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Cusp or core in the Sculptor dSph?

Simon White
Max Planck Institute for Astrophysics

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3D motions in the Sculptor dwarf galaxy as a glimpse of a new era

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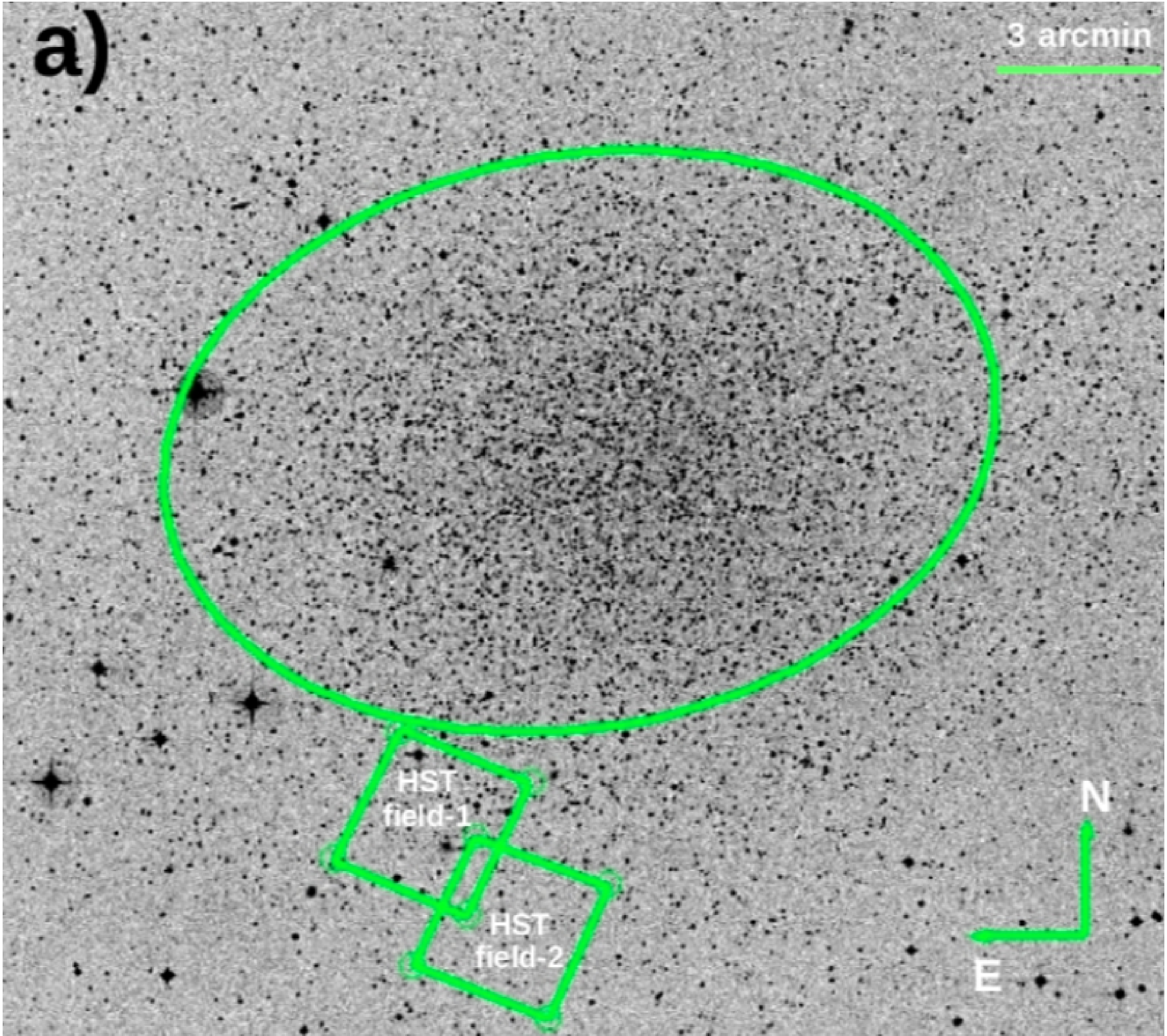
Here we report, based on data from the *Gaia* space mission[8] and the *Hubble Space Telescope*, a new precise measurement of Sculptor's mean proper motion. From this we deduce that Sculptor is currently at its closest approach to the Milky Way and moving on an elongated high-inclination orbit that takes it much farther away than previously thought. For the first time we