.21	167.8	---	---	---
-30.88	32.14	19.52	8.19	660.0	11.76	6.30	206.6	18.96	23.59	154.7	---	---	---
-29.11	31.12	19.20	8.36	859.9	11.53	6.19	290.8	19.04	23.50	200.1	---	---	---
-27.34	30.09	19.62	7.79	1013.3	12.29	6.44	378.6	18.95	22.78	256.3	---	---	---
-25.58	29.07	19.37	8.73	1105.4	12.05	5.12	374.9	18.61	22.24	307.1	---	---	---
-23.81	28.05	20.39	7.71	1003.2	13.70	7.33	670.4	18.87	23.65	302.4	---	---	---
-22.04	27.03	19.70	8.86	1223.8	12.61	5.86	628.6	19.20	25.06	237.8	---	---	---
-20.27	26.01	20.38	8.75	1243.8	14.34	7.72	758.4	21.35	30.57	131.9	---	---	---
-18.51	24.99	18.85	9.29	1709.2	12.81	5.13	332.2	21.15	28.93	152.9	---	---	---
-16.74	23.97	18.38	9.50	1853.8	12.87	3.34	262.3	22.16	28.57	155.0	---	---	---
-14.97	22.95	18.01	10.14	1958.4	13.38	3.82	470.3	21.28	29.13	166.0	---	---	---
-13.20	21.93	19.25	9.23	1763.7	13.68	6.14	780.3	20.17	29.08	184.8	---	---	---
-11.44	20.91	20.87	7.71	1643.7	14.61	7.84	1030.3	20.48	29.73	174.1	---	---	---
-9.67	19.89	21.24	7.82	1775.5	13.98	7.43	903.9	20.25	29.50	188.6	---	---	---
-7.90	18.87	21.74	7.89	1629.7	14.15	7.71	1032.8	20.55	31.23	180.1	---	---	---
-6.13	17.85	22.95	6.61	1379.6	15.09	8.99	1339.9	21.29	30.44	187.4	---	---	---
-4.36	16.83	22.92	6.73	1516.0	14.58	8.59	1471.9	21.26	31.89	172.8	---	---	---
-2.60	15.81	23.05	6.57	1234.0	15.50	10.58	1634.3	22.53	31.81	186.1	---	---	---
-0.83	14.79	20.10	9.57	1238.5	16.62	12.20	1833.8	23.52	35.02	148.9	---	---	---
0.94	13.77	23.57	4.82	474.6	17.47	12.54	2017.5	23.06	36.19	152.8	---	---	---
2.71	12.75	23.53	4.16	550.2	17.79	12.16	2029.3	21.18	36.70	176.4	---	---	---
4.47	11.73	22.96	5.49	553.2	17.82	11.75	1966.8	19.25	33.11	245.6	---	---	---
6.24	10.71	22.03	6.63	741.5	17.00	11.62	1731.0	17.16	27.65	445.4	---	---	---
8.01	9.68	20.16	10.91	1451.5	13.26	16.92	935.8	30.95	26.66	111.9	---	---	---
9.78	8.66	17.87	12.46	1987.6	6.83	10.91	656.0	26.67	31.16	139.8	---	---	---
11.54	7.64	16.05	13.05	2329.4	5.13	7.66	554.2	24.33	33.64	159.2	---	---	---
13.31	6.62	15.41	11.87	2926.4	5.66	7.34	583.5	24.46	34.32	165.8	---	---	---
15.08	5.60	14.65	11.35	3605.7	6.20	7.19	303.5	22.05	36.60	178.6	---	---	---
16.85	4.58	14.42	11.37	4098.3	---	---	---	22.06	38.21	155.6	---	---	---
18.61	3.56	14.03	11.40	4106.7	---	---	---	26.60	25.11	164.5	---	---	---
20.38	2.54	14.17	10.93	3589.8	9.53	4.67	870.0	20.47	31.08	209.5	---	---	---
22.15	1.52	14.01	10.61	3481.8	9.56	3.18	739.0	19.77	32.12	183.4	---	---	---
23.92	0.50	17.52	9.71	1115.4	11.80	8.53	3526.5	19.76	38.60	148.3	---	---	---
25.68	-0.52	14.97	10.95	1515.1	10.39	7.57	2885.3	18.56	41.89	149.2	---	---	---
27.45	-1.54	14.38	10.82	1224.0	10.04	7.86	3200.1	20.75	45.14	126.3	---	---	---
29.22	-2.56	16.42	18.56	380.0	10.65	8.59	4329.1	---	---	---	---	---	---
30.99	-3.58	---	---	---	10.76	8.68	5002.0	20.01	30.97	207.3	---	---	---
32.75	-4.60	---	---	---	11.09	9.83	4725.4	24.86	37.89	147.1	---	---	---
34.52	-5.62	13.79	7.43	3848.7	7.56	7.88	2152.0	20.85	37.61	209.9	---	---	---
36.29	-6.64	14.29	7.25	3954.4	6.87	8.26	1811.8	19.88	36.56	246.1	---	---	---
38.06	-7.66	14.65	7.96	3501.4	6.35	8.39	1484.1	18.68	37.83	281.4	---	---	---
39.82	-8.68	15.70	8.05	2790.9	7.18	9.22	1490.9	17.28	37.30	342.9	---	---	---
41.59	-9.70	16.32	8.06	2538.0	7.10	8.73	1276.3	15.90	37.01	403.0	---	---	---
43.36	-10.73	16.75	8.48	2219.6	7.27	9.30	1103.6	12.68	24.36	732.2	---	---	---
45.13	-11.75	17.24	9.00	1987.1	7.15	9.31	948.1	19.84	36.74	359.9	---	---	---
46.89	-12.77	18.09	9.50	2044.7	7.42	10.26	1014.9	32.53	20.27	215.6	10.96	47.68	72.3
48.66	-13.79	18.21	8.61	1941.9	7.31	9.71	871.7	22.37	36.21	261.6	---	---	---
50.43	-14.81	18.08	8.57	2048.1	7.20	10.11	957.8	22.72	36.64	244.5	---	---	---
52.20	-15.83	17.44	9.26	1979.1	6.91	9.89	998.5	22.22	37.44	233.1	---	---	---
53.96	-16.85	16.42	10.93	2035.6	5.58	8.44	940.7	21.61	41.76	203.7	---	---	---
55.73	-17.87	15.96	10.96	2120.6	5.06	8.85	1024.7	23.90	37.39	173.0	---	---	---
57.50	-18.89	14.91	11.11	2242.9	4.60	9.29	1032.7	32.40	23.10	145.9	---	---	---
59.27	-19.91	14.26	11.17	2185.4	4.10	9.63	893.5	33.12	21.17	142.7	---	---	---
61.03	-20.93	14.73	10.98	1943.4	4.13	9.92	802.2	34.71	20.25	123.3	---	---	---
62.80	-21.95	15.67	9.62	1647.2	5.51	11.64	889.7	32.84	21.71	116.0	---	---	---
64.57	-22.97	15.37	10.11	1466.1	4.55	10.58	798.6	32.94	21.55	110.4	---	---	---
66.34	-23.99	15.48	9.81	1204.8	3.81	10.23	767.9	22.32	38.12	118.5	---	---	---
68.10	-25.01	15.25	10.26	1067.2	2.73	9.32	833.6	20.23	41.25	118.2	---	---	---
69.87	-26.03	15.15	9.99	963.6	2.49	8.65	995.1	20.61	39.94	121.7	---	---	---

TABLE I-9: VELOCITY COMPONENTS FOR THE SPECTRA ORION A POSITION ANGLE 330°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
19.98	26.34	13.24	8.94	1818.1	22.95	9.90	621.1	19.10	29.85	181.3	---	---	---
18.96	24.57	13.17	9.15	1683.3	23.55	8.44	643.1	18.20	28.37	274.1	---	---	---
17.94	22.80	16.71	19.41	1007.5	---	---	---	---	---	---	---	---	---
16.92	21.04	13.65	8.59	1190.8	---	---	---	---	---	---	---	---	---
15.90	19.27	14.76	18.00	1198.4	---	---	---	---	---	---	---	---	---
14.88	17.50	14.06	18.18	1063.5	---	---	---	---	---	---	---	---	---
13.86	15.73	15.20	12.77	1638.4	3.14	7.86	315.8	33.13	25.87	152.5	---	---	---
12.84	13.97	16.31	13.92	1497.6	3.38	8.40	347.1	34.40	22.89	146.5	---	---	---
11.82	12.20	17.83	14.23	1454.0	3.77	9.66	431.0	---	---	---	---	---	---
10.80	10.43	18.14	13.72	1475.1	4.51	9.53	470.6	31.86	25.00	110.1	---	---	---
9.78	8.66	18.44	12.53	1546.2	7.32	11.11	513.7	30.52	26.54	100.2	---	---	---
8.76	6.90	19.09	11.67	1350.6	10.98	11.19	739.7	23.58	32.11	137.5	---	---	---
7.73	5.13	18.03	14.91	1394.8	11.16	9.13	371.0	27.44	33.55	107.0	---	---	---
6.71	3.36	19.78	15.94	1113.9	11.15	9.82	603.6	30.66	33.17	97.5	---	---	---
5.69	1.59	19.24	18.30	1243.3	10.07	8.02	348.2	39.99	24.13	89.4	---	---	---
4.67	-0.17	20.75	19.54	1190.7	9.04	6.25	235.6	---	---	---	---	---	---
3.65	-1.94	22.73	15.58	1001.0	9.82	7.61	314.8	27.02	43.39	98.9	---	---	---
2.63	-3.71	22.12	15.63	1010.4	10.70	8.86	380.6	26.94	42.64	64.4	---	---	---
1.61	-5.48	20.90	16.67	906.3	11.48	9.95	513.2	---	---	---	---	---	---
0.59	-7.24	19.33	15.47	1020.0	11.26	9.46	669.5	35.06	25.38	73.8	---	---	---
-0.43	-9.01	18.90	14.67	1003.5	11.64	9.01	677.9	28.85	26.41	132.7	---	---	---
-1.45	-10.78	17.83	13.41	884.9	12.27	7.41	519.1	23.80	20.84	462.0	---	---	---
-2.47	-12.55	26.31	11.83	724.1	15.80	10.82	1415.6	28.65	35.86	86.8	---	---	---
-3.49	-14.31	25.05	11.59	923.3	15.83	9.48	1267.5	24.88	35.56	120.5	---	---	---
-4.51	-16.08	21.25	12.41	1076.9	14.89	6.90	576.8	23.32	32.48	164.4	---	---	---
-5.53	-17.85	19.66	12.16	1398.4	15.90	8.61	476.7	22.80	29.44	175.9	---	---	---
-6.55	-19.62	19.50	16.04	444.5	17.81	10.07	1531.6	22.77	30.73	126.8	---	---	---
-7.57	-21.38	17.65	11.95	1733.5	17.46	5.55	428.9	23.27	30.90	112.1	---	---	---
-8.59	-23.15	16.92	13.17	818.5	17.29	9.34	1379.3	24.07	32.03	85.1	---	---	---
-9.61	-24.92	16.95	10.46	2174.9	---	---	---	20.50	34.60	92.0	---	---	---
-10.63	-26.69	17.51	8.48	1082.2	18.47	11.49	1002.8	19.30	32.93	100.3	---	---	---
-11.65	-28.45	16.85	10.27	2040.3	---	---	---	19.11	30.20	130.0	---	---	---
-12.68	-30.22	16.48	9.52	1815.6	---	---	---	17.59	24.13	245.8	---	---	---
-13.70	-31.99	16.16	9.59	1659.4	---	---	---	17.85	28.97	154.4	---	---	---
-14.72	-33.76	16.34	9.59	1490.0	---	---	---	15.34	22.50	161.9	---	---	---
-15.74	-35.52	18.93	7.99	1046.4	13.72	7.52	902.7	19.24	32.02	130.1	---	---	---
-16.76	-37.29	18.78	8.48	1254.1	12.24	6.58	757.3	19.33	34.75	114.9	---	---	---
-17.78	-39.06	19.22	8.39	1278.0	12.17	7.05	811.1	18.77	34.55	120.3	---	---	---
-18.80	-40.83	19.11	8.59	1368.3	11.51	6.92	751.1	17.95	34.14	141.1	---	---	---
-19.82	-42.60	19.36	8.99	1107.0	11.53	7.34	771.3	15.86	29.48	187.8	---	---	---
-20.84	-44.36	20.01	7.74	941.5	12.71	9.86	778.6	15.80	30.25	191.5	---	---	---

