Dwarf spheroidal galaxies and the physical properties of dark matter

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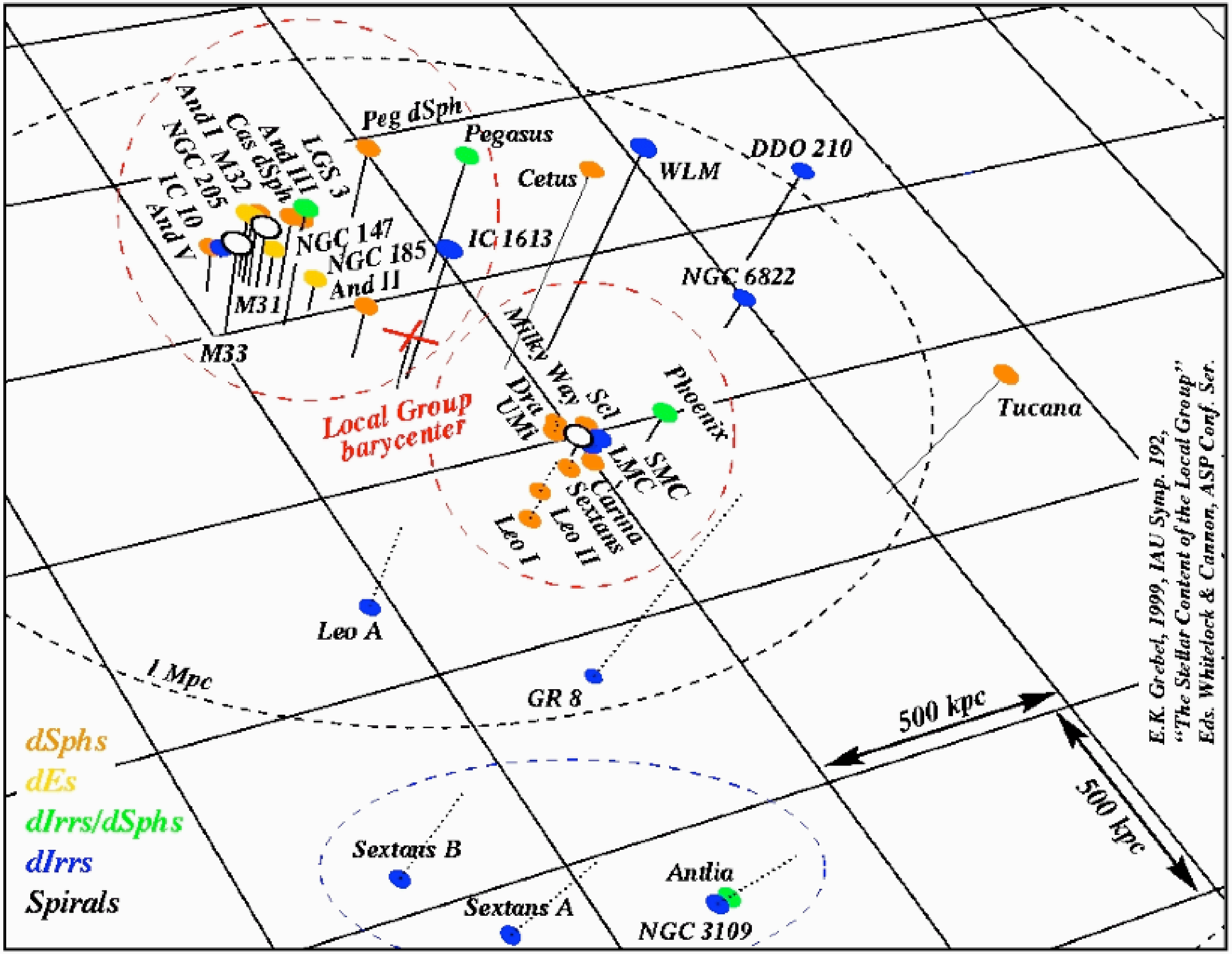
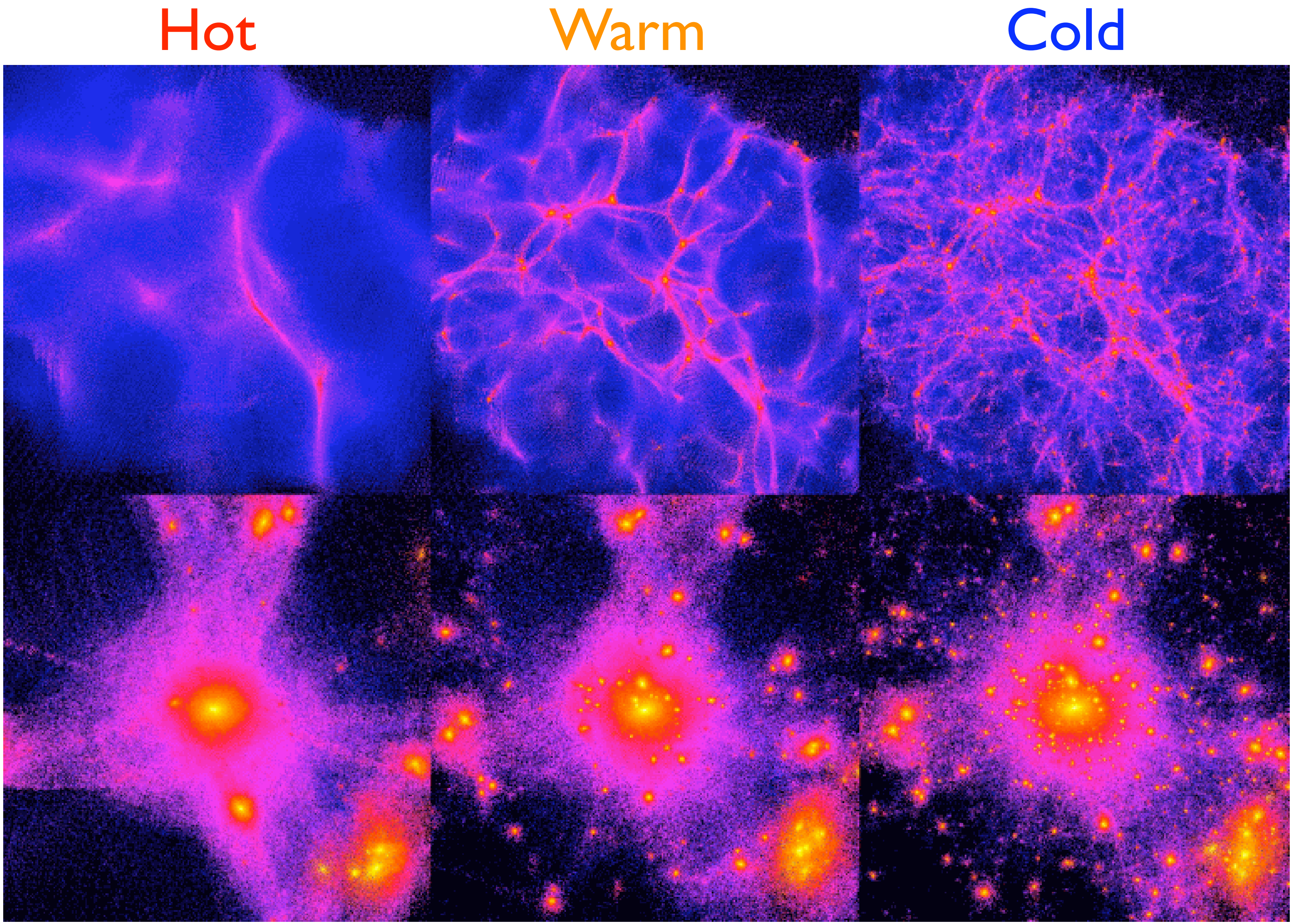
Local Group satellites



