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INVESTIGATING THE OUTSKIRTS OF THE MILKY WAY: THE PISCES OVERDENSITY

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RESUMEN

La sobre-densidad de Piscis fue descubierta como un exceso de estrellas RR Lyrae en datos multi-época de SDSS. Localizada a una distancia de 85 kpc del Sol, es la sub-estructura más distante conocida a la fecha en el halo Galáctico. En este trabajo estudiamos las propiedades de la sobre-densidad de Piscis usando datos espectroscópicos de varias estrellas RR Lyrae observadas con el Telescopio Gemini-Sur. Encontramos que la distribución de velocidades radiales en la sobre-densidad es bimodal, sugiriendo que dos corrientes diferentes están presentes en ese volumen del halo. La gran extensión espacial de ambos grupos sugiere que son sistemas desligados, probablemente restos de una o varias galaxias destruídas por fuerzas de marea. No es claro si los dos grupos cinemáticos tienen el mismo progenitor.

ABSTRACT

The Pisces overdensity was discovered as an excess of RR Lyrae stars in multi-epoch data of SDSS. Located at a distance of about 85 kpc from the Sun, it is the most distant substructure in the Galactic halo known to date. In this work we study the properties of the Pisces overdensity using spectroscopic data of several RR Lyrae stars observed with the Gemini-South telescope. We find that the distribution of radial velocities in the overdensity is bimodal, suggesting that two different streams are present in that volume of the halo. The large spatial extension of both groups suggests they are unbound systems, likely debris of a tidally disrupted galaxy or galaxies. Whether both kinematic groups have the same or different progenitors is unclear.

Key Words: Galaxy: halo — Galaxy: kinematics and dynamics — Galaxy: structure — stars: variables: other

1. INTRODUCTION

Many different techniques and tracers have been used by different groups to discover sub-structures in the halo. Among them, studies using RR Lyrae stars as tracers have the advantage of providing the best possible 3D maps of the streams, since these stars are excellent standard candles. Watkins et al. (2009) and Sesar et al. (2010a) have recently detected independently a significant excess of RR Lyrae stars in the outer halo, at ∼85 kpc from the Sun. This is the most distant substructure discovered in our Galaxy until now. The structure is known as the Pisces overdensity after the constellation in which is located in the sky. This discovery was made by studying the spatial distribution of RR Lyrae stars detected in the SDSS multi-epoch observations of Stripe 82.

To confirm that the Pisces overdensity is indeed a coherent structure we observed spectroscopically several of the RR Lyrae stars in the group. The details of this study may be found in Sesar et al. (2010b).

2. OBSERVATIONS

We used the 8.1 m Gemini-South telescope (Cerro Pachón, Chile) with GMOS to observe 5 RR Lyrae stars in the Pisces overdensity. Bad weather during our run prevent us to observe more targets. Spectra have a resolution of ∼2.5 Å, at 4500 Å. The spectral range, from 3800 Å to 5250 Å, included the Balmer lines (starting at Hβ) and the Ca II H and K lines. We derived radial velocities and metallicities following the methods described in Vivas et al. (2008).

We combined our results obtained for 5 stars with the sample measured by Kollmeier et al. (2009) of 8 RR Lyrae stars in the overdensity. One star was common in both samples and there was good agreement between both works.

3. RESULTS

Figure 1 shows the distribution of radial velocities of the RRLS in the galactic rest frame, $V_{\rm gsr}$ for the complete sample of 12 RR Lyrae stars. It