TABLE I-10: VELOCITY COMPONENTS FOR THE SPECTRA ORION B POSITION ANGLE 270°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
70.27	15.98	12.93	8.14	1365.6	---	---	---	16.87	33.82	196.4	---	---	---
68.23	15.98	12.58	8.33	1100.6	---	---	---	11.14	21.57	476.8	---	---	---
66.19	15.98	12.53	7.51	1416.3	11.52	22.32	488.7	---	---	---	---	---	---
64.15	15.98	12.59	7.20	1675.0	11.40	23.48	444.3	---	---	---	---	---	---
62.11	15.98	12.70	7.22	1991.8	11.83	24.65	421.3	---	---	---	---	---	---
60.07	15.98	12.70	6.26	1652.8	12.99	11.85	796.8	14.87	42.10	209.1	---	---	---
58.03	15.98	13.11	6.94	1940.8	12.95	13.88	647.3	16.83	42.34	195.6	---	---	---
55.99	15.98	13.74	9.43	1844.5	12.96	4.56	795.7	12.04	24.20	410.1	37.35	16.13	99.4
53.94	15.98	13.27	8.42	2239.1	---	---	---	13.23	22.11	624.0	39.41	10.23	86.4
51.90	15.98	13.34	7.90	2513.2	---	---	---	13.50	21.31	700.3	39.40	10.78	76.2
49.86	15.98	13.67	5.64	2119.2	14.02	10.98	1686.9	13.88	30.06	327.7	---	---	---
47.82	15.98	13.65	5.62	2615.0	14.39	11.12	1665.9	15.04	31.14	320.1	---	---	---
45.78	15.98	13.41	5.31	2514.4	14.79	9.95	2076.8	15.22	30.32	357.7	---	---	---
43.74	15.98	13.99	6.02	2657.8	14.60	10.92	1714.7	19.13	36.79	194.7	---	---	---
41.70	15.98	14.32	6.11	2870.1	15.11	10.43	1744.0	19.67	36.32	183.9	---	---	---
39.66	15.98	14.27	6.45	3235.1	15.86	10.55	1279.7	21.18	34.85	170.8	---	---	---
37.62	15.98	14.24	6.65	3808.8	18.56	8.31	621.5	21.17	33.96	173.4	---	---	---
35.57	15.98	13.94	6.07	2992.0	16.65	8.77	1712.3	20.88	33.69	169.6	---	---	---
33.53	15.98	13.84	6.47	3141.6	17.84	8.55	738.9	20.29	32.28	192.9	---	---	---
31.49	15.98	13.70	6.27	2189.5	15.51	10.97	1052.5	20.95	34.18	152.4	---	---	---
29.45	15.98	13.83	10.33	1777.1	14.65	5.90	1292.2	22.73	33.26	120.9	---	---	---
27.41	15.98	14.41	7.67	2838.6	8.17	5.74	739.5	19.79	31.50	167.0	---	---	---
25.37	15.98	14.72	6.85	2773.6	8.35	6.42	1373.8	19.78	29.76	194.4	---	---	---
23.33	15.98	14.43	7.98	2557.6	7.34	6.68	1286.4	21.01	30.28	194.6	---	---	---
21.29	15.98	14.55	8.56	2327.1	6.62	7.41	1159.8	21.66	9.87	218.9	---	---	---
19.25	15.98	14.44	9.48	2172.6	5.41	7.57	883.6	23.20	31.15	215.1	---	---	---
17.21	15.98	14.38	10.82	1912.3	4.05	7.34	581.9	25.22	33.64	197.2	---	---	---
15.16	15.98	14.79	12.18	1713.4	3.34	7.65	407.2	31.96	27.57	161.5	---	---	---
13.12	15.98	16.35	9.60	858.3	---	---	---	---	---	---	---	---	---
11.08	15.98	17.14	12.27	1558.5	5.25	10.89	285.4	35.62	22.18	115.3	---	---	---
9.04	15.98	18.24	11.33	1545.2	7.49	13.31	326.6	36.06	19.18	98.3	---	---	---
7.00	15.98	18.66	10.96	1468.2	9.54	14.36	364.1	---	---	---	---	---	---
4.96	15.98	20.81	7.32	576.9	15.98	12.18	1031.6	20.38	33.64	171.2	---	---	---
2.92	15.98	21.30	6.40	539.2	16.00	12.07	1164.8	22.69	34.05	142.3	---	---	---
0.88	15.98	20.67	7.71	1026.6	14.05	10.12	1016.9	23.16	32.34	159.6	---	---	---
-1.16	15.98	21.28	8.46	984.4	14.87	10.72	1043.1	23.63	35.03	125.5	---	---	---
-3.20	15.98	22.90	6.91	1030.1	15.13	9.68	1201.1	22.37	32.62	130.2	---	---	---
-5.24	15.98	23.38	6.69	1178.8	15.00	8.69	1086.3	21.21	30.35	170.4	---	---	---
-7.29	15.98	23.03	7.12	1215.7	14.84	7.33	918.7	19.74	24.55	243.6	---	---	---
-9.33	15.98	22.90	7.34	1132.2	15.39	7.85	883.5	20.54	27.82	261.7	---	---	---
-11.37	15.98	22.21	6.73	1136.4	15.66	8.00	872.4	20.00	25.17	243.2	---	---	---
-13.41	15.98	21.82	6.67	977.4	16.03	8.08	1069.6	19.75	27.36	176.3	---	---	---
-15.45	15.98	22.31	6.71	668.9	16.55	8.19	1396.1	19.92	29.81	135.4	---	---	---
-17.49	15.98	21.98	7.53	837.7	16.09	7.15	1443.6	19.50	28.94	141.6	---	---	---
-19.53	15.98	21.84	7.95	971.4	16.25	7.44	1327.7	20.22	32.02	124.2	---	---	---
-21.57	15.98	22.43	7.72	787.1	16.81	7.90	1506.4	20.30	31.82	127.0	---	---	---
-23.61	15.98	21.78	7.60	1193.9	16.00	7.11	1226.1	19.87	30.14	122.4	---	---	---
-25.65	15.98	22.27	6.30	1062.3	16.33	7.06	1361.4	19.19	24.10	164.3	---	---	---
-27.70	15.98	22.53	5.96	951.8	16.82	7.47	1269.3	19.46	27.01	141.6	---	---	---
-29.74	15.98	23.74	6.04	504.5	17.63	8.05	1185.0	19.11	26.32	129.4	---	---	---
-31.78	15.98	21.73	7.61	1034.0	16.04	6.57	783.7	19.03	25.59	142.2	---	---	---
-33.82	15.98	22.07	7.39	892.4	16.59	7.32	676.6	19.16	25.83	131.9	---	---	---
-35.86	15.98	22.64	7.27	339.2	17.77	9.06	499.4	18.79	24.93	118.0	---	---	---
-37.90	15.98	20.61	10.42	413.7	14.68	16.30	148.9	38.34	11.43	19.4	---	---	---
-39.94	15.98	21.95	6.68	160.6	17.46	11.05	182.3	---	---	---	---	---	---
-41.98	15.98	20.93	7.78	178.3	16.01	14.80	170.7	23.75	47.58	17.8	---	---	---
-44.02	15.98	20.04	9.29	206.4	15.04	18.32	122.0	40.14	9.60	12.8	---	---	---
-46.07	15.98	21.70	4.44	109.2	17.89	8.66	154.0	---	---	---	---	---	---
-48.11	15.98	21.12	6.64	154.4	16.09	12.37	145.4	17.50	33.89	33.4	---	---	---
-50.15	15.98	20.95	7.62	176.6	15.02	13.48	108.6	18.52	33.78	33.3	---	---	---
-52.19	15.98	20.99	7.98	234.3	15.83	11.73	298.4	17.73	23.07	116.9	---	---	---
-54.23	15.98	21.32	8.98	146.6	14.82	16.47	125.8	---	---	---	---	---	---
-56.27	15.98	21.47	8.09	124.1	15.35	15.31	115.1	20.64	32.49	20.6	---	---	---
-58.31	15.98	20.27	10.42	181.4	13.13	17.05	85.5	---	---	---	---	---	---
-60.35	15.98	20.00	8.87	141.9	16.00	18.65	113.3	39.97	26.89	4.9	---	---	---