Grebel (1999)

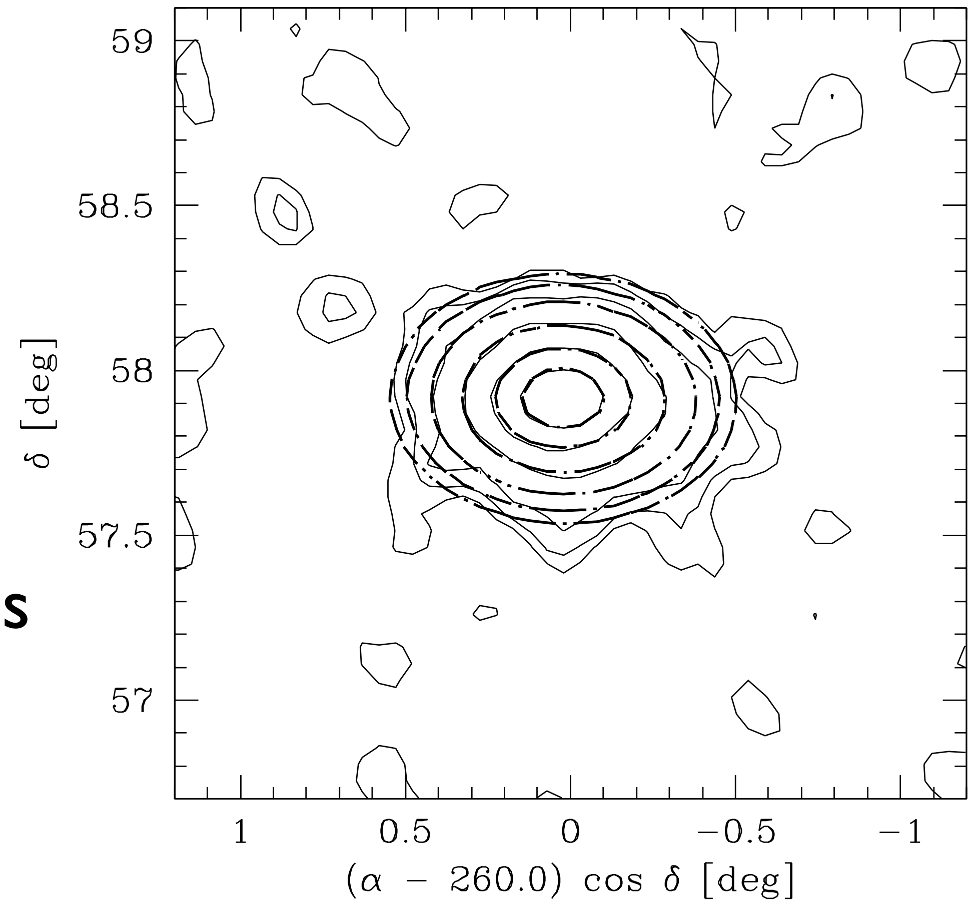
Satellites and dark matter



Moore

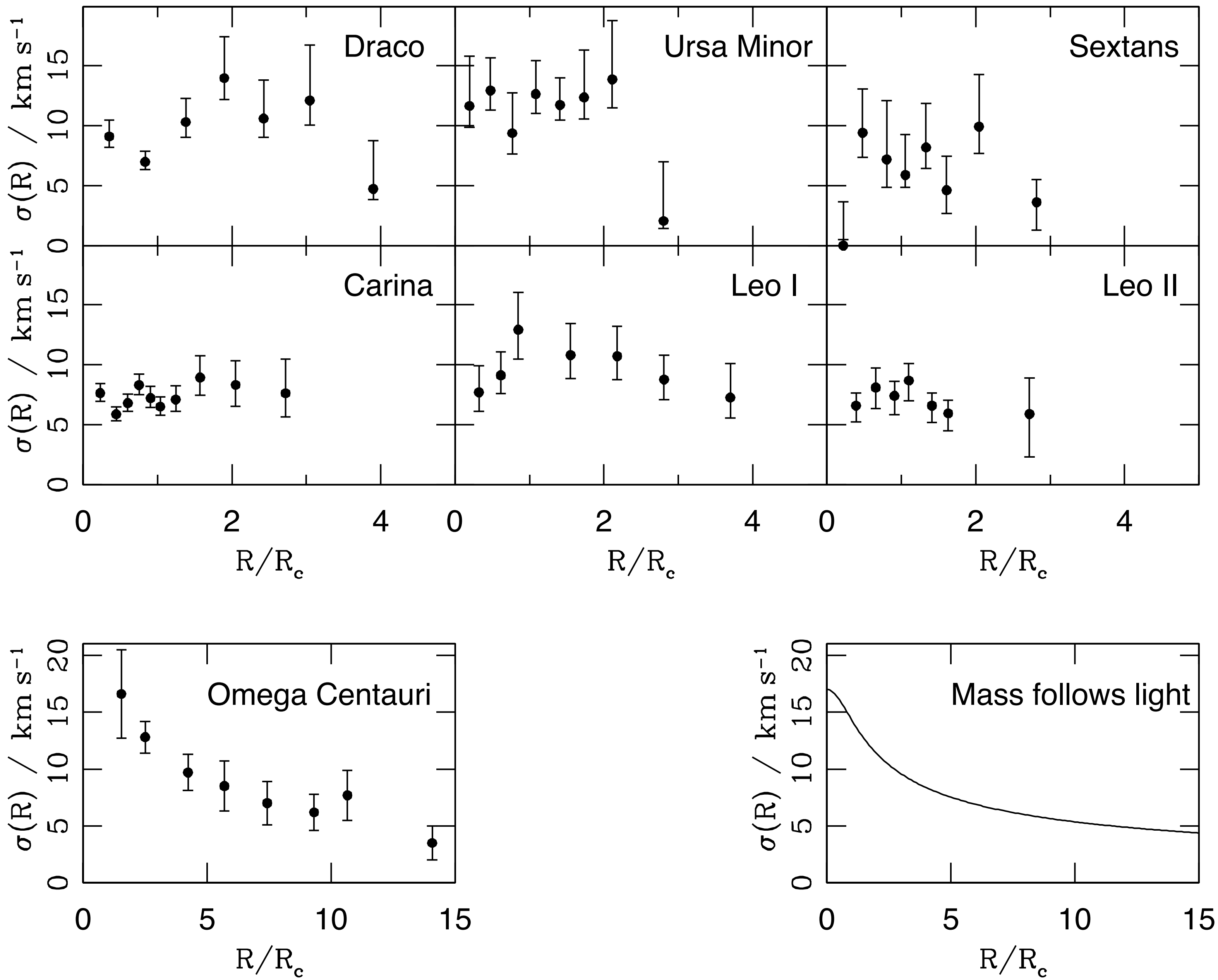
Dwarf spheroidal galaxies

- Low luminosity, gas-poor satellites of Milky Way and M31
- $L = 3 \times 10^4 L_\odot - 2 \times 10^7 L_\odot$
- No well-defined tidal radii
