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Notes:

¹ *Mt. Wilson Contr.*, **10**, 1921 (181-198), from the corrected radial velocities in table VI.

² *Astron. J.*, **31**, 1918 (130-131).

³ *Mt. Wilson Contr.*, **11**, 1922 (322).

⁴ Russell, Adams and Joy, *Publ. Astr. Soc. Pacific*, **35**, 1923 (193), give values for the mean masses that would make the "giants" nearly twice as massive as the "dwarfs" of these spectral types.

⁵ *Astron. J.*, **35**, 1923 (141-144).

ON A POSSIBLE RELATION BETWEEN GLOBULAR CLUSTERS AND STARS OF HIGH VELOCITY

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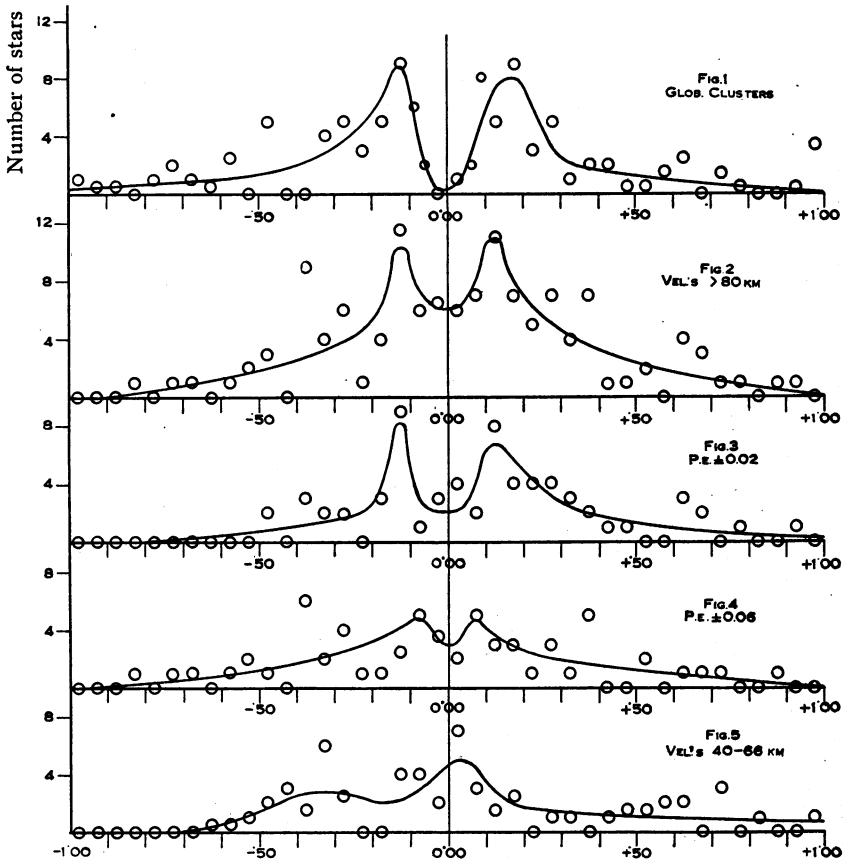
Several facts are known that might suggest a connection between globular clusters and stars of high velocity. The ten clusters for which radial velocities have been published by Slipher¹ give an average velocity of 140 km., well comparable with the higher star-velocities. The motions of the high velocity stars are known to be directed toward one hemisphere of the sky,² the center of which lies in the galactic equator at about 230° longitude; the directions of the radial velocities of these ten clusters lie between 123° and 334° galactic longitude and therefore fall practically within the same hemisphere.³ Strömberg has remarked that a recent computation by Lundmark, with the aid of seven unpublished radial velocities gives a systematic motion of the clusters which nearly coincides with that of the stars of highest velocity.⁴ It may be of significance that the mean antapex of the high velocity stars has been found to shift with decreasing average velocity towards lower galactic longitude⁵; that is, in the direction of the hemisphere in which nearly all the globular clusters are situated.

It has also been shown that the short-period Cepheids which are the typical variables in globular clusters generally have high velocities with the same characteristics as the other high velocity stars.