are also able to measure the internal motions of stars in Sculptor. We find $\sigma_R = 11.5 \pm 4.3\ \mathrm{km\,s^{-1}}$ and $\sigma_T = 8.5 \pm 3.2\ \mathrm{km\,s^{-1}}$ along the projected radial and tangential directions, implying that the stars in our sample move preferentially on radial orbits as quantified by the anisotropy parameter, which we find to be $\beta \sim 0.86^{+0.12}_{-0.83}$ at a location beyond the core radius. Taken at face value such a high radial anisotropy requires abandoning conventional models[9] for the mass distribution in Sculptor. Our sample is dominated by metal-rich stars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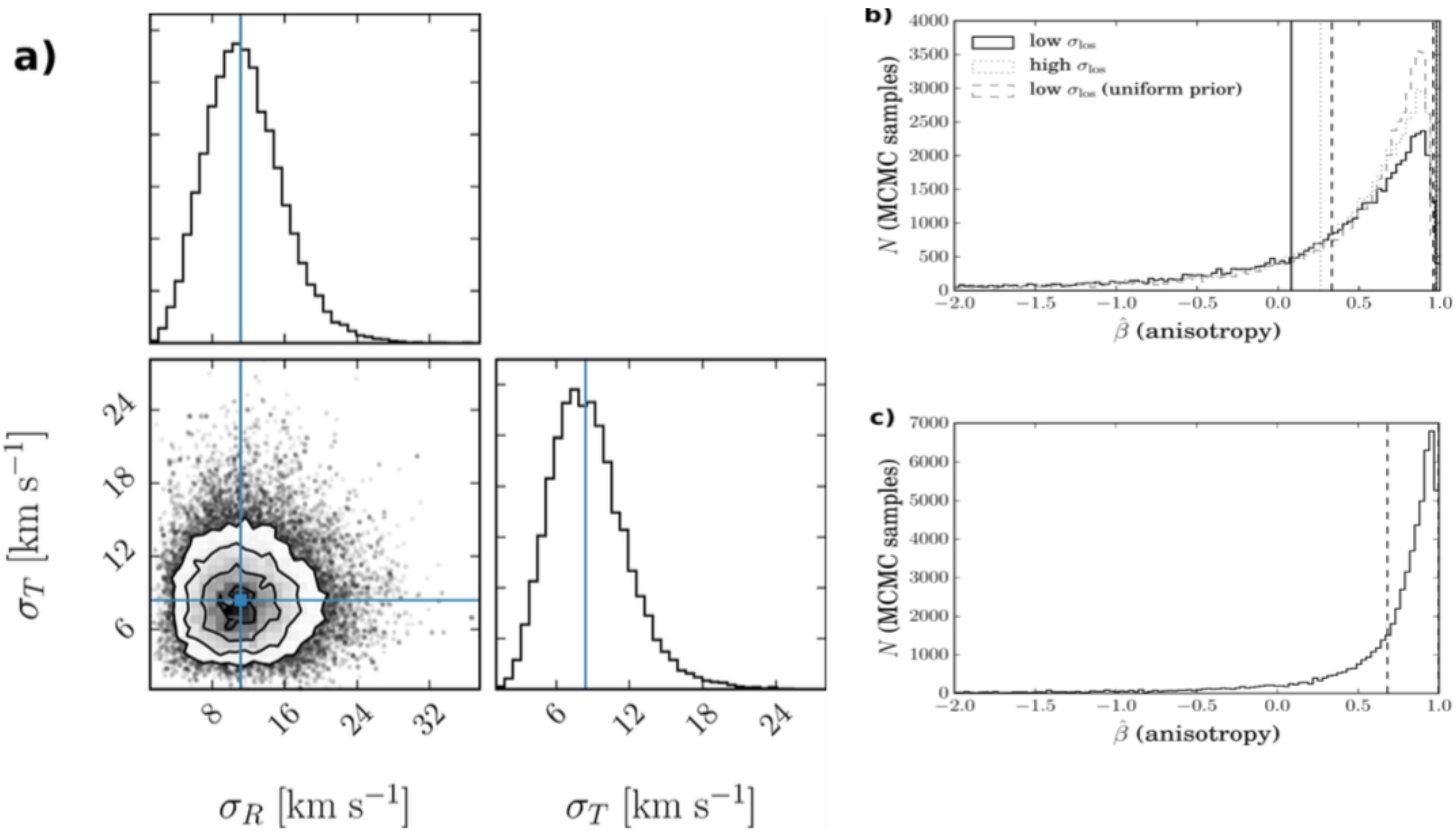
Massari et al 2017