TABLE I-11: VELOCITY COMPONENTS FOR THE SPECTRA ORION B POSITION ANGLE 330°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
14.14	31.39	14.74	15.48	799.6	14.22	9.89	598.6	35.33	26.98	45.7	---	---	---
13.12	30.12	15.05	13.81	1027.6	---	---	---	23.91	40.79	68.8	---	---	---
12.10	28.36	14.79	12.38	990.0	22.52	5.16	221.0	21.10	38.29	103.1	---	---	---
11.08	25.59	14.97	11.67	1325.1	22.66	6.68	235.1	19.05	35.89	153.3	---	---	---
10.06	24.82	18.15	9.46	741.0	14.24	17.83	667.9	38.40	24.81	72.4	12.52	6.72	568.0
9.04	23.05	16.37	13.61	1226.1	9.04	17.77	146.3	38.26	22.55	82.1	---	---	---
8.02	21.29	16.16	13.74	1452.9	4.37	10.65	176.6	34.65	23.83	118.0	---	---	---
7.00	19.52	17.99	12.43	943.9	12.26	14.19	552.7	37.51	17.33	70.4	---	---	---
5.98	17.75	20.57	7.28	557.9	15.24	13.01	1171.0	20.66	34.16	176.0	---	---	---
4.96	15.98	21.02	6.60	660.0	16.28	12.20	1370.1	20.87	34.42	192.7	---	---	---
3.94	14.22	21.75	7.39	827.8	16.80	11.62	1457.1	22.04	37.01	154.7	---	---	---
2.92	12.45	23.75	5.19	504.0	17.91	11.96	1825.9	20.84	35.34	173.8	---	---	---
1.90	10.68	24.37	5.85	879.4	17.40	11.19	1966.4	20.85	34.13	211.8	---	---	---
0.88	8.91	24.96	6.08	748.4	18.04	12.73	1994.9	22.82	38.81	177.0	---	---	---
-0.14	7.15	25.15	7.76	1169.2	16.83	12.40	1684.4	26.76	40.06	161.0	---	---	---
-1.16	5.38	24.54	8.36	1578.8	14.65	10.72	1260.5	27.14	38.31	218.7	---	---	---
-2.18	3.61	24.39	8.36	1702.6	13.60	10.08	924.7	24.95	34.06	199.4	---	---	---
-3.20	1.84	23.94	8.46	1716.3	12.96	10.64	849.1	27.38	32.98	120.0	---	---	---
-4.22	-0.08	22.99	8.89	1638.6	13.27	8.91	1145.2	25.37	38.15	118.8	---	---	---
-5.24	-1.69	22.62	9.99	1320.5	14.00	9.15	1562.0	29.35	47.84	170.4	---	---	---
-6.27	-3.46	24.78	9.73	777.3	15.01	11.72	1768.2	35.04	46.47	195.6	---	---	---
-7.29	-5.23	25.30	11.48	869.4	14.92	12.23	1922.4	36.66	43.54	110.9	---	---	---
-8.31	-6.99	25.75	15.52	643.9	16.17	13.92	1231.0	47.40	27.38	58.3	---	---	---
-9.33	-8.75	19.78	10.14	1344.4	11.53	5.36	558.8	24.28	33.37	220.9	30.77	7.29	354.8
-10.35	-10.53	19.82	8.78	1220.6	12.60	5.62	546.1	23.76	29.92	331.9	31.32	5.86	187.0
-11.37	-12.30	20.00	8.47	1371.0	12.97	5.43	564.8	22.57	29.61	297.9	31.44	6.58	263.7
-12.39	-14.06	19.57	12.70	1293.4	---	---	---	21.86	39.28	74.9	---	---	---
-13.41	-15.83	23.38	11.65	866.2	17.05	7.13	646.6	21.29	30.72	157.8	---	---	---
-14.43	-17.60	23.74	10.86	824.3	17.38	6.90	926.0	21.17	27.14	204.7	---	---	---
-15.45	-19.37	23.43	9.90	874.6	17.52	6.92	1308.7	20.38	27.46	188.4	---	---	---
-16.47	-21.13	23.74	8.28	876.2	17.67	7.01	1705.7	19.65	25.78	202.9	---	---	---
-17.49	-22.90	23.19	7.48	1023.6	17.84	7.07	1781.7	19.55	25.75	207.0	---	---	---
-18.51	-24.67	24.50	6.75	1023.1	18.43	7.95	2305.0	20.03	25.31	249.3	---	---	---
-19.53	-26.44	21.61	10.40	1110.6	17.08	7.51	1576.6	19.66	28.95	159.6	---	---	---
-20.55	-28.20	19.83	10.29	1195.8	15.86	6.61	1712.0	19.94	26.29	208.6	---	---	---
-21.57	-29.97	19.13	10.17	1166.9	15.30	7.25	1794.7	19.59	29.28	184.2	---	---	---
-22.59	-31.74	19.99	8.63	1504.7	14.70	8.11	2359.0	20.02	32.23	179.3	---	---	---
-23.61	-33.51	18.57	9.67	1660.3	12.32	6.91	1024.9	19.03	34.80	127.7	---	---	---
-24.63	-35.27	19.54	9.48	1325.6	12.26	8.14	1372.0	18.56	40.64	101.7	---	---	---
-25.65	-37.04	19.27	9.58	1368.8	11.71	7.82	1260.2	16.18	36.45	143.5	---	---	---
-26.68	-38.81	19.71	8.46	1221.9	11.89	8.00	1258.7	15.79	31.25	211.8	---	---	---

TABLE I-12: VELOCITY COMPONENTS FOR THE SPECTRA ORION C POSITION ANGLE 180°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
0.00	-65.31	14.81	16.75	521.3	5.90	11.29	2033.6	32.90	24.18	86.9	---	---	---
0.00	-63.27	18.69	9.64	344.9	6.97	11.53	1954.4	18.09	41.65	166.5	---	---	---
0.00	-61.23	11.05	16.75	908.2	6.28	8.54	981.2	19.12	42.60	154.3	---	---	---
0.00	-59.19	13.43	12.30	801.9	5.72	8.33	1115.5	17.91	40.52	218.4	---	---	---
0.00	-57.15	15.94	10.54	379.1	8.16	11.90	924.5	20.77	37.85	206.6	---	---	---
0.00	-55.11	12.71	14.20	757.6	7.02	11.32	811.0	31.03	23.78	166.9	---	---	---
0.00	-53.07	12.72	18.98	780.1	9.08	10.02	862.4	---	---	---	---	---	---
0.00	-51.02	19.55	8.63	473.3	10.02	13.43	1323.8	31.93	20.74	167.2	10.02	3.72	352.9
0.00	-48.98	19.63	6.56	734.6	10.72	10.86	1310.0	19.99	35.09	255.5	---	---	---
0.00	-46.94	19.67	6.87	614.9	12.02	12.04	1443.7	21.72	34.06	223.3	---	---	---
0.00	-44.90	15.19	20.42	577.7	13.85	12.30	1389.1	---	---	---	---	---	---
0.00	-42.86	14.80	22.30	689.0	14.76	10.28	1401.1	---	---	---	---	---	---
0.00	-40.82	15.47	12.18	2243.2	---	---	---	32.41	24.48	140.2	---	---	---
0.00	-38.78	15.51	10.49	2337.9	---	---	---	15.76	37.24	257.2	---	---	---
0.00	-36.74	16.29	10.68	2481.4	---	---	---	18.08	41.21	175.6	---	---	---
0.00	-34.70	16.16	9.50	2348.0	---	---	---	17.34	38.72	195.7	-28.33	17.29	75.6
0.00	-32.66	15.85	10.04	2256.4	---	---	---	19.05	42.92	170.2	-28.61	22.48	54.5
0.00	-30.62	15.58	10.92	2326.1	---	---	---	21.69	32.41	175.5	---	---	---
0.00	-28.57	15.38	11.72	2457.4	---	---	---	22.13	32.27	182.5	---	---	---
0.00	-26.53	15.15	12.49	2756.4	---	---	---	23.29	42.27	124.4	---	---	---
0.00	-24.49	15.76	12.26	2748.0	8.42	7.03	490.5	22.83	37.64	134.1	---	---	---
0.00	-22.45	12.88	10.89	2018.0	19.79	10.45	1626.8	25.08	30.43	174.2	---	---	---
0.00	-20.41	17.78	13.31	2743.8	11.74	5.76	340.3	24.72	32.84	207.1	---	---	---
0.00	-18.37	19.72	13.38	2028.2	14.29	9.85	803.9	24.94	30.27	239.4	---	---	---
0.00	-16.33	26.83	8.47	763.3	16.88	11.45	2237.1	24.83	32.04	214.1	---	---	---
0.00	-14.29	24.26	12.77	1054.5	15.18	10.39	1779.6	25.01	36.36	151.6	---	---	---
0.00	-12.25	20.29	7.41	1268.4	13.24	8.66	1659.5	24.86	35.31	190.5	26.55	10.09	662.4
0.00	-10.20	19.46	12.46	1397.2	11.49	8.58	1181.1	24.02	27.33	351.6	---	---	---
0.00	-8.16	18.25	15.26	1377.3	11.07	9.27	995.9	28.53	24.91	202.3	---	---	---
0.00	-6.12	21.01	16.42	1175.0	11.94	11.06	1172.5	---	---	---	---	---	---
0.00	-4.08	21.14	14.66	1511.2	11.17	9.48	781.5	28.76	43.16	97.6	---	---	---
0.00	-2.04	22.80	13.15	1872.4	11.07	9.93	760.3	---	---	---	---	---	---
0.00	0.00	23.68	11.36	1859.8	11.00	9.72	803.4	26.08	34.95	200.1	---	---	---
0.00	2.04	24.35	10.33	1932.8	11.96	10.63	969.8	25.32	31.89	251.8	---	---	---
0.00	4.08	24.67	9.76	1986.1	13.64	10.73	1411.3	25.09	36.72	239.4	---	---	---
0.00	6.12	25.15	8.19	1618.3	15.98	12.44	1991.0	26.42	38.57	258.1	---	---	---
0.00	8.16	25.10	7.08	1119.3	17.45	12.91	2394.2	24.44	39.57	252.6	---	---	---
0.00	10.20	24.80	6.56	1184.0	17.06	12.14	2566.4	23.01	37.70	244.0	---	---	---
0.00	12.25	24.34	5.34	1024.3	16.91	12.52	2486.8	23.83	36.51	209.9	---	---	---
0.00	14.29	23.08	5.83	520.0	17.46	12.75	2401.9	22.19	36.95	193.1	---	---	---
0.00	16.33	21.19	7.06	765.9	16.34	12.35	2002.5	22.75	33.59	225.5	---	---	---
0.00	18.37	20.28	7.32	1450.6	13.14	9.46	1684.3	22.17	33.78	262.1	---	---	---
0.00	20.41	19.61	8.16	1240.3	12.13	9.34	1614.4	24.01	36.98	191.4	---	---	---
0.00	22.45	21.44	4.61	220.3	14.81	13.38	1941.3	35.43	23.80	116.4	---	---	---
0.00	24.49	16.87	11.97	1647.7	10.54	12.45	493.9	37.07	21.64	117.3	---	---	---
0.00	26.53	17.21	11.32	1601.1	9.61	11.15	517.8	36.21	22.98	121.6	---	---	---
0.00	28.57	17.13	10.85	1554.8	8.87	9.20	553.2	34.18	25.31	110.6	---	---	---
0.00	30.62	17.40	10.02	1581.0	8.93	7.83	567.7	22.48	41.09	106.4	---	---	---
0.00	32.66	17.55	9.25	2038.6	9.38	7.78	525.5	22.75	35.76	156.4	---	---	---
0.00	34.70	17.09	9.53	2718.2	9.33	7.10	421.5	21.23	34.62	169.3	---	---	---
0.00	36.74	16.06	10.63	3281.7	---	---	---	17.71	34.18	185.6	---	---	---
0.00	38.78	15.35	11.05	3592.7	---	---	---	19.98	34.81	157.6	---	---	---
0.00	40.82	15.20	11.45	3543.4	---	---	---	22.42	33.10	139.6	---	---	---
0.00	42.86	15.68	11.74	2344.8	13.86	10.40	877.9	22.59	25.08	205.6	---	---	---

