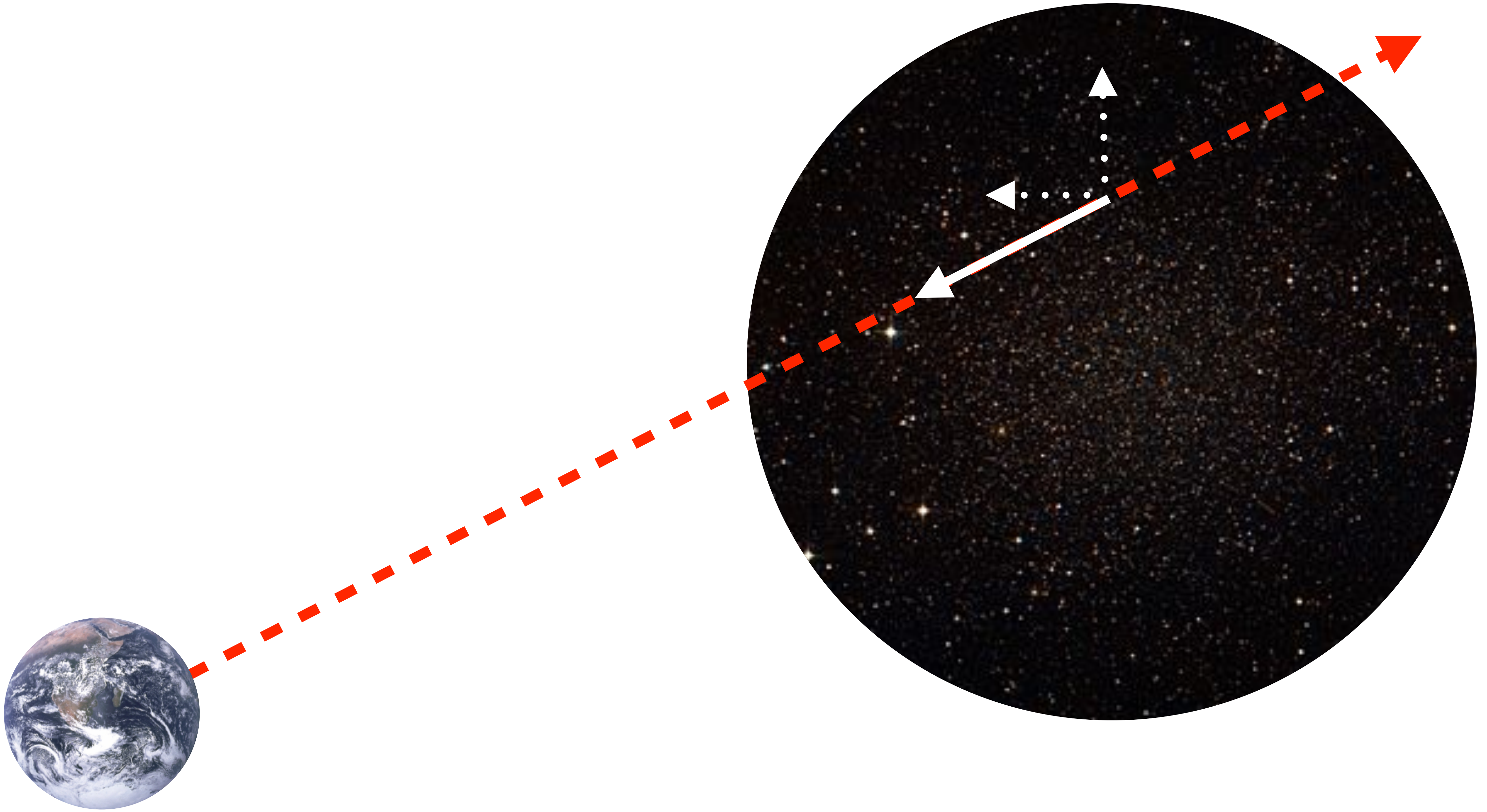
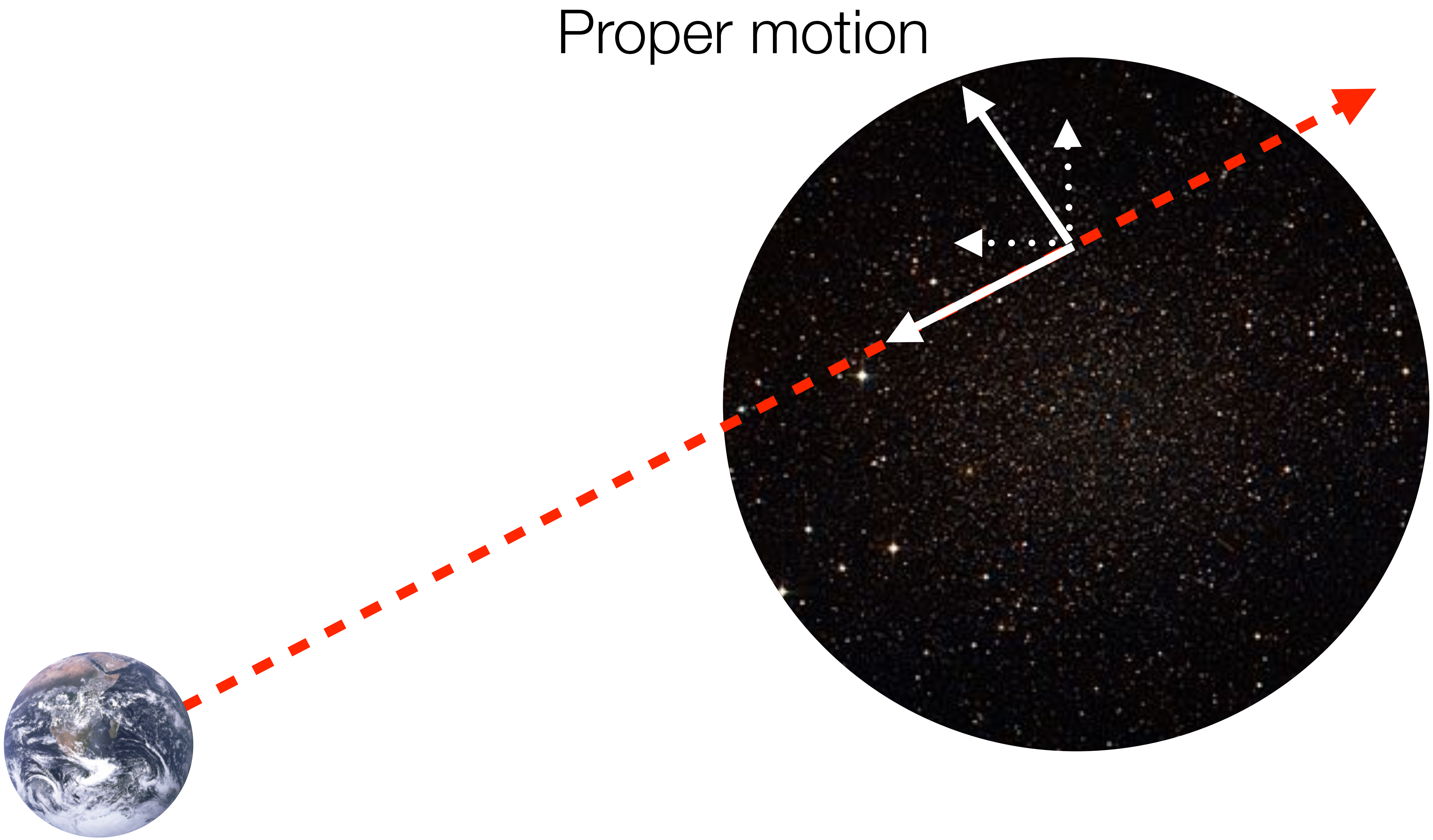
Dark matter properties of dwarf galaxies in the GAIA era

