Mem. S.A.It. Vol. 86, 360

Memorie della

Kinematic analysis of the M31 halo globular clusters

J. Veljanoski[1], A.M.N. Ferguson[1], M. Irwin[2], D. Mackey[3], A. Huxor[4], P. Côté[5], and E. Bernard[1]

[1] Institute for Astronomy, University of Edinburgh, Royal Observatory, Blackford Hill, Edinburgh, EH9 3HJ, UK; e-mail: jv@roe.ac.uk
[2] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK
[3] Research School of Astronomy & Astrophysics, Australian National University, Mt Stromlo Observatory, Weston Creek, ACT 2611, Australia
[4] Astronomisches Rechen-Institut, Zentrum fur Astronomie der Universität Heidelberg, Mönchhofstr. 12-14, 69120 Heidelberg, Germany
[5] NRC Herzberg Inst of Astrophysics, 5071 W Saanich Rd, Victoria BC V9E 2E7, Canada

Abstract. Using low resolution spectroscopy, we present the first kinematic analysis for a significant sample of the globular clusters found in the extended halo of M31. Most of these had no previous spectroscopic information. We find a strong rotational signature exhibited by these objects. In addition, we use all available kinematic information for the entire globular cluster subsystem beyond 30 kpc in projection to estimate the M31 mass.

Key words. galaxies: haloes – galaxies: kinematics and dynamics – methods: observational – techniques: radial velocities – techniques: spectroscopic

1. Introduction

Important clues about the galaxy assembly process come from studies of galactic stellar halos, including their globular cluster (GC) systems. Indeed, given the low surface brightness of these parts, GCs are far easier to study in the remote parts of galaxies than the associated field star component.

Due to its proximity of ∼ 800 kpc, our nearest large neighbour M31 is a desirable target to study. It has a rich GC system with over 400 confirmed members listed in the Revised Bologna Catalogue v4.0 (Galleti et al. 2004), most of which lie within 30 kpc of the galaxy centre. Over the last several years, we have used state-of-the-art ground-based surveys (Ferguson et al. 2002; Ibata et al. 2007; McConnachie et al. 2009) to search for new GCs at large radii. We have found more than 90 such objects extending to projected radii of 140 kpc, and 3D radii of at least 200 kpc (Huxor et al. 2005, 2008, 2011; **?**; Mackey et al. 2006, 2007, 2010).

Here we present the first kinematic measurements for a significant sample of the newly-discovered halo GCs. Using the ISIS spectrograph on the WHT 4.2-m and the RC Spectrograph on the KPNO 4-m, we obtained low resolution spectra (~3800-9000Å) during the course of four observing runs conducted between 2005 and 2010. Data were obtained for 57 M31 GCs spanning projected radii from 20-120 kpc, 48 of which had no previous spectroscopic information. The data were reduced using standard IRAF routines. The radial velocities were obtained through a variety of independent methods, and were found to be consistent in all cases. Those presented here are derived from a chi-squared minimisation technique between spectra of the GCs and radial velocity templates observed during the four observing runs. The mean uncertainty is 12 km/s.

2. Results

2.1. Rotation of the outer halo GCs

It is already known that the GCs in the inner regions of M31 rotate around the optical minor axis of the galaxy (Perrett et al. 2002). This motivated us to search for a rotation in the M31 outer halo GC subsystem. We used the method described in detail in Côté et al. (2000), where circular orbits are fit to the GCs with projected radii larger than 30 kpc. We find these clusters to exhibit significant rotation with amplitude of 79±19 km/s, and a rotation axis of 123°±27, which is consistent with the optical minor axis of M31. This is displayed on Figure 1, where we show the Galactocentric radial velocities, corrected for the systemic motion of the M31 centre, versus their projected distances along the optical major axis of M31. The measurements done as part of this work are shown as black squares, while the grey points mark velocities taken from the RBC. The horizontal black lines represent the rotation amplitude. The figure shows that the M31 outer halo GCs rotate in the same sense as the GCs in the inner regions, albeit with a different amplitude.

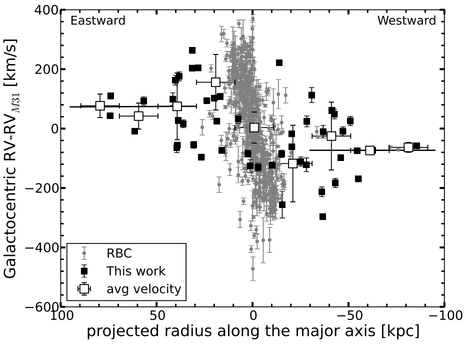

Fig. 1. Galactocentric radial velocity, corrected for the M31 systemic motion, versus projected radius along the M31 major axis. See text for details.

2.2. The mass of M31

We further use the radial velocity information for the outer halo GCs to constrain the M31 mass. For this purpose we employ the tracer mass estimator (TME) derived by Evans et al. (2003). This approach assumes that the halo GC system is spherically symmetric, and that the GCs radial number density profile is well described by a power law. We use all GCs with projected radii larger then 30 kpc as this allows us to estimate the mass of M31 out to large distances. It is important to note that even though the TME uses a GC sample in a shell around the M31 centre, it calculates the total mass enclosed by the furthest tracer, which for our sample is ~200 kpc. We find $M_{M31} = 1.3 \times 10^{12} \pm 0.4 M_{\odot}$. This result is in excellent agreement with past studies (eg. Watkins et al. 2010; Lee et al. 2008; Evans et al. 2003).

References

Binney, J., & Tremaine, S. 1987, Galactic Dynamics (Princeton Univ. Press, Princeton)
Côté, P., et al. 2000, ApJ, 537, L91
Evans, N. W., et al. 2003, ApJ, 583, 752
Ferguson, A. M. N., et al. 2002, AJ, 124, 1452
Huxor, A. P., et al. 2005, MNRAS, 360, 1007
Huxor, et al. 2008, MNRAS, 385, 1989
Huxor, A. P., et al. 2011, MNRAS, 414, 770
Huxor, A. P., et al. 2014, MNRAS, 442, 2165
Ibata, R., et al. 2007, ApJ, 671, 1591
Galleti, S., et al. 2004, A&A, 416, 917
Lee, et al. 2008, ApJ, 674, 886
Mackey, A. D., et al. 2006, ApJ, 653, L105
Mackey, A. D., et al. 2007, ApJ, 655, L85
Mackey, A. D., et al. 2010, MNRAS, 401, 533
McConnachie, et al. 2009, Nature, 461, 66
Perrett, K. M., et al. 2002, AJ, 123, 2490
Watkins, et al . 2010, MNRAS, 406, 264