THE IMPACT OF STAR PARALLAXES AND VERY ACCURATE PROPER MOTIONS ON GALACTIC STRUCTURE AND DYNAMICS STUDIES

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Assuming that we have the absolute parallaxes and homogeneous set of proper motions for a large number of stars as described by the previous speakers - how should we use them in studies of galactic structure and dynamics?

A. Parallaxes

Concerning the parallaxes I will be very brief - the subject has already been discussed by Dr. Pagel. Clearly, the main importance of the absolute parallaxes obtained is in the calibration of photometric or spectrophotometric absolute magnitude scales. For a sufficient number of stars observed in the Hyades cluster at a distance of 50 pc and in the Scorpius-Centaurus association the systematic error, which lies at the bottom of all subsequent calibration of distance indicators, may be reduced to the same order as the accuracy of photometric measurements.

B. Proper motions

Let us keep in mind that an error, as quoted, of $\pm 0\overset{''}{.}002$/year corresponds to ±10 km/sec per kpc. This means that the studies generally are confined to a local region of the Galaxy. The question then is: What conclusions can be drawn about the global properties of the Galaxy from a study of local kinematics?

1. Statistical studies

a. Local statistics of space motions. In statistical studies of space motions the first step would be the determination of the mean motion (relative to the Sun) and the velocity dispersion around that mean motion for various groups of stars. When this is done one gets the familiar picture given in Figure 1. We see how the different classes of objects display the Strömberg asymmetric drift motions, where the dispersions around the mean motion increases with the size of the mean motion relative to the Sun.

Patrick A. Wayman (ed.), Highlights of Astronomy, Vol. 5, 799–804.

We know from theory that the ratio of the drift velocity to the velocity dispersion gives the radial density gradient in the solar neighborhood for the stellar type considered. It is important to do this analysis for groups of various ages and chemical abundances. One will in many cases have to do it for rare objects and thus extend the analysis to distant and faint stars. An extrapolation of the scheme of Figure 1 to zero velocity dispersion is probably the best method to determine the solar motion relative to the circular velocity, i.e. to determine the dynamic local standard of rest.

The presence of a density wave would modify this kinematic scheme. This is particularly so for the small dispersions where actually deviations from circular motion and vertex deviations of velocity ellipsoids have been interpreted in terms of density wave motions. It would be interesting to look for a discontinuity in the velocity properties at some age which could indicate systematically different orbits for stars born before or after the star-forming clouds passed the galactic shock.

b. Velocity gradients. Having established the mean motion at the Sun for a group of stars the next step would be to study the variation of the mean motion with position in the Galaxy.

Consider a star at the distance r and the galactic longitude ℓ. Consider only the component of its motion which is parallel to the galactic plane and split that component into two, one of which (Vr) is directed radially away from the Sun and one (V_T) which is directed at right angles to the line of sight and counted positive in the direction of increasing ℓ. With the mean motion with respect to the Sun eliminated we can expand an arbitrary velocity field to the first order:

$$\begin{cases} \dfrac{Vr}{r} = C_1 + C \sin 2\,(\ell+\varphi) + \ldots + \dfrac{1}{r}\, v_r \\[2ex] \dfrac{V_T}{r} = 4.74\mathrm{x}10^3\mu = C_2 + C \cos 2\,(\ell+\varphi) + \ldots + \dfrac{1}{r}\, v_T \end{cases}$$

where v_r and v_T are the components of the peculiar velocity of the star. C, C_1, C_2 and are the parameters of the velocity field. $C_1 r$ would correspond to the K-term.