Louis E. Strigari (Texas A&M University)
Small Galaxies, Cosmic Questions
Durham University
July 30, 2019

Astrometry + dark matter

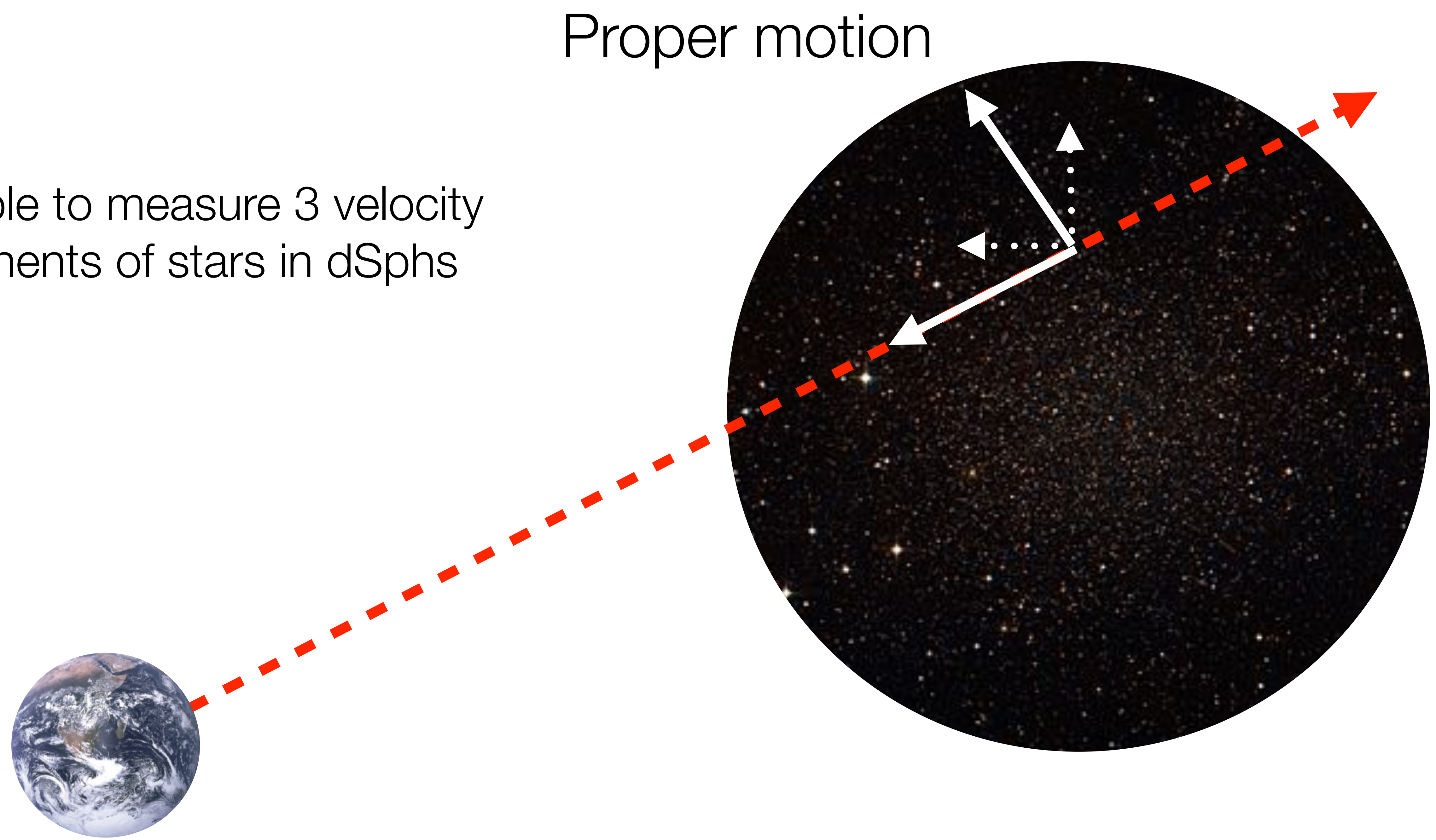


Astrometry + dark matter



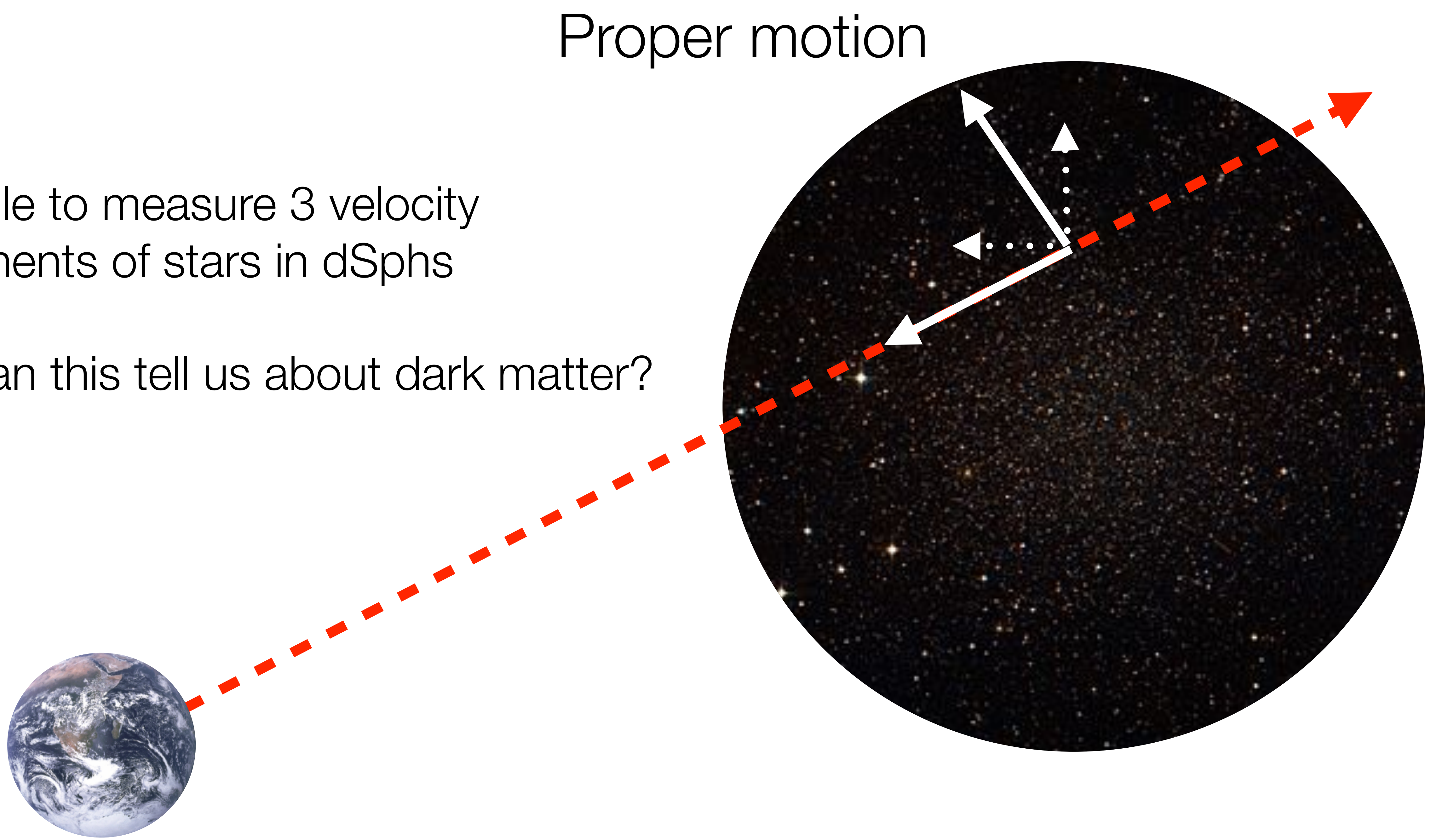
Astrometry + dark matter

