The Art of Modelling Stars in the 21^{st} Century
Proceedings IAU Symposium No. 252, 2008
L. Deng & K.L. Chan, eds.

doi:10.1017/S1743921308023004

The Dynamics Of Galactic Globular Cluster

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Abstract. We have used the Hubble Space Telescope (HST) to measure proper motion of the globular cluster NGC 6656 (M22) with respect to the background bulge stars and its internal velocity dispersion profile. With the space velocity of (Π, Θ, W) = (184±3, 209±14, 132±15) km s^{-1}, we also calculate the orbit of the cluster. The central velocity dispersion in both components of the proper motion of cluster stars is 16.99 km s^{-1}. We derive the mass-to-ration (M/L)∼1.7 which is relatively higher than the past works.

Keywords. astrometry, globular clusters: general

NGC6656 (M22) is one of the nearest globular clusters from the Sun, being about 3 kpc distant (Peterson & Cudworth 1994; Harris 2003). The metallicity of this cluster is rather low ([Fe/H] $= -1.62 \pm 0.08$, Richter, Hilker, & Richtler 1999). It should have belong to the population of "halo" clusters (Zinn 1985) but its galactic orbit (Douphole *et al.* 1996; Dinescu, Girard, & van Altena 1999) reveal some ambiguous features of "disk", or "bulge" (Côt*é* 1999) clusters. Proper motions give us two more components to each star's six-dimensional phase-space coordinate. When combined with its radial velocity and position, the phase space coordinate of a star can be fully determined. It can lead to greater understanding of the structure and evolution of globular clusters.

Our proper motions are based on data of three epoch observations taken with Wide Field Planetary Camera 2 (WFPC2) aboard the HST. The first epoch data consist of four frames taken as part of program GO 5404 on 7 April 1994 through the F502N filter. The second epoch data are taken by program GO 7615 from 22 February to 15 June 1999 through F814W and F606W filter. This program also took a few observations in February 2000, which provide an additional epoch data that strengthen the proper-motion measurements.

Thanks to the well overlap of all epoch frames, we have enough stars in each CCD field that it is not necessary to combine different CCDs to obtain the more stars. We just match the same CCD of all epochs. Taking a frame taken in 2000 as the reference, we then construct a matched star list and calculate the relative proper motions of stars in each CCD field.

By means of the Gaussian fit along the RA and Dec axis, respectively, we obtained the relative proper motion of NGC 6656 with respect to the bulge of $\mu_\alpha \cos\delta = 10.19 \pm 0.20\,\mathrm{mas\,yr^{-1}}$ and $\mu_\delta = -3.34 \pm 0.10\,\mathrm{mas\,yr^{-1}}$. Giving the radial velocity of NGC 6656, $V_r = -148.9 \pm 0.4\,\mathrm{km\,s^{-1}}$ and the Sun motion of $(U_\odot, V_\odot, W_\odot) = (10,\ 15,\ 8)\,\mathrm{km\,s^{-1}}$,[2,18] the rotational velocity of the Local Standard of Rest $V_{LSR} = 220\,\mathrm{km\,s^{-1}}$ and the solar distance to the galactic center 8.0 kpc,[19] and the cluster distance $d = 3.2 \pm 0.3$ kpc from the Harris'[2] catalog of clusters, we got the three components of space velocity for NGC 6656 with respect to the bulge: $(\Pi, \Theta, W) = (184 \pm 3, 209 \pm 14, -132 \pm 15)\,\mathrm{km\,s^{-1}}$. Errors in velocities include the uncertainties in the proper motions, radial velocities, and the distance of the cluster.

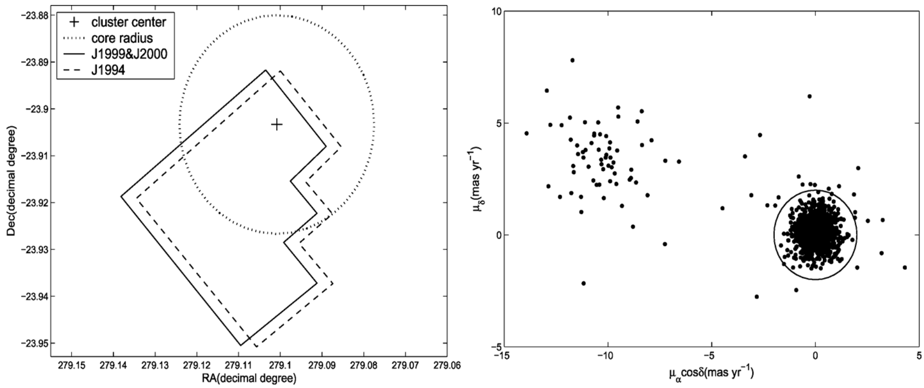

Figure 1. [A]: Location of HST observations of NGC 6656 from different epochs. [B]: Vector–point-diagram of relative proper motions in the J2000 equatorial coordinate system, the stars in the circle of radius $2\,\mathrm{mas\,yr^{-1}}$ centered at (0, 0) are considered to be the cluster stars, while the stars with $\mu_\alpha \cos\delta < -5\,\mathrm{mas\,yr^{-1}}$ are mainly bulge stars.

Using three epoch WFPC2 images, we measured the relative proper motion of NGC 6656 with respect to the bulge and the internal velocity dispersion of the cluster. Combining the result of proper motion with the motion of the Sun, rotation of the Local Standard of Rest and radial velocity of the cluster, we derived the 3-dimensional motion of the cluster. Given the gravitational potential function of our Galaxy, the orbit of the cluster during the past 10 Gyr was calculated. From the results we found, NGC 6656 has a moderate eccentricity and relatively lower obliquity orbit and is near its perigalacticon now. More observations are needed to confirm the results presented here: longer time baseline can further improve the precision of the proper motion; a larger field will contain more cluster and field stars to give a more distinct separation.

Acknowledgements

We would like to thank Philip Warner and Frank Valdes from STScI for the many help on the data reduction, and Jay Anderson, Jon Holtzman, William E. Harris, Peter Stetson and Gordon Drukier for useful discussion and comments.

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