- Individual stellar velocities measurable with ≥ 4m telescopes
- $\sigma_0 \sim 7 - 12\,\mathrm{km\,s^{-1}}$
- Core radii $r_0 \approx 130 - 500\,\mathrm{pc}$
- Inferred mass-to-light ratios in range $3 - 300\,M_\odot/L_\odot$



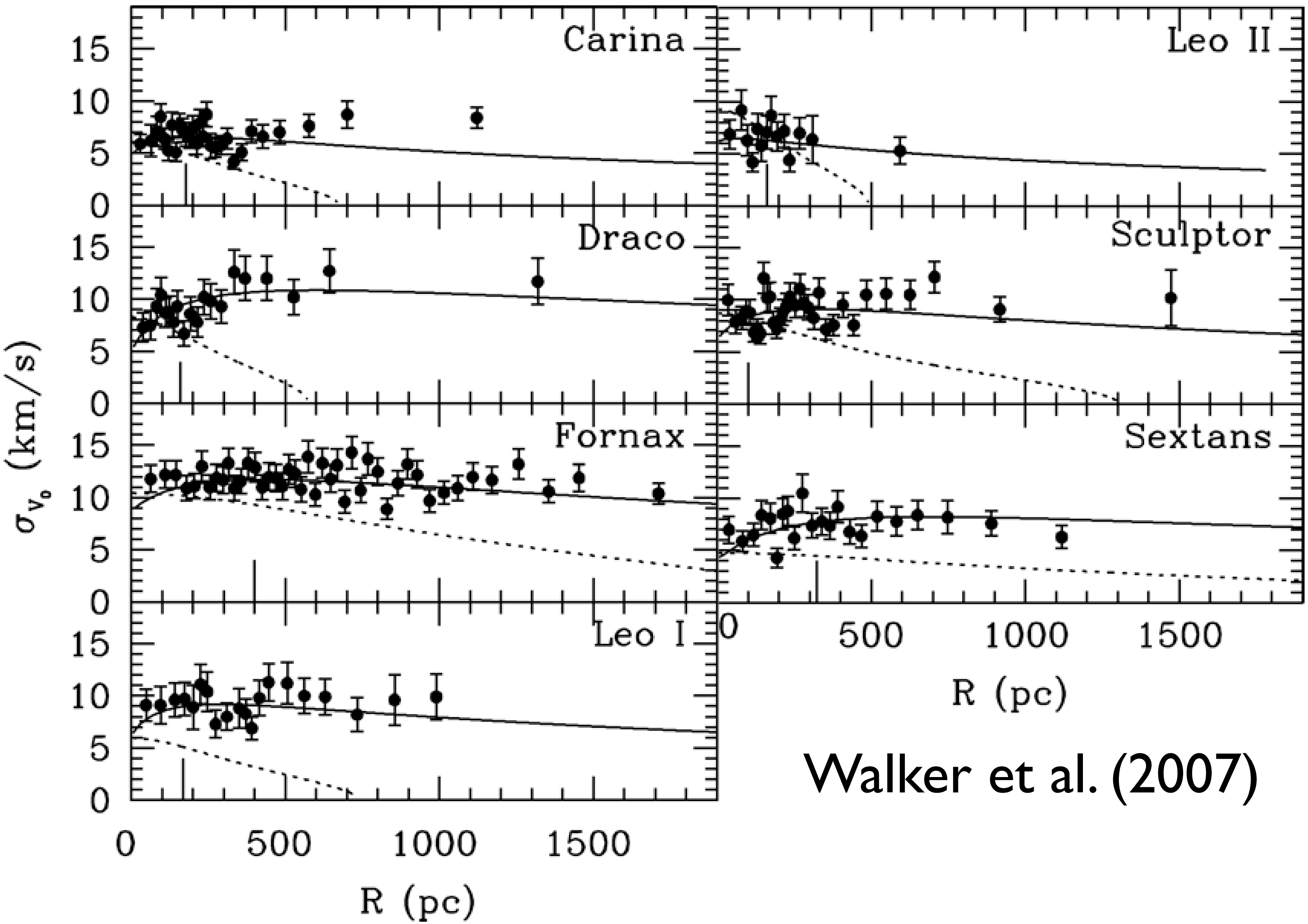
Odenkirchen et al. (2001)