- Now able to measure 3 velocity components of stars in dSphs

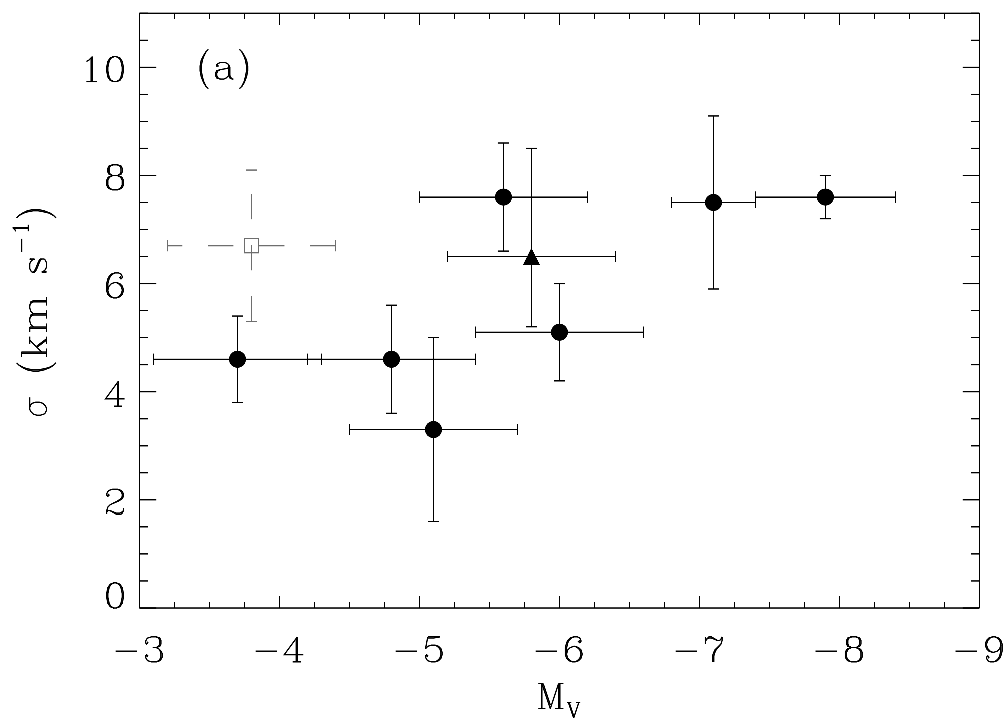


Astrometry + dark matter

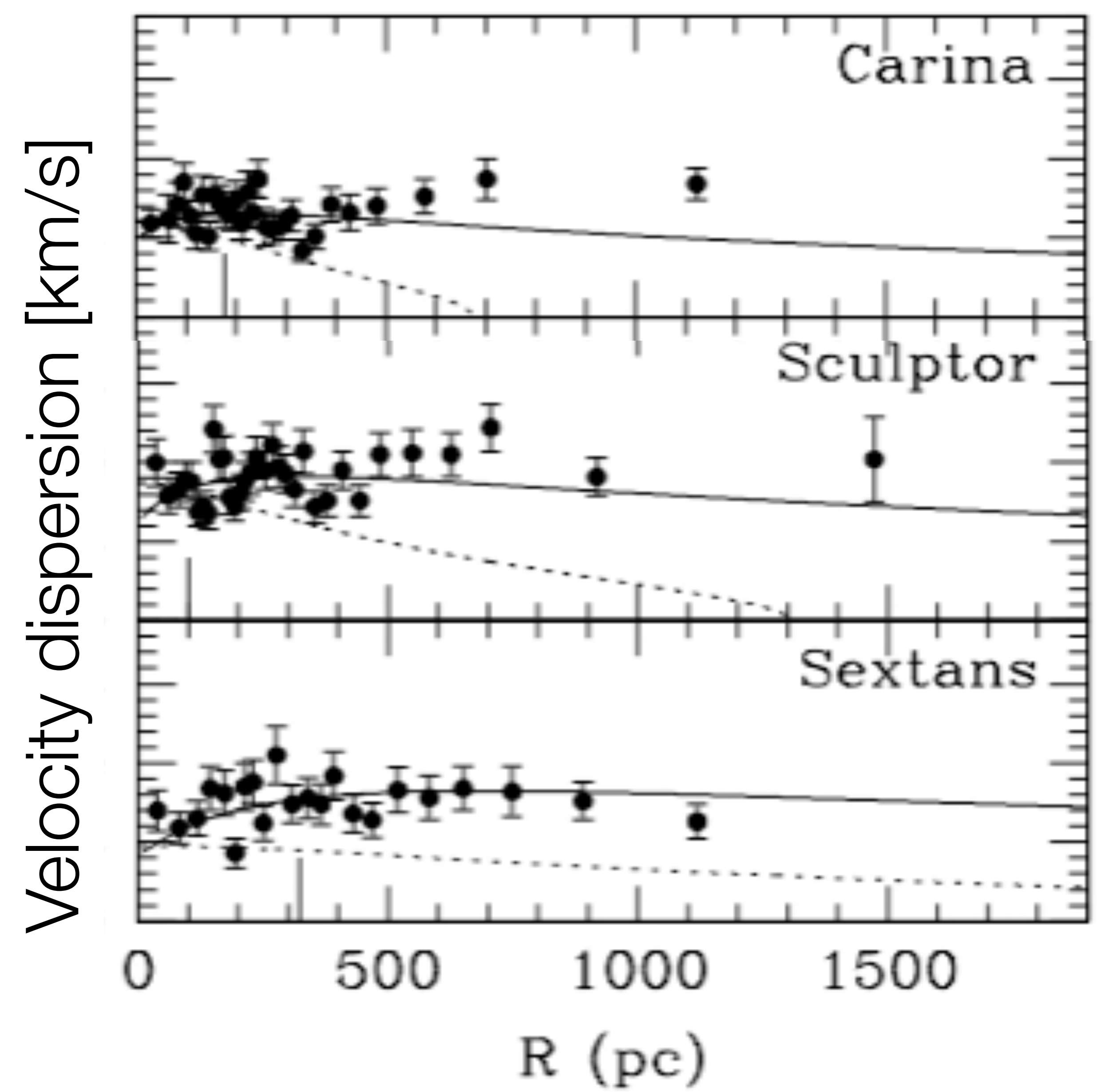
- Now able to measure 3 velocity components of stars in dSphs
- What can this tell us about dark matter?