One of the most striking peculiarities of the globular clusters is their general avoidance of mid-galactic regions,^{5,11} only one globular cluster being found within 5° of the galactic equator. Figure 1 shows the distribution according to the sine of the galactic latitude for the 88 clusters known to be globular.⁶ Part of this avoidance may be explained by the existence of dark absorbing matter in the Milky Way⁷; Shapley however, has pointed out that there are several indications which favor the hypothe-

sis that globular clusters actually do not exist near the central plane of the galaxy (the minimum distance from this plane observed being 1200 parsecs).

It seemed of interest to inquire whether the total motions of the high velocity stars show an analogous avoidance, which might exist if these stars were in some way related to the system of the globular clusters. Dr. Strömberg very kindly sent me a list of 89 stars whose total velocities after the solar motion had been subtracted were higher than 100 km. I recom-



Comparison of the galactic distribution of globular clusters with that of the antipices of the motions of high velocity stars

puted the total motions of the 82 stars for which parallaxes, radial velocities and proper motions had been published. Mt. Wilson spectroscopic parallaxes⁸ were used in this computation if smaller than 0."050; for the nearer stars I used trigonometric determinations. In addition a provisional

computation of lower velocities, from 40 to 80 km. was made in which only radial velocities published before 1923 were used. After correcting for solar motion the galactic latitudes of the antapices were computed. The results for 126 total velocities higher than 80 km. are shown in figure 2, giving the number of antapices for intervals of 0.05 in the sine of the latitude. Beyond $\pm 6^\circ$ galactic latitude the antapices show a strong increase in frequency towards the galaxy, but between $+6^\circ$ and -6° , where a maximum might have been expected, is a decided shortage of antapices.

That this phenomenon is not due to a local group of velocities is shown by dividing the antapices into three groups of different galactic longitude. The avoidance is exhibited by each of the three groups.

The probability that the shortage of motions in the plane of the Milky Way is due to chance is presumably small. Moreover the following consideration furnishes independent evidence for the reality of the phenomenon. Assuming a probable error of 20% in the parallaxes, the average probable error of the sine of the galactic latitude of the apex is about ± 0.04 ; accordingly the appearance of an avoidance of this narrow belt must have been considerably obscured by the errors in the parallaxes. In order to test this I divided the stars into two groups, those for which the angle χ between the great circle through the star's apex and the star, and that through the apex and the galactic pole is larger than 45° , and those for which it is smaller. The frequency-curves for the two groups are shown in figures 3 and 4; the average probable error of the sine of the galactic latitude is evidently three times as large for the stars represented in figure 4 as for those in figure 3. Supposing that the gap shown by figure 2 were accidental, we should expect figures 3 and 4 to have approximately the same appearance. Now the ratio of the number of antapices between $+6^\circ$ and -6° galactic latitude to that between $\pm 6^\circ$ and $\pm 12^\circ$ is 0.4 in figure 3 and 1.6 in figure 4. The chance of a difference of this magnitude in a certain direction is about one thousandth, bringing the total probability of a chance coincidence somewhere in the neighborhood of one millionth.

The strong concentration towards the Milky Way (only 7 out of the 65 antapices have a latitude higher than 30°) and the two sharp maxima on each border are very striking in figure 3. In a previous paper³ I have drawn attention to the fact that the characteristic property of moving towards one hemisphere which is so strongly exhibited by all the stars with velocities higher than 66 km. disappears almost entirely below this limit. The Mt. Wilson radial velocities which were published after that article appeared agree well with the rather sudden change in the asymmetry of the velocities at this point. The distribution of the antapices of stars with total velocities between 40 and 66 km. does not disprove the existence of the limit: the curve in the last diagram which represents this distribution

for the stars with χ larger than 45° does not show any trace of a minimum in the Milky Way. On the other hand the stars with velocities between 80 and 100 km. still show the avoidance as far as the scantiness of material permits us to judge. We cannot make use of the velocities between 66 and 80 km. because of the large probable error existing in the lengths of the velocity-vectors. The question whether the secondary maximum at -20° latitude shown by figure 5 (and which is more or less visible in the other curves) is real must be postponed till a more complete investigation.