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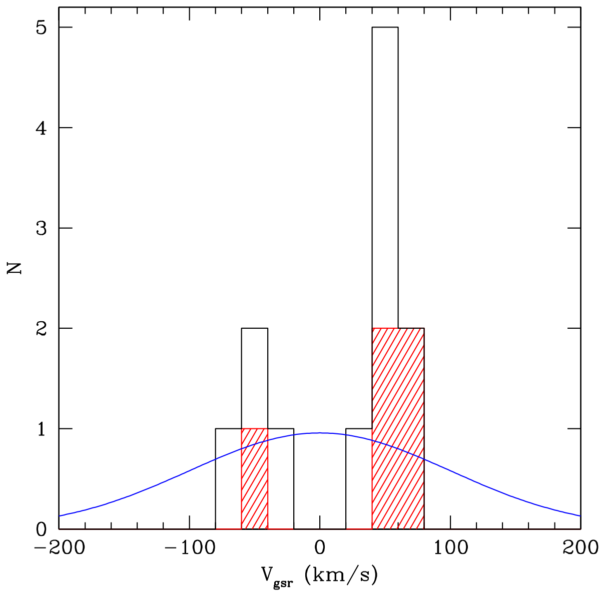

Fig. 1. Histogram of V_{gsr} of RR Lyrae stars in the Pisces overdensity. The shaded histogram corresponds to the stars measured in this work. The Gaussian curve represents a smooth halo normalized to the number of RRLS in the sample.

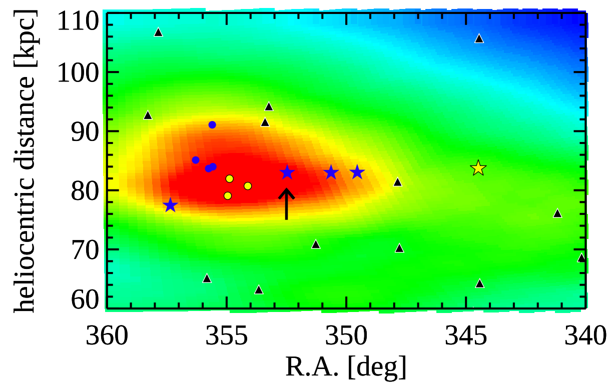

Fig. 2. Density contours of RR Lyrae stars in the Pisces region, from Sesar et al. (2010a). Symbols on top show the location of the RR Lyrae stars. Circles and star symbols represent the samples observed spectroscopically by Kollmeier et al. (2009) and this work, respectively. The arrow denotes the star in common between the two datasets.

is clear that the velocities of the RR Lyrae stars do not behave as a normal distribution. Indeed, normality is rejected, with $> 95\%$ confidence level, by using a Shapiro-Wilk statistical test. The distribution of radial velocities shown in Figure 1 is bimodal. One peak, the largest, contains 8 stars and $\langle V_{\mathrm{gsr}} \rangle = 50$ km s^{-1} ($\sigma = 10$ km s^{-1}). On the other hand, the second peak contains the remaining 4 stars and $\langle V_{\mathrm{gsr}} \rangle = -52$ km s^{-1} ($\sigma = 23$ km s^{-1}).

Both groups have large extensions in the sky (Figure 2), which is hard to reconcile with the groups being bound systems. Thus, most likely these are tidal debris from a destroyed galaxy or galaxies. The positive velocity group extends $\sim 8°$ in right ascension, which corresponds to ~ 9 kpc at the distance of the Pisces overdensity (blue symbols in the online-only color version of Figure 2). The second group (yellow symbols) has a slightly larger angular extension. In declination, both groups may extend beyond the limits of the narrow Stripe 82 ($\pm 1.°27$).

The positive velocity group has a metallicity of [Fe/H] $= -1.4$, while the smaller group has [Fe/H] $= -1.7$. However, given the errors of our measurements, the dispersion observed in each group, and the low number statistics, we cannot say that the groups have different metallicities. The important point, however, is that the progenitor(s) must have been a system(s) with a metal-poor population. Recently, there has been indication that a group of M-giants (which trace a intermediate age population) may be related with the Pisces overdensity (Sharma et al. 2010). If confirmed, the progenitor may then be a system with multiple stellar populations, like many of the dwarf satellite galaxies of the Milky Way.

We conclude that the Pisces overdensity is composed of two different kinematic groups occupying about the same volume of the halo. The two groups may come from the same disrupting galaxy as tidal tails stripped at different epochs may overlap on the sky (e.g. Sagittarius). On the other hand, it is possible that these are two overlapping streams from two different merger events. Available data do not allow us to discriminate between those two scenarios.

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