For pure differential rotation in circular orbits the parameters take the values

$$\begin{aligned} C_1 &= 0 \\ C &= A \\ C_2 &= B \\ \varphi &= 0 \end{aligned}$$

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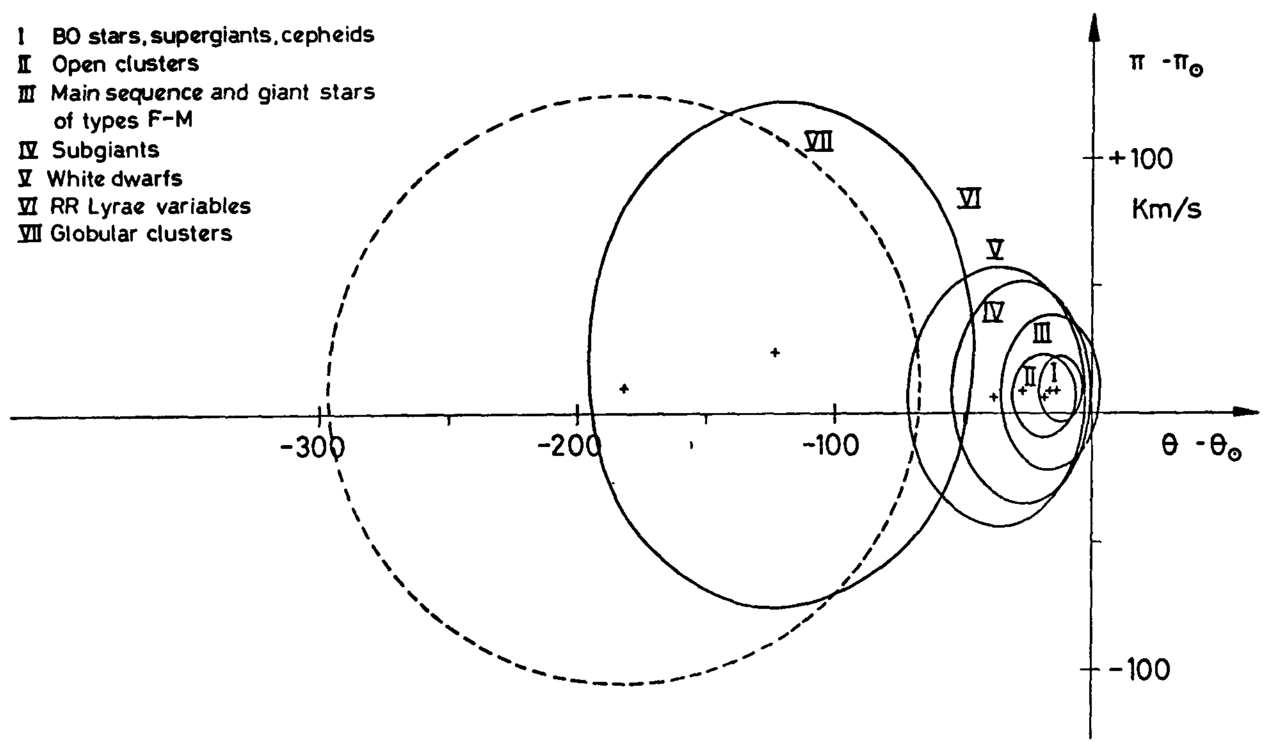

Figure 1. Mean motions and velocity dispersions for various types of objects. Π is the velocity radially outwards from the galactic centre. Θ is velocity in the direction of galactic rotation.

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where A and B are Oort's constants of differential rotation.

As has been demonstrated by Bonneau, Lesh and more recently by Fricke and Tsioumis for the young, nearby stars constituting the Gould Belt system

$C_1=0, \ \varphi=0$

As an illustration of various possibilities adopt for the moment the simple model that this system once was concentrated to a small volume and then left free to expand, each star describing its own orbit around the centre of the Galaxy. Then the parameters of eq. (1) are functions of A and B and of the expansion age of the system.

This is illustrated in Figure 2 which gives the expected proper motions (independent of distance) as a function of ℓ to be expected for three different expansion ages. In addition, the relation expected for galactic rotation in circular orbits is given. One may note that the values of A and B are of the order of the accuracy quoted for the proper motion of a single star.

From the figure it is obvious that certain longitude intervals are particularly suited for separation of the different models. Also, as is evident from eq. (1), it is desirable to go to relatively large distances in order to minimize the influence of the peculiar stellar velocities. Further, if the expanding system is limited in space we would expect a drop back to the relation for pure galactic rotation at the distance of the edge of the system.

If, on the other hand, we adopt the model of the linear density wave theory the parameters of eq. (1) will be functions of A, B and of spiral structure parameters. It is to be expected that this Gould Belt system may possess some of the fundamental keys to the problem of star formation and its relation to spiral structure.

2. Individual velocities

a. Birthplaces of very young stars. A topic of great importance for our understanding of star formation is the time - space sequence of stellar births through an association or a group of associations. This can be studied with very accurate proper motions and age determinations. A related problem is that of the run-away stars and their assignments to different associations. One may remember that an error of $\pm0''.002$/year over 10^6 years corresponds to about $\pm30'$. Only relative proper motions are necessary and the Space Telescope may be quite useful in this connection.

b. Birthplaces of stars in relation to spiral arms. From accurate space motions and ages of relatively young stars one may try to outline the spiral structure in our Galaxy and derive its pattern

