# I

## IN THE SOLAR NEIGHBORHOOD

CURRENT custom leads us to define the galactic system as the sidereal organization that includes all known stars and nebulae, bright and faint, except those in the globular clusters and in the external galaxies. The galactic system is, therefore, essentially the whole stellar system—it includes the naked-eye stars, the remote Milky Way clouds, the intervening fields of stars and nebulae. Hence the explorations in this system, which contains our first four territories, extend over a wide range of distance and employ several techniques.

Following the outline given in the introduction, we shall go into the various territories, travelling from the Earth outward, and deal with each in turn, recognizing of course that the regions overlap somewhat and that the same methods of exploration and analysis may appear in several different fields.

We begin with the problem of hunting down the Sun's nearest neighbors; but before we get too far from Earth let us refer briefly to three new explorations inside the solar system.

*a. Meteors.* Within a hundred miles of the Earth's surface there is a continual astronomical display that has deeper significance in our understanding of cosmic matters than has any individual planet, star, or nebula. The shooting star is allied, in a manner too little known, with comets, dark nebulae, and the wandering population of interstellar space, and throws light on the terrestrial atmosphere and on the mystery of planetary origin. We shall also know more concerning the mass of the universe, the transparency of space, and the evolution and ages of stars when we have added to our fragmentary knowledge of meteors. To be sure, prolonged and informative investigations of meteors have been made in the past, but the field is still largely unexplored; the professional has too often left the subject to the amateur whose equipment and time are insufficient for the work.

Realizing the opportunities in the study of meteors, we have slowly but persistently developed this work at the Harvard Observatory. Nearly ten years ago a search for meteor trails on photographs was begun. Approximately one hundred thousand plates in the Harvard collection have now been examined, and a total of 386 meteor trails discovered.

The study of the meteor photographs goes forward steadily under the supervision of Dr. Fisher. It involves considerations of such factors as brightness, altitude, radiants, multiple trails, and interruptions of trails through rotation of the meteors. The meteors have in general been photographed accidentally in the course of routine stellar photography; their rapid motions permit only the brightest to be recorded on the plates. Practically, we get only the relatively slow-moving and exceedingly bright fireballs, and we have no photographic record whatever of the common shooting stars that can be seen by dozens on any clear moonless night. Further development of photographic technique for the specific purpose of photographing faint meteors is an immediate and difficult problem.

Because the photographic methods are still ineffective except for the brightest objects, the quantitative investigation of meteors depends on the eye. We have here a department of astronomy—one of the few—in which visual observations are still superior to photographic records.

It would be premature to discuss in detail the current program for the systematic visual observation of meteors. It will suffice to say that it involves special photographic work in addition to the more general visual program. A well-equipped observing expedition to a specially favorable locality in the Southwest is a major part of the plan. Emphasis will be placed on the casual meteor rather than on the meteoric showers. Simultaneous observations from stations separated by twenty or thirty miles will provide information on meteor heights. Special devices will be tried for the determination of meteoric speeds. Telescopic observations will supplement the naked-eye work in providing information on the frequency of faint meteors and will contribute ultimately to our knowledge of the dispersions in size and the distribution in height. We have yet to learn whether the majority of shooting stars are members of our solar system or are drifting representatives of the sparse population of interstellar space.

*b. Eros.* At the moment of writing (March, 1931) the asteroid Eros is the Earth's nearest companion, except the obvious Moon and perhaps some undiscovered comet. Thirty years ago the variation of the light of Eros came under study with Harvard photometers, first by Professor Wendell and later by Professor Bailey. The periodic variations in the brightness of this small body, which travels a very eccentric orbit, suggested long ago an irregular form, or perhaps a spotted surface. That the variation at that time was vigorous and easily measurable for a few months and later was nearly or quite undiscernible is well known; a completely satisfactory explanation of this peculiarity is not yet at hand.

Miss Harwood's subsequent photometric studies of Eros at the Nantucket and Harvard observatories have also shown varying degrees of variability in its light. During the present most favorable opposition Mr. Campbell has followed the asteroid photometrically throughout several months. At first the variation was more than a magnitude and the period a little more than two and a half hours. Then throughout January, without a change of period, came a rapid decrease in the amplitude of variation to less than one half its earlier value.