$$\hat{\beta} = 1 - \frac{\sigma_T^2}{\sigma_{\rm los}^2 + \sigma_R^2 - \sigma_T^2}.$$

with the transverse dispersions estimated from 15 stars and the l.o.s. dispersion from just 10 stars!

Models for a stellar population in a given potential

Strigari et al 2017

$$\rho(r) = \frac{\rho_s}{x(1+x)^2},$$

with corresponding gravitational potential

$$\Phi(r) = \Phi_s \left[1 - \frac{\ln(1+x)}{x}\right],$$

where we define $\Phi_s = 4\pi G \rho_s r_s^2$ and $x = r/r_s$.

N.B. these are spherical models in equilibrium

$$f(E, J) = g(J) h(E),$$

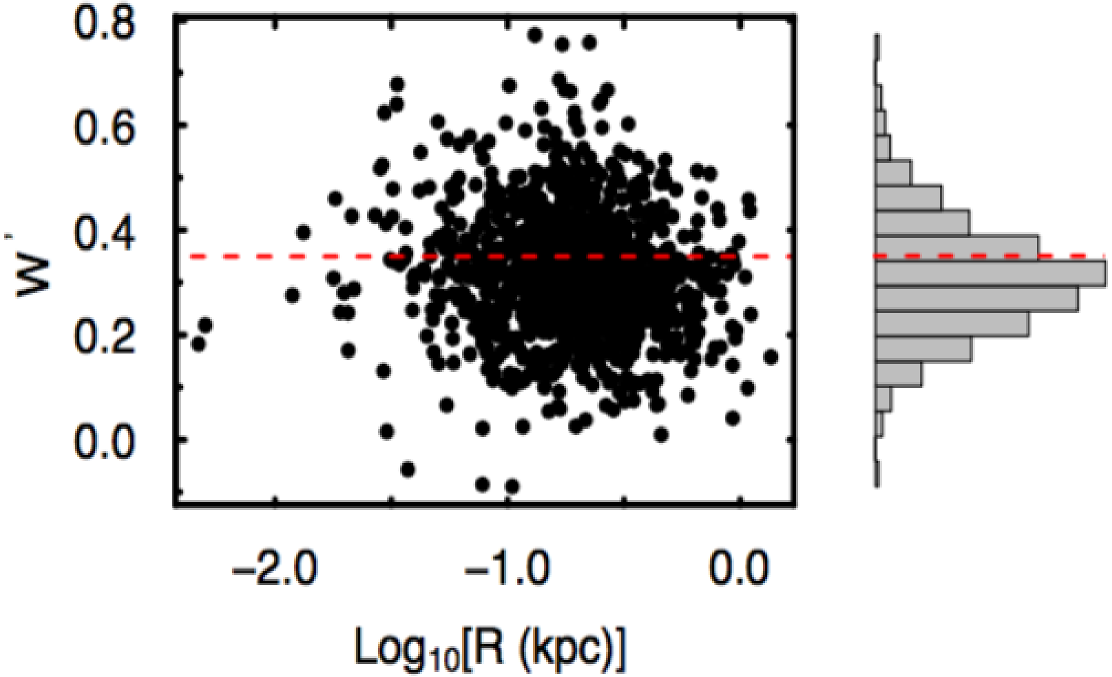
$$g(J) = \left[\left(\frac{J}{J_\beta}\right)^{\frac{b_0}{\alpha}} + \left(\frac{J}{J_\beta}\right)^{\frac{b_1}{\alpha}}\right]^{\alpha},$$