TABLE I-13: VELOCITY COMPONENTS FOR THE SPECTRA ORION C POSITION ANGLE 270°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
65.31	0.00	11.60	8.47	3411.9	2.36	5.65	743.8	18.35	41.07	257.4	0.00	---	---
63.27	0.00	11.72	8.21	3919.7	2.60	5.05	627.1	16.83	44.36	280.4	---	---	---
61.23	0.00	12.14	6.65	2882.1	10.75	16.32	1583.3	---	---	---	---	---	---
59.19	0.00	12.43	6.89	2689.9	11.60	16.70	1642.3	---	---	---	---	---	---
57.15	0.00	13.05	7.01	2566.0	11.80	16.81	1647.1	35.74	16.06	192.6	---	---	---
55.11	0.00	13.81	9.29	3517.0	3.51	6.59	556.1	22.30	33.87	319.7	---	---	---
53.07	0.00	15.14	8.77	3290.6	5.27	9.83	576.2	16.15	42.40	393.1	---	---	---
51.02	0.00	15.74	7.85	3323.9	6.31	12.35	648.4	17.29	39.82	401.0	---	---	---
48.98	0.00	15.68	7.62	3502.6	5.97	12.49	741.6	19.28	38.85	340.1	---	---	---
46.94	0.00	15.32	7.53	3880.3	5.70	10.60	943.6	19.62	37.53	347.5	---	---	---
44.90	0.00	15.05	5.86	3219.2	11.38	16.37	2005.0	34.85	17.50	214.1	---	---	---
42.86	0.00	14.30	7.38	5037.8	6.61	7.50	1666.2	20.33	36.17	337.6	---	---	---
40.82	0.00	13.85	7.72	5137.2	7.31	6.56	2180.4	19.65	37.51	329.8	---	---	---
38.78	0.00	13.74	7.88	5430.5	8.23	6.38	2677.4	20.74	39.72	302.0	---	---	---
36.74	0.00	12.24	9.53	7208.1	---	---	---	28.56	28.20	220.6	---	---	---
34.70	0.00	12.02	8.99	7250.4	---	---	---	24.06	28.90	231.6	---	---	---
32.66	0.00	11.72	9.29	6851.2	---	---	---	23.29	25.70	218.3	---	---	---
30.62	0.00	11.64	10.25	6154.1	---	---	---	25.56	25.82	189.3	---	---	---
28.57	0.00	13.16	10.11	4237.7	8.93	5.74	2096.5	17.86	40.33	184.5	---	---	---
26.53	0.00	14.13	10.13	3387.1	9.99	6.19	2485.7	17.59	37.86	222.4	---	---	---
24.49	0.00	16.64	11.12	1630.7	12.14	8.54	3876.0	18.99	44.85	167.2	---	---	---
22.45	0.00	16.16	14.37	1373.6	13.33	9.38	3634.1	25.66	39.94	119.4	---	---	---
20.41	0.00	16.71	11.74	2595.2	12.02	9.48	2512.4	25.32	37.46	158.6	---	---	---
18.37	0.00	15.84	11.78	4073.2	10.65	5.65	1016.0	22.81	36.66	221.4	---	---	---
16.33	0.00	16.16	11.93	4072.2	10.61	4.52	704.9	22.54	40.31	227.9	---	---	---
14.29	0.00	16.39	12.27	3561.2	10.53	3.67	589.4	22.99	40.36	257.8	---	---	---
12.25	0.00	19.20	11.24	2056.5	12.04	8.40	1721.6	24.25	40.24	310.3	---	---	---
10.20	0.00	21.34	13.29	1588.2	12.20	9.97	1598.5	22.00	43.06	207.3	42.35	15.62	179.6
8.16	0.00	20.35	17.69	1761.0	11.62	11.05	783.9	42.55	17.52	236.1	---	---	---
6.12	0.00	19.04	17.19	1856.1	8.41	6.19	310.6	40.65	20.95	186.0	---	---	---
4.08	0.00	22.35	16.95	1831.0	8.92	7.97	596.8	46.43	10.14	134.7	---	---	---
2.04	0.00	24.16	13.45	1880.3	10.03	8.89	781.6	27.51	42.95	163.4	---	---	---
0.00	0.00	24.04	11.17	1923.9	10.79	9.20	816.4	27.09	33.99	195.9	---	---	---
-2.04	0.00	23.57	9.62	2071.8	12.12	10.06	974.9	28.82	31.84	140.5	---	---	---
-4.08	0.00	23.24	8.75	2013.3	13.54	9.19	1388.1	25.02	35.19	162.4	---	---	---
-6.12	0.00	22.94	9.31	1714.0	14.55	8.68	1708.7	23.36	39.49	144.6	---	---	---
-8.16	0.00	25.05	8.30	819.9	16.81	10.65	2109.9	24.27	36.67	142.6	---	---	---
-10.20	0.00	20.09	16.79	1424.6	16.59	7.60	1235.9	45.26	10.39	59.4	---	---	---
-12.25	0.00	17.14	8.26	1702.0	21.02	18.48	981.3	29.61	49.46	45.1	---	---	---
-14.29	0.00	17.41	7.17	1620.4	21.39	16.56	1175.6	23.86	42.14	83.5	---	---	---
-16.33	0.00	16.93	7.15	1394.8	22.92	11.69	1297.1	21.25	30.10	261.2	---	---	---
-18.37	0.00	22.49	11.34	1577.3	16.11	6.44	1001.6	20.93	29.80	210.9	---	---	---
-20.41	0.00	24.05	8.99	1446.8	16.17	7.17	1367.3	20.22	28.24	197.9	---	---	---
-22.45	0.00	24.37	8.23	1443.9	16.09	7.24	1366.0	19.00	28.01	188.6	---	---	---
-24.49	0.00	23.32	9.99	1455.9	15.26	6.47	1042.3	17.53	27.87	158.6	---	---	---
-26.53	0.00	22.13	11.27	1526.7	14.65	5.58	698.3	18.60	29.51	146.8	---	---	---
-28.57	0.00	22.45	10.18	1509.3	14.83	5.31	777.4	18.47	25.64	190.2	---	---	---
-30.62	0.00	23.71	7.59	1583.8	16.04	7.48	1118.1	17.88	29.85	118.1	---	---	---
-32.66	0.00	23.04	8.12	1770.0	15.72	7.03	1159.2	19.48	28.31	140.1	---	---	---
-34.70	0.00	21.30	9.55	2008.5	15.17	5.76	945.6	18.77	28.22	140.4	---	---	---
-36.74	0.00	20.71	9.15	1800.0	16.43	6.37	1176.8	19.15	27.66	151.5	---	---	---
-38.78	0.00	21.45	8.87	1023.7	17.47	6.66	2043.7	19.04	29.65	129.6	---	---	---
-40.82	0.00	20.45	8.09	1217.2	16.97	5.93	1548.8	19.27	26.50	160.9	---	---	---
-42.86	0.00	20.53	8.58	842.2	16.95	6.45	1216.0	18.15	26.17	151.8	---	---	---
-44.90	0.00	18.40	8.33	1386.6	---	---	---	19.12	22.34	191.9	---	---	---
-46.94	0.00	18.59	8.06	1250.3	---	---	---	18.08	23.80	173.3	---	---	---
-48.98	0.00	18.82	8.04	1249.0	---	---	---	17.74	23.87	165.4	47.13	16.81	9.5
-51.02	0.00	18.99	7.78	1240.8	---	---	---	16.39	21.02	191.2	31.15	29.58	27.0
-53.07	0.00	18.93	7.93	1246.3	---	---	---	15.92	21.03	176.0	31.28	28.08	31.4
-55.11	0.00	18.42	8.49	1103.1	---	---	---	15.55	18.58	207.7	26.30	38.38	41.2
-57.15	0.00	18.31	8.89	1056.1	---	---	---	16.50	21.50	233.3	41.99	17.90	22.5
-59.19	0.00	18.22	9.38	944.2	---	---	---	16.42	22.83	184.7	40.05	28.60	21.6
-61.23	0.00	18.27	11.40	758.9	---	---	---	17.78	27.66	128.7	---	---	---

TABLE I-14: VELOCITY COMPONENTS FOR THE SPECTRA ORION D POSITION ANGLE 180°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
-11.81	-56.79	18.90	7.78	1073.3	9.75	8.02	1952.7	21.37	39.58	229.7	0.98	7.69	187.5
-11.81	-54.75	18.69	7.57	973.7	10.37	6.58	1475.3	13.64	21.35	693.0	38.68	15.33	137.5
-11.81	-52.71	18.07	9.10	1152.6	10.34	5.92	1371.3	13.48	22.95	519.1	38.50	17.21	127.7
-11.81	-50.66	18.78	8.84	1243.6	10.44	6.71	1389.9	18.64	38.67	268.4	---	---	---
-11.81	-48.62	19.49	8.73	1350.1	10.61	6.69	1252.7	18.72	38.13	243.3	---	---	---
-11.81	-46.58	20.34	7.86	1574.4	11.73	7.78	1204.6	19.66	38.44	221.2	---	---	---
-11.81	-44.54	20.27	7.66	1807.1	12.29	7.73	1173.3	19.52	37.64	213.1	---	---	---
-11.81	-42.50	19.53	7.59	1967.9	12.17	7.16	1069.6	18.93	35.52	220.9	---	---	---
-11.81	-40.46	18.64	7.53	2132.6	11.70	6.72	1003.6	18.85	35.27	212.9	---	---	---
-11.81	-38.42	18.93	6.72	1412.9	13.65	9.37	1300.3	18.90	34.73	182.3	---	---	---
-11.81	-36.38	17.57	7.43	1196.3	13.89	10.85	1181.9	18.30	38.04	163.9	-29.02	18.63	35.5
-11.81	-34.34	15.93	8.63	2012.9	13.80	17.82	532.3	34.20	23.25	70.6	---	---	---
-11.81	-32.30	15.39	7.67	2215.2	20.76	5.95	974.1	16.38	21.19	515.9	---	---	---
-11.81	-30.25	15.39	7.82	2352.6	20.98	5.60	808.0	16.39	21.70	475.0	---	---	---
-11.81	-28.21	17.26	10.68	3065.5	---	---	---	19.88	37.52	117.4	---	---	---
-11.81	-26.17	17.39	9.54	3274.7	---	---	---	19.24	29.14	201.6	---	---	---
-11.81	-24.13	17.28	8.52	3207.2	---	---	---	19.12	21.04	382.2	---	---	---
-11.81	-22.09	17.33	7.76	2672.6	---	---	---	---	---	---	---	---	---
-11.81	-20.05	19.64	12.08	1157.8	17.31	7.29	1617.4	20.46	31.57	146.6	---	---	---
-11.81	-18.01	21.72	10.53	1033.8	16.84	7.41	1246.8	21.19	27.72	240.8	---	---	---
-11.81	-15.97	21.13	11.47	1255.9	15.73	6.86	556.9	22.22	28.50	258.0	---	---	---
-11.81	-13.93	20.75	12.30	841.5	14.67	5.86	564.1	23.37	26.78	377.8	---	---	---
-11.81	-11.89	20.18	7.92	1348.1	13.26	6.17	582.0	23.76	28.21	406.9	31.65	7.86	214.8
-11.81	-9.84	19.73	8.26	1454.8	11.92	6.04	509.1	23.63	28.54	365.1	31.48	7.50	365.4
-11.81	-7.80	19.78	9.01	1424.0	11.42	6.46	502.7	24.32	32.49	255.6	30.01	8.22	451.1
-11.81	-5.76	19.08	14.74	1409.7	---	---	---	26.83	32.03	218.3	30.33	4.90	260.2
-11.81	-3.72	18.24	12.80	1739.0	---	---	---	26.19	34.70	186.8	28.77	6.66	380.8
-11.81	-1.68	17.78	11.61	2195.3	---	---	---	24.91	35.31	175.1	28.43	6.59	425.4
-11.81	0.36	17.59	10.73	2379.6	---	---	---	23.36	32.54	188.3	28.46	7.25	502.3
-11.81	2.40	18.22	11.55	2232.8	---	---	---	23.86	34.17	157.8	29.15	8.18	520.0
-11.81	4.44	20.00	10.81	1821.3	12.40	4.39	374.1	21.49	21.04	643.5	---	---	---
-11.81	6.48	20.91	8.81	2146.6	13.07	6.89	677.0	21.07	23.87	427.2	---	---	---
-11.81	8.52	21.10	8.24	2233.6	13.77	9.21	858.3	21.85	27.92	247.1	---	---	---
-11.81	10.57	21.81	6.09	1026.3	17.81	12.25	1712.6	21.77	31.67	189.3	---	---	---
-11.81	12.61	21.83	6.80	1696.7	15.59	8.17	1486.3	19.99	25.58	350.6	---	---	---
-11.81	14.65	22.27	6.40	1437.6	16.09	9.21	1721.3	20.77	27.02	277.2	---	---	---
-11.81	16.69	21.55	7.22	1847.5	15.34	8.76	1467.1	20.69	28.46	222.3	---	---	---
-11.81	18.73	21.24	7.43	1957.6	15.17	8.53	1315.8	20.48	31.11	212.8	---	---	---
-11.81	20.77	20.33	8.37	2088.3	14.16	7.55	1107.6	20.18	30.02	208.4	---	---	---
-11.81	22.81	17.56	11.45	2568.7	---	---	---	25.39	30.54	136.3	---	---	---
-11.81	24.85	17.14	10.41	2809.9	---	---	---	23.52	25.94	213.9	---	---	---
-11.81	26.89	17.30	9.58	3047.6	---	---	---	21.25	32.26	207.9	---	---	---
-11.81	28.93	17.05	9.86	2930.5	---	---	---	21.57	33.04	186.9	---	---	---
-11.81	30.98	16.44	10.77	2490.6	12.09	4.15	268.6	23.52	35.94	140.4	---	---	---