Dark matter properties of dwarf satellites



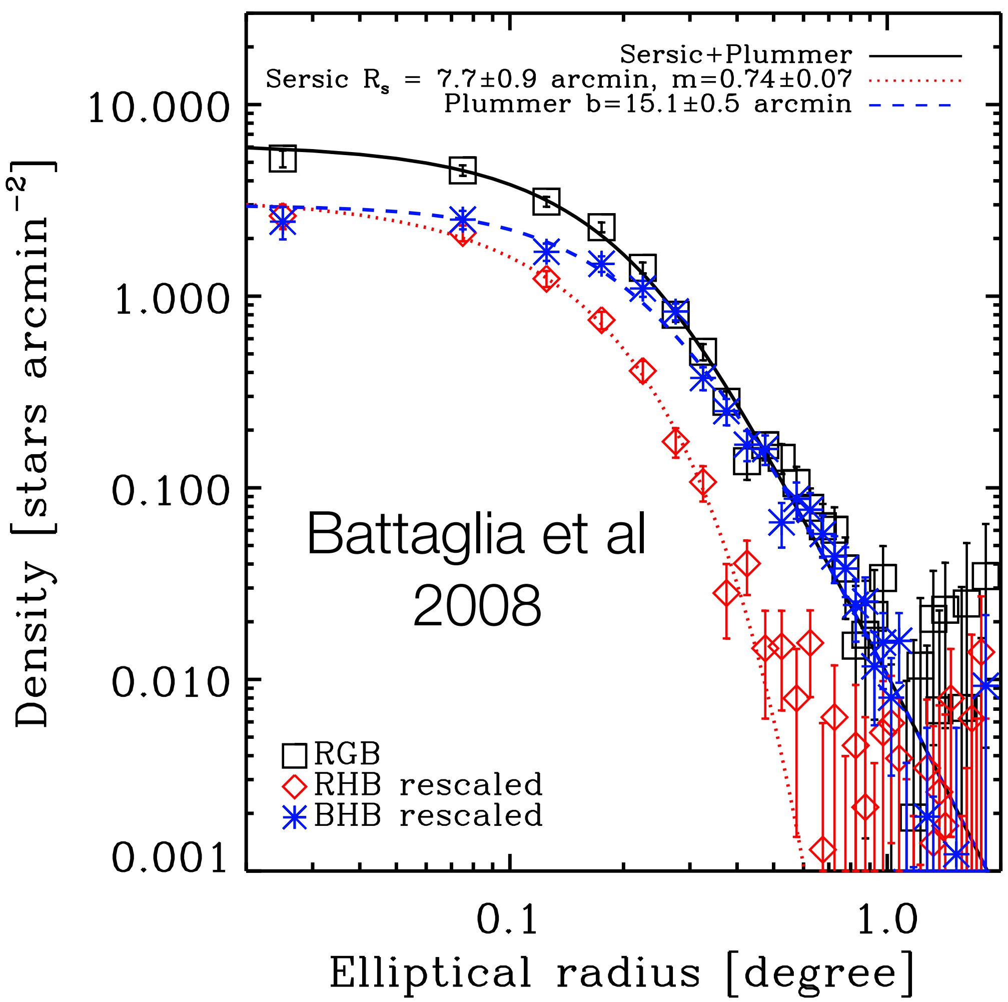
Simon & Geha 2007

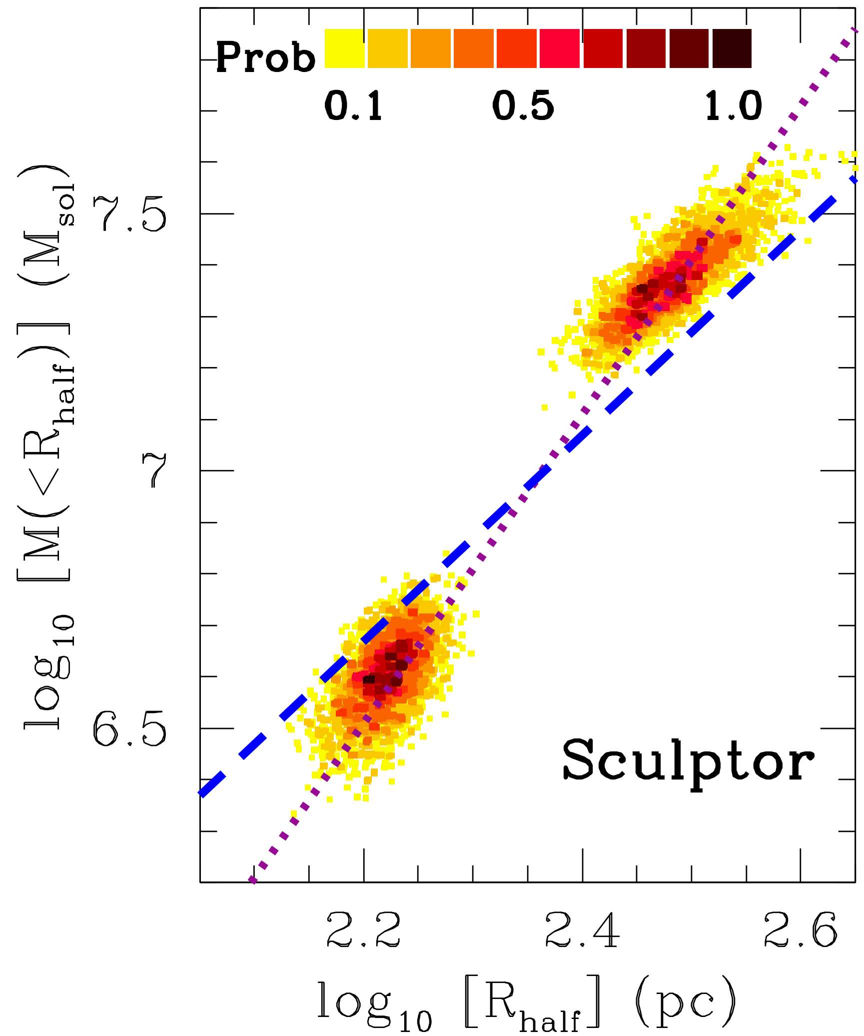


Walker et al. 2007

- Jeans-based equilibrium models
- Corrections from non-spherical potentials
- Self-consistent distribution function-based models
- Orbit-based models
- Action/angles
- *Integrated* mass within characteristic radius is well-measured

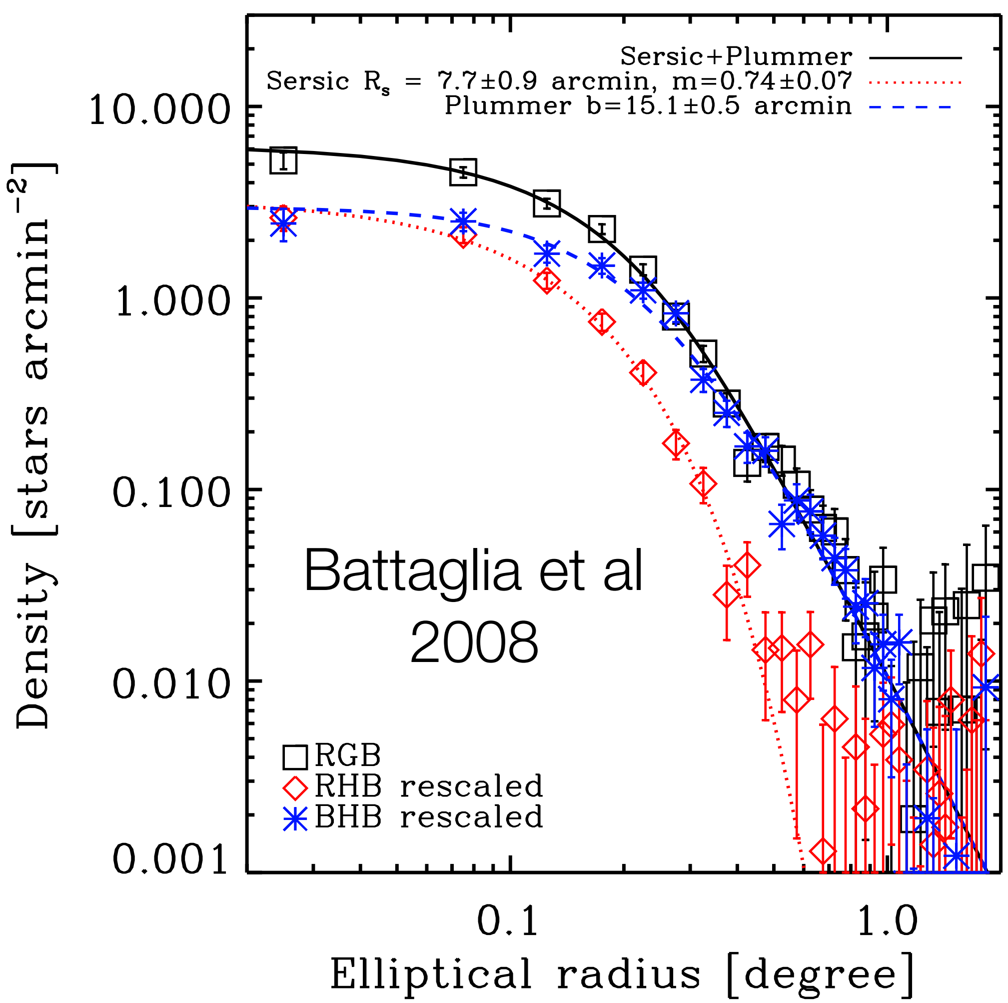
Multiple stellar populations in dwarf galaxies