Velocity dispersion profiles



Gilmore et al. (2007)

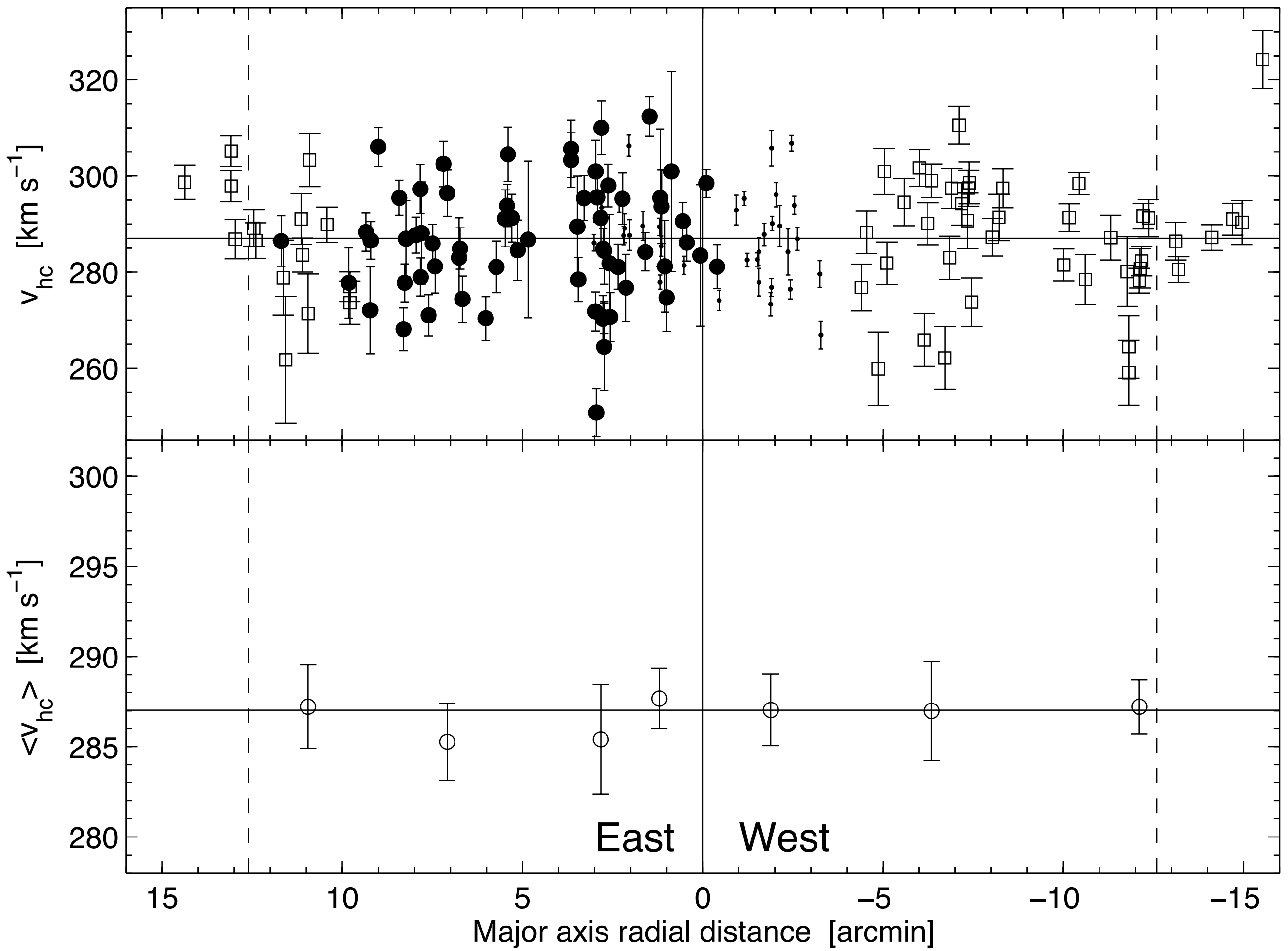
Velocity dispersion profiles II



Walker et al. (2007)

dSph dispersion profiles generally remain flat to large radii

Are dSphs in equillibrium?



