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Stellar Kinematics in the Remote Leo I and II Dwarf Spheroidals

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Leo I

- Galactocentric distance d = 254 kpc,
- Mean radial velocity $\langle v_r \rangle$ = 284 km/s,
- Global velocity dispersion σ = 9.9 km/s

We observed 120 red giants using the Gemini/GMOS and Keck/DEIMOS low-resolution (R~2500) spectrographs in the wavelength region around the calcium triplet at λ~8600Å. These data reach beyond the stellar boundary at 12.6' (~0.93 kpc). This sample was supplemented by the 33 stars within ~3' from the study of Mateo et al. (1998).

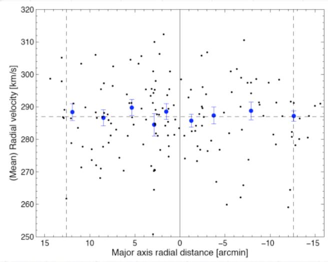
Overview:

At their large Galactocentric distances, the Leo I and II dwarf spheroidal (dSph) galaxies are of paramount importance for studying the evolution of small galaxies and the distribution of dark matter on the smallest scales. Similarities in its dynamics with *nearby* dwarfs would strengthen our confidence that Galactic tides are generally not a major effect in the assessment of the dSphs' dark matter distributions. Previous works (e.g., Vogt et al. 1995; Mateo et al. 1998) have indicated that these two systems have high central velocity dispersions of ~10 km/s and high mass-to-light (M/L) ratios of about 7, pointing to a considerable dark matter content.

Leo II

- Galactocentric distance d = 233 kpc,
- Mean radial velocity $\langle v_r \rangle$ = 78 km/s,
- Global velocity dispersion σ = 7.6 km/s

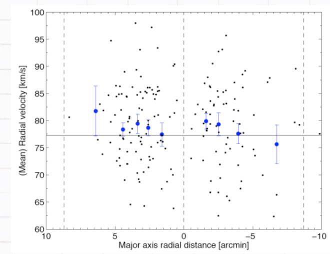
We observed 171 red giant spectra using the FLAMES multi-object spectrograph at ESO/VLT in medium-resolution mode (R~8500) at ~8500Å. Our data reach out to the stellar boundary at "r_{tid}" = 12.6' (~600 pc).

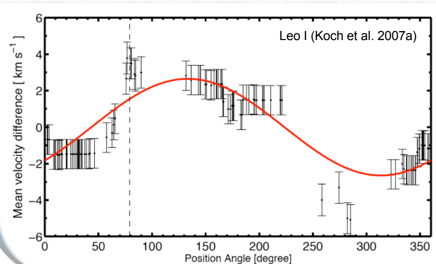


Tests for Tidal Damage:

A possible test for tidal heating of stellar orbits during a galaxy's orbit in the external tidal field of the Milky Way is the apparent rotation of the *outer* stellar component of the pressure supported dSphs. Thus we investigate the occurrence of tidal perturbation in two ways:

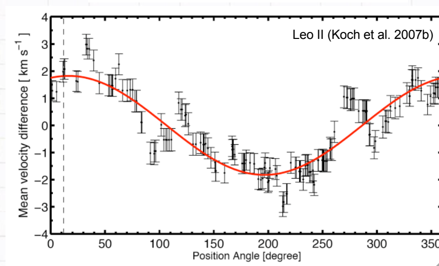
(1) By searching for radial gradients in the velocities, as tidal distortions of the outskirts could lead to excesses of low- and high velocity stars w.r.t. the systemic mean on opposite sides of the galaxy. Our data in Leo I and II do not support evidence of any significant velocity asymmetry out to and beyond the stellar boundaries.

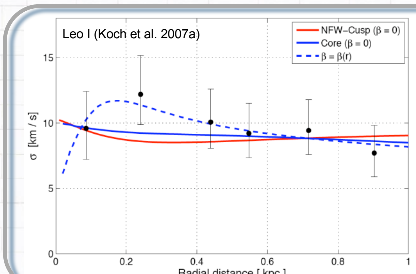




(2) By measuring the mean velocity difference on either side of bisecting lines through the galaxy center as a function of position angle (PA). If the galaxies were rotating, an apparent signal around the galaxy's systemic PA is expected. Although apparent rotational signals are discernible near the PAs of Leo I and II, these amplitudes are only statistically significant by less than 15%, as we tested via Monte Carlo simulations.