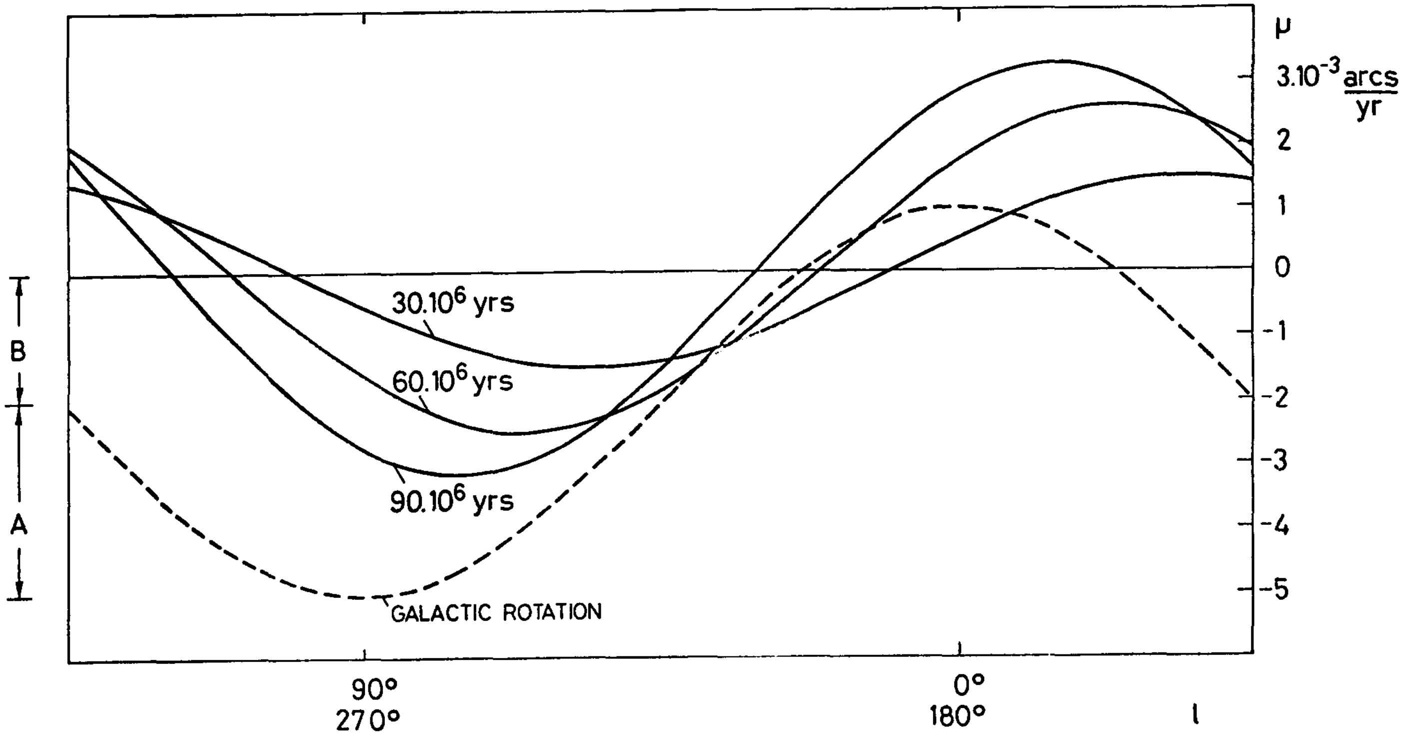

Figure 2. Mean proper motion as a function of galactic longitude expected for a certain model for the local expansion of the Gould Belt System. The rotation is given for three different expansion ages, and the relation for galactic rotation in circular orbits is given by the dashed curve.

velocity. Even though there may be many difficulties of a dynamical and kinematic nature, this may ultimately be a very interesting method to prove the existence of galactic shocks and determine stellar birth frequences in and between spiral arms.

c. Eggen's moving groups. The existence or not of moving groups of stars, also such of rather high age, and whether these constitute parts of so called dispersion orbits is of great interest for our picture of the kinematics of the Galaxy. This implies very accurate determinations of individual space velocities.

3. Conclusions

In all of the statistical studies it is of fundamental interest to separate the stars according to ages and chemical abundances. However, the resolution of age determinations is very different for different ages and it is important to select a sufficient number of stars within every resolution element.

Some of the parameters discussed above could be derived from radial velocities alone if a sufficient number of stars would be available. Even so, proper motions would provide the indispensable confirmation necessary for the acceptance of a particular model. Proper motions may thus be particularly important for rare types of stars where one also would have to go to larger distances to get a sufficient number.

Thus the choice of the stars to be observed in the space missions is very important in order that the material should be useful for galactic structure studies. A close coordination of the programs for the Space Telescope and Hipparchus is, of course, necessary.

In order to permit conclusions to be drawn from the proper motion data, narrow band photometry to derive distances and ages as well as radial velocities is needed. The photometry would require a massive attack with small to moderate size telescopes. Ideally it should be carried out in advance of the space observations, because it would greatly aid the selection of stars to be observed from space. To obtain the radial velocities would also require a substantial observing effort.

Complimentary studies should also be done in the radio domain. The stellar kinematic studies concern a rather local region around the Sun. The very local neutral hydrogen gas, the kinematics of which seems to be related to that of the Gould's Belt, can only be studied in intermediate galactic latitudes. Data of this kind are severly missing from the southern hemisphere, but again could be acquired with a very moderate sized telescope.

Finally, further theoretical studies of the behaviour of the velocity ellipsoid as a function of position in the Galaxy will be required for the proper interpretation of the data.