TABLE I-15: VELOCITY COMPONENTS FOR THE SPECTRA ORION D POSITION ANGLE 225°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
32.93	-38.26	9.82	14.28	1069.9	5.34	7.78	1703.9	34.10	26.31	156.1	---	---	---
31.49	-36.81	10.12	13.81	1209.6	5.43	8.49	2094.0	34.75	26.72	174.5	---	---	---
30.04	-35.37	10.07	13.02	1364.7	5.39	8.80	1872.6	30.50	35.77	182.2	---	---	---
28.60	-33.93	11.55	15.26	1088.9	6.43	9.82	2145.3	37.04	22.55	189.5	---	---	---
27.16	-32.48	12.21	16.74	1446.4	5.89	9.73	1626.2	38.19	19.89	228.0	---	---	---
25.72	-31.04	13.26	17.17	1411.3	5.20	8.93	1092.0	38.42	18.20	198.9	---	---	---
24.27	-29.60	12.93	16.70	1760.8	4.58	7.22	837.7	---	---	---	---	---	---
22.83	-28.15	12.62	15.29	2146.4	4.51	7.20	708.1	35.99	18.97	211.7	---	---	---
21.39	-26.71	12.50	15.09	2460.3	4.74	8.20	656.1	34.30	22.05	246.0	---	---	---
19.94	-25.27	14.28	15.00	2580.6	5.01	9.66	1125.4	37.60	18.13	222.0	---	---	---
18.50	-23.82	14.84	15.63	2510.5	4.10	7.88	681.3	39.78	16.05	145.4	---	---	---
17.06	-22.38	14.51	13.84	2945.7	3.83	7.21	372.3	32.82	28.12	127.3	---	---	---
15.61	-20.94	14.90	13.67	1905.4	15.00	6.56	397.4	20.69	47.60	98.5	---	---	---
14.17	-19.49	15.05	13.04	2224.2	13.54	6.41	766.7	23.23	37.39	128.3	---	---	---
12.73	-18.05	21.25	8.00	1009.6	13.87	9.65	2389.0	20.45	32.26	205.9	---	---	---
11.28	-16.61	19.90	9.30	1782.6	12.51	8.45	1852.6	22.38	32.32	206.0	---	---	---
9.84	-15.16	19.35	9.51	1968.0	11.47	7.72	1698.2	22.73	32.23	224.9	---	---	---
8.40	-13.72	19.37	8.93	2021.9	11.02	7.92	1658.0	22.91	31.67	226.5	---	---	---
6.95	-12.28	19.10	9.95	2164.4	10.20	7.66	1402.3	23.71	34.99	164.4	---	---	---
5.51	-10.83	19.49	11.04	1914.5	9.76	7.79	1112.1	25.54	37.74	120.2	---	---	---
4.07	-9.39	20.05	13.02	1584.9	10.02	8.76	952.9	35.55	26.29	81.4	---	---	---
2.62	-7.95	21.48	12.64	1173.4	11.71	10.78	1211.3	36.31	25.80	82.6	---	---	---
1.18	-6.51	20.81	15.01	1013.7	11.95	11.06	1014.4	38.83	23.96	70.0	---	---	---
-0.26	-5.06	20.81	16.62	1141.6	11.47	9.90	754.4	33.16	14.59	717.9	---	---	---
-1.71	-3.62	21.68	13.88	1327.3	11.65	9.37	805.7	43.57	19.94	56.0	---	---	---
-3.15	-2.18	22.10	11.52	1540.5	12.64	9.21	991.1	28.80	44.14	108.4	---	---	---
-4.59	-0.73	22.72	9.31	1633.6	13.60	8.96	1301.9	26.88	41.58	129.4	---	---	---
-6.04	0.71	22.68	9.03	1609.1	13.81	8.58	1158.9	23.12	34.63	152.1	---	---	---
-7.48	2.15	22.62	9.95	1547.4	13.79	8.53	834.9	22.52	32.20	152.2	---	---	---
-8.92	3.60	22.47	10.81	1706.9	13.38	7.74	642.7	22.19	31.71	167.0	---	---	---
-10.36	5.04	21.72	10.20	1800.8	12.96	6.70	548.3	21.49	27.18	257.5	---	---	---
-11.81	6.48	21.01	9.12	1891.8	12.88	7.40	583.9	21.76	27.07	242.2	---	---	---
-13.25	7.93	19.92	8.58	2275.1	13.02	9.06	648.8	22.38	29.73	184.7	---	---	---
-14.69	9.37	20.46	7.75	1149.3	17.07	11.35	1140.2	21.82	32.71	135.2	---	---	---
-16.14	10.81	21.85	6.58	927.1	16.57	8.20	1803.9	19.63	28.33	198.7	---	---	---
-17.58	12.26	20.61	8.26	1188.4	15.95	7.56	1630.4	19.85	29.54	175.2	---	---	---
-19.02	13.70	22.05	8.08	968.6	15.96	7.18	2033.5	19.47	29.26	143.1	---	---	---
-20.47	15.14	22.55	7.79	1087.1	15.45	6.62	2014.3	18.91	25.38	223.4	---	---	---
-21.91	16.59	22.66	7.74	1276.0	15.37	6.83	1889.6	18.84	30.01	163.9	---	---	---
-23.35	18.03	22.76	7.21	1217.4	15.98	7.38	1553.4	18.62	24.78	220.6	---	---	---
-24.80	19.47	23.02	6.95	924.3	17.03	8.92	1450.6	19.59	28.35	173.2	---	---	---
-26.24	20.92	22.91	6.91	732.4	17.27	8.88	1312.2	19.13	27.05	175.5	---	---	---
-27.68	22.36	20.06	9.81	1163.6	13.38	7.06	276.9	19.46	28.56	129.8	---	---	---
-29.13	23.80	19.87	8.62	1392.5	12.82	6.15	319.1	19.12	23.31	249.6	---	---	---
-30.57	25.25	19.89	7.92	1144.7	12.39	5.77	296.3	18.85	21.16	319.6	---	---	---
-32.01	26.69	19.77	8.10	851.0	12.02	6.41	275.6	18.80	24.57	188.4	---	---	---
-33.46	28.13	19.20	8.40	639.3	11.09	6.65	177.6	18.42	23.99	166.3	---	---	---
-34.90	29.57	19.10	4.44	410.8	16.01	13.80	398.7	19.09	33.29	43.3	---	---	---
-36.34	31.02	19.20	6.86	296.7	15.88	15.10	322.0	23.70	33.49	33.8	---	---	---
-37.79	32.46	18.27	8.89	262.6	14.86	17.78	215.1	31.40	34.03	15.1	---	---	---
-39.23	33.90	18.37	9.28	299.6	12.05	11.52	161.8	19.91	29.82	50.5	---	---	---
-40.67	35.35	18.23	8.41	227.4	12.87	11.57	209.6	19.18	29.20	50.0	---	---	---
-42.12	36.79	16.25	7.90	150.4	14.35	15.62	201.2	26.60	45.30	17.9	---	---	---
-43.56	38.23	15.71	10.16	285.4	11.53	15.23	90.1	23.14	34.70	22.3	---	---	---
-45.00	39.68	15.64	7.71	237.5	13.94	15.80	184.2	25.84	33.31	19.1	---	---	---
-46.45	41.12	15.52	6.79	234.2	14.42	15.31	222.2	29.23	31.23	18.1	---	---	---
-47.89	42.56	15.90	7.45	275.5	14.06	14.71	182.8	20.16	35.03	23.9	---	---	---
-49.33	44.01	16.52	7.36	245.6	13.85	13.82	212.9	20.86	31.90	32.1	---	---	---
-50.77	45.45	16.49	7.31	316.9	14.31	16.79	208.0	32.99	19.46	17.0	---	---	---
-52.22	46.89	16.64	8.25	323.6	12.90	15.27	196.0	25.32	33.16	24.9	---	---	---
-53.66	48.34	16.50	9.20	345.8	12.89	16.77	165.4	25.01	27.21	23.1	---	---	---
-55.10	49.78	18.96	6.94	209.3	14.09	9.06	237.2	15.27	22.54	119.2	---	---	---
-56.55	51.22	17.68	10.16	274.1	13.47	15.41	164.2	25.12	34.76	21.6	---	---	---

Appendix II

The θ^1 Orionis region: The solution for Components C and D and the values of the most intense and second most intense components for nine different position angles.

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Velocity and FWHM in km s^{-1} ; peak intensity in units of A.D.U; position in units of arcseconds.

Positions measured with respect to θ^1 Orionis C (West and North are positive).

TABLE II-1: VELOCITY COMPONENTS FOR THE SPECTRA ORION A TO B

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Peak Inten.
-32.36	76.18	15.78	11.36	660.8	23.38	7.18	403.3	17.44	25.30	180.6	---	---	---
-31.30	74.45	15.65	18.42	562.6	13.54	8.02	354.0	---	---	---	---	---	---
-30.22	72.72	15.55	17.27	578.2	18.94	9.17	453.9	---	---	---	---	---	---
-29.14	70.99	13.25	7.79	863.6	12.47	4.57	565.0	15.13	19.48	449.5	---	---	---
-28.06	69.26	18.58	6.03	1192.7	13.41	5.79	865.1	15.15	20.59	472.5	---	---	---
-26.98	67.53	15.60	8.38	2047.4	15.83	22.77	488.5	---	---	---	---	---	---
-25.90	65.79	15.33	8.52	2313.6	18.72	10.19	543.6	16.88	29.10	325.4	---	---	---
-24.82	64.06	14.39	5.87	2488.3	18.15	8.84	1023.6	17.26	27.17	403.8	---	---	---
-23.73	62.33	13.98	6.05	2325.3	17.50	7.20	1199.5	17.10	26.66	355.7	---	---	---
-22.55	60.60	15.36	8.36	1967.6	13.83	5.21	1904.7	16.80	29.34	294.9	---	---	---
-21.57	58.67	13.67	5.62	3222.1	15.19	10.28	1217.8	17.43	34.21	239.7	---	---	---
-20.49	57.14	13.35	5.63	3895.1	15.38	12.55	1026.9	17.77	38.83	210.0	---	---	---
-19.41	55.41	13.34	5.58	3715.2	15.09	12.43	1271.0	17.65	37.59	208.3	---	---	---
-18.33	53.68	13.64	6.40	3409.8	14.97	12.48	1239.4	19.19	36.81	167.0	---	---	---
-17.25	51.95	13.43	6.80	2848.5	15.13	10.85	1555.8	17.01	35.27	200.8	---	---	---
-16.17	50.21	12.81	6.36	2787.1	14.98	10.93	1601.1	17.58	34.51	182.2	---	---	---
-15.09	48.48	12.17	5.56	2316.9	14.34	9.48	2094.2	18.22	32.40	220.4	---	---	---
-14.01	46.75	12.32	6.11	2759.3	14.27	10.89	1315.3	19.87	35.75	177.9	---	---	---
-12.92	45.02	12.24	6.91	2325.5	14.38	11.23	1088.3	20.74	38.01	145.5	---	---	---
-11.84	43.29	11.71	6.72	1150.7	13.69	10.71	1646.4	20.98	35.97	135.5	---	---	---

