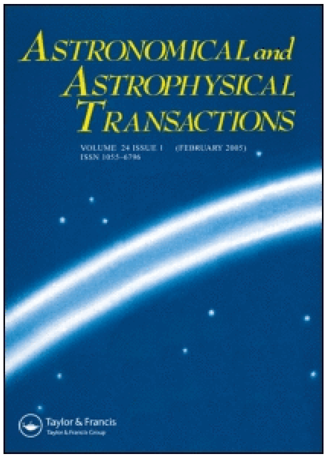

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DISTANCE TO THE GALACTIC CENTRE

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This is a short review of the modern determination of the galactocentric distance R_0 and some new results on the derivation of the value of R_0 due to the metallicity distribution of globular clusters. We obtain $R_0 = 8.6 \pm 1.0$ in good agreement with current IAU recommendations, but this is longer than most recent evaluations by other techniques.

KEY WORDS Galactocentric distance, structure of the Galaxy, globular clusters

1 INTRODUCTION

For 80 years astronomers have expended considerable effort to determine the size of our Galaxy. Knowledge of R_0, the distance from the Sun to the centre of the Galaxy, is especially important for studing the Galaxy, its structure and dynamics. Any change in the value of R_0 has widespread impact on different branches of astronomy – from stellar to extragalactic. That is why the particular value of R_0 is a matter of regular discussions (see reviews: Kerr and Linden-Bell, 1986; Feast, 1987; Reid, 1988; Reid, 1993). Many well-known and new methods were used to determine R_0 during recent years. We have collected most of the results concerning the value of R_0 in Table 1 and in Figures 1 and 2.

Historically, astronomers have measered distances to nearby stars, used these distances to calibrate their luminosities, and estimated R_0 from the spatial distributions of stars and globular clusters. Among other methods of R_0 determination the most traditional one is the globular cluster method. This technique assumes that globular clusters are symmetrically distributed about the Galactic centre. Ever since Harlow Shapley's (1918) study of globular clusters enabled him to establish the direction toward the region of the Galactic centre and to estimate its distance (he obtained $R_0 \approx 13$ kpc), efforts have repeatedly been made to take advantage of various properties of the globular cluster system for this purpose. There are three tools which we may use to derive R_0 from the globular cluster data: centroid of distribution (Shapley, 1918), cone of avoidance (Wright and Innanen, 1972; Sasaki and Ishizava, 1978), and metallicity distribution (Surdin, 1980). The first method