Koch et al. (2007)

- Velocity gradients are signature of tidal disturbance
- No dSph shows evidence of significant velocity gradient in inner regions ⇒ bulk mass estimates are robust

dSphs: the case for cored haloes

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

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

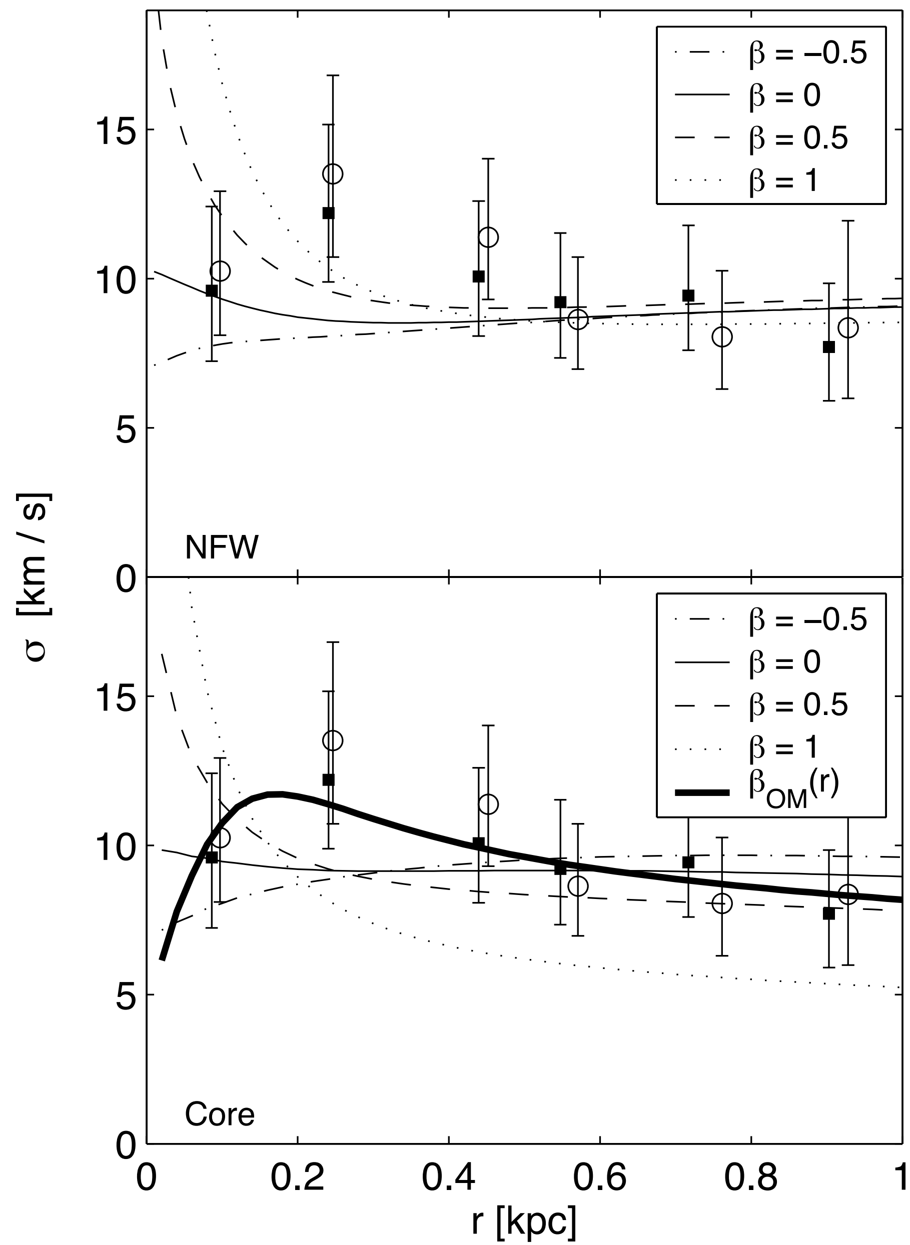
We can either:

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

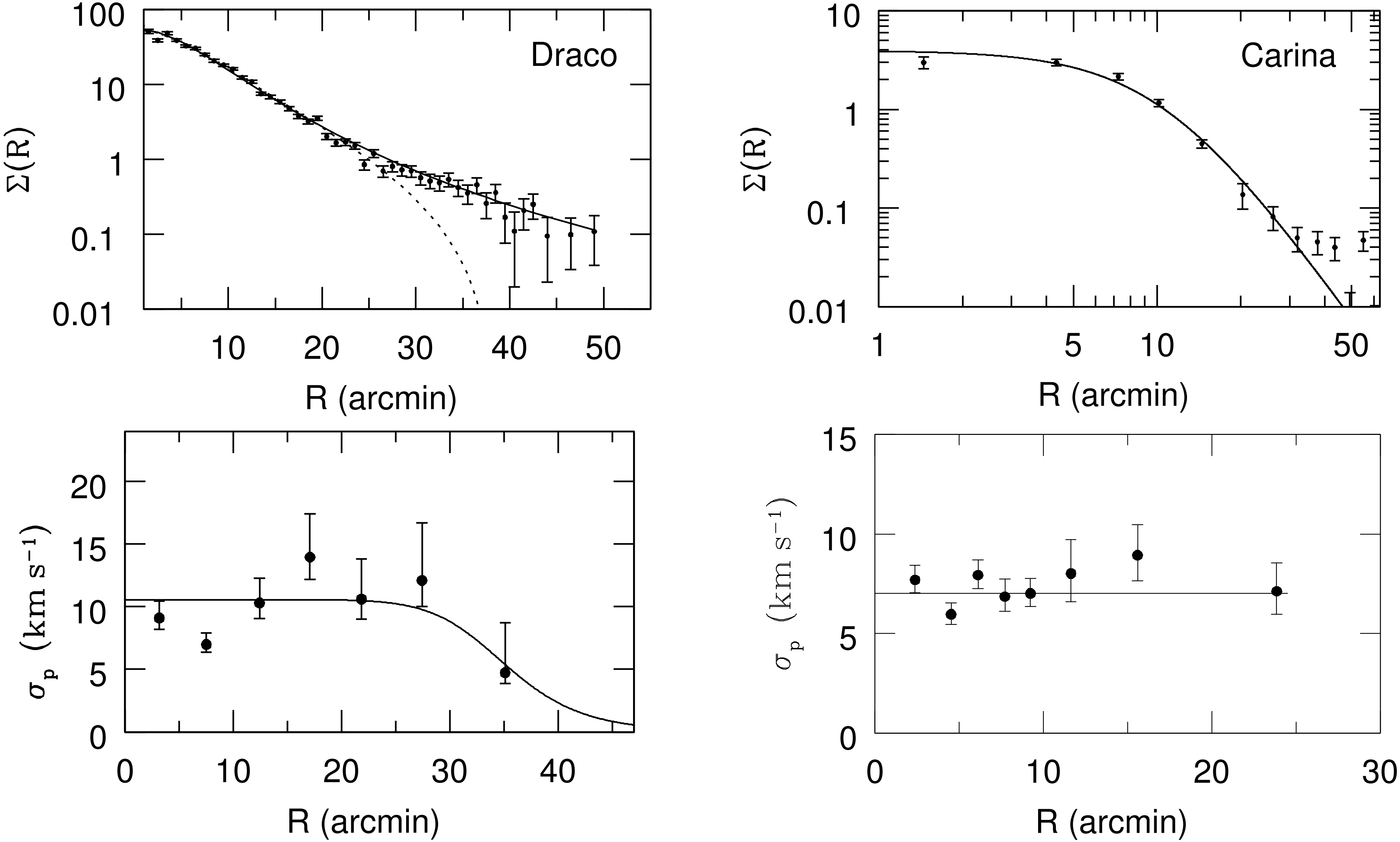
Fitting dSph dispersion profiles: Leo I



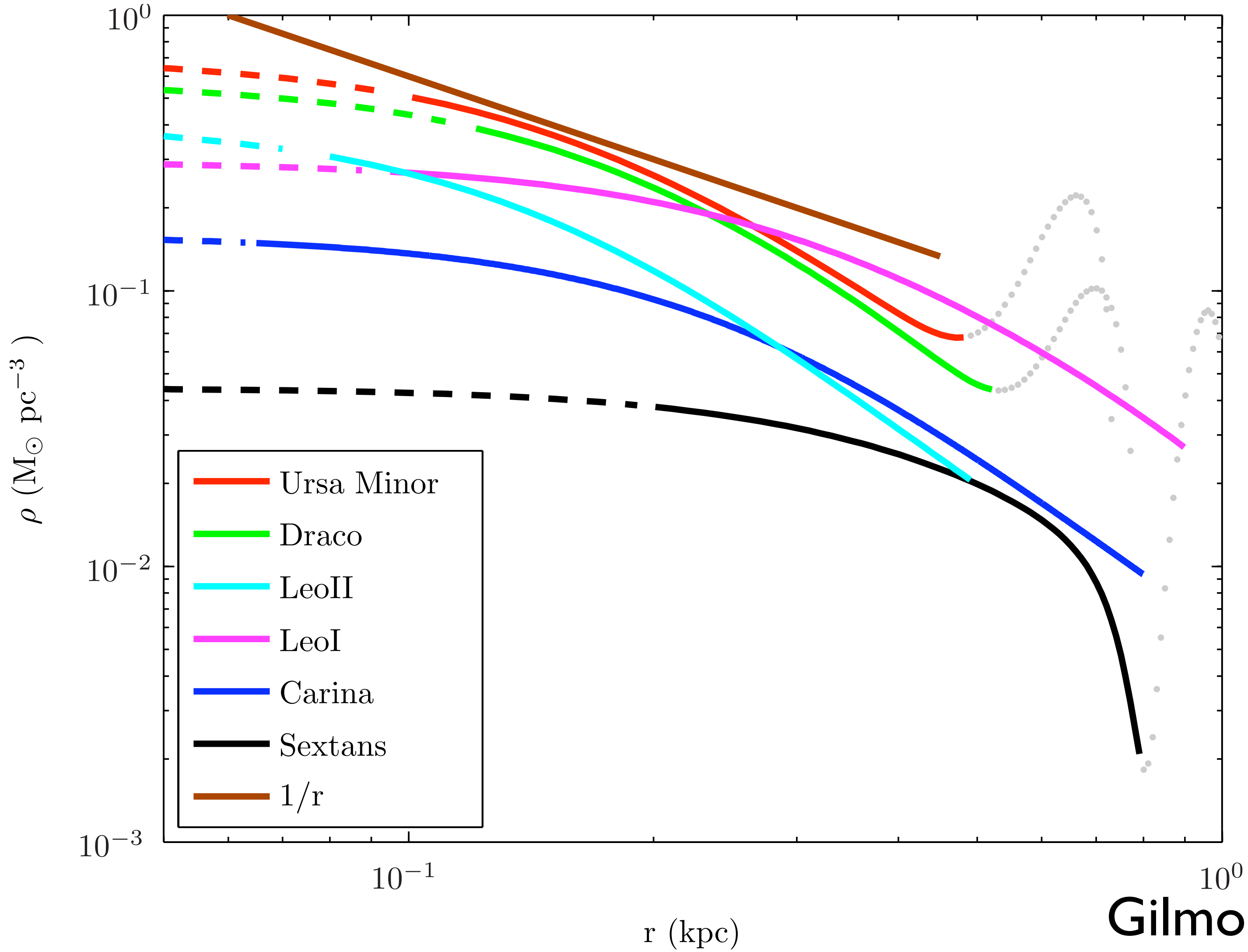
Koch et al. (2007)

- Assume either NFW halo ($\rho \propto r^{-1}$) or more general profile ($\rho \propto r^{-\alpha}$)
- Best-fit dispersion obtained for cored profiles with roughly isotropic velocity dispersions
- Significant velocity anisotropy not favoured (but not excluded)
- Enclosed mass $\sim 8 \times 10^7 M_\odot$ in both cored and cusped haloes