TABLE II-2: VELOCITY COMPONENTS FOR THE SPECTRA ORION A TO C

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
53.46	47.38	12.11	8.99	2501.7	8.66	5.27	1117.2	18.99	35.81	163.1	---	---	---
51.93	46.03	12.36	9.08	2825.8	---	---	---	19.43	34.45	188.4	14.32	20.17	944.4
50.41	44.67	13.27	8.99	3090.0	9.53	5.58	2102.9	19.87	33.34	227.1	---	---	---
48.88	43.32	14.28	8.65	2919.8	9.79	5.79	2513.0	19.05	32.24	262.9	---	---	---
47.35	41.97	13.70	9.63	3804.7	9.49	4.45	1362.4	19.99	32.26	281.3	---	---	---
45.82	40.61	14.62	8.81	3817.1	9.66	5.59	1510.9	19.74	31.90	308.0	---	---	---
44.30	39.26	15.39	7.99	3796.0	10.23	6.49	1528.9	19.27	31.11	312.9	---	---	---
42.77	37.90	14.75	8.77	4287.5	---	---	---	17.84	33.66	289.3	---	---	---
41.24	36.55	14.75	9.94	4031.5	---	---	---	20.83	31.30	257.1	---	---	---
39.71	35.20	15.36	10.15	3316.2	11.78	5.90	897.7	20.18	34.41	226.8	---	---	---
38.19	33.84	15.48	10.00	2854.3	11.41	6.19	1093.7	20.36	31.01	211.5	---	---	---
36.66	32.49	14.72	9.08	2914.3	11.82	6.19	1723.8	18.54	32.06	234.0	---	---	---
35.13	31.14	13.33	8.12	3003.1	17.64	8.88	1644.3	18.46	31.50	249.8	---	---	---
33.60	29.78	12.67	7.05	2431.8	17.28	8.45	1944.0	17.38	30.57	261.0	---	---	---
32.08	28.43	12.63	6.11	2520.7	16.68	8.43	1806.6	16.84	27.94	326.8	---	---	---
30.55	27.07	12.95	6.33	2755.1	15.67	11.67	1230.5	18.51	32.65	249.6	---	---	---
29.02	25.72	12.42	5.22	2733.8	13.91	11.74	1491.4	19.59	35.16	198.1	---	---	---
27.49	24.37	12.12	6.20	2529.2	13.73	13.51	1119.3	22.04	33.97	162.0	---	---	---
25.97	23.01	11.50	7.10	2217.5	13.66	15.90	956.9	29.19	27.12	97.7	---	---	---
24.44	21.66	11.41	7.92	2491.6	14.82	18.49	923.4	---	---	---	---	---	---
22.91	20.31	11.96	10.18	3051.6	---	---	---	17.97	31.37	291.9	---	---	---

TABLE II-3: VELOCITY COMPONENTS FOR THE SPECTRA ORION B TO C

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
23.59	75.02	14.45	8.21	1791.6	5.16	8.47	323.4	19.49	31.32	209.1	---	---	---
22.99	74.07	15.81	6.33	1279.7	12.10	13.70	907.6	21.27	35.60	165.6	---	---	---
22.38	72.12	16.38	5.93	1412.6	12.10	13.62	1056.6	21.55	34.21	189.9	---	---	---
21.76	70.17	13.24	15.70	1336.7	16.42	5.63	1336.6	31.76	23.62	109.5	---	---	---
21.13	68.10	16.28	9.18	1548.4	7.36	7.88	505.3	18.41	29.11	230.8	---	---	---
20.57	66.28	17.78	8.59	1427.1	9.50	9.84	685.2	18.91	30.49	199.5	---	---	---
19.96	64.33	19.08	7.16	1354.1	11.33	11.66	876.8	20.11	30.50	185.0	---	---	---
19.35	62.38	19.10	7.25	1610.1	10.68	10.24	891.1	19.36	24.19	578.5	---	---	---
18.75	60.43	19.10	7.47	1643.0	11.12	10.57	979.4	19.34	32.35	190.6	---	---	---
18.15	58.46	19.04	7.52	1517.8	11.77	11.40	1101.1	19.72	31.96	182.9	---	---	---
17.54	56.53	19.17	7.89	1342.3	11.93	10.30	1149.1	19.24	31.08	168.8	---	---	---
16.94	54.58	12.33	9.60	1204.2	19.72	8.10	1070.0	18.05	31.95	159.5	---	---	---
16.33	52.63	11.82	7.50	1187.0	19.53	8.84	992.7	16.31	28.37	208.1	---	---	---
15.73	50.68	12.70	7.68	1322.0	20.14	9.35	850.3	15.47	28.60	212.2	---	---	---
15.12	48.73	12.16	7.27	1398.7	20.21	10.09	748.6	15.90	24.63	350.5	---	---	---
14.52	46.78	12.35	7.61	1504.0	20.10	11.35	616.8	16.39	24.75	352.9	---	---	---
13.91	44.83	12.81	7.14	1730.1	---	---	---	16.97	18.49	1052.9	---	---	---
13.31	42.88	12.57	6.60	2149.7	---	---	---	16.60	17.35	1212.0	---	---	---
12.70	40.94	12.81	6.58	2340.7	---	---	---	16.35	18.04	1183.2	---	---	---
12.10	38.99	12.71	7.57	2274.7	---	---	---	15.89	20.06	925.5	---	---	---
11.49	37.04	12.42	8.54	2210.9	---	---	---	15.23	22.05	690.5	---	---	---
10.89	35.09	12.83	10.90	2087.8	---	---	---	17.08	26.51	352.4	---	---	---
10.28	33.14	13.75	12.53	1821.4	---	---	---	21.59	42.23	115.8	---	---	---

TABLE II-4: VELOCITY COMPONENTS FOR THE SPECTRA ORION B TO D

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity
56.31	-6.03	10.41	6.50	5195.3	14.64	8.10	2317.3	19.49	37.14	299.2	---	---	---
57.39	45.82	10.08	5.80	4002.2	13.35	8.89	3850.9	20.62	36.57	300.4	---	---	---
55.62	44.82	13.45	8.51	4513.0	10.06	5.58	4246.5	20.25	35.98	337.3	---	---	---
53.84	43.81	10.32	5.58	4724.3	13.82	8.92	4521.4	20.63	37.14	339.5	---	---	---
52.07	-2.80	13.98	9.02	5031.4	10.36	5.83	4071.7	21.02	34.87	374.9	---	---	---
50.12	-1.69	13.91	9.73	4009.0	10.33	5.75	3003.6	20.28	34.04	328.3	---	---	---
48.52	40.78	14.54	9.93	4548.3	10.21	5.59	2604.4	21.07	34.85	364.3	---	---	---
46.74	39.77	14.91	9.43	5180.9	10.23	6.24	1954.8	21.26	32.95	365.1	---	---	---
44.97	38.76	14.59	9.74	6387.5	---	---	---	20.96	38.98	311.1	---	---	---
43.20	37.75	15.13	9.03	6288.1	---	---	---	17.75	35.12	420.7	---	---	---
41.42	36.75	15.16	9.50	5903.3	---	---	---	19.24	34.93	364.8	---	---	---
39.65	35.74	15.16	10.03	5428.4	---	---	---	21.16	32.87	317.2	---	---	---
37.87	34.73	15.25	10.55	5078.9	---	---	---	20.45	35.89	275.0	---	---	---
36.10	33.72	15.18	10.98	4321.0	---	---	---	17.90	36.39	273.3	---	---	---
34.32	32.71	15.28	11.31	3772.1	---	---	---	17.46	36.84	259.9	---	---	---
32.55	31.70	15.23	11.54	3257.3	---	---	---	18.90	34.87	217.7	---	---	---
30.78	30.69	12.53	7.03	2470.9	17.78	8.80	2253.2	15.67	28.54	453.2	---	---	---
29.00	29.68	15.72	10.92	2572.0	12.95	5.73	1573.4	14.58	29.62	483.1	---	---	---
27.23	28.68	13.19	5.31	2266.8	15.32	12.10	2195.3	15.55	30.99	398.7	---	---	---
25.45	27.67	13.05	5.85	2493.0	15.10	13.87	1739.3	19.20	35.51	229.1	---	---	---
23.68	26.66	12.75	6.60	2595.6	16.03	15.98	1652.4	23.02	36.36	158.1	---	---	---
21.90	25.65	12.85	6.89	1685.2	16.52	17.49	1288.8	22.49	41.36	80.9	---	---	---

TABLE II-5: VELOCITY COMPONENTS FOR THE SPECTRA ORION A POSITION ANGLE 180°

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
9.78	37.24	14.52	8.19	1186.2	14.49	16.10	920.2	21.73	31.31	119.1	---	---	---
9.78	39.28	12.88	7.29	1998.3	15.56	18.25	766.5	27.35	32.58	58.2	---	---	---
9.78	41.32	13.10	6.58	1979.7	16.84	13.93	804.6	16.84	28.55	179.2	---	---	---
9.78	43.36	13.44	7.11	1860.6	17.94	11.32	550.0	18.27	24.51	344.3	---	---	---
9.78	45.40	15.34	8.18	921.3	12.02	4.94	580.0	---	---	---	---	---	---
9.78	47.44	16.74	13.13	1277.4	11.54	4.31	274.7	17.89	29.07	174.2	---	---	---
9.78	49.48	13.60	9.70	1000.5	20.54	9.00	749.6	18.59	29.73	145.5	---	---	---
9.78	51.53	13.60	9.44	971.8	20.13	7.35	791.3	17.74	26.11	187.2	---	---	---
9.78	53.57	15.36	12.14	1173.4	19.59	5.51	251.3	18.13	33.21	95.8	---	---	---
9.78	55.61	14.61	13.64	1036.4	18.75	8.05	431.8	---	---	---	---	---	---
9.78	57.65	18.46	8.40	987.3	11.07	10.28	650.9	19.38	30.49	124.6	---	---	---
9.78	59.69	18.16	8.42	1061.3	9.86	9.76	635.2	19.85	31.94	128.6	---	---	---
9.78	61.73	12.72	14.60	978.9	17.94	6.52	438.3	25.98	26.70	97.7	---	---	---
9.78	63.77	15.90	9.62	855.4	9.76	11.29	772.9	23.81	25.47	133.3	---	---	---
9.78	65.81	12.53	11.78	1325.1	---	---	---	18.76	33.73	151.7	---	---	---
9.78	67.85	13.01	10.84	1105.7	---	---	---	18.63	32.87	140.4	---	---	---
9.78	69.89	11.80	11.88	995.0	15.53	5.91	287.0	18.81	33.56	148.6	---	---	---
9.78	71.94	12.01	11.36	761.6	16.87	5.84	429.9	17.82	32.58	140.0	---	---	---
9.78	73.98	16.96	6.68	799.3	10.00	10.65	747.4	17.93	33.12	179.3	---	---	---