One conclusion of Mr. Campbell's study is that the period of variation is the same now as it was thirty years ago—it has not changed a measurable fraction of a second in thirty years. Since the variation is probably associated with the rotation of an elliptical or binary body (the elongation of Eros has recently been directly observed by van den Bos and Finsen at the Union Observatory, Johannesburg and by Nakamura at Kyoto), the "day" of this twenty-mile minor planet is double that of the period of light variation. Mr. Campbell finds this double period to be

$$5^h\ 16^m\ 12^s.94$$

*c. The ecliptic patrol.* Moving in more nearly circular orbits than that of Eros, and at much greater distances from the Earth, is the main body of asteroids. More than a thousand are definitely recorded, and additional thousands will undoubtedly be revealed by explorations of the region between the orbits of Mars and Jupiter. The general study of asteroids is not a part of the Harvard program; but to provide for the future needs of astronomers in checking the motions of known and unknown asteroids, a systematic patrol of regions along the ecliptic has recently been initiated at the Cambridge station. Two photographic telescopes take care of this program. One is the 12-inch Metcalf refractor; the other a 3-inch Ross-Lundin lens attached to the mounting of the 12-inch telescope. The 3-inch covers a field several times as extensive as that effectively photographed with the larger instrument. The program is so designed that the zodiacal belt is covered three times a year, each time with widely overlapping plates. Stars to the fifteenth magnitude are recorded; but because of their motions, the asteroidal images are elongated and the magnitude limits are appreciably brighter.

With their useful distribution throughout a wide range of galactic latitude, the plates of the ecliptic patrol should also provide in the course of a few years valuable material for a systematic study of certain types of variable stars.

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Proceeding to the Sun's neighbors, we note that the brighter stars are the nearer stars. This plain statement seems to border on the obvious. It is true, however, only when a great many stars and their average distances are considered. Some of the bright stars are near; many are not. Actually, the majority of the *nearest* stars are invisible to unaided eyes; and some of the brightest naked-eye stars are beyond the range of trigonometric measurement.

The reason why brightness is a poor criterion of distance lies in the great variety found in the intrinsic luminosities of stars. Some stars are thousands of times as bright as the Sun; others less than a thousandth as luminous. The weakly shining stars, which may actually be very numerous throughout space, naturally can be known to us, even telescopically, only if they are very near. A star a thousand times as bright as the Sun, however, can be seen with the unaided eye at a distance of fifteen hundred light years.

The problem of finding the solar neighbors is therefore not a search among the few thousand naked-eye stars. The exploration must clearly lead down into the fainter magnitudes. Our task is to pick out in some manner from the millions of stars shown on photographic plates those objects which are in the immediate vicinity of the Sun. We have seen that we cannot safely pick them out by brightness. A more adequate tool is found to be the angular motion of the stars across the sky. Individual stars, to be sure, differ somewhat in linear speed, but still the angular displacement is a better indicator of distance than is the observed brightness. Once the large angular motion of a star is discovered, the nearness can not only be confirmed but actually be measured through the usual trigonometric method of measuring stellar parallax.

The angular motion on the surface of the sky observed for individual stars may be attributed in part to the star's own motion, in part to a reflection of the annual motion of the observer around the Sun, in part to a reflection of the motion of the solar system through space. For all these sources of angular motion, the nearer the star the greater the displacement. Again, however, though in lesser degree, we are confronted with the same difficulty that made observed brightness a weak criterion. These displacements would all be excellent indicators of distance, except for two reasons: (1) the considerable dispersion in the real motion of the stars; (2) the smallness of the angular motion of all but a few hundred nearby stars, with resulting uncertainties in their measurement.

The data assembled in Table I show the proper motions of the sixteen nearest stars that are now known. The magnitudes range from $-1.6$ to $+13.5$, and correspond to a ratio of a million to one in brightness; but the angular motions show a range only from one to ten.

The practical search for the Sun's neighbors is simply the problem of comparing duplicate early and recent plates made with a telescope of sufficient focal length to show the relative displacements of nearby stars. Such a comparison discloses the fact that in the time elapsing between the dates of the two plates, certain stars have moved noticeably in the field. The instrument used by the Harvard Observatory for this purpose is the Bruce photographic doublet of twenty four inches aperture, mounted for many years at Arequipa, Peru, and now at the Harvard station in South Africa; for more than thirty years it has been photographing southern stars. Hundreds of the photographs, for which the exposures range from fifty minutes to four hours and more, were made before 1900. A program of repeating, under comparable conditions, the older photographs made at Arequipa was taken up systematically a few years ago, and is carried forward under the supervision of Dr. Paraskevopoulos at the Boyden Station near Bloemfontein.

Before this systematic program was inaugurated there had been made, for one reason and another, many duplicate photographs on the old regions, with intervals in excess of twenty five years. Dr. Luyten's examination of many of these pairs of plates has resulted in the discovery of several hundred stars with annual motions in excess of 0″.1. Some of these, to be sure, may be high velocity stars more than a hundred light years distant; but the majority are nearby stars of normal velocity. Only those of conspicuously large angular motion, however, are likely to be in the immediate solar neighborhood.