Density profiles from Jeans equations: assumptions



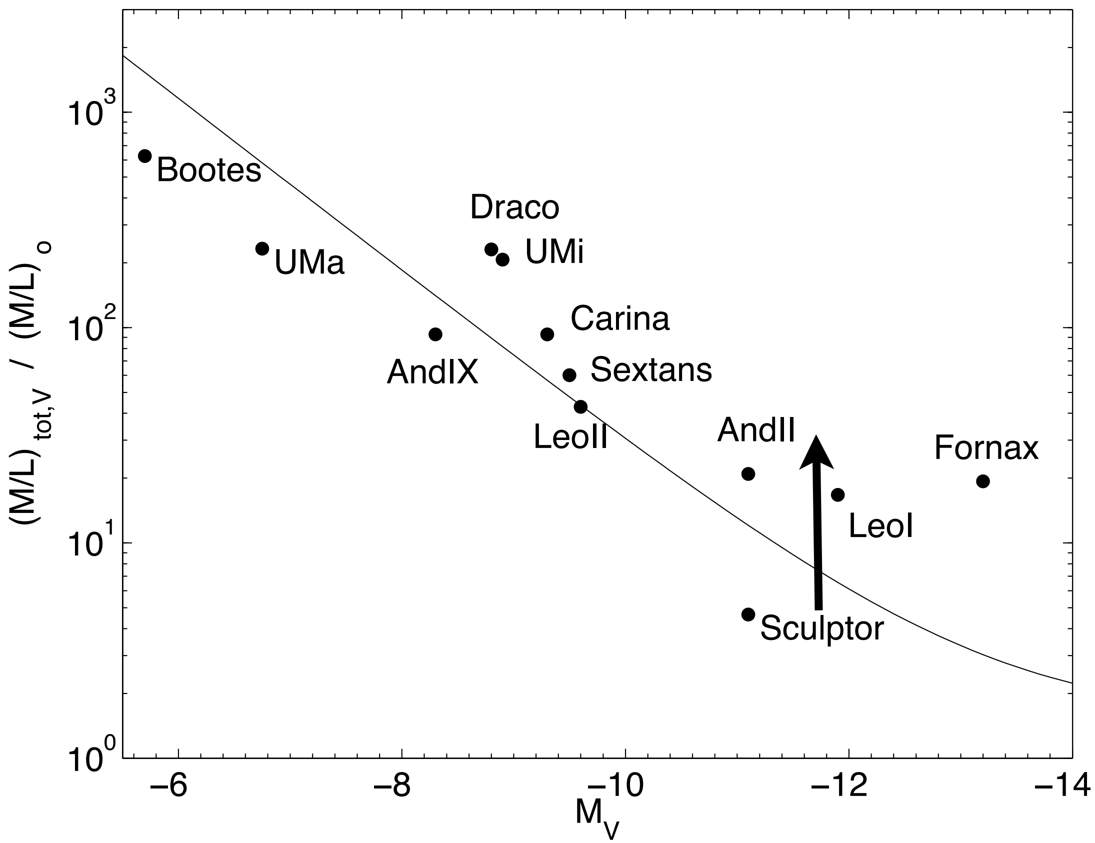
Density profiles from Jeans equations



Gilmore et al. (2007)

- Masses: $3 - 8 \times 10^7\,\mathrm{M}_\odot \implies M/L = 13 - 240\,\mathrm{M}_\odot/L_\odot$
- Conclusion: dSph kinematics are consistent with cored haloes