TABLE II-6: VELOCITY COMPONENTS FOR THE SPECTRA ORION A POSITION ANGLE 330°

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
44.47	56.75	17.19	6.80	708.7	9.64	7.10	443.2	18.39	30.84	147.6	---	---	---
43.45	55.99	17.26	6.80	797.8	9.74	6.80	502.6	17.59	32.06	134.5	---	---	---
42.43	55.23	17.29	6.38	899.0	9.86	7.01	607.4	18.20	33.71	133.8	---	---	---
41.41	53.46	17.13	6.59	1006.1	9.74	6.82	669.6	17.78	34.50	129.0	---	---	---
40.39	51.59	15.88	6.76	1094.5	9.43	5.60	727.5	16.29	31.45	144.0	---	---	---
39.37	59.92	16.68	6.61	1243.6	9.70	6.21	775.9	16.94	34.32	125.5	---	---	---
38.35	58.16	16.22	6.42	1423.2	9.58	6.26	887.4	16.90	31.31	133.9	---	---	---
37.33	56.39	14.98	8.07	1516.1	8.79	4.95	734.2	16.70	33.06	137.2	---	---	---
35.31	54.52	15.33	8.23	1552.7	8.84	5.26	870.6	16.85	31.43	155.2	---	---	---
35.29	52.85	15.23	9.43	1617.0	8.27	4.63	845.4	18.46	28.04	197.7	---	---	---
34.27	51.09	14.49	10.14	1578.3	8.78	4.65	690.2	16.44	31.47	171.8	---	---	---
33.25	49.32	13.99	10.19	1777.2	8.90	5.29	571.2	16.89	30.84	162.5	---	---	---
32.23	47.55	13.03	10.88	2158.4	---	---	---	22.26	28.84	107.8	---	---	---
31.21	45.78	13.03	10.52	2120.8	---	---	---	21.65	25.69	133.2	---	---	---
30.19	44.01	14.54	10.56	1531.9	10.30	6.62	842.0	19.57	38.38	101.5	---	---	---
29.17	42.25	15.48	10.19	1351.4	10.78	7.10	1264.6	19.89	38.72	90.6	---	---	---
28.14	40.48	14.76	9.79	1725.0	10.30	6.41	983.1	19.27	35.54	104.6	---	---	---
27.12	38.71	11.60	8.02	2128.0	16.31	10.89	811.1	22.59	42.41	83.7	---	---	---
26.10	36.95	12.65	8.19	1881.1	16.44	11.78	598.9	20.15	39.24	96.8	---	---	---
25.08	35.15	12.31	7.32	1652.1	16.47	10.14	918.8	18.34	34.26	137.6	---	---	---
24.06	33.41	12.38	6.52	1447.8	16.79	9.52	1183.3	18.10	32.38	168.3	---	---	---
23.04	31.64	15.31	11.67	1432.9	12.27	5.74	1160.2	20.15	32.03	141.8	---	---	---
22.02	29.87	12.81	6.73	1108.3	16.35	14.00	1028.1	22.55	33.23	103.9	---	---	---
21.00	28.11	12.94	7.25	1248.6	17.71	16.77	890.4	23.71	41.23	55.9	---	---	---

TABLE II-7: VELOCITY COMPONENTS FOR THE SPECTRA ORION B POSITION ANGLE 330°

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
36.60	70.78	17.43	7.53	885.6	7.93	7.39	384.7	18.48	30.41	144.6	---	---	---
35.57	69.01	17.80	6.93	1011.4	8.58	7.83	430.3	17.85	30.48	146.8	---	---	---
34.55	67.24	17.94	6.96	1031.3	8.97	7.73	452.1	16.77	31.63	148.1	---	---	---
33.53	65.48	18.23	6.50	1078.9	9.66	8.46	479.7	16.47	30.04	168.8	---	---	---
32.51	63.71	18.36	6.14	1190.1	9.99	8.06	561.4	16.20	30.36	176.9	---	---	---
31.49	61.94	18.34	6.12	1300.7	10.05	7.35	660.1	15.65	30.98	169.9	---	---	---
30.47	60.17	18.31	6.06	1317.2	10.41	7.36	765.4	15.27	29.49	179.7	---	---	---
29.45	58.41	18.23	6.29	1271.3	10.61	7.39	824.4	15.13	29.49	169.6	---	---	---
28.43	56.64	17.88	6.53	1220.6	10.71	7.15	881.3	14.40	27.89	199.3	---	---	---
27.41	54.87	17.22	7.45	1220.9	10.35	6.62	903.1	14.18	27.26	206.9	---	---	---
26.39	53.10	16.28	9.07	1218.4	9.97	6.12	782.1	14.95	27.55	190.8	---	---	---
25.37	51.34	15.30	11.64	1216.9	10.37	5.71	517.5	16.74	33.71	112.0	---	---	---
24.35	49.57	11.25	6.96	1167.5	16.55	11.62	734.6	18.47	33.58	101.1	---	---	---
23.33	47.80	11.47	7.06	846.7	17.23	12.01	577.9	18.22	32.22	86.6	---	---	---
22.31	46.03	15.17	10.78	1003.5	10.48	5.67	948.9	17.52	27.49	145.3	---	---	---
21.29	44.27	10.50	5.20	1110.1	15.68	12.01	935.2	17.91	30.30	107.7	---	---	---
20.27	42.50	10.90	5.25	1358.4	15.88	13.47	652.4	19.22	32.80	88.5	---	---	---
19.25	40.73	11.18	5.71	1723.1	15.27	12.55	885.8	18.83	29.84	123.1	---	---	---
18.23	38.96	11.04	5.90	2195.4	13.93	12.46	1271.2	20.75	31.40	103.5	---	---	---
17.21	37.20	11.89	6.77	1616.8	14.78	14.95	892.1	23.94	35.49	59.1	---	---	---
16.19	35.43	12.13	7.59	1307.9	15.01	16.50	718.6	29.20	33.73	49.2	---	---	---
15.16	33.66	12.91	8.34	992.8	14.38	16.18	757.9	31.23	29.25	51.9	---	---	---

TABLE II-8: VELOCITY COMPONENTS FOR THE SPECTRA ORION C POSITION ANGLE 180°

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity
0.00	44.90	13.29	8.91	2312.9	20.40	11.52	1240.5	21.12	36.84	122.8	---	---	---
0.00	46.94	12.99	8.61	1995.5	21.11	11.10	1226.9	21.27	33.38	157.7	---	---	---
0.00	48.98	12.70	8.92	1735.5	20.42	8.63	1460.1	20.60	27.73	258.7	---	---	---
0.00	51.02	14.20	10.98	2070.6	20.80	6.30	1080.2	20.06	29.83	201.3	---	---	---
0.00	53.07	13.71	9.95	2147.8	20.28	6.77	1062.7	18.70	31.08	206.8	---	---	---
0.00	55.11	13.21	9.20	2111.6	19.59	8.14	847.2	17.91	31.95	215.1	---	---	---
0.00	57.15	14.14	10.63	2133.3	---	---	---	19.34	25.67	259.2	---	---	---
0.00	59.19	14.15	10.84	1946.0	---	---	---	20.05	30.18	197.6	---	---	---
0.00	61.23	13.57	10.30	1785.4	---	---	---	19.27	27.87	218.8	---	---	---
0.00	62.86	12.69	8.84	1710.3	18.43	6.02	319.2	17.59	29.68	239.6	---	---	---

TABLE II-9: VELOCITY COMPONENTS FOR THE SPECTRA ORION D POSITION ANGLE 180°

Position		Most Intense Component			Second Most Intense Component			Component C			Component D		
x	y	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity	Peak veloc.	FWHM	Intensity
-11.31	33.02	12.83	7.89	1723.8	18.60	8.45	1317.5	20.56	35.54	179.1	---	---	---
-11.61	35.06	13.68	10.45	1903.4	20.33	7.86	436.7	22.22	35.85	153.0	---	---	---
-11.61	37.10	13.61	12.31	1846.1	8.36	4.63	206.0	26.78	30.73	120.9	---	---	---
-11.61	39.14	13.00	11.26	1973.6	8.19	4.17	304.2	23.01	30.03	149.6	---	---	---
-11.61	41.18	11.45	8.25	1643.4	14.42	11.51	1087.3	24.13	34.99	121.1	---	---	---
-11.61	43.22	11.45	6.65	2018.2	14.29	10.44	1406.5	21.59	35.64	141.8	---	---	---
-11.31	45.26	11.58	6.52	3011.9	14.96	10.10	1219.6	21.34	37.34	133.3	---	---	---
-11.61	47.30	11.64	5.92	2855.9	14.38	9.79	1651.9	21.47	35.74	168.9	---	---	---
-11.61	49.34	11.84	6.64	2788.2	15.07	8.93	1604.3	19.59	35.06	176.3	---	---	---
-11.61	51.39	13.33	8.21	3431.1	---	---	---	17.65	22.97	326.6	---	---	---
-11.61	53.43	12.33	6.68	2177.1	15.68	8.80	1525.2	17.23	33.06	187.1	---	---	---
-11.61	55.47	12.64	6.55	2830.1	16.71	8.48	1038.5	18.35	32.90	167.9	---	---	---
-11.61	57.51	12.03	5.56	1936.1	15.43	8.28	1627.4	18.89	32.67	171.0	---	---	---
-11.61	59.55	14.93	8.39	1724.9	11.62	4.58	1277.2	18.18	32.12	178.9	---	---	---
-11.61	61.59	15.04	8.86	1509.9	11.57	4.84	991.6	17.79	31.73	178.8	---	---	---
-11.61	63.63	16.00	7.99	1184.9	11.77	5.44	1133.9	16.83	28.93	216.8	---	---	---
-11.61	65.67	12.77	6.65	1587.1	18.51	5.77	778.5	16.73	27.63	244.5	---	---	---
-11.61	67.71	12.12	6.34	1138.8	18.14	7.14	1069.2	16.77	29.19	223.0	---	---	---
-11.61	69.75	18.53	7.64	1294.1	11.20	6.08	821.7	16.41	29.92	212.4	---	---	---
-11.61	71.80	19.14	7.83	1345.5	11.17	6.00	817.9	16.03	29.14	245.3	---	---	---
-11.61	73.84	19.46	8.32	1136.0	11.45	5.93	714.0	15.94	28.00	283.1	---	---	---
-11.61	75.88	18.66	10.07	1007.3	11.05	5.88	479.0	15.25	28.07	288.6	---	---	---

Appendix III

The θ^2 Orionis region: The system of velocity components for two different position angles.

Table III-1: Velocity Components for the spectra θ^2 Ori A Position Angle 225° 175

Table III-2: Velocity Components for the spectra θ^2 Ori A Position Angle 270° 176

Velocity and FWHM in km s^{-1} ; peak intensity in units of A.D.U; position in units of arcseconds.

Positions measured with respect to θ^2 Orionis A (West and North are positive).