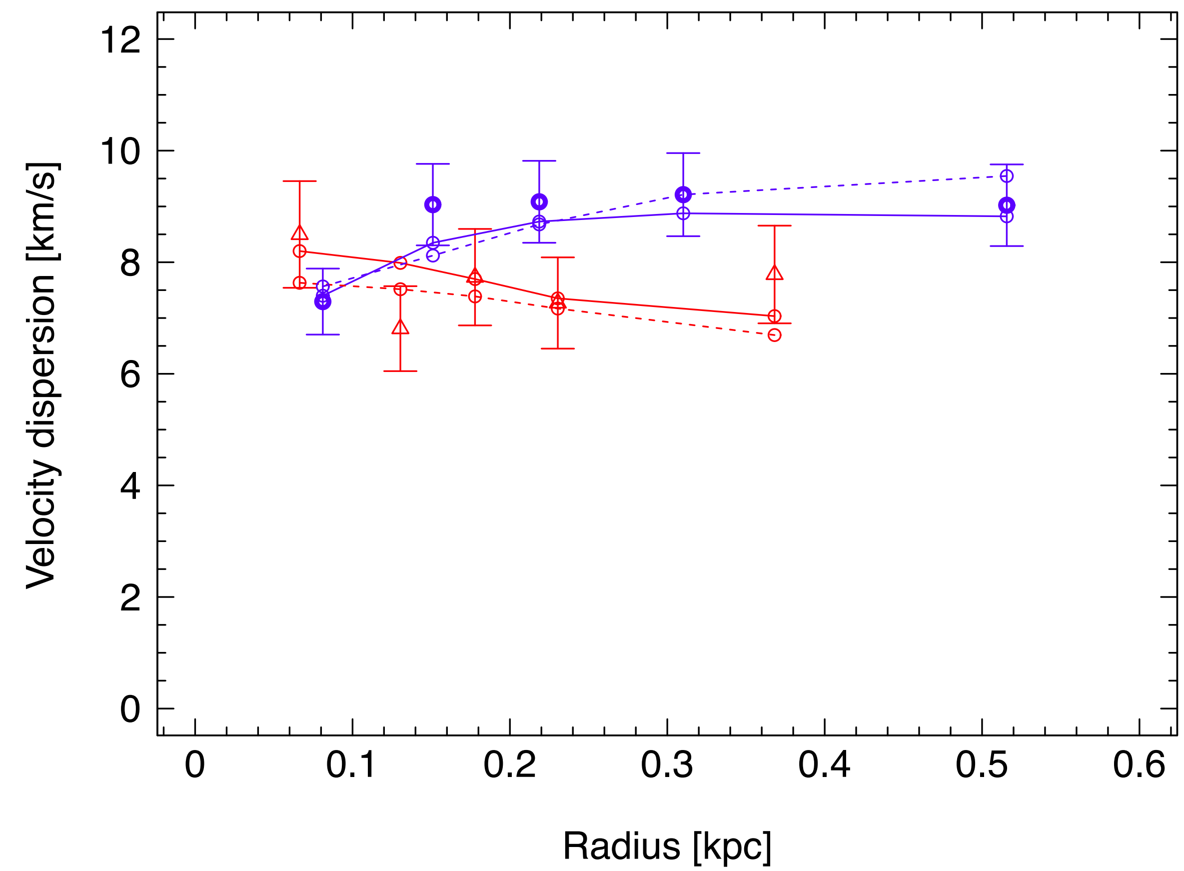




- Some dwarf galaxies (Sculptor, ANDII) show evidence for multiple stellar populations
- Some kinematic studies disfavor NFW for Sculptor (Walker & Penarrubia 2011; Amorisco & Evans: Agnelle & Evans 2012)
