A RECONSIDERATION OF THE GALACTIC CONSTANTS

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ABSTRACT

Whereas the I.A.U. standard values of the constants R_o, Θ_o, A, and B, differ from those currently considered best, the errors of current determinations are still rather large. Although the means of recent determinations lead to a fairly consistent set of values for the four main constants, the agreement may be largely coincidental. However, a case can be made for agreeing on a new pair of standard values for R_o and Θ_o as a matter of practical convenience.

The currently used values for the galactic constants R_o, Θ_o, A, and B date from 1963. They are: R_o = 10 kpc, Θ_o = 250 km s^{-1}, A = 15 km s^{-1} kpc^{-1} and B = -10 km s^{-1} kpc^{-1}. The choice of this set of values was largely based on the paper by M. Schmidt in Volume V of the series "Stars and Stellar Systems".

It has always been recognized that the main reason for adopting a conventional set of values is to provide a good basis for comparisons between the work of different astronomers and astrophysicists. The chosen values should be consistent with the best determinations available at the time, to within their uncertainties, and the set should be physically reasonable, e.g. they should follow the relationship $\Theta_o = (A-B) R_o$. Recently, evidence has been growing that R_o and Θ are very likely lower than the conventional values, and in fact a number of authors have been using somewhat lower values in their work. At present, however, there is no uniformity, and some of the advantages of having an agreed system have been lost.

At the Patras General Assembly in 1982, Dr. R. Wielen, then Acting President of Commission 33, proposed setting up a Working Group to develop a critical review of the values of the main galactic constants, for publication before the General Assembly in 1985. It would not be specifically charged to come up with a proposal for a revised set of values, although it could do so if it wished. This proposal was adopted, and a review of information about the galactic constants was

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commissioned by the Working Group. This review is being published elsewhere (Kerr and Lynden-Bell 1986), and the present paper is a shortened version of the main points.

R_o, THE DISTANCE TO THE GALACTIC CENTRE

Three direct methods have been much exploited:

1. Shapley's method of finding the centre of the system of globular clusters.
2. Baade's method of finding holes in the galactic obscuration and determining the peak in the number of RR Lyrae stars as a function of magnitude.
3. Mira variables in galactic windows.

Recent applications of Shapley's method give results which vary from R_o = 6.8 to 8.5 kpc. Two applications of Baade's method give 8.5 and 7.3, while study of the Mira variables has led to R_o = 8.3. Several more indirect methods have also been used. Those based on kinematic considerations generally came up with somewhat higher values for R_o.

The full review lists 25 determinations which have been published in the period 1974-1985. We have preferred to take the straight mean of the published determinations, without attempting any weighting, because we believe that systematic uncertainties are more important than the formal errors. In this case, the straight mean, together with the standard deviation of the individual determinations, comes out to:

$$R_o = 8.54 \pm 1.1 \text{ kpc.}$$

Θ_o, CIRCULAR VELOCITY

A wide variety of methods has been used for the determination of Θ_o, most of which are indirect to a greater or lesser degree. A common approach is to attempt to measure the motion of the Local Standard of Rest (LSR) with respect to some group of objects whose motions are sufficiently different from that of the LSR that their average can be taken as zero or some other known value. This method has been especially applied to the globular cluster system, generalized halo objects, and the Local Group of galaxies.

Some other determinations have made use of an apparently good relation between the velocity dispersion and the rotational velocity which has been demonstrated for a number of other galaxies. Another important method is based on the extreme radial velocities observed for the HI emission in the outer parts of the galactic disk, but uncertainty arises because different results are obtained for the two sides of the Sun-centre line, due to a marked asymmetry in the outer Galaxy.

A straight mean of 20 determinations published in the period 1984-1985 gives a value:

$$\Theta_o = 222.2 \pm 20 \text{ km sec}^{-1}$$

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OORT'S CONSTANTS, A AND B

The quantities A and B have been used for many years to characterize the local kinematics. A is a measure of the rate of shearing of the (assumed) circular motion, and B of the vorticity. A can be determined from either radial velocities or proper motions, while B can come from proper motions only. We have listed 19 determinations from radial velocities, and 15 from proper motions. The straight means are:

$$A = 14.5 \pm 1.3 \text{ from radial velocities}$$
$$A = 14.4 \pm 2.7 \text{ from proper motions}$$
$$B = -12.0 \pm 2.8 \text{ from proper motions}$$

CONCLUSIONS

To assess the reasonableness of the above values, we have looked at several combinations of the constants. The product of A and R_o has been compared with direct determinations of AR_o; the value of the expression $R_o(A-B)$ obtained from the individual values has been compared with Θ_o, as these two should be identically equal for circular motion; and the value of $B/(B-A)$ has been compared with the square of the velocity ellipsoid ratio.

The results of these comparisons indicate that the mean values that have been derived form a reasonably consistent set of values for the four galactic constants and their interrelationships. The results suggest that R_o and Θ_o are both lower than the currently accepted standard values, but the spread of the individual determinations and the possibility of problems that could arise due to the existence of non-circular motions and departures from axial symmetry indicate that the quantities are still not known with very great precision.

However, astronomers have already lost confidence in the current values for the constants, and many are using lower values for R_o and Θ_o. There are great practical advantages in having widespread use of an agreed set of values, to enable comparisons to be more readily made between the results, both observational and theoretical, of different groups of investigators. The Working Group has recommended, therefore, that astronomers should now use the following values, which are within the error range of recent determinations, and are equal to or close to values which are coming into de facto use:

$$R_o = 8.5 \text{ kpc}$$
$$\Theta_o = 220 \text{ km s}^{-1}$$

The constants A and B have been closely studied also, but there is little need to prescribe standard values for these quantities, as they are not so widely used in large-scale comparisons. It was noted, however, that rounded-off values of the means of recent determinations are $A = 14$ and $B = -12$ km s^{-1} kpc^{-1}. A flat rotation curve requires $A = -B$, and a value of 13 for both A and -B would be well inside the errors. However, it is not clear whether a flat rotation curve is appropriate for the local area in which the rotation constants are derived.

No recommendation has been made for standardized values of A and B.

REFERENCE

Kerr, F.J. and Lynden-Bell, D., 1986, "Review of Galactic Constants", submitted to Mon. Not. Roy. Astron. Soc.

At the November 21 meeting of Commission 33, a resolution was adopted, whose main sentence reads:

"Commission 33 recommends, on the basis of the conclusions of its Working Group on 'Galactic Constants', use of the values

$$R_o = 8.5 \text{ kpc}$$
$$\Theta_o = 220 \text{ km s}^{-1}$$

in cases where standardization on a common set of galactic parameters is desirable."

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