TABLE III-1 VELOCITY COMPONENTS FOR THE SPECTRA θ^2 ORIONIS A POSITION ANGLE 225°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
44.74	-44.74	10.54	6.70	281.5	14.56	9.20	147.6	15.46	25.44	113.8	---	---	---
43.30	-43.30	11.12	5.74	403.0	14.23	15.48	181.5	16.70	37.23	47.6	---	---	---
41.85	-41.85	11.67	8.06	342.6	10.42	2.24	240.7	14.73	24.18	129.1	---	---	---
40.41	-40.41	10.60	5.25	358.4	13.33	6.84	183.8	14.13	23.31	152.7	---	---	---
38.97	-38.97	11.17	5.39	448.1	13.76	8.80	101.3	13.53	24.27	150.0	---	---	---
37.52	-37.52	11.40	5.79	494.9	13.65	16.21	98.8	13.84	26.55	99.1	---	---	---
36.08	-36.08	11.44	5.86	517.9	---	---	---	12.54	20.11	162.9	---	---	---
34.64	-34.64	11.54	6.16	512.0	---	---	---	13.14	24.46	124.2	---	---	---
33.19	-33.19	12.14	5.43	478.1	17.08	3.39	71.6	12.94	21.90	156.1	---	---	---
31.75	-31.75	12.80	6.70	362.0	12.81	19.00	170.7	23.37	38.64	17.3	---	---	---
30.31	-30.31	12.86	8.39	330.2	1.15	6.49	38.4	14.51	21.71	140.4	---	---	---
28.86	-28.86	13.11	8.30	223.3	12.73	20.58	192.3	---	---	---	---	---	---
27.42	-27.42	13.55	9.20	223.6	11.61	19.78	175.8	28.29	31.64	21.2	---	---	---
25.98	-25.98	13.82	9.88	241.0	10.92	17.90	174.4	24.45	30.24	37.4	---	---	---
24.53	-24.53	14.04	9.12	234.8	11.24	18.77	233.5	29.54	23.66	26.3	---	---	---
23.09	-23.09	13.53	12.07	416.0	2.90	9.39	81.2	20.00	27.56	63.5	---	---	---
21.65	-21.65	14.86	12.00	349.5	6.98	11.52	183.1	19.12	32.91	62.3	---	---	---
20.20	-20.20	13.60	12.96	378.6	5.88	12.13	163.3	19.62	31.05	68.3	---	---	---
18.76	-18.76	12.17	11.46	464.4	1.88	8.28	97.9	15.37	28.08	122.8	---	---	---
17.32	-17.32	11.60	16.53	322.8	12.70	6.21	318.2	12.66	37.38	72.6	---	---	---
15.88	-15.88	12.43	14.70	339.4	13.07	5.41	378.8	11.19	37.44	79.6	---	---	---
14.43	-14.43	12.65	16.58	354.0	12.77	5.90	351.4	9.31	65.22	38.7	---	---	---
12.99	-12.99	12.95	15.85	375.2	12.67	4.54	214.2	11.06	56.71	43.4	---	---	---
10.10	-10.10	13.86	10.37	294.2	2.08	5.53	76.8	14.05	31.05	127.6	---	---	---
8.66	-8.66	12.68	21.76	257.5	13.55	5.53	134.9	---	---	---	---	---	---
7.22	-7.22	12.57	20.60	247.2	13.88	6.28	113.2	37.20	20.16	18.4	---	---	---
5.77	-5.77	13.47	13.38	247.8	1.40	5.41	69.8	18.29	28.93	67.7	---	---	---
4.33	-4.33	13.91	18.23	255.6	0.81	3.91	49.4	37.50	19.00	18.8	---	---	---
2.89	-2.89	13.89	17.62	224.0	0.81	4.68	54.4	28.62	31.57	24.0	---	---	---
1.44	-1.44	14.04	16.06	171.5	0.83	3.39	81.1	20.44	27.22	65.1	---	---	---
0.00	0.00	16.76	22.21	145.7	1.61	4.18	92.1	13.47	8.85	88.9	---	---	---
-1.44	1.44	15.01	12.19	157.4	1.98	3.06	95.5	17.95	31.92	62.7	---	---	---
-2.89	2.89	14.90	10.58	156.8	2.20	5.95	77.4	17.86	26.81	81.1	---	---	---
-4.33	4.33	14.65	9.08	163.8	2.14	6.07	70.0	17.36	24.06	93.8	---	---	---
-5.77	5.77	14.60	7.36	167.1	2.03	7.81	75.4	17.02	20.39	126.6	---	---	---
-7.22	7.22	15.13	7.11	182.5	2.71	7.11	60.5	16.34	22.98	100.6	---	---	---
-8.66	8.66	14.83	6.26	161.0	3.16	9.71	97.1	16.80	17.12	156.9	---	---	---
-10.10	10.10	15.03	10.75	215.0	2.37	7.36	96.0	17.76	32.04	64.3	---	---	---
-11.55	11.55	15.04	12.68	199.9	1.94	8.35	85.5	18.42	34.30	46.1	---	---	---
-12.99	12.99	15.68	15.43	210.7	2.35	11.48	92.9	---	---	---	---	---	---
-14.43	14.43	16.56	14.66	170.5	3.91	12.65	104.4	24.33	42.13	16.7	---	---	---
-15.88	15.88	17.31	13.22	175.2	4.63	12.23	137.3	---	---	---	---	---	---
-17.32	17.32	16.40	16.49	170.8	3.67	10.94	121.1	---	---	---	---	---	---
-20.20	20.20	15.46	22.40	168.4	3.79	9.08	103.5	---	---	---	---	---	---
-21.65	21.65	17.05	17.27	155.6	4.72	11.64	134.1	---	---	---	---	---	---
-23.09	23.09	19.97	9.79	67.2	7.84	13.31	147.9	19.85	39.07	35.6	---	---	---
-24.53	24.53	15.56	16.98	152.7	4.10	8.85	89.3	23.51	47.85	21.4	---	---	---
-25.98	25.98	14.79	19.88	171.8	3.32	7.55	80.5	---	---	---	---	---	---
-27.42	27.42	15.37	16.56	148.4	3.47	7.67	114.2	22.07	40.53	22.8	---	---	---
-28.86	28.86	15.48	16.39	157.3	3.24	7.29	138.5	23.99	39.26	19.6	---	---	---
-30.31	30.31	15.77	15.27	168.3	3.33	7.51	173.2	26.07	37.97	21.4	---	---	---
-31.75	31.75	15.68	14.18	176.5	3.10	7.83	184.9	23.57	38.75	26.3	---	---	---
-33.19	33.19	15.53	15.55	193.1	3.25	8.63	175.4	32.77	29.97	22.7	---	---	---
-34.64	34.64	14.79	17.81	189.3	3.19	8.56	133.9	36.92	32.49	13.6	---	---	---
-36.08	36.08	14.94	16.86	20---	3.25	8.16	140.4	36.94	22.13	15.8	---	---	---
-37.52	37.52	14.17	18.28	201.0	2.84	6.92	126.4	36.01	27.57	15.4	---	---	---
-38.97	38.97	14.85	18.56	199.7	3.29	8.00	120.0	39.67	16.85	18.2	---	---	---
-40.41	40.41	13.61	19.64	206.4	2.76	5.32	112.1	34.26	30.00	15.9	---	---	---
-41.85	41.85	14.38	20.44	207.8	3.20	6.49	107.5	36.91	27.33	18.9	---	---	---
-43.30	43.30	14.27	20.02	203.0	3.16	7.10	99.9	32.21	30.56	29.5	---	---	---
-44.74	44.74	15.19	18.33	210.1	3.91	9.46	120.0	36.08	22.79	31.2	---	---	---

TABLE III-2: VELOCITY COMPONENTS FOR THE SPECTRA θ^1 ORIONIS A POSITION ANGLE 270°

Position		Component A			Component B			Component C			Component D		
x	y	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Intensity	veloc.	FWHM	Peak Inten.
28.57	0.00	14.91	14.70	449.8	0.87	12.91	75.8	22.30	31.64	125.0	---	---	---
26.53	0.00	15.51	12.19	318.9	7.99	20.63	164.2	23.98	26.46	128.2	---	---	---
24.49	0.00	11.99	15.55	197.2	15.66	8.28	176.0	17.48	30.91	181.6	---	---	---
22.45	0.00	13.14	21.69	308.6	14.00	8.09	214.4	33.70	19.60	43.2	---	---	---
20.41	0.00	12.79	20.11	323.2	13.24	5.91	209.3	34.67	21.59	39.0	---	---	---
18.37	0.00	12.78	20.42	280.6	12.69	5.86	208.7	35.74	22.91	30.9	---	---	---
16.33	0.00	15.48	23.57	172.6	11.64	8.28	237.4	---	---	---	---	---	---
12.25	0.00	12.32	20.56	222.2	13.24	5.58	103.6	31.12	27.43	27.9	---	---	---
10.20	0.00	12.64	21.74	198.8	14.55	6.80	88.1	28.19	31.26	24.1	---	---	---
8.16	0.00	13.73	23.24	194.0	15.55	7.83	70.9	---	---	---	---	---	---
6.12	0.00	14.28	23.15	194.4	14.34	6.33	54.0	---	---	---	---	---	---
4.08	0.00	13.90	15.03	180.0	0.52	4.84	63.0	19.17	28.02	58.9	---	---	---
2.04	0.00	14.40	13.99	187.4	0.93	4.31	91.9	21.42	29.48	50.7	---	---	---
0.00	0.00	14.27	12.49	136.9	2.23	2.54	109.7	19.29	27.54	87.7	---	---	---
-2.04	0.00	14.61	10.85	125.0	2.17	4.40	84.5	18.45	27.31	87.8	---	---	---
-4.08	0.00	15.26	12.89	160.9	1.69	6.23	76.6	20.37	28.63	52.6	---	---	---
-6.16	0.00	15.03	13.22	174.6	1.26	4.77	82.3	19.16	34.30	34.5	---	---	---
-10.20	0.00	13.98	9.36	136.5	1.54	6.44	64.0	18.63	21.36	65.3	---	---	---
-12.25	0.00	13.62	5.77	108.5	1.22	7.20	74.9	15.89	16.79	132.8	---	---	---
-14.29	0.00	14.00	7.29	123.1	1.35	5.95	61.9	16.33	23.12	91.2	---	---	---
-16.33	0.00	14.46	8.18	136.5	2.39	3.36	44.2	14.11	30.75	65.6	---	---	---
-18.37	0.00	13.74	7.29	110.6	1.60	6.84	56.8	16.73	19.76	91.1	---	---	---
-20.41	0.00	13.73	7.76	100.7	0.98	6.98	41.6	16.13	19.88	93.8	---	---	---
-22.45	0.00	14.07	9.17	121.6	1.58	6.07	40.3	17.15	22.94	68.1	---	---	---
-24.49	0.00	14.58	6.84	82.4	---	---	---	19.90	31.05	20.4	---	---	---
-26.53	0.00	13.43	9.67	136.8	2.28	6.89	57.4	20.63	14.87	49.5	---	---	---
-28.57	0.00	13.33	9.60	108.2	2.02	6.56	55.4	18.81	20.18	62.8	---	---	---
-30.62	0.00	13.69	8.58	96.5	2.69	6.05	53.3	15.94	23.15	70.2	---	---	---
-32.66	0.00	13.21	5.43	62.8	2.86	5.24	52.1	15.59	20.66	78.2	---	---	---
-34.70	0.00	13.03	8.31	88.3	3.15	6.64	49.7	16.59	20.94	82.6	---	---	---
-36.74	0.00	12.77	8.89	79.7	3.10	3.62	44.9	14.86	22.26	89.1	---	---	---
-38.78	0.00	13.01	7.93	78.8	3.37	4.84	36.1	14.75	20.84	95.5	---	---	---
-42.86	0.00	12.66	12.63	116.1	2.03	5.79	28.8	17.18	26.66	50.3	---	---	---
-44.90	0.00	13.09	13.05	99.4	4.81	6.02	33.4	17.05	26.25	51.0	---	---	---
-46.94	0.00	13.17	18.65	132.2	3.23	1.20	60.1	32.93	41.21	10.4	---	---	---
-48.98	0.00	---	---	---	7.49	11.76	89.1	---	---	---	---	---	---
-51.02	0.00	13.72	17.18	139.9	4.75	4.30	42.5	25.38	39.76	13.7	---	---	---
-53.07	0.00	13.56	17.60	148.8	4.97	5.84	40.7	36.73	21.78	8.2	---	---	---
-55.11	0.00	13.64	16.54	139.3	5.24	6.84	58.0	27.46	38.75	10.0	---	---	---
-57.15	0.00	12.62	15.43	142.7	3.99	4.73	57.5	20.59	25.79	21.2	---	---	---
-59.19	0.00	---	---	---	4.35	3.69	50.4	---	---	---	---	---	---
-61.23	0.00	12.74	16.09	165.5	3.85	3.74	68.7	26.57	36.09	12.7	---	---	---
-63.27	0.00	12.25	16.89	180.8	4.18	2.16	58.8	31.31	35.19	11.1	---	---	---