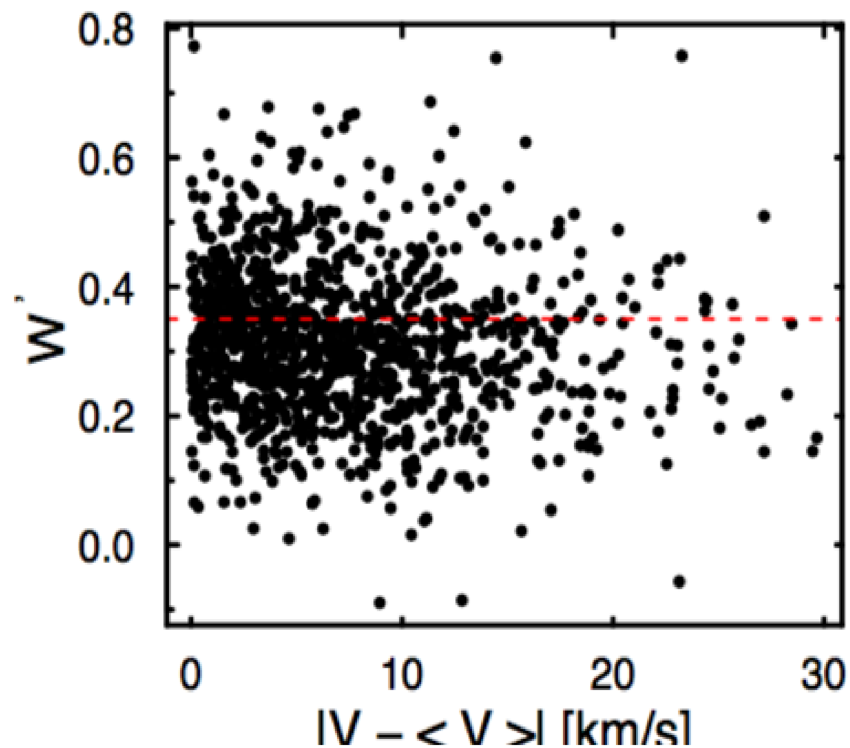
$$h(E) = \begin{cases} N E^a (E^q + E_c^q)^{d/q} (\Phi_{lim} - E)^e & \text{for } E < \Phi_{lim} \\ 0 & \text{for } E \geq \Phi_{lim}, \end{cases}$$

Two parameters for the potential and eleven for *each* stellar population can be varied using MCMC to find acceptable fits to the observational data.

Two stellar populations in Sculptor?

Strigari et al 2017

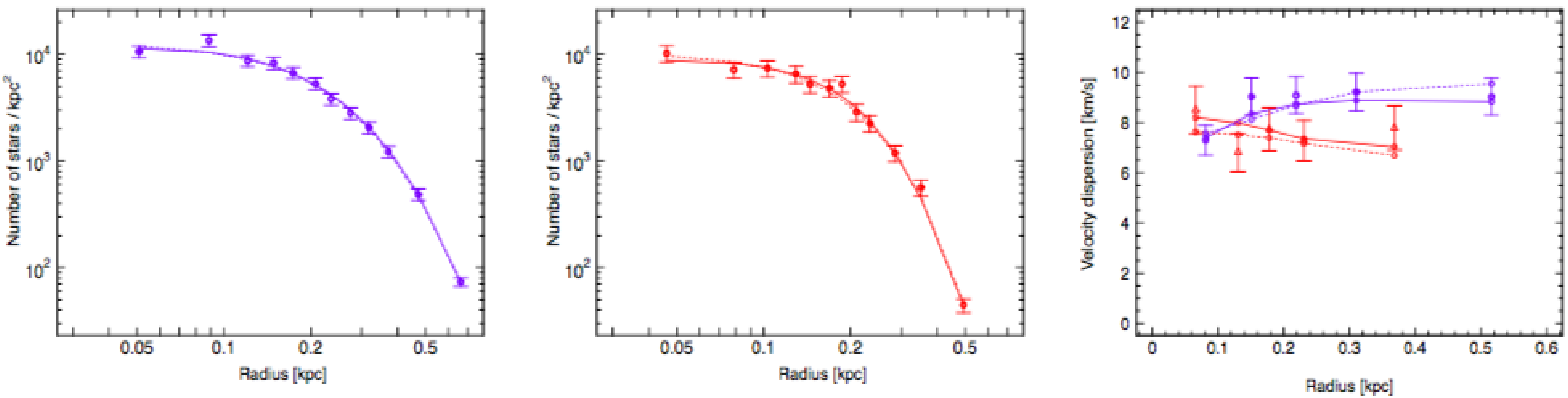




Data from Walker & Penarrubia (2011).
W is the directly measured indicator of metallicity.
The red line is the split which maximizes the difference in radial distribution between "metal-rich" (W > 0.35) and "metal-poor" (W < 0.35) stars