- Some studies show NFW cannot be ruled out for Sculptor (Breddels & Helmi 2014; Strigari, Frenk, White 2014)

Multiple stellar populations in dwarf galaxies





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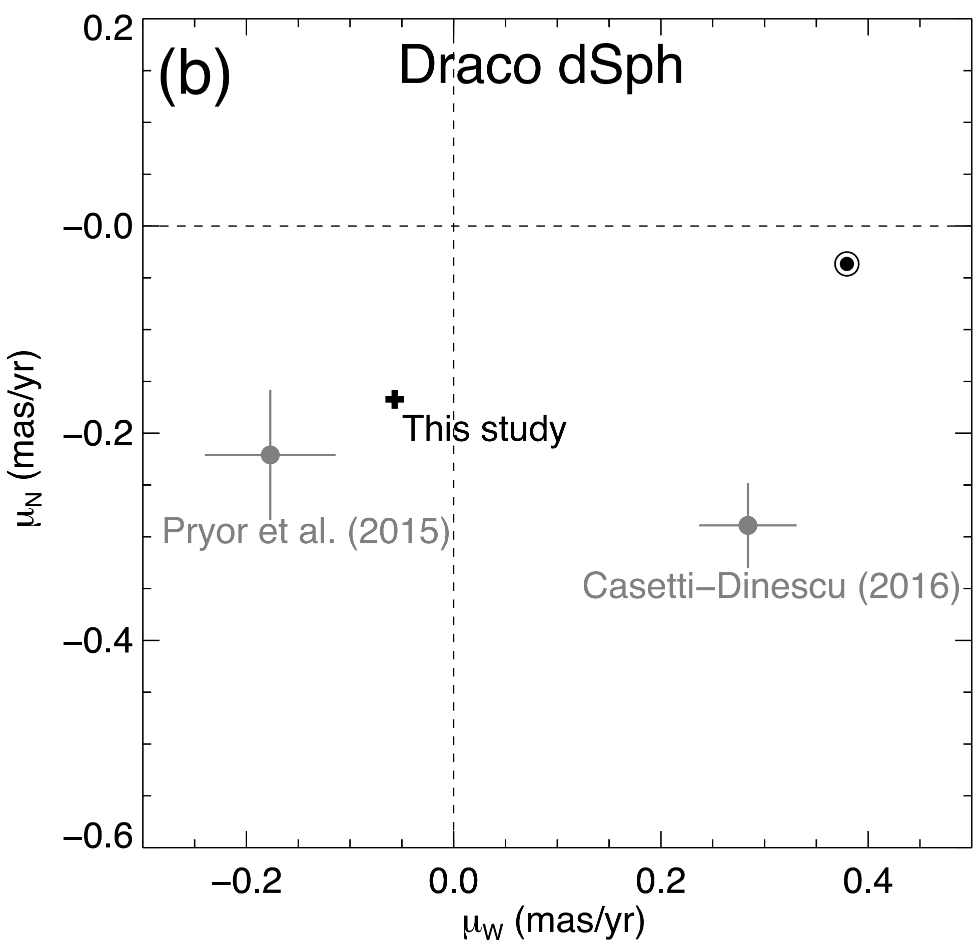
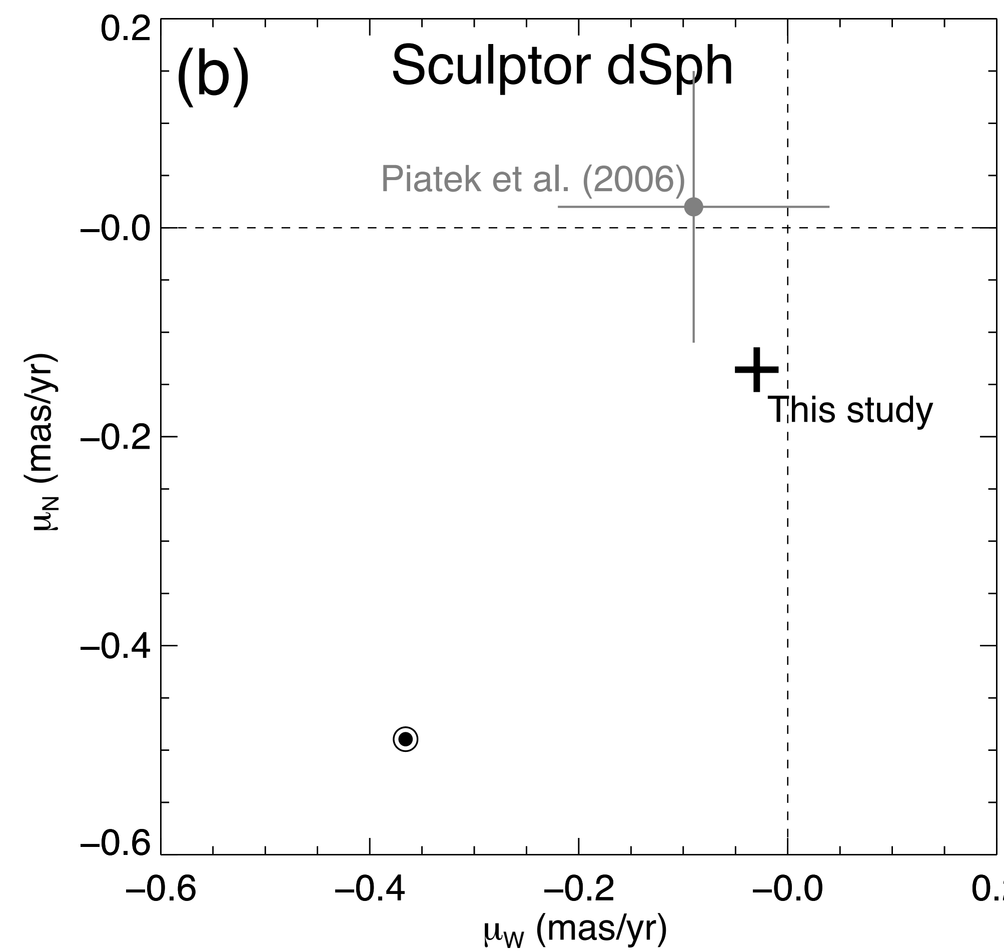
Internal proper motions with HST