It will be many years before the whole southern sky is systematically covered a second time with photographs suitable for the study of large angular motions. Within the past two years three hundred and fifty plates have been

TABLE I

SIXTEEN STARS NEARER THAN FIVE PARSECS*

| Name | R.A. 1900 | | Dec. 1900 | | Visual Magnitude | Spectrum | Annual Proper Motion | Parallax | Distance in Light Years | Absolute Visual Magnitude | Luminosity in Terms of the Sun |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | h | m | ° | ′ | | | ″ | ″ | | | |
| Proxima Centauri | 14 | 22.9 | −62 | 2 | 11. | dM | 3.76 | 0.786 | 4.15 | +15.5 | 0.000055 |
| α Centauri A | 14 | 32.8 | −60 | 25 | 0.3 | G0 | 3.68 | .758 | 4.30 | + 4.7 | 1.15 |
| α Centauri B | 14 | 32.8 | −60 | 25 | 1.7 | K5 | 3.68 | .758 | 4.30 | + 6.1 | 0.32 |
| Barnard's Star | 17 | 52.9 | + 4 | 28 | 9.7 | dM3 | 10.30 | .542 | 6.01 | +13.4 | 0.00038 |
| Wolf 359 | 10 | 51.6 | + 7 | 36 | 13.5 | dM4e | 4.84 | .407 | 8.0 | +16.5 | 0.000022 |
| Lalande 21185 | 10 | 57.9 | +36 | 38 | 7.6 | dM2 | 4.77 | .403 | 8.1 | +10.6 | 0.0050 |
| Sirius A | 6 | 40.7 | −16 | 35 | −1.6 | A0 | 1.32 | .363 | 9.0 | + 1.2 | 29. |
| Sirius B | 6 | 40.7 | −16 | 35 | 8.4 | dA7 | 1.32 | .363 | 9.0 | +11.2 | 0.0029 |
| B.D. −12°4523 | 16 | 24.4 | −12 | 24 | 9.5 | dM5 | 1.24 | .351 | 9.3 | +12.2 | 0.0011 |
| Innes' Star | 11 | 12.0 | −57 | 2 | 12. | ..... | 2.69 | .340 | 9.6 | +14.7 | 0.00011 |
| B. D. −7°4003 | 15 | 14.3 | − 7 | 21 | 9.2 | dM5 | 1.33 | .331 | 9.8 | +11.8 | 0.0017 |
| Kapteyn's Star | 5 | 7.7 | −44 | 59 | 9.2 | dK2 | 8.70 | .320 | 10.2 | +11.7 | 0.0018 |
| τ Ceti | 1 | 39.4 | −16 | 28 | 3.6 | K0 | 1.92 | .319 | 10.2 | + 6.1 | 0.32 |
| ε Eridani | 3 | 28.2 | − 9 | 48 | 3.8 | K0 | 0.97 | .305 | 10.7 | + 6.2 | 0.29 |
| Procyon A | 7 | 34.1 | + 5 | 29 | 0.5 | F5 | 1.24 | .304 | 10.7 | + 2.9 | 6.0 |
| Procyon B | 7 | 34.1 | + 5 | 29 | 13. | ..... | 1.24 | .304 | 10.7 | +15.4 | 0.00006 |

*P. van de Kamp, *List of Stars Nearer than Five Parsecs*, Pop. Astr., **38**, 1, 1930.

made on this program, chiefly by Dr. Luyten. The survey of the solar neighborhood from this standpoint will not be completed until the Bruce telescope, or some similar instrument, has provided material for the north such as that rapidly accumulating in the Harvard plate collection for southern stars.

At present there are more than sixty stars known to be within twenty five light years of the Sun. On the basis of simple theory we can predict, not too securely, how many more are likely to be found. It is important, however, to find them, and to measure their distances accurately, to study their spectra, to note any abnormalities of color, and of course to determine with the spectroscope, if possible, the component of the motion in the line of sight.

When we have these data complete, and thus know the relative number of giants, normal stars, dwarfs, and subdwarfs in the solar neighborhood, we shall be well on our way toward a general knowledge of the total numbers of stars, and of the significance in stellar evolution of their distribution in luminosity and mass; for the solar neighborhood is the only place where we can effectively study dwarf and subdwarf stars. We have abundant samples of areas on the surface of the sky, and we explore them intensively, but the solar neighborhood is the only adequate sample of a volume of sidereal space. Its exploration is a long and painstaking task for the observers of trigonometric parallax, and especially for the investigators of angular motions of the faint stars.