Two population fits to the MP11 data for Sculptor

Strigari et al 2017

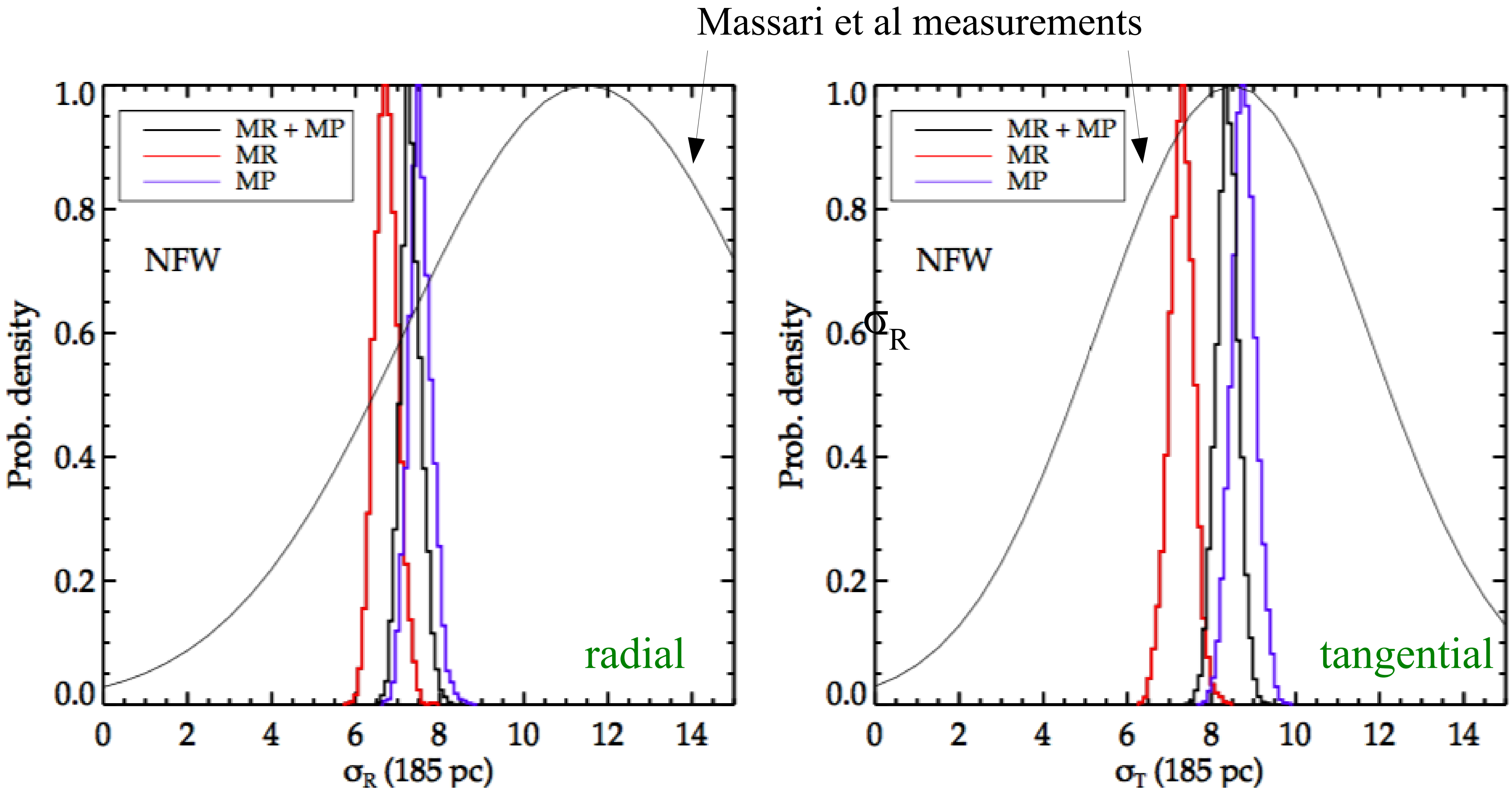


Good simultaneous fits can be found to the star count and velocity dispersion data from WP11 for both MR and MP stars