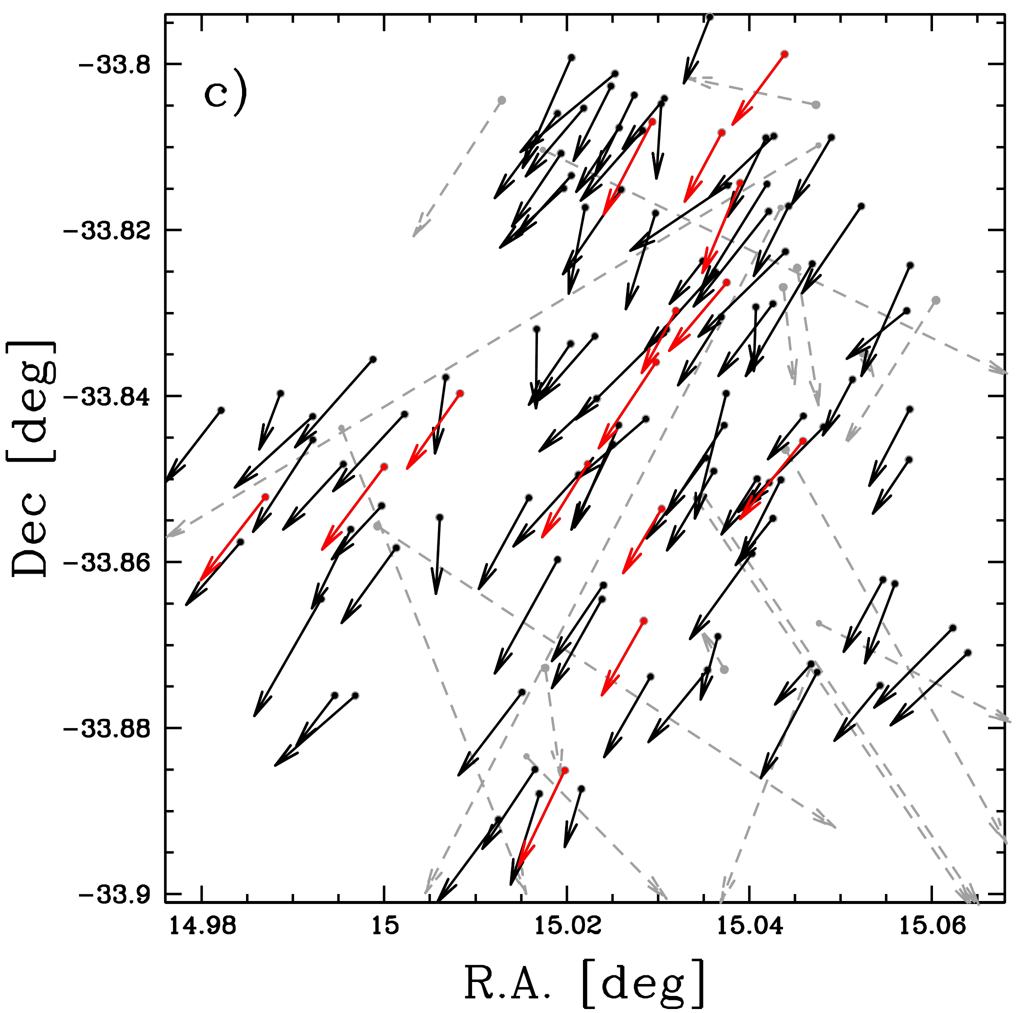
- Sculptor requires PMs ~ 22 micro-arcsec/year
- Positional accuracy of 0.003 ACS/WFC per epoch
- For N exposures, the positional accuracy per exposure is 0.003 sqrt(N)
- For N ~5-19, positional accuracy per exposure is ~ 0.01 pixel