From the foregoing it appears likely that the avoidance of the galactic plane by the velocities higher than 80 km. is real and not an appearance due to local streams of stars. This peculiar characteristic would at first sight seem to point to a direct connection with the globular clusters; there are also other peculiarities in the motions of the high velocity star that would favor the hypothesis that these objects had actually escaped from the system of globular clusters. Our knowledge about the motions and the arrangement of the clusters, and especially about the velocities of these stars, is, however, so preliminary that it does not seem of much use to work out the consequences of such a hypothesis before more data about high total velocities have been collected.*

It may be of interest to mention briefly the other objects which show an avoidance of the Milky Way.

It is well known that the spiral nebulae are totally absent from the region near the galactic equator. A remarkable feature of these nebulae is that their belt of avoidance is more than twice as wide as that of the globular clusters: in the drawings published by Reynolds⁹ no spiral is found within 12° of the galactic equator although with a random distribution we should expect to find about 80 nebulae below this latitude. Except perhaps for the stars constituting the clouds of the Milky Way the only other objects that seem to occur less frequently in the central parts of the galaxy than on its borders are the planetary nebulae. I counted the numbers of these nebulae in different galactic latitudes from the list published in Volume XIII of the Lick Publications. The frequencies show a very strong increase towards the lower latitudes except for a probably real and not local deficiency between $+3^\circ$ and -3° latitude, where only 12 nebulae are counted, whereas the number we should expect from the rest of the curve is about 35. Here the apparent zone of avoidance is much narrower than in the case of the clusters and can possibly be explained by absorbing clouds. But the fact that neither the most distant c-stars¹⁰ nor the open clusters¹¹ show any trace of this absorption would then indicate a very great average distance (presumably over 2000 parsec) for both the required obstructing matter and the planetary nebulae.

* It may be remarked that the hypothesis of an extended ring of obstructing matter such as has been suggested to account for the absence of globular clusters from the central

parts of the Milky Way could hardly explain the shortage of high velocity-apices in those regions: in order to diminish the speed of a passing star perceptibly the mass of this ring would have to be of the order of 10^{20} stars or 10^{10} times the mass which Kapteyn attributes to the whole stellar system. According to the theory of relativity (De Sitter, *Mon. Not. R. Astron. Soc.* 77, p. 176) a ring of this mass cannot exist at a distance of the order of that of globular clusters, as the resulting shift toward the violet in the spectra of globular clusters and spiral nebulae would be much greater than the observations permit.

¹ *Pop. Astron.*, 26, 1918 (8).

² This was first observed by B. Boss, *Ann. Rep. Director Dep. Merid. Astr.*, Carnegie Inst. of Washington, 1918.

³ Oort, *Bull. Astr. Inst. Netherlands*, 1, 1922 (134).

⁴ These PROCEEDINGS, 9, 1923 (315).

⁵ Shapley, *Mt. Wilson Contr.*, 8, 1918 (134-139, 218-222, especially 314-319).

⁶ *Mt. Wilson Contr.*, 8, 1918 (314), *H. C. O. Bull.*, 776, 1922.

⁷ Charlier, *Lund Meddel.*, 2nd Series, No. 19, 1917 (Plate VII).

⁸ *Mt. Wilson Contr.*, 9, 1920 (423).

⁹ *Mon. Not. R. A. S.*, 83, 1923 (147-152).

¹⁰ Schilt, *Bull. Astr. Inst. Netherlands*, 2, 1924 (49).

¹¹ Shapley, These PROCEEDINGS, 5, 1919 (344-351).

NOTE ON SOME STATISTICAL CONSEQUENCES OF THE LUMINOSITY LAW

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The luminosity curve derived by Kapteyn and van Rhijn is based on considerations of parallactic motions, and, as far as the part near and beyond the maximum is concerned, on the available material of numbers and parallaxes of stars with large proper motion. Although the rapid accumulation of the last two kinds of observational data will make a revision of the luminosity curve possible in the near future, it may be of interest to compare the statistical behavior of certain groups of selected stars with that to be expected from the luminosity law and some auxiliary assumptions, principally the velocity law.

For some parts of the sky our meridian and astrographic catalogues give complete lists of stars, brighter than a given apparent magnitude and with proper motions exceeding a given value. It is then an easy matter to derive the frequency function of $H = m + 5 + 5 \log \mu$ for these stars. A simple theoretical expression for this frequency curve $F(H)$ may be found in the following way.

The number of stars whose distances lie between r and $r + dr$, whose