ASTROMETRIC DISTANCES OF GLOBULAR CLUSTERS

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ABSTRACT. With high-precision radial velocities and proper motions, one can equate the proper motion and radial velocity dispersions to obtain astrometric distances independent of any standard candles. We discuss the method and the small distance it yields to M 22.

1. INTRODUCTION

The distance scale of globular clusters has historically been based upon assuming an absolute magnitude for the RR Lyrae variables or the horizontal branch immediately redward or blueward. A more recent approach depends upon main-sequence fits of CCD photometry to magnitudes from ground-based parallaxes (e.g. Vilkki et al. 1986). Any such "standard candle" method is subject to uncertainties in the calibration of the candle and in reddening/extinction corrections.

These problems do not affect astrometric distances, in which the internal dispersion in radial velocities RV is matched to the apparent dispersion in proper motions PM. Cudworth (1979) and Lupton et al. (1985) have used Yerkes PMs and Palomar RVs to derive distances for M 3, M 13, and M 92. These agreed well with standard-candle distances, but the PM uncertainties were too large for definitive confirmation.

2. STATISTICAL PARALLAX METHOD

Recent PM measurements, such as those of Cudworth (1986) for M 22, have errors of 20 milliarcsec/century/star, if first-epoch plates are old enough and of sufficient number and quality. Such accuracy is essential, as is a proper error analysis, for even at 5 kpc a cluster with an RV dispersion of 5 km/s has a PM dispersion of 20 mas/cen.

The following problems must also be avoided. 1) In crowded fields, spuriously large PM values may be deduced for certain stars where subtle blending has arisen from plate-to-plate seeing and guiding differences. 2) The method is sensitive to the assumption that the velocity distribution is isotropic. Fortunately, this is usually the case in the inner regions of a well-populated cluster. Where

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departures from isotropy do occur in the outer regions, as a rule they are radial; their presence can be detected in the PMs alone by comparing the mean radial PM with the meant tangential PM. 3) Rotation, another form of anisotropy, must also be taken into account. Both PMs and RVs should show it. 4) RVs for the brightest giants show an extra dispersion ("jitter") of about 1 km/s, attributed to atmospheric motions; many such stars are photometric variables. (Giants in populous clusters are rarely spectroscopic binaries.)

3. APPLICATION TO M 22

Cudworth (1986) derived PMs with errors 20 mas/cen for more than 200 stars in M 22 with V < 14. Between 200" and 400", the internal dispersion was well-defined and radial and tangential PMs were equal. In July Peterson used the MMT echelle to obtain radial velocities good to ± 1 km/s (Latham 1985) for essentially all giants within this annnulus with $12.9 < V < 14$, i.e. more than 1.5 mag from the tip. The RV dispersion of the 87 giants is 6.9 ± 0.5 km/s; peak-to-peak rotation is < 6 km/s; the PM dispersion is 61 ± 4 mas/cen yielding a distance of 2.4 kpc ± 10%, or $(m-M)_0 = 11.9 \pm 0.22$. The distance derived taking $E(B-V) = 0.32 \pm 0.04$ and M_V(blue HB) = +0.70 ± 0.20 is $(m-M)_0 = 12.43 \pm 0.24$, or 3.06 ± 0.33 kpc, a significant discrepancy.

Support for the shorter distance is offered by the presence of three RV members whose total space motion would marginally exceed the cluster escape velocity if the larger distance were adopted. To be sure, our final analysis will include fitting a dynamical model to the data to fully account for dynamical effects.

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