Dark matter in dwarf spheroidal galaxies

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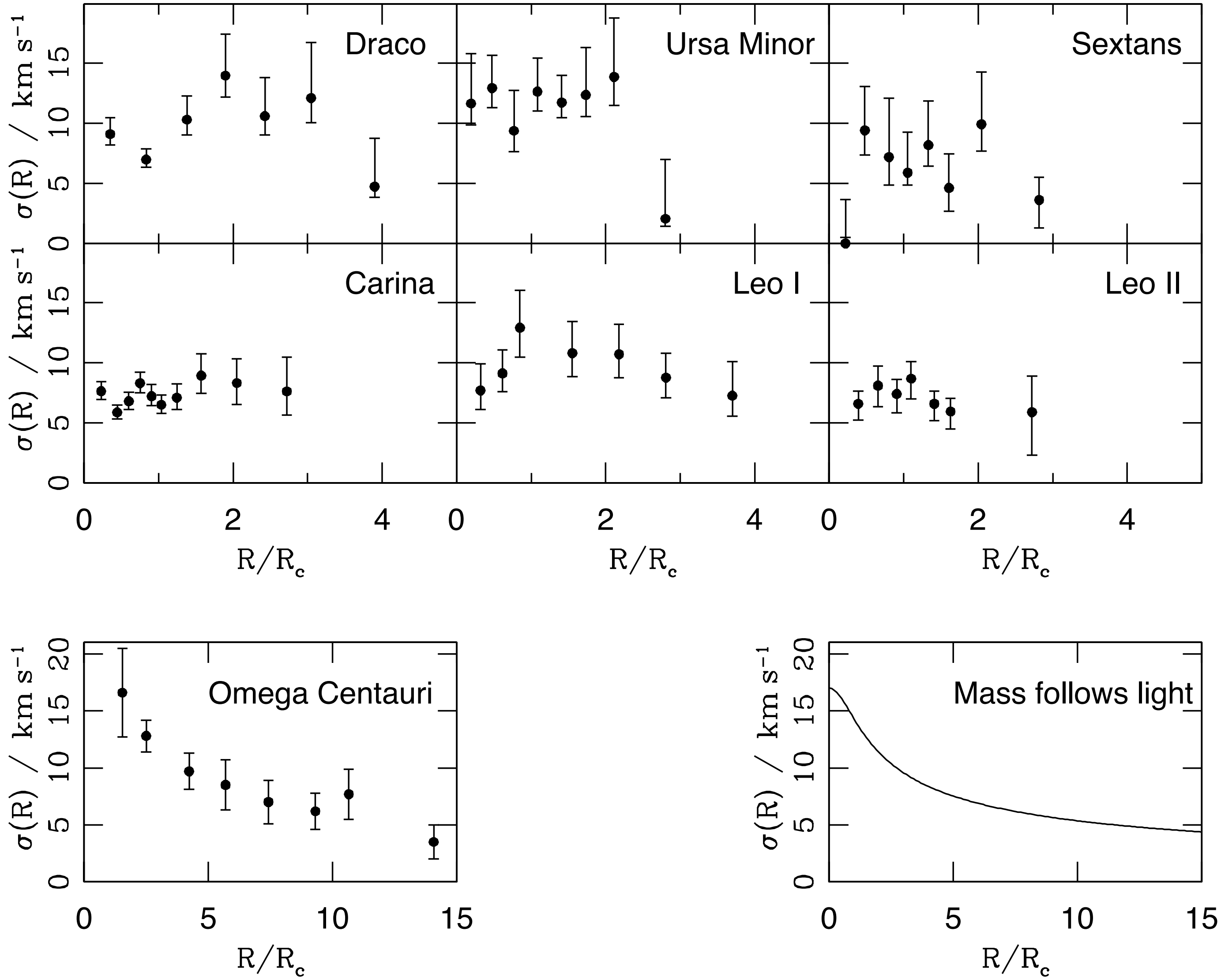
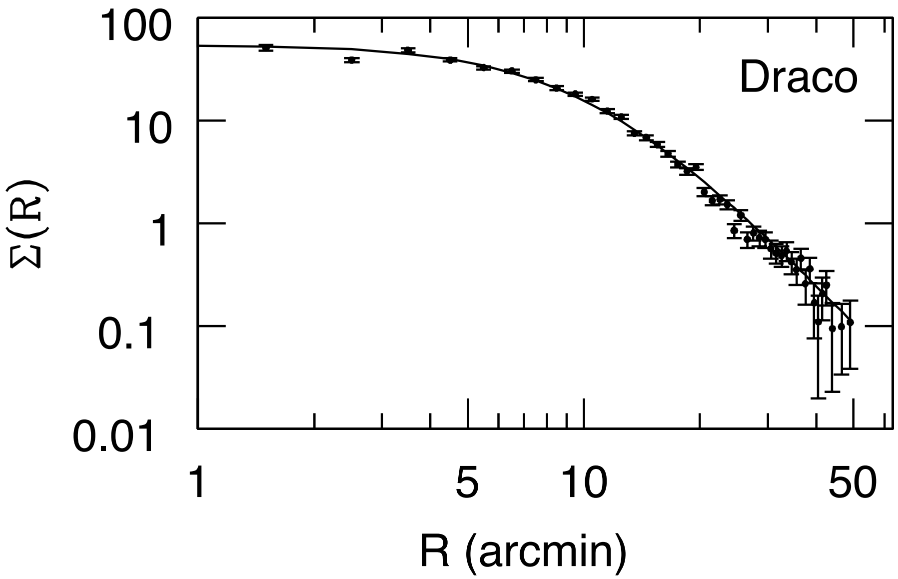
See also: Posters on Leo I and Leo II by Andreas Koch

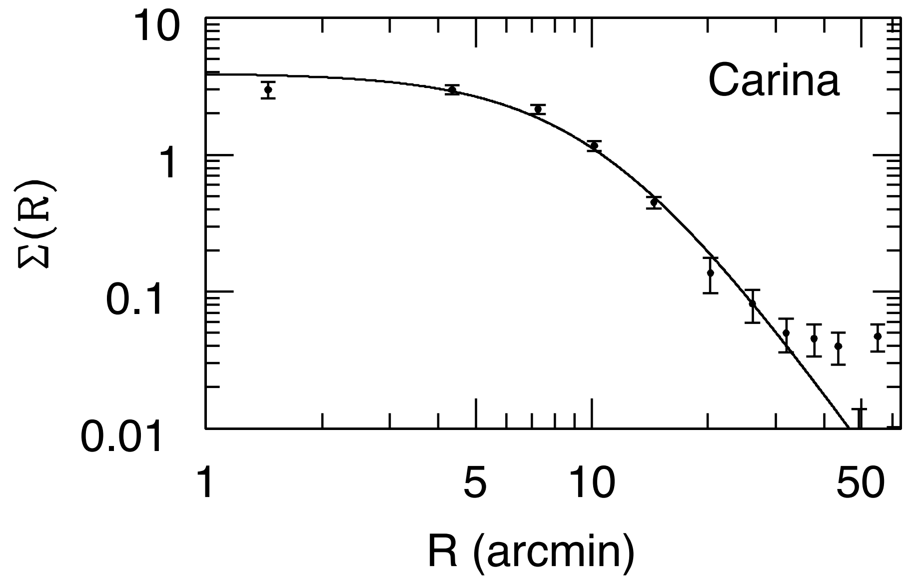
Dispersion Profiles

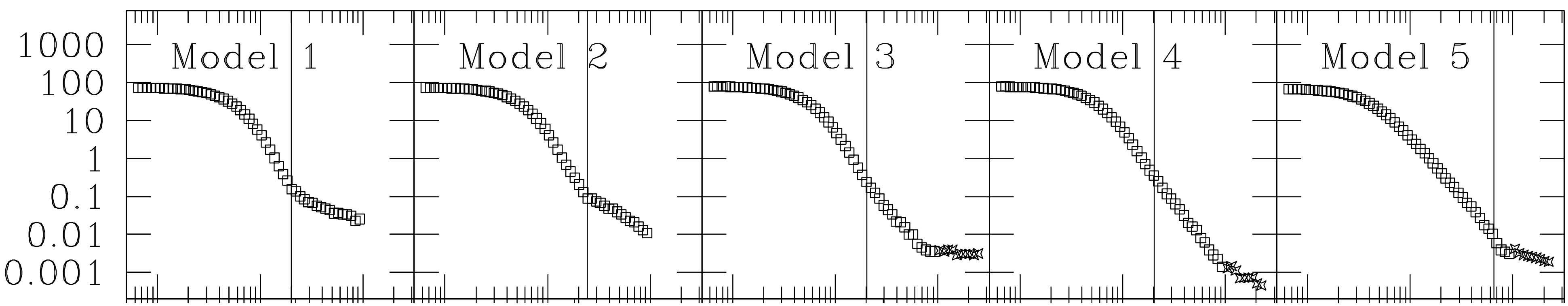


Gilmore et al. (2007)