Table 1. Modern history of galactocentric distance determination

Year	*Author*	*Object*	R_0, kpc
1974	van den Bergh, Herbst	Field stars of the bulge	9.9 ± 2.2
1974	Balona, Feast	OB stars of the disk	9.0 ± 1.6
1974	Rybicki *et al.*	Rotation curve, model of the disk	9.0
1974	Cruz–Gonzalez	Density gradient of nearby stars	8.9 ± 0.5
1975	Oort, Plaut	RR Lyrae stars in galactic bulge	8.7 ± 0.6
1976	Cramptom *et al.*	OB stars, radial velocities	8.4 ± 1.0
1976	Harris	Globular clusters	8.5 ± 1.6
1977	Belikov, Syrovoi	Globular clusters	8.5
1978	de Vaucoulers, Buta	Globular clusters	7.0 ± 0.7
1978	Sasaki, Ishizawa	Globular clusters	9.4 ± 1.2
1978	Clube, Watson	RR Lyrae stars in galactic bulge	6.7
1978	Byl, Ovenden	Disk OB stars, Cepheids, open cl.	10.4 ± 0.7
1979	Loktin	Disk OB stars, kinematic	8.1 ± 1.7
1980	Surdin	Globular clusters	10.3 ± 0.6
1980	Surdin	Globular clusters	9.9 ± 0.3
1980	Quiroga	H I and H II regions, OB stars	8.5 ± 0.7
1980	Clube, Dawe	RR Lyrae, Cepheids, stat. parallax	7.0 ± 1.0
1981	Caldwell, Ostriker	Model of mass distribution	9.1 ± 0.6
1982	Frenk, White	Globular clusters	6.8 ± 0.8
1982	Glass, Feast	Miras and RR Lyrae variables	9.2 ± 0.6
1983	Knapp	Disk population	8.0 ± 2.0
1983	Herman	OH masers in circumstellar shells	9.2 ± 1.2
1983	Ostriker, Caldwell	Mass model for the Galaxy	8.2
1985	Blanco, Blanco	M giants star counts in the bulge	7.3 ± 0.5
1986	Rohlfs *et al.*	H II regions	7.9 ± 0.7
1986	Iurevich	OH clouds, rotation curve	8.2 ± 0.8
1986	Walker, Mack	RR Lyrae in Baade's window	8.1 ± 0.4
1987	Ferney *et al.*	RR Lyrae stars in galactic bulge	8.0 ± 0.65
1987	Caldwell, Coulson	Cepheids, radial velocities	7.8 ± 0.7
1988	Reid *et al.*	H_2O masers in the Sgr B2 North	7.1 ± 1.5
1989	Racine, Harris	Globular clusters	7.5 ± 0.9
1990	Pottasch	Planetary nebulae	7.7 ± 0.5
1992	Gwinn, Moran	H_2O masers in W49	8.1 ± 1.1
1993	Reid	Combination of different methods	8.0 ± 0.5
1993	Maciel	Globular clusters	7.6 ± 0.4
1994	Nikiforov, Petrovskaya	H I and H II rotation curve	7.5 ± 1.0
1994	Rastorguev *et al.*	Globular clusters	7.0 ± 0.5
1995	Carney *et al.*	RR Lyrae, infrared photometry	8.3 ± 1.0
1995	Dambis *et al.*	Classical Cepheids	7.1 ± 0.5
1996	Layden *et al.*	RR Lyrae statistical parallax	7.6 ± 0.4
1996	Backer; Reid (1998)	Proper motion of Sgr A*	7.5 ± 0.7
1998	Glushkova *et al.*	Cepheids, open cl., red supergiants	7.3 ± 0.3
1998	Metzger *et al.*	Cepheids, radial velocities	7.7 ± 0.5
1998	Surdin, Feoktistov	Globular clusters	8.6 ± 1.0

is the most popular one; the other two were used only once. We are going to discuss the last one now, taking into account new observational data and new modifications of the method.

It is well known that the metallicity of globular clusters decreases with distance from the Galactic centre. If the globular cluster distribution is axially symmetric

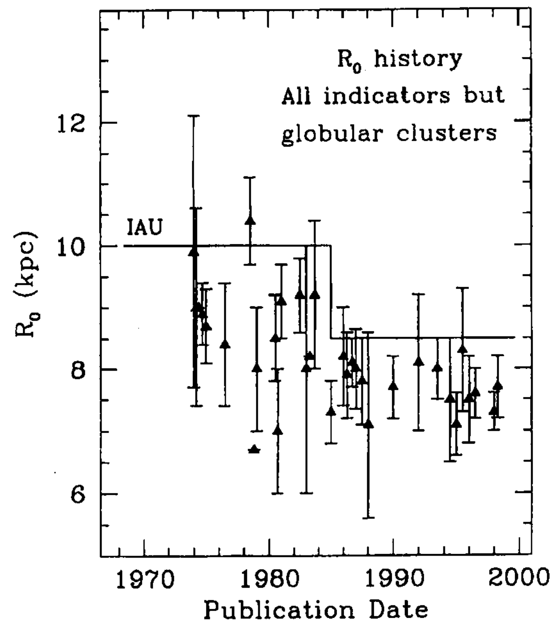

Figure 1 Estimates of the distance to the Galactic centre versus publication date since 1974. Results obtained with different objects except globular clusters are plotted. The solid line is the IAU recommendation.