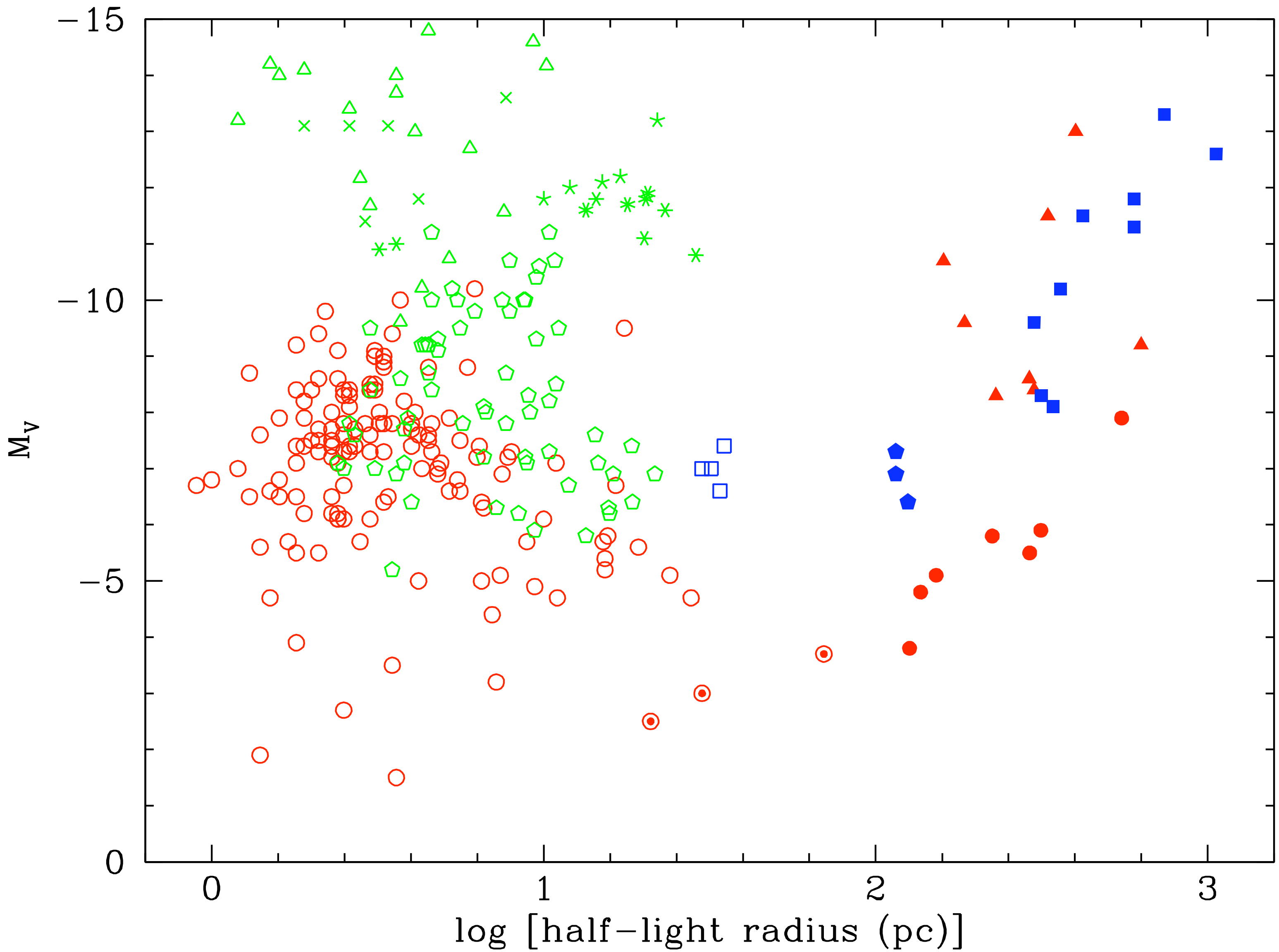
Global trend of dSph haloes



Mateo et al. (1998), Wilkinson et al. (2006), Gilmore et al. (2007)

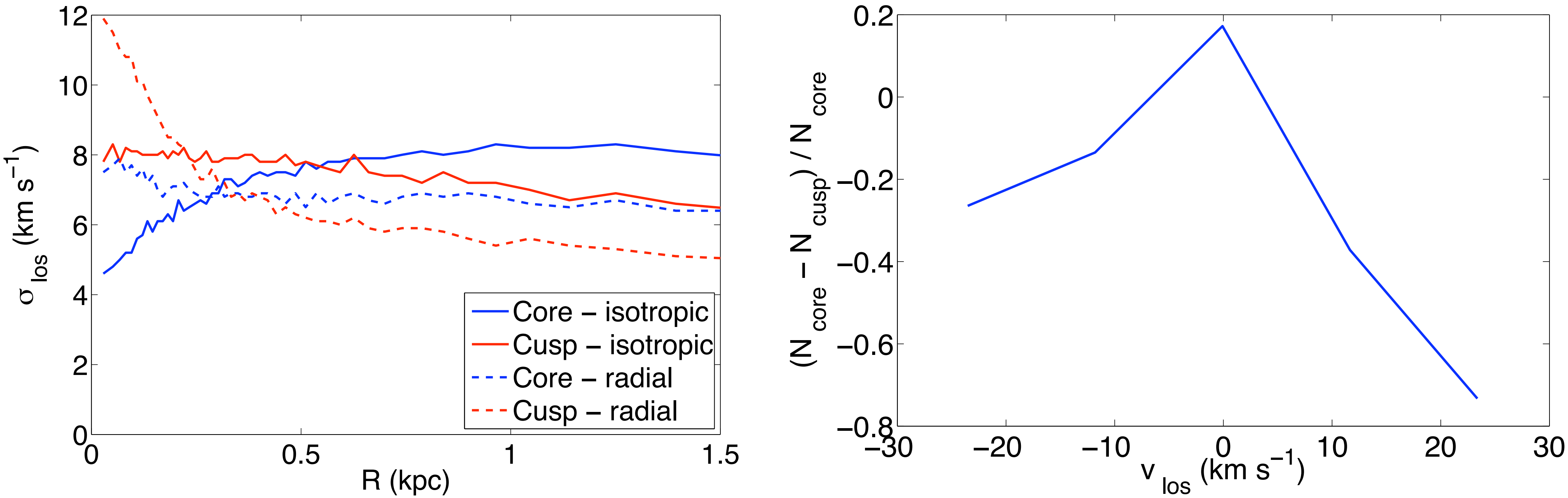
- Majority of current data consistent with cored dark matter distributions and a mass scale (interior to light) of $\sim 3 \times 10^7 \mathrm{M}_\odot$
- Mean dark matter density $\lesssim 0.1\,\mathrm{M}_\odot\,\mathrm{pc}^{-3}(5\mathrm{GeV}/\mathrm{c}^2\,\mathrm{cm}^{-3})$
- NFW halo: $\overline{\rho}(r < 10\,\mathrm{pc}) \approx 60\,\mathrm{M}_\odot\,\mathrm{pc}^{-3}(2\,\mathrm{TeV}/\mathrm{c}^2\mathrm{cm}^{-3})$

Size distribution of stellar systems



Gilmore et al. (2007)

The next step - resolving the cusp/core issue with the VLT



- Degeneracy between velocity anisotropy and inner density profile can be broken using ~500 radial velocities in the inner 0.2 kpc
- Program to apply this to Carina dSph currently underway at VLT

Conclusions

- Dwarf spheroidal galaxies are valuable laboratories for testing the properties of dark matter
- No kinematic evidence that tides have inflated central velocity dispersions of dSphs
- Current kinematic data are consistent with high M/L ratio, cored dark matter distributions - mass scale ($r \lesssim 400\,\mathrm{pc}$): $\sim 3 \times 10^7 \mathrm{M}_\odot$
- Mean dark matter density: $\lesssim 0.1\,\mathrm{M}_\odot\,\mathrm{pc}^{-3} (5 \mathrm{GeV}/\mathrm{c}^2\,\mathrm{cm}^{-3})$
- In cusped halo: $\overline{\rho}(r < 10\,\mathrm{pc}) \approx 60\,\mathrm{M}_\odot\,\mathrm{pc}^{-3} (2\,\mathrm{TeV}/\mathrm{c}^2 \mathrm{cm}^{-3})$
- More data being obtained to place more robust constraints on density profiles