dSphs - the case against tides

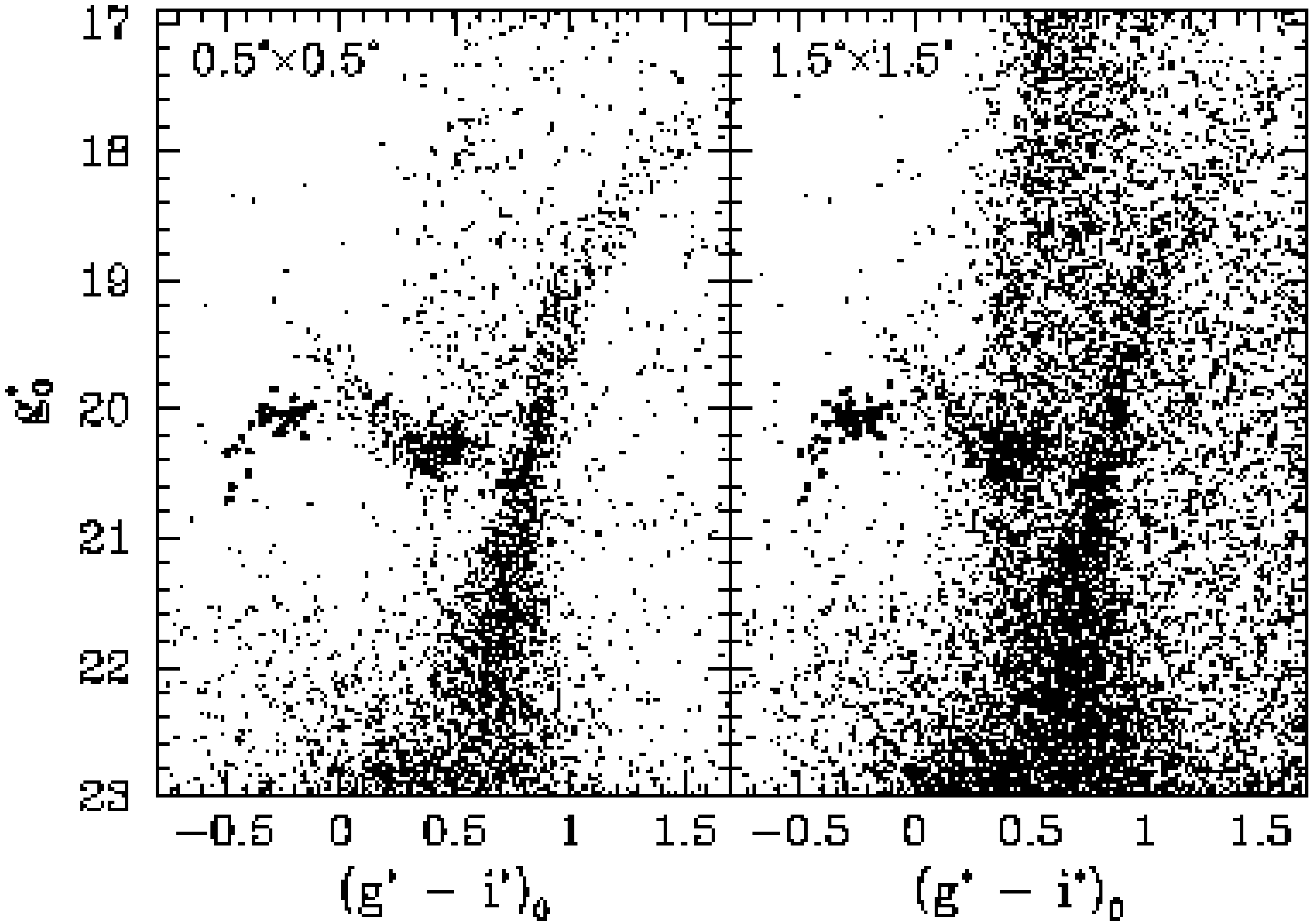






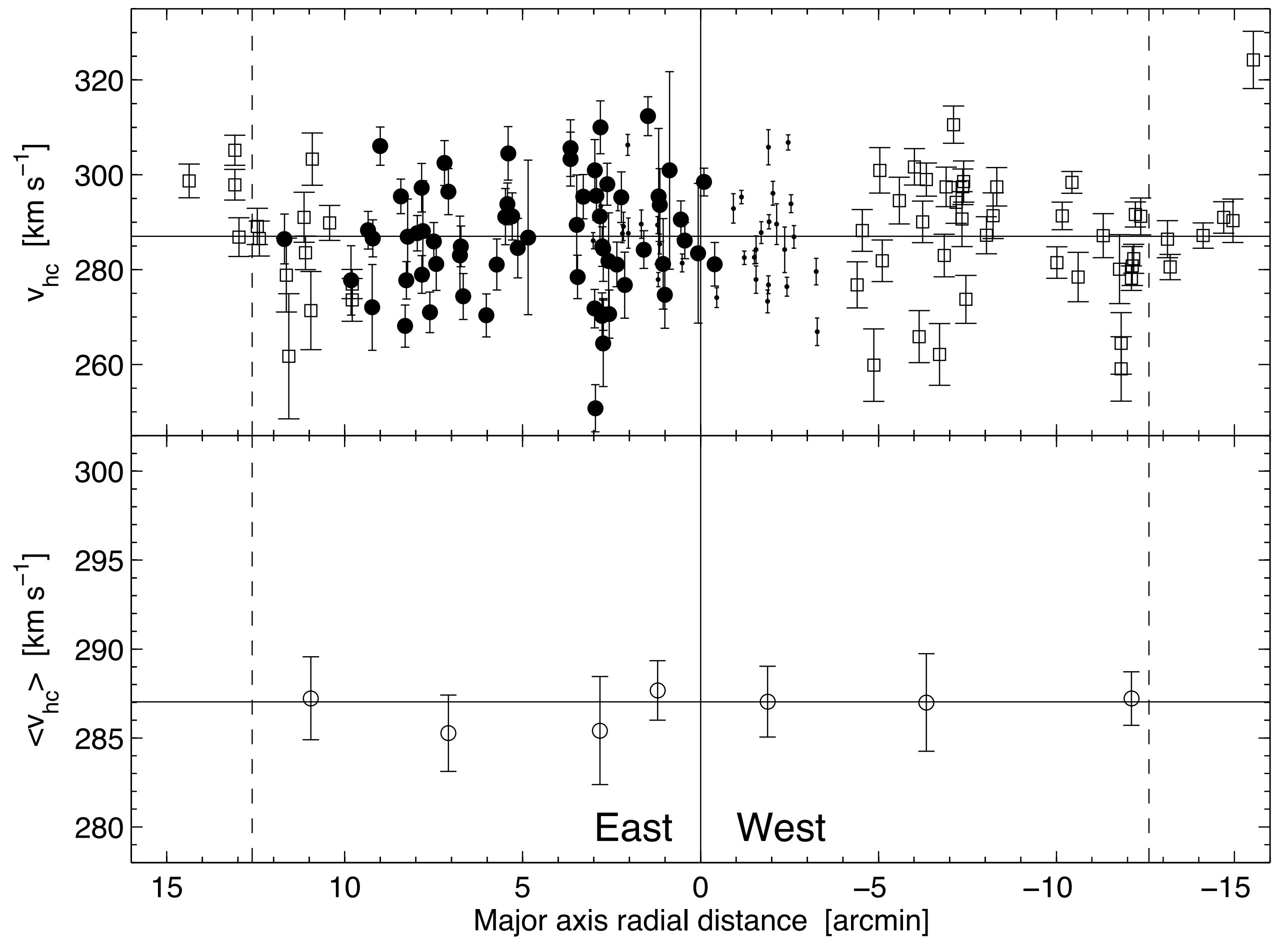
Johnston et al. (2002)

Draco: No evidence for HB broadening



Klessen et al. (2003)