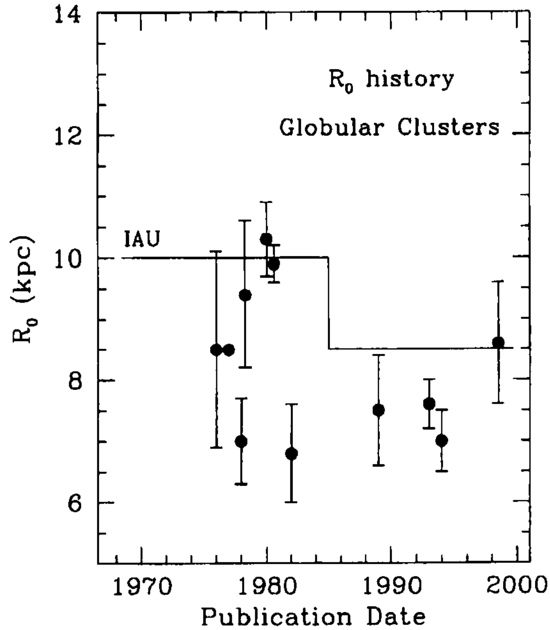

Figure 2 The same as Figure 1, but for globular clusters as indicators only.

about the Galactic rotation axis, then R_0 can be estimated by adjusting its value (and rescaling the cluster distance) until the cluster metallicity is uncorrelated with the galactocentric azimuth. Metallicity estimates are not strongly affected by extinction corrections, thus minimizing this source of systematic error.

2 THE METHOD

Our method was proposed by Surdin (1980). The method rests on three assumptions:

(1) there is a metallicity gradient of a globular cluster system to the Galactic centre;

(2) the globular cluster metallicity is independent of the galactocentric azimuth θ;

(3) globular clusters are distributed axisymmetrically about the Galaxy's rotation axis.

Regarding the globular cluster system as axisymmetric about the rotation axis of the Galaxy, we shall seek the value of R_0 such that certain parameters describing the globular clusters become independent of their azimuthal angle θ, that is, the angle between the directions from the Galactic centre toward the Sun and toward the projection of a cluster on the Galactic plain. If we describe a cluster in terms of parameters that depend on its galactocentric distance (such as its metallicity or spectral type, its limiting radius, or its mean density), then clearly the only way we can expect to eliminate the mean θ-dependence of these cluster parameters is correctly to choose R_0 equal to the Sun's true distance from the Galactic centre.

It is obvious that our proposed method of determining R_0 is not sensitive to the oblateness of the globular cluster system. In order to render this method stable against ellipsoidal distortions in the shape of the system (independently of the orientation of the axes of the triaxial ellipsoid), we have introduced the following procedures:

(1) The galactocentric azimuth θ is measured on either side of the direction to the Sun, its absolute value being taken (from 0 to π).

(2) The θ-dependence of the metallicity of clusters is determined by taking a linear regression that is stable against distortions symmetric about the direction $\theta = \pi/2$.

To derive random and systematic errors of this method caused by the finite number of globular clusters in the Galaxy and interstellar extinction we used Monte Carlo modelling of the process of searching and identifying globular clusters taking into account the interstellar absorption of light (Surdin, 1994).

3 RESULTS

In our analysis we have used data on 126 globular clusters from the catalogue by Harris (1996). As a result we have obtained the value of $R_0 = 8.6 \pm 1.0$ kpc. This rms error reflects both the intrinsic uncertainty in the catalogue values of $(m - M)_0^V$ and [Fe/H], and the error inherent in the method inself, due to the finite number of clusters and their random distribution in space. Our estimation of R_0 is a maximum among other current ones, but is not in contradiction with them.

Data for main-sequence stars with precise *Hipparcos* parallax measurements and accurate abundance determinations led to new globular cluster distances (Reid, 1998) which are higher than those derived in pre-*Hipparcos* investigations. It may increase the value of R_0 derived from globular clusters.

Until recently, the value of R_0 was difficult to determine precisely, but it can be constrained between 7 and 8.5 kpc.

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