Sohn, Patel et al. 2017

Internal stellar proper motions

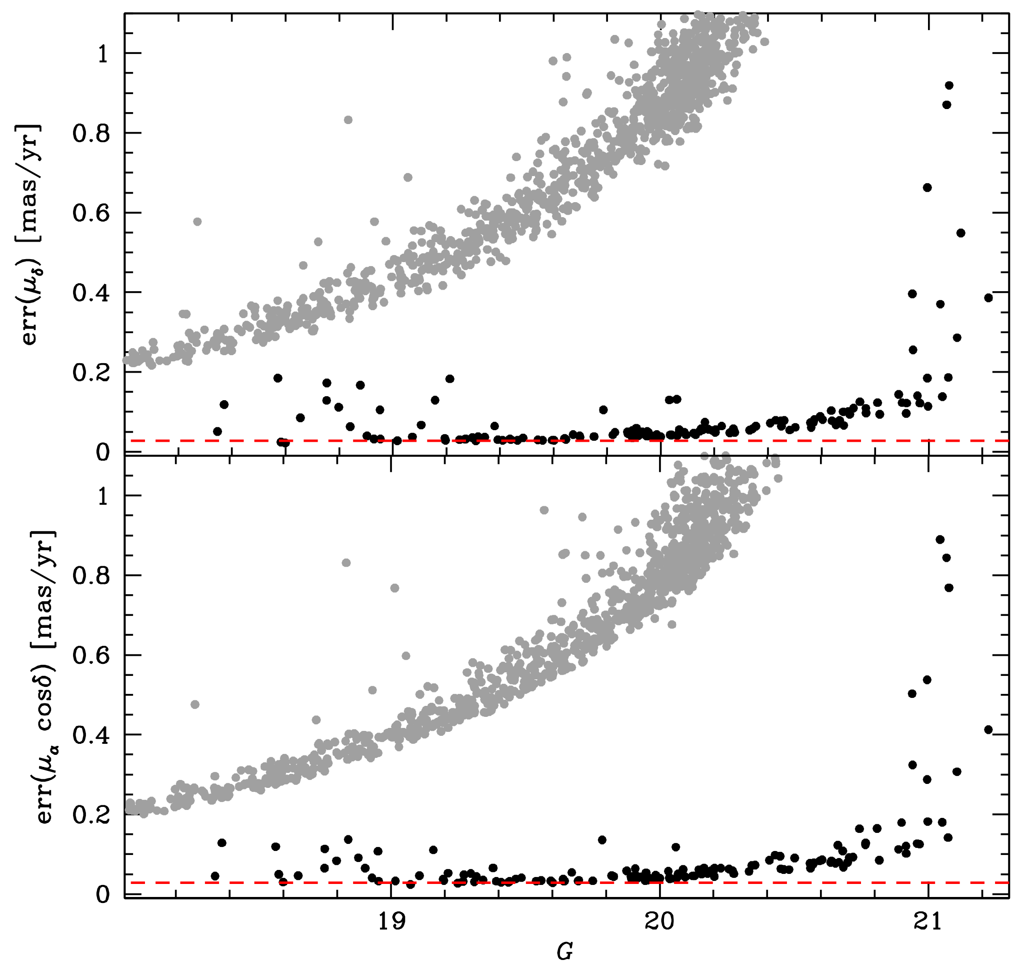
Sculptor

$$\sigma_R = 11.5 \pm 4.3 \ \mathrm{km\,s^{-1}} \quad \sigma_T = 8.5 \pm 3.2 \ \mathrm{km\,s^{-1}}$$



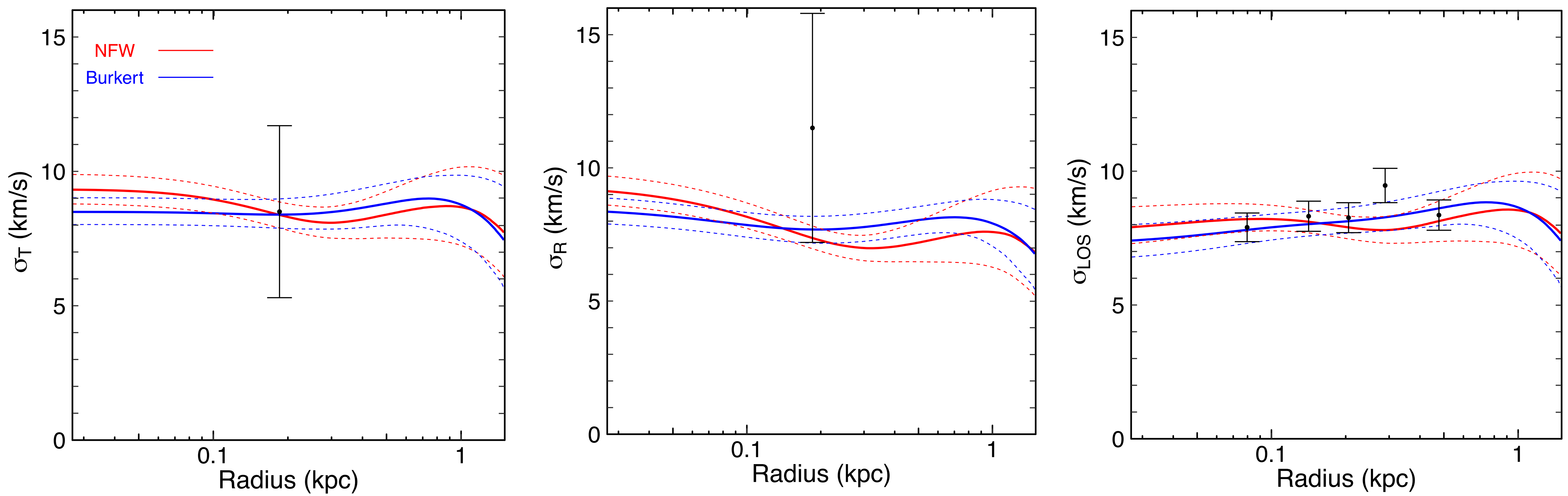
Draco

$$\sigma_R = 11.0^{+2.1}_{-1.5} \ \mathrm{km/s}, \ \sigma_T = 9.9^{+2.3}_{-3.1} \ \mathrm{km/s}$$

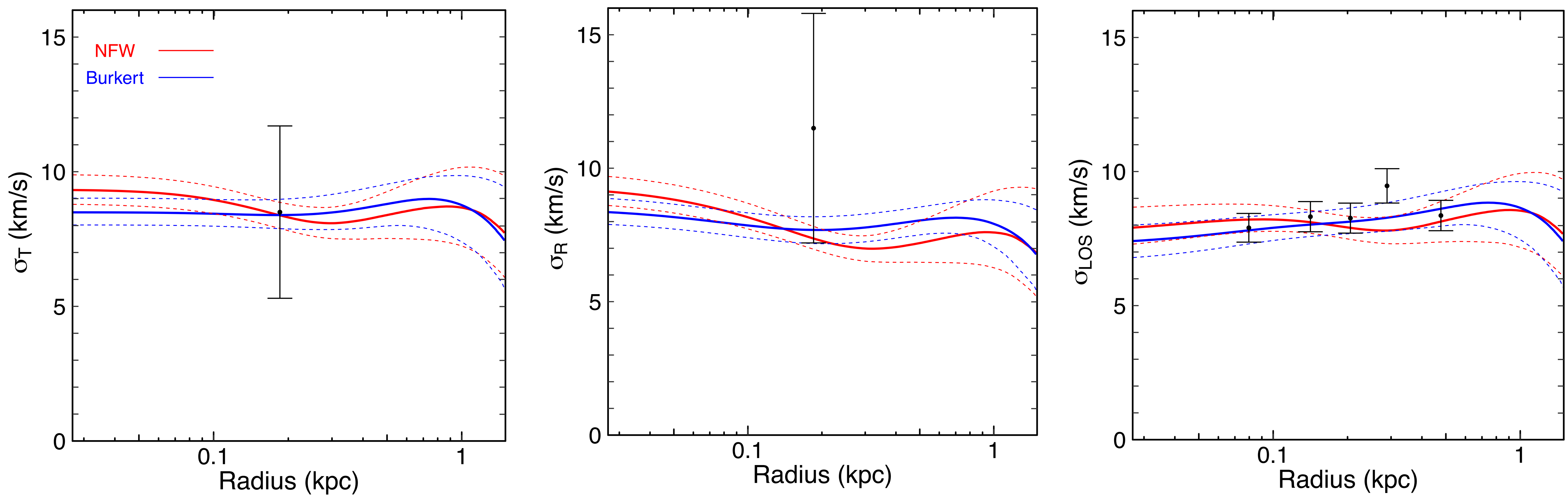


Massari et al. 2018, 2019