The fits for cored (Burkert) and cusped (NFW) potentials are equally good

The parameters found for NFW profiles are consistent with those expected from simulations of the standard ΛCDM model

Transverse dispersions predicted in the HST fields by models fit to the WP11 data



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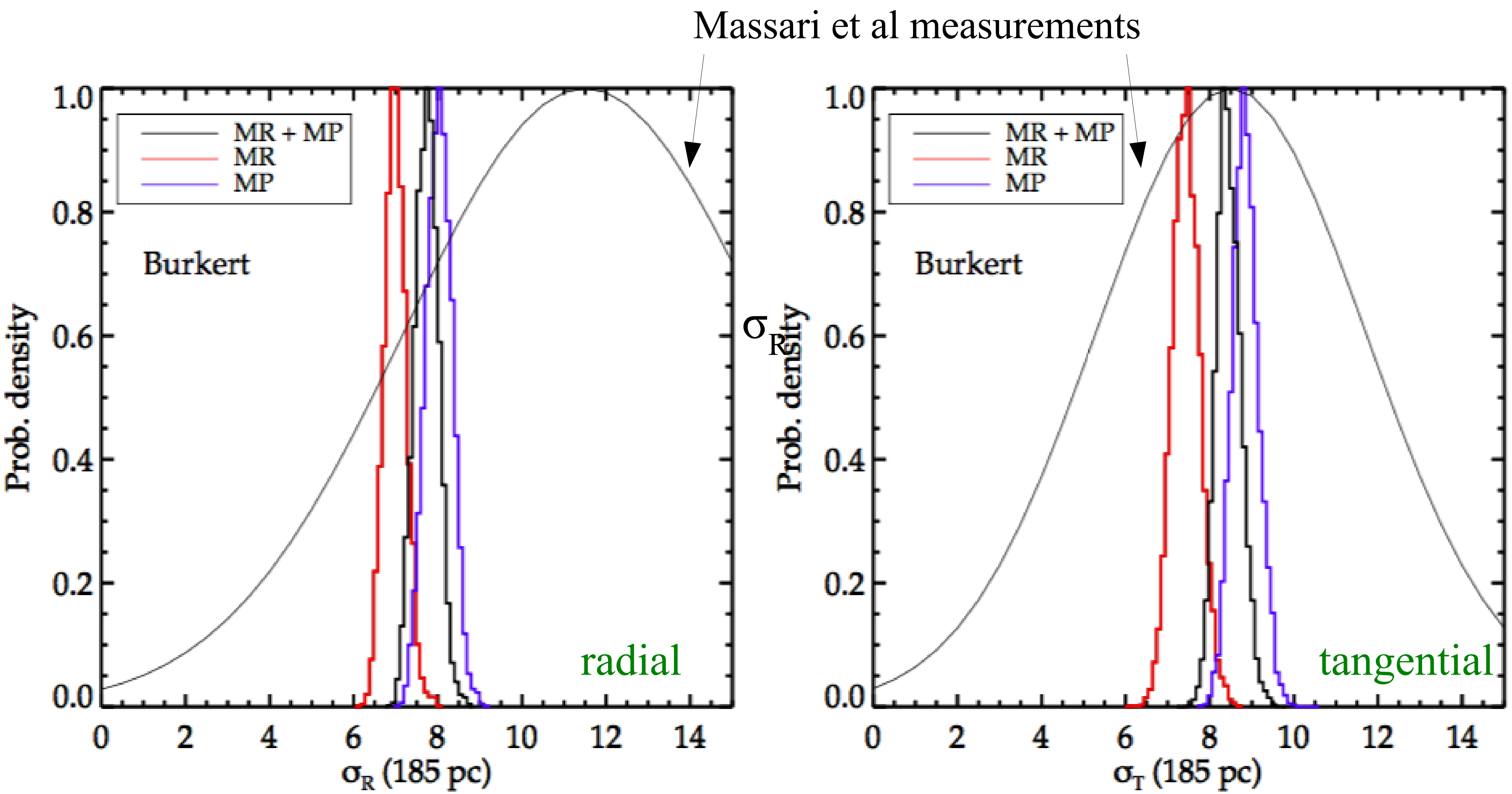
The models predict $\sigma_R < \sigma_T$!

Transverse dispersions predicted in the HST fields by models fit to the WP11 data



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The models predict $\sigma_R < \sigma_T$!

Transverse and l.o.s. dispersion profiles predicted by models fit to the WP11 data

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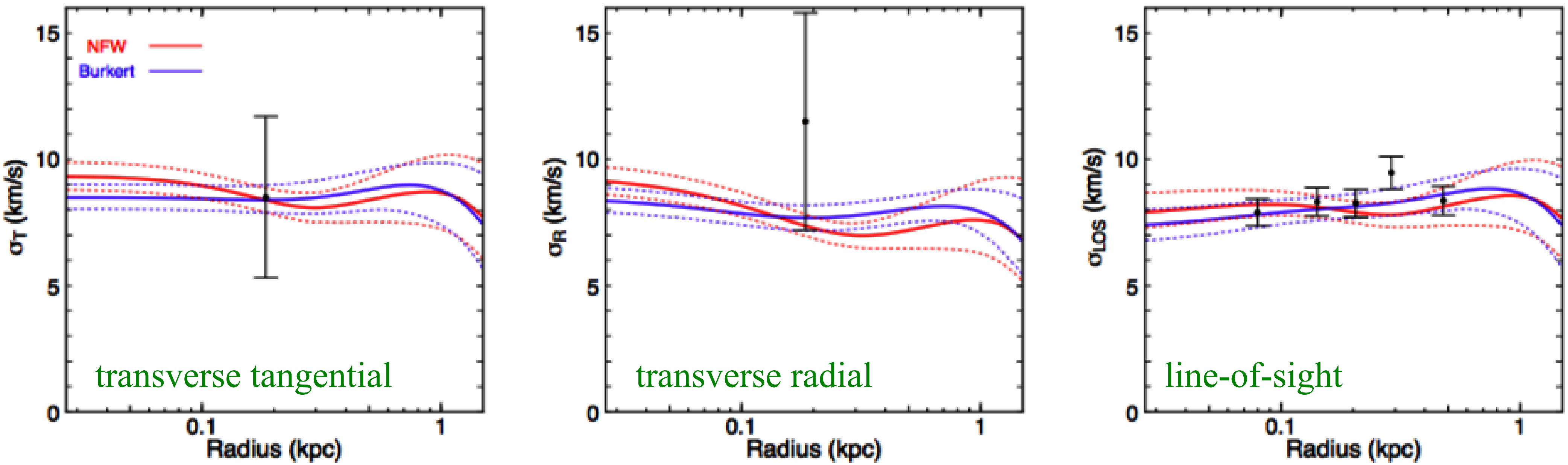
All stars



The dispersion profiles predicted for cored and cusped potentials differ little

Differences are small at the radius of the HST fields and largest at small radii

Transverse dispersions are no more discriminating than l.o.s. dispersions

Transverse and l.o.s. dispersion profiles predicted by models fit to the WP11 data