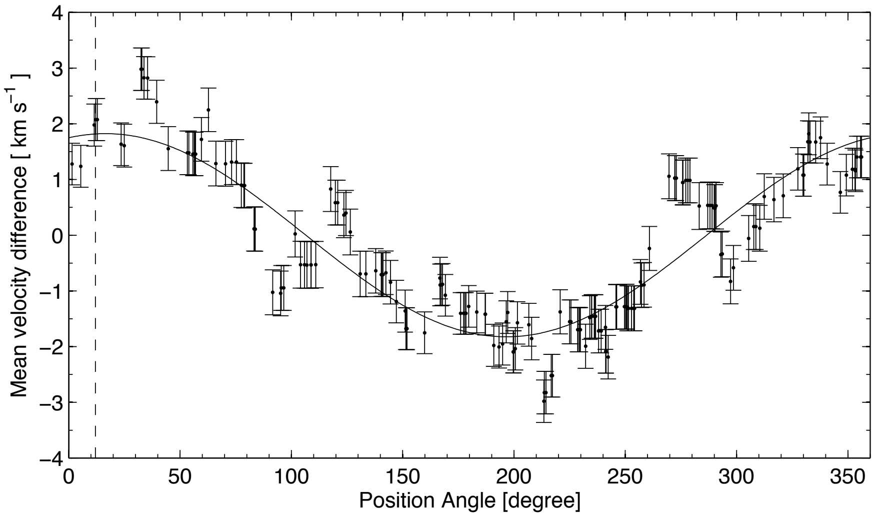
Testing for velocity asymmetry in Leo I

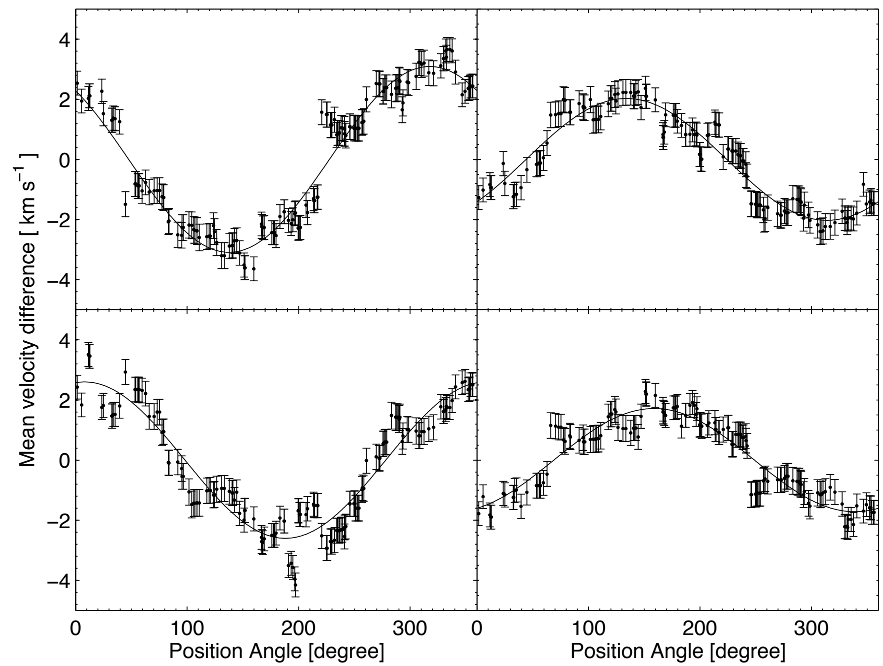


Koch et al. (2007)

Conclusion: No velocity asymmetry seen in Koch et al. data

No apparent rotation in Leo II





Koch et al. (2007)

Conclusion: No kinematic evidence that central dispersions of dSphs have been inflated by *strong* tidal effects

Some kinematic evidence that *outer* regions of Carina may be experiencing tidal disturbance by the Milky Way

dSphs: the case for cores

Jeans equations give simple relation between kinematics, the light distribution and the underlying mass distribution

$$M(r) = -\frac{r^2}{G}\left(\frac{1}{\nu}\frac{\mathrm{d}\,\nu\sigma_r^2}{\mathrm{d}\,r} + 2\,\frac{\beta\sigma_r^2}{r}\right)$$

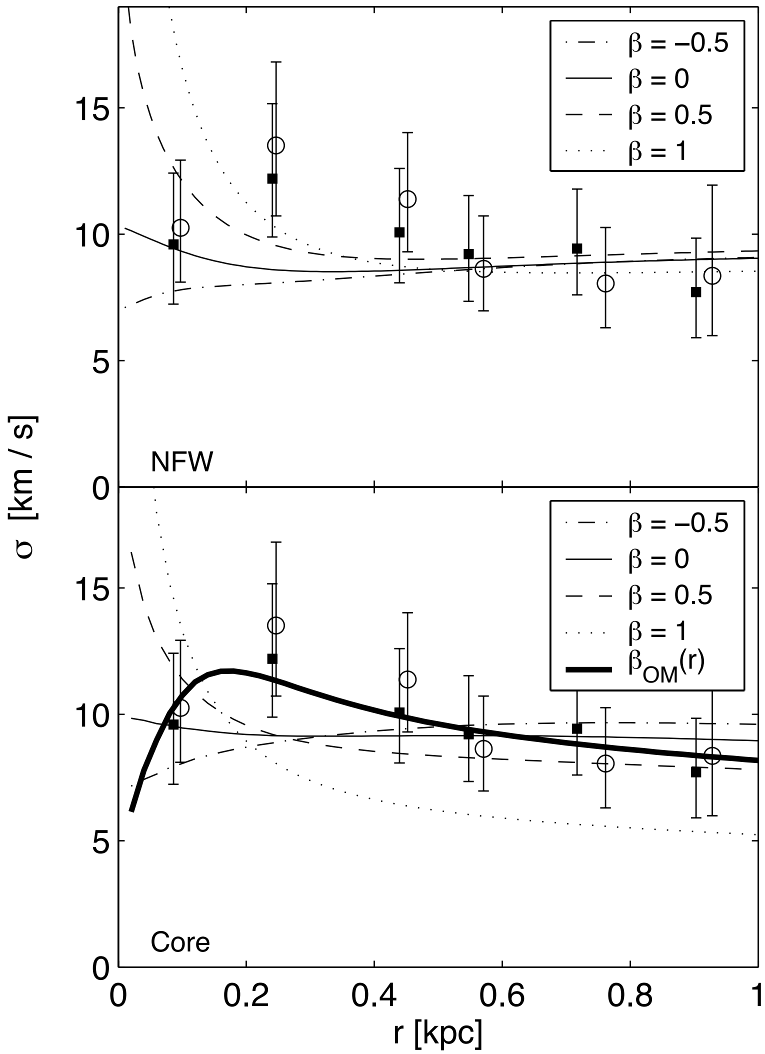
We can either:

1. Assume a parameterised mass model $M(r)$ and velocity anisotropy $\beta(r)$ and fit dispersion profile

   or

2. Use Jeans equations to determine mass profile from projected velocity dispersion profile and a fit to the light distribution