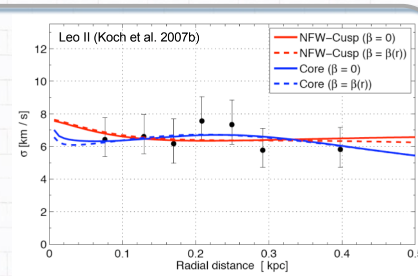
We conclude that neither Leo I nor Leo II have experienced any significant tidal perturbation to significantly alter their dynamics. Given their large present-day distance to the Galaxy, this is not surprising, and such interactions would be expected only, if the systems were on highly eccentric orbits, bringing them close the the Milky Way.

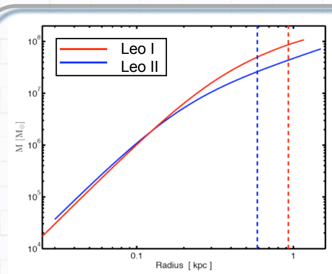




Radial velocity dispersion profiles:

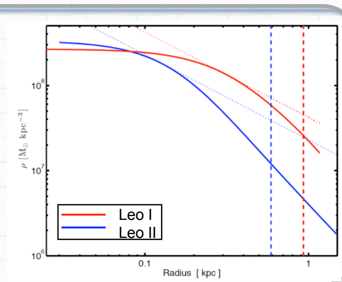
Dispersion profiles were determined under the assumption of a Gaussian velocity distribution, accounting for Galactic interlopers, but neglecting binaries (e.g., Kleyna et al. 2002; Walker et al. 2006). In both Leo I and II, the dispersion profiles are essentially flat out to the reach of our data near the stellar boundaries. We then calculated theoretical dispersion profiles using Jeans equation, adopting (1) both a cored (Read & Gilmore 2005) and a cusped halo profile (Navarro et al. 1995; NFW) and (2) varying degrees of velocity anisotropy. We find that the cored profiles with a mild degree of tangential anistropy are marginally favored to account for the observed kinematics, while also cusps with radially varying anisotropy cannot fully be excluded by the present data.

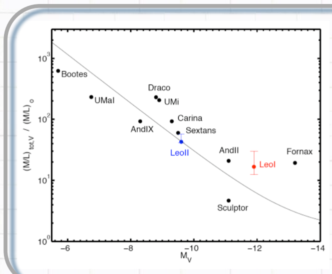




Mass and density profiles:

From Jeans equation and adopting light profiles from the literature, we derive the mass and density profiles that are overplotted here for both galaxies. The total masses out to the limiting radii of our data, indicated as dashed lines, are 8x$10^7 M_o$ for Leo I and 3x$10^7 M_o$ for Leo II. As noted by Gilmore et al. (2007), the central density profiles of dSphs are remarkably similar and exhibit shallow central trends. As our data show, also the Leo dwarfs' inner density slopes bear close resemblance. Shown for comparison are also r^{-1} profiles, which are predicted by many cosmological theories.





Mass-to-Light ratios - Just bricks in the wall:

Given our derived "total" masses out to our data and the satellites' luminosities from the literature, we estimate the $(M/L)_V$ of to Leo I and II to be 24 ± 6 $(M/L)_{V,o}$ and 45 ± 11 $(M/L)_{V,o}$, resp. These high values, coupled with the flat dispersion profiles and the absence of significant tidal perturbations clearly indicate that these galaxies are strongly dark matter dominated. Their location in the "Mateo-plot" of (M/L) vs. their luminosity (Mateo et al. 1993; Gilmore et al. 2007) supports the view that all these dSphs are embedded in dark matter halos of the same mass of about 3x$10^9 M_o$ (indicated by the solid line). Although there is no a priori reason to expect this empirical relation, it clearly underscores the role of the remote Leo I and Leo II dSphs as typical representatives of the dark matter family.

For further details see:

Gilmore et al. 2007, ApJ, in press (astro-ph/0703308)
Kleyna et al. 2002, MNRAS, 330, 792
Koch et al. 2007a, ApJ, 657, 241
Koch et al. 2007b, AJ, in press (astro-ph/0704.3437)
Mateo et al. 1993, AJ, 105, 510
Mateo et al. 1998, AJ, 116, 2315
Navarro et al. 1995, MNRAS, 275, 720
Read & Gilmore 2005, MMNRAS, 356, 107
Sohn et al. 2006, AJ, in press (astro-ph/0608151)
Vogt et al. 1995, AJ, 109, 151
Walker et al. 2006, AJ, 131, 2114

Talk by M. Wilkinson (Sat.,09:50)