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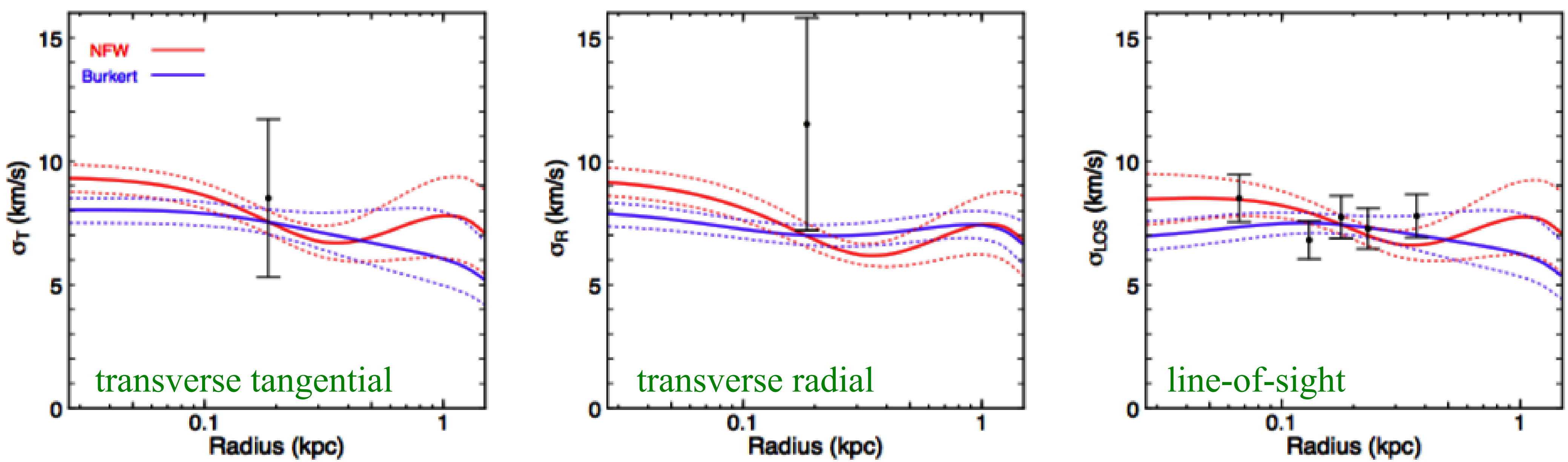
MR stars



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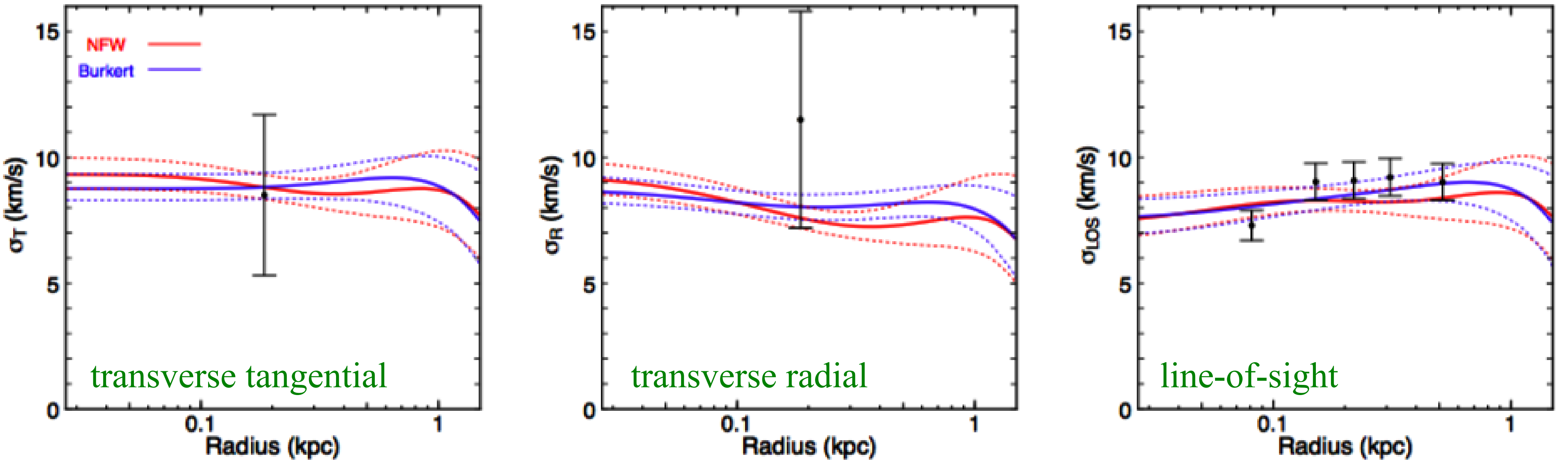
MP stars



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Conclusions?

- Current data on Sculptor cannot distinguish between an (NFW) cusp and a (Burkert) core, even including PMs
- It may be possible to tell the difference with dispersion profile measures over a broad range in radii and with an accuracy for individual points of 0.5 km/s or less
- This will require measurement of $\sim 10^4$ radial velocities and/or proper motions with high individual accuracy
- Good data in the inner regions (<100pc) are particularly important