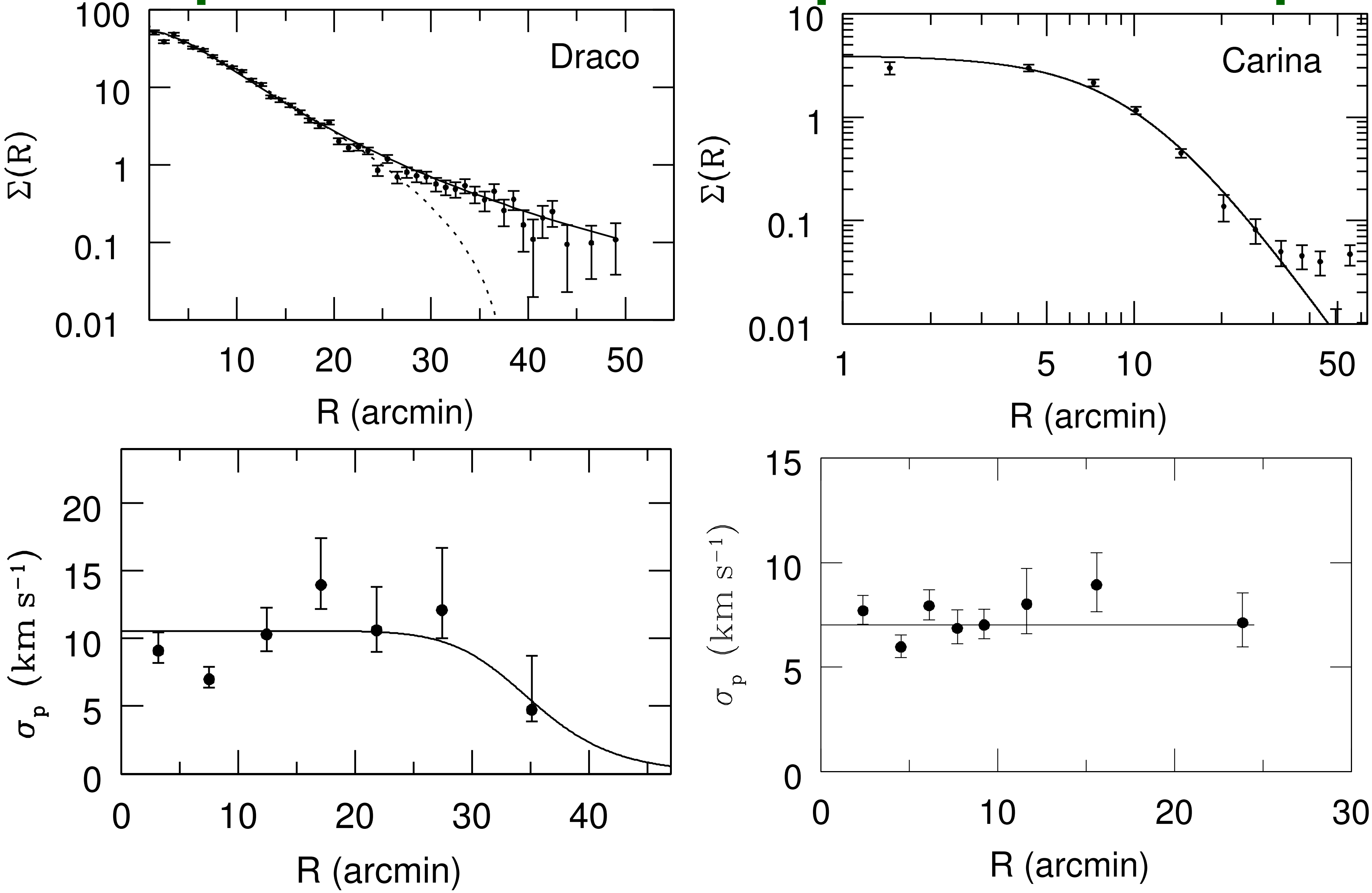
Fitting dSph dispersion profiles: Leo I



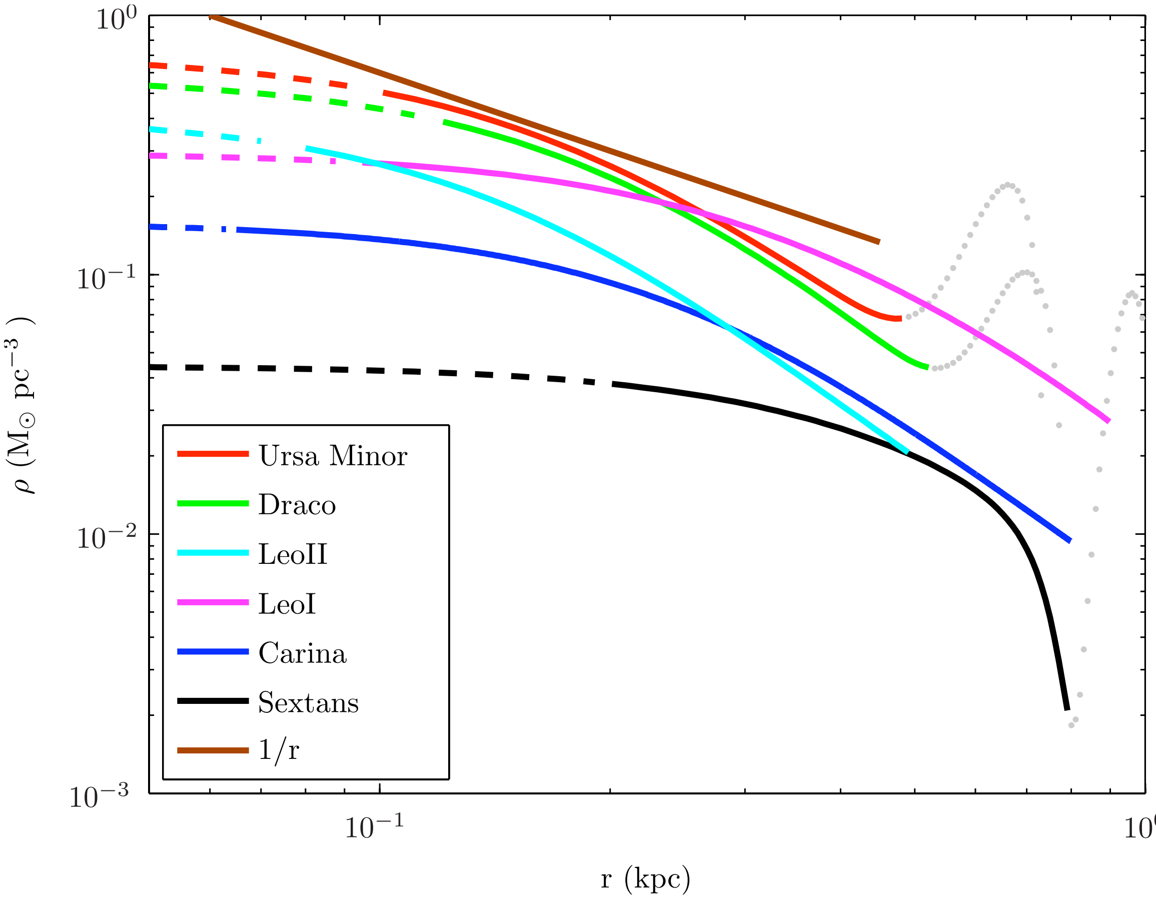
Koch et al. (2007)

- Assume either NFW halo (1 free halo parameter) or generalised Hernquist profile (4 free halo parameters)
- Best-fit dispersion obtained for cored profiles with roughly isotropic velocity distributions
- Significant velocity anisotropy not favoured (but not excluded)
- Enclosed mass $\sim 8 \times 10^7 \mathrm{M}_\odot$ in both cored and cusped haloes

Mass profiles from Jeans equations: assumptions

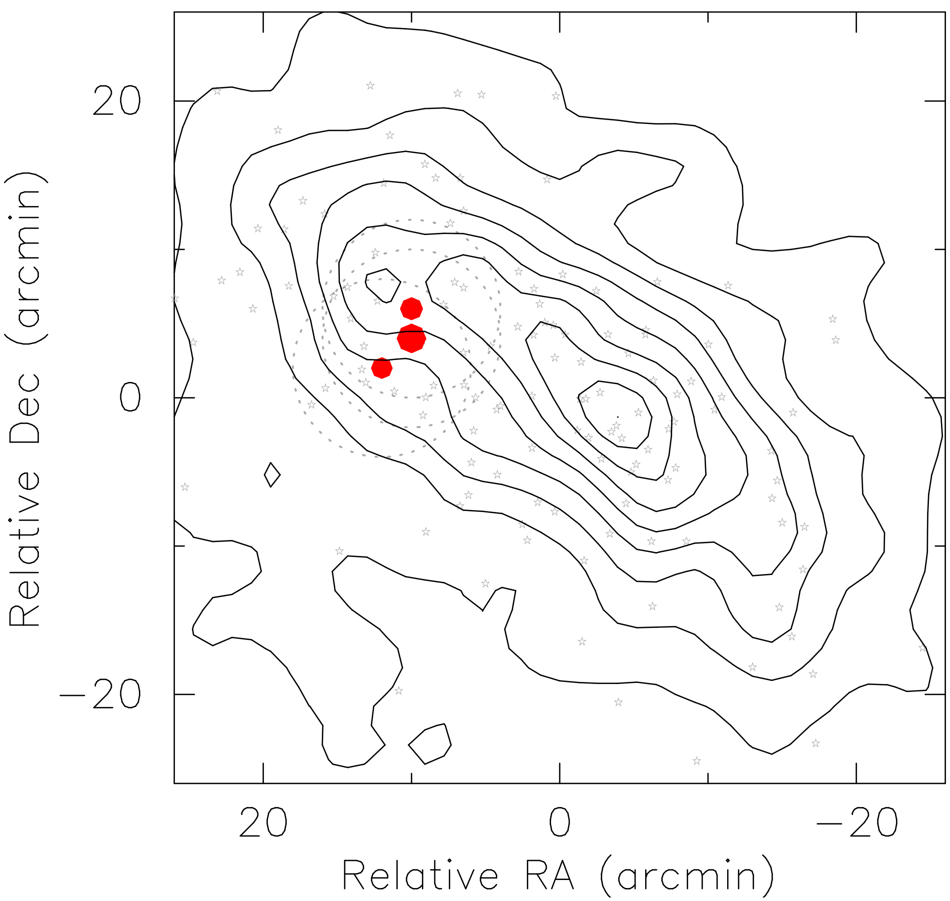


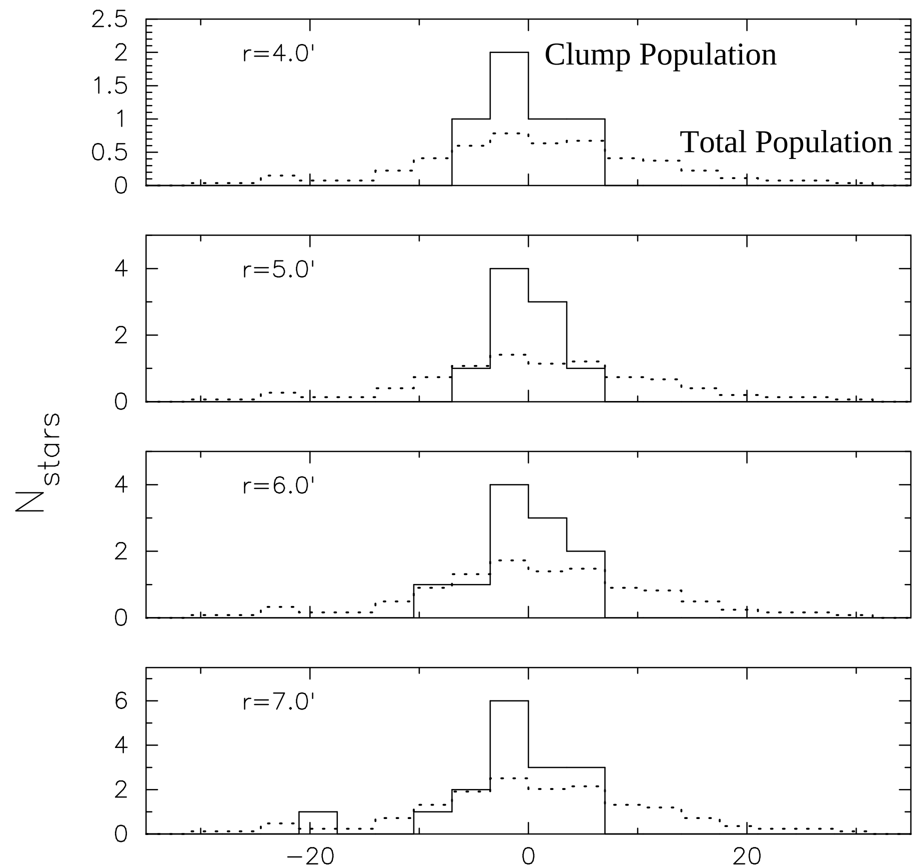
Density profiles from Jeans equations



- Masses in range $3 - 8 \times 10^7\,M_\odot \implies$ M/L in range $13 - 240 M_\odot/L_\odot$
- Conclusion: Kinematics are consistent with **cored** haloes, in contrast to predictions of cosmological simulations

Localised kinematic substructure in Ursa Minor

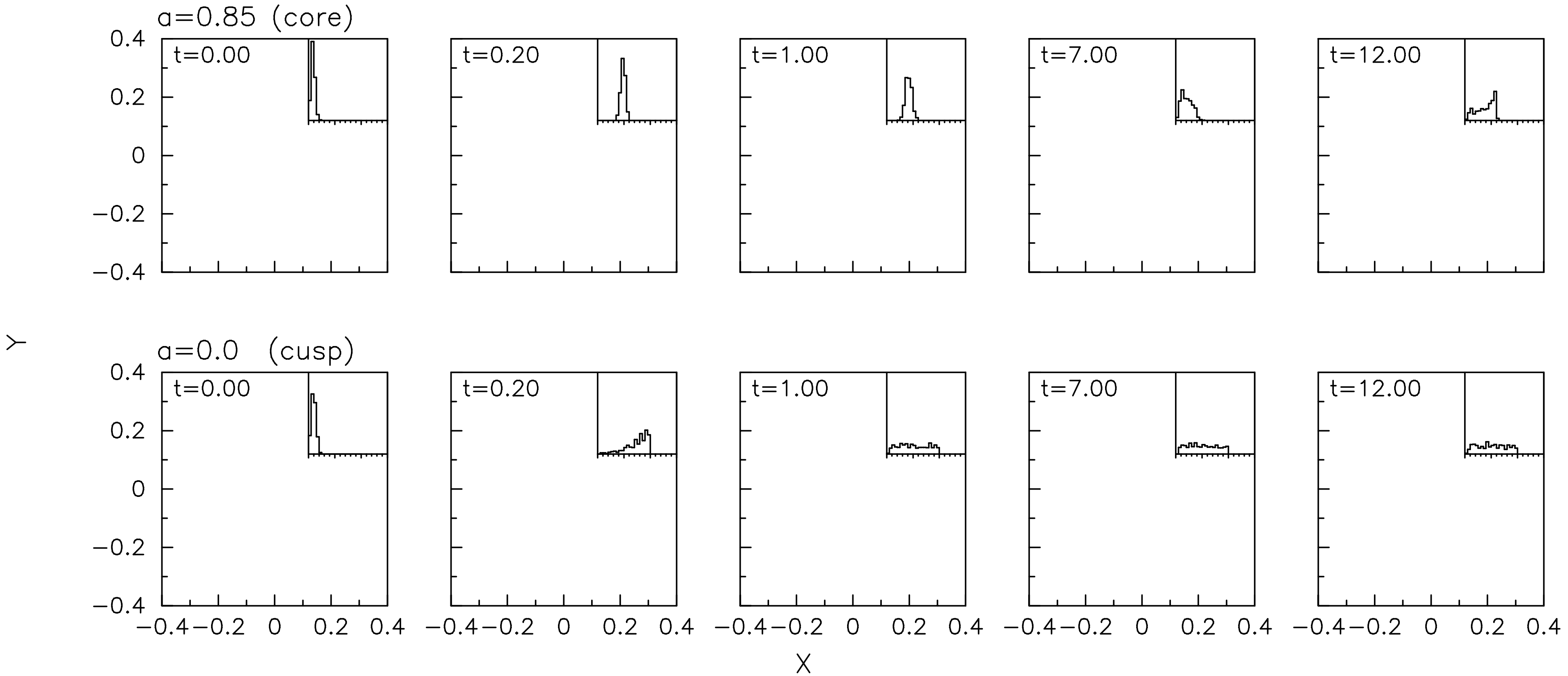




Kleyna et al. (2002)

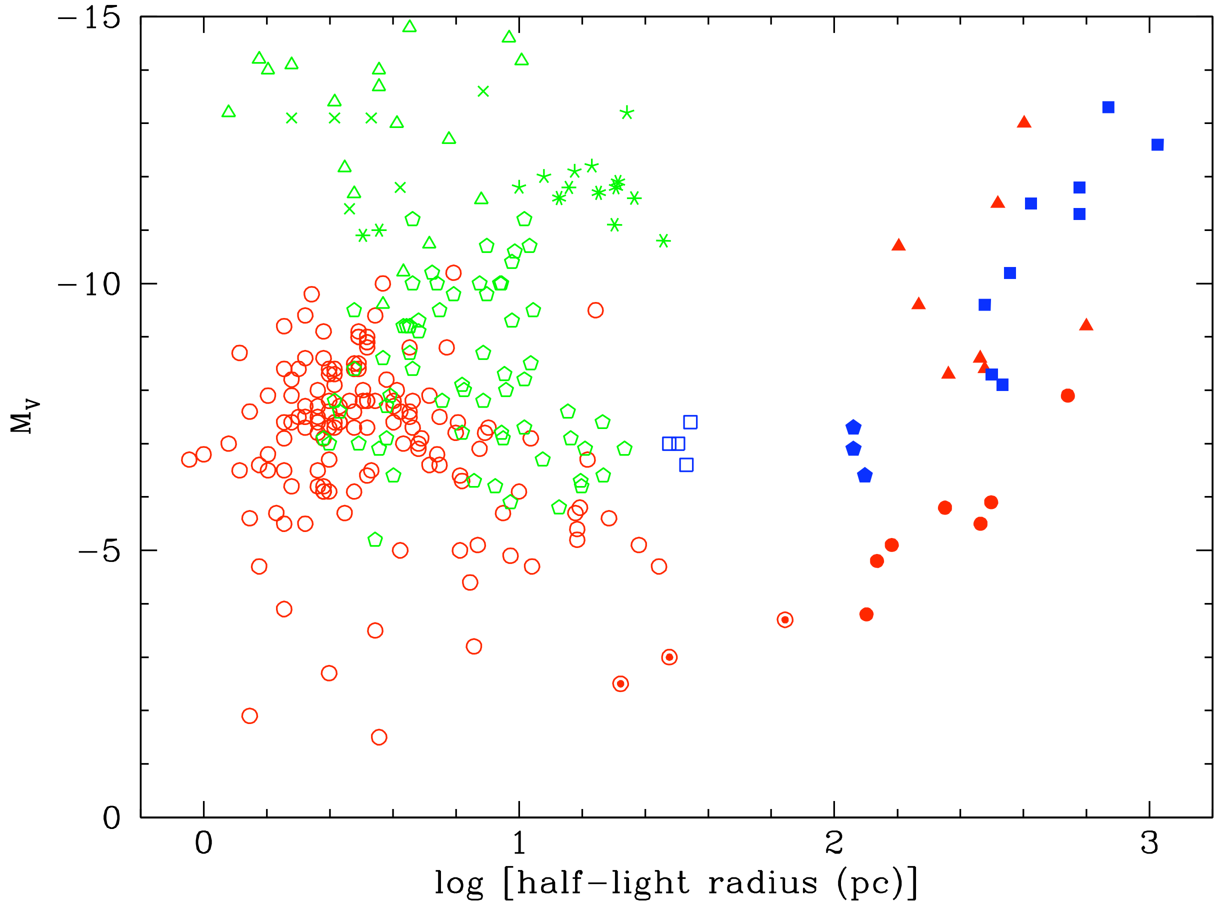
Similar feature in Sextans (*Kleyna et al. (2004); Walker et al. (2006)*)

Substructure and the profiles of dSph haloes



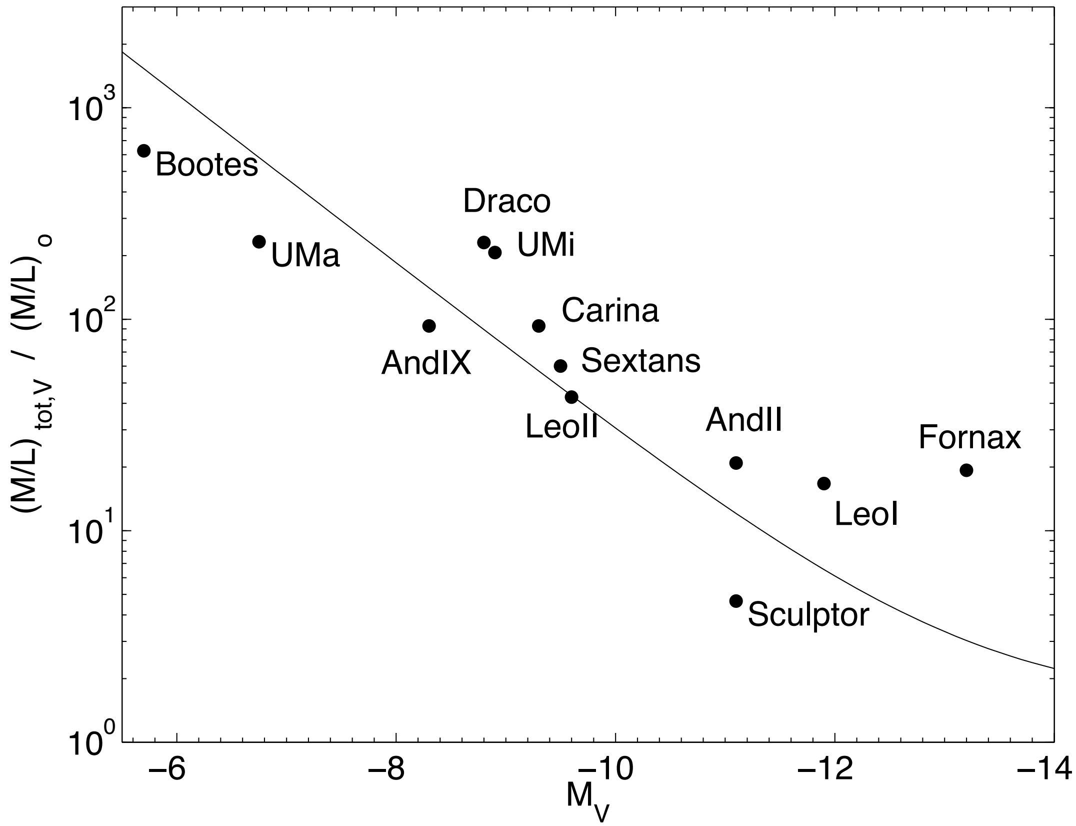
- Conclusion: existence of long-lived, cold substructure in Ursa Minor is incompatible with a cusped dark halo
- Star clusters in Fornax also imply cored halo *(Goerdt et al. 2006)*

Size distribution of satellites



Gilmore et al. (2007)

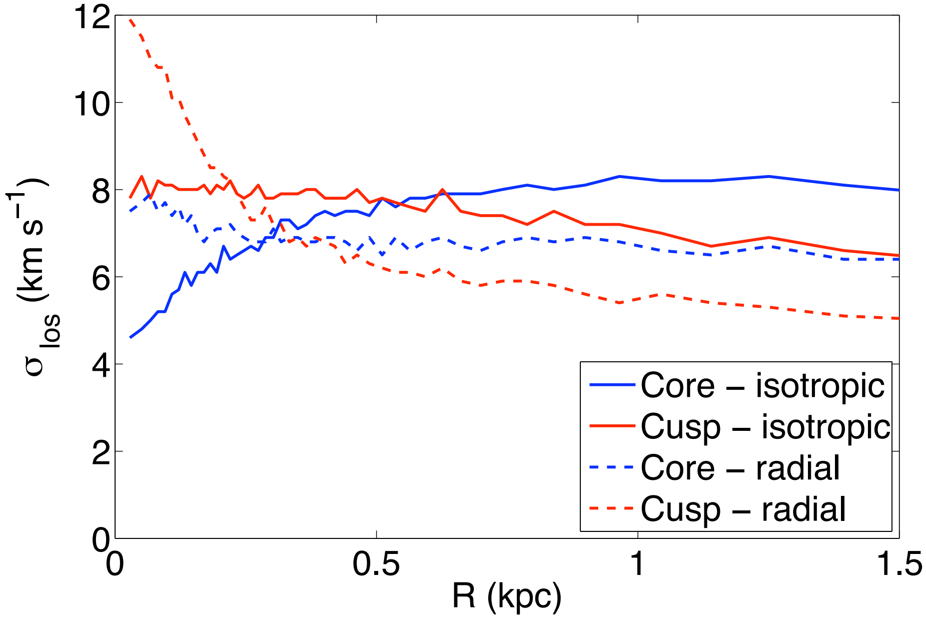
Global trend of dSph haloes

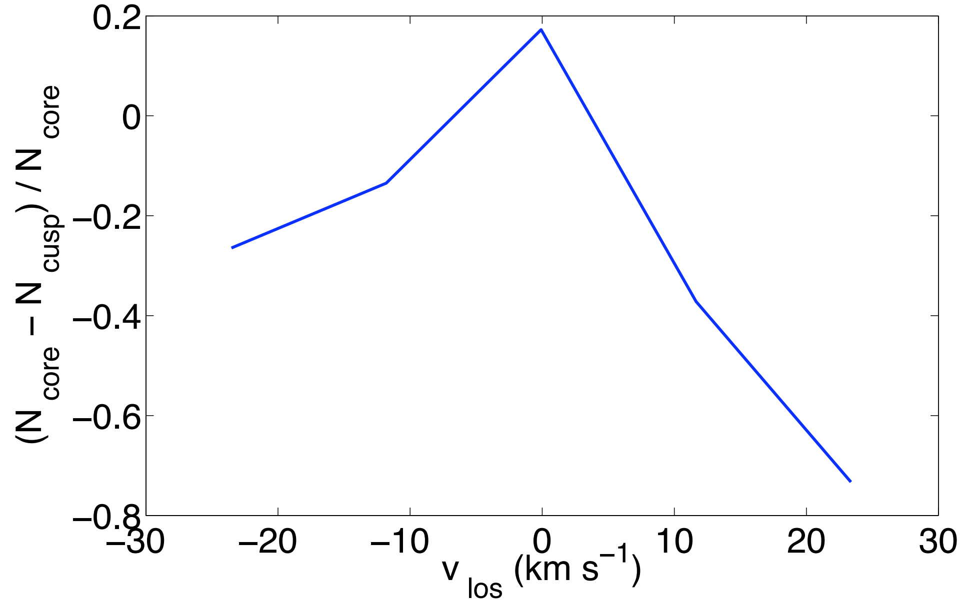


Wilkinson et al. (2006), Gilmore et al. (2007)

- Mean dark matter density $< 0.1 M_{\odot}$ pc^{-3} (5 GeV/c^2 cm^{-3})
- If haloes are cusped, mean density inside 10pc: $60 M_{\odot}$ pc^{-3} (2 TeV/c^2 cm^{-3})

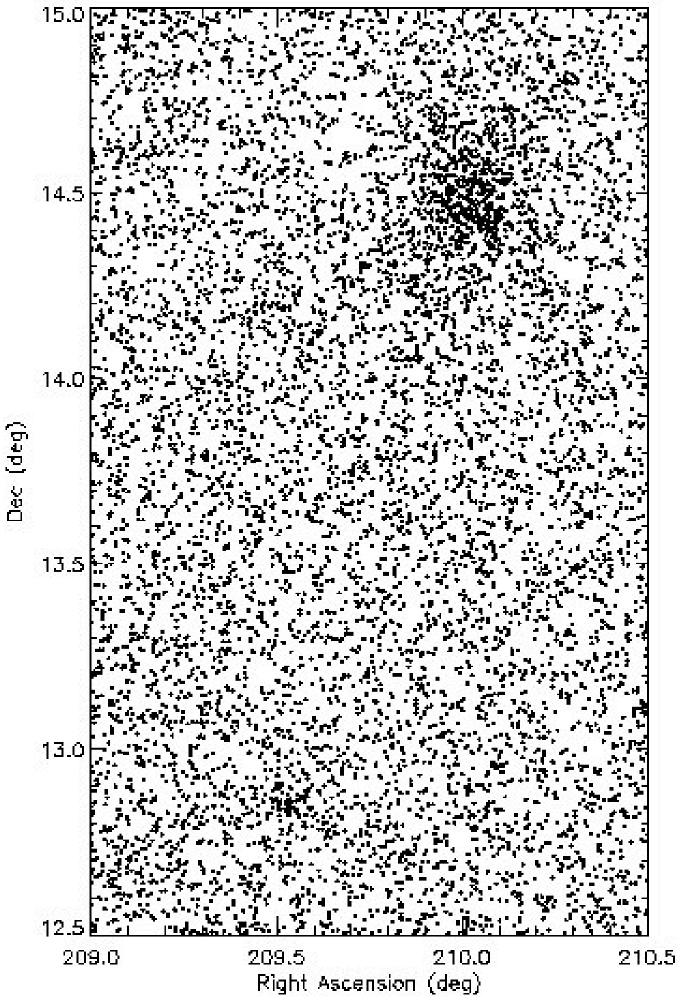
Future work: breaking the core/cusp degeneracy with the VLT





The degeneracy between velocity anisotropy and density profile can be broken using radial velocities of 500 stars in the inner 0.2 kpc

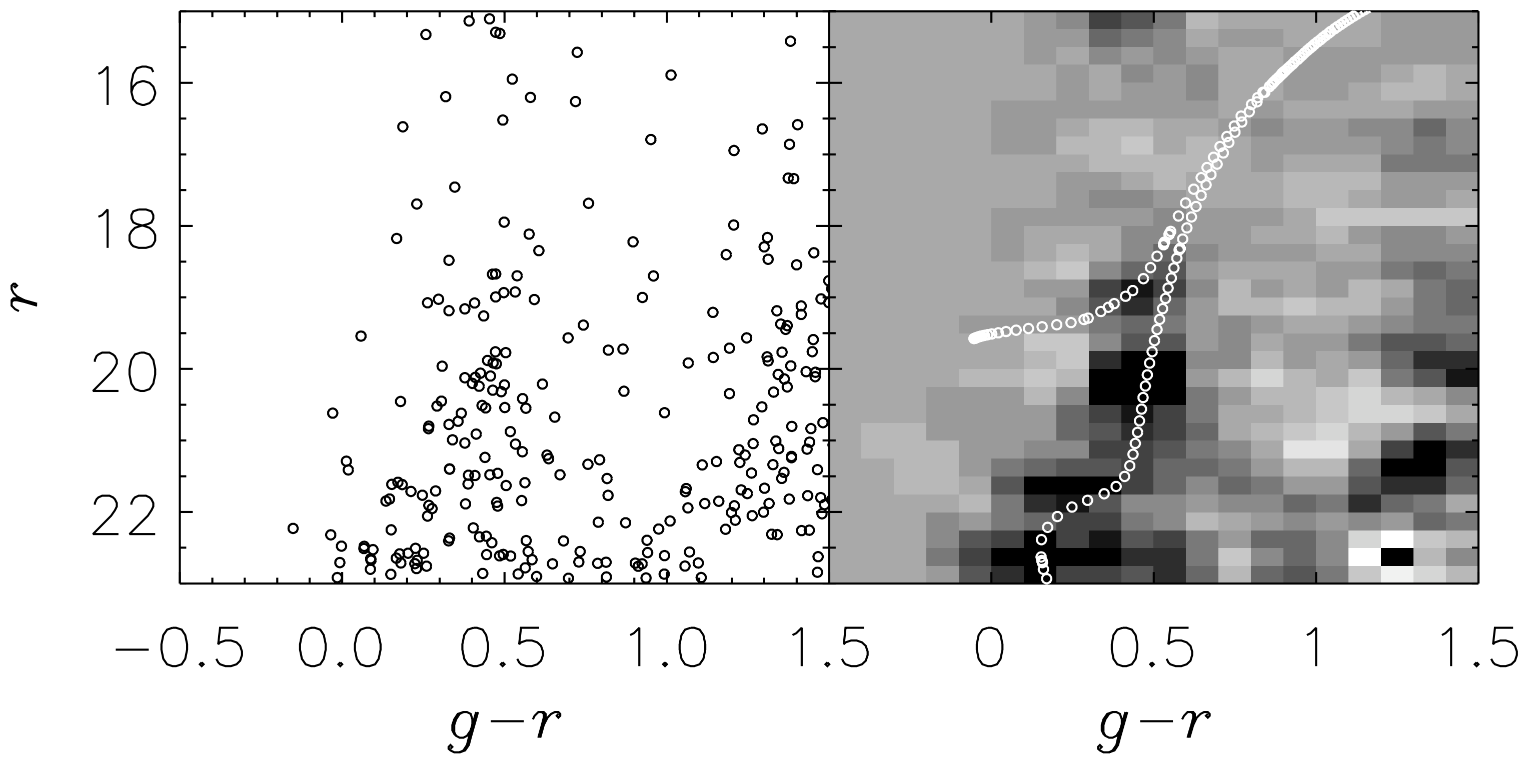
The Bootes II dSph



Walsh et al. (2007)

- Discovered by Walsh et al. (2007 - May)
- Lowest luminosity dSph discovered to date
- $M_V = -3.1 \pm 1.1$
- $r_h = 4'.1 \pm 1'$ = 70 pc
- Lies in size “gap” between dSphs and star clusters

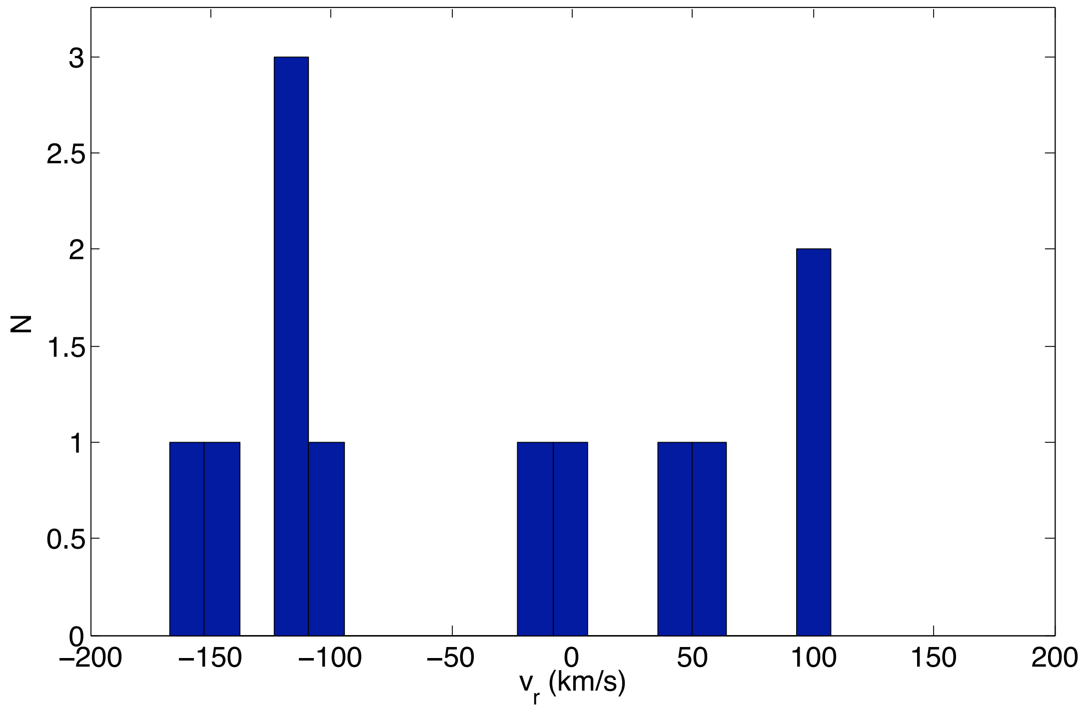
The Bootes II dSph



Walsh et al. (2007)

- Spectra of 17 stars in Bootes II obtained by J. Kleyna using GMOS in April 2007

Spectroscopic confirmation of Bootes II



Wilkinson et al. (in prep.)

- V$_{\rm los} \sim -120$ km/s
- Bulk motion renders association with Bootes I very unlikely (V$_{\rm los} \sim +100$ km/s)

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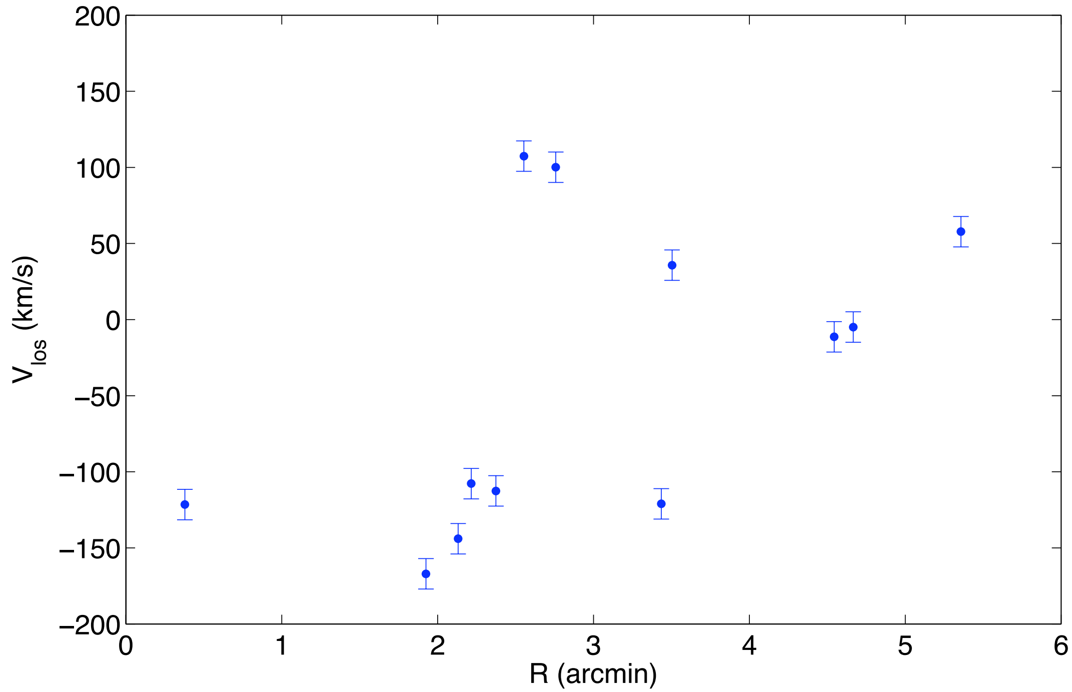

Wilkinson et al. (in prep.)

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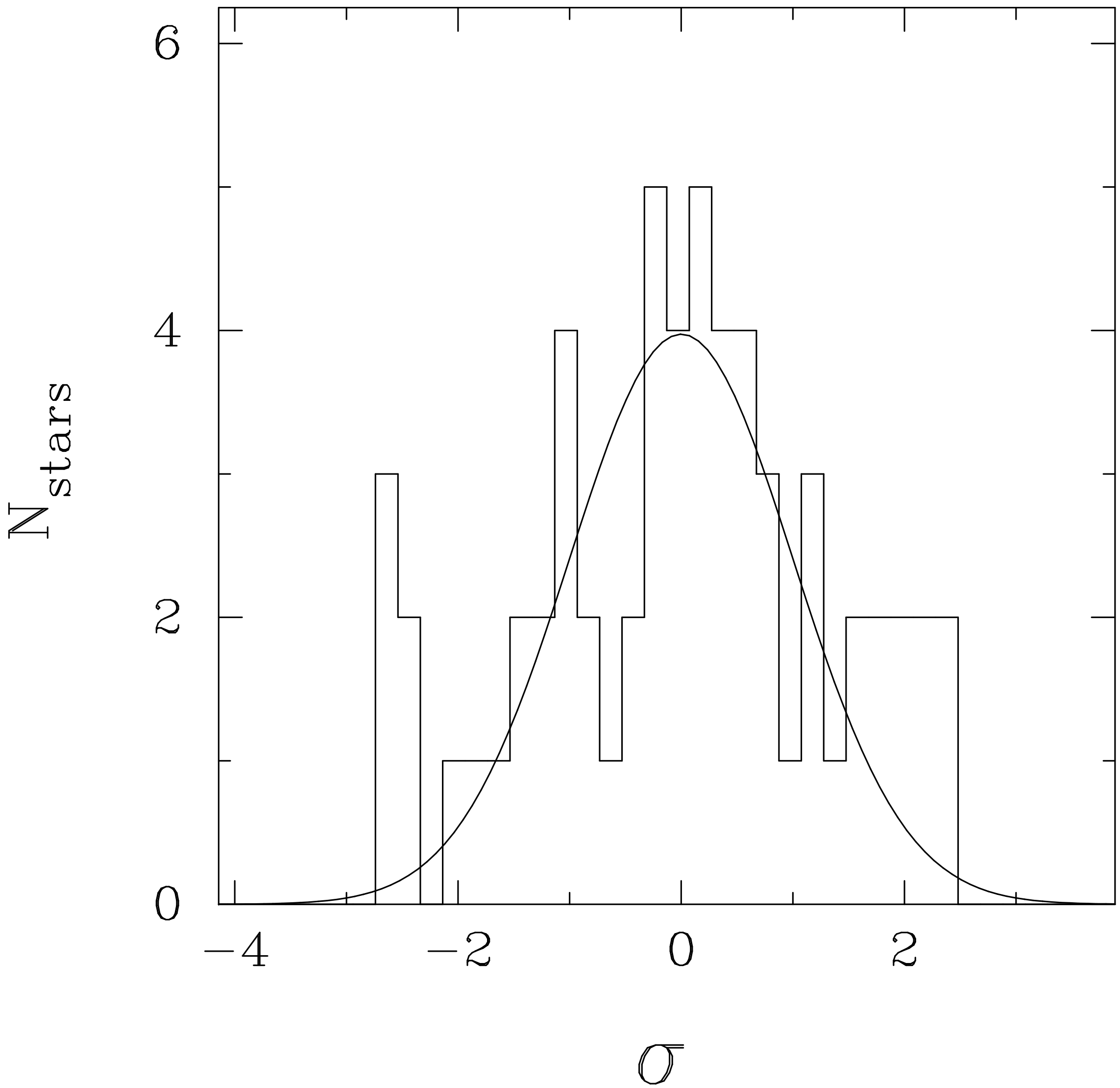
Conclusions

- DSph galaxies are crucial laboratories for testing the properties of dark matter
- No kinematic evidence that tides have inflated inner dispersion profiles of dSphs - some evidence of tidal disturbance at larger radii
- Current kinematic data are consistent with high M/L ratio, cored dark matter distributions – mass scale $\sim 3 \times 10^7\,\mathrm{M}_\odot$ ($r \lesssim 400$pc)
- Mean dark matter density $\lesssim 0.1\mathrm{M}_\odot\,\mathrm{pc}^{-3}$; Maximum circular velocity $\gtrsim 15\mathrm{km\,s}^{-1}$
- GMOS spectra of newly discovered Bootes II satellite show a bulk velocity of ~ -120km/s, suggesting it is unrelated to Bootes I

Draco: Binary Fraction



$f_b < 50\%$
(95% confidence)

Kleyna et al. (2002)

Besancon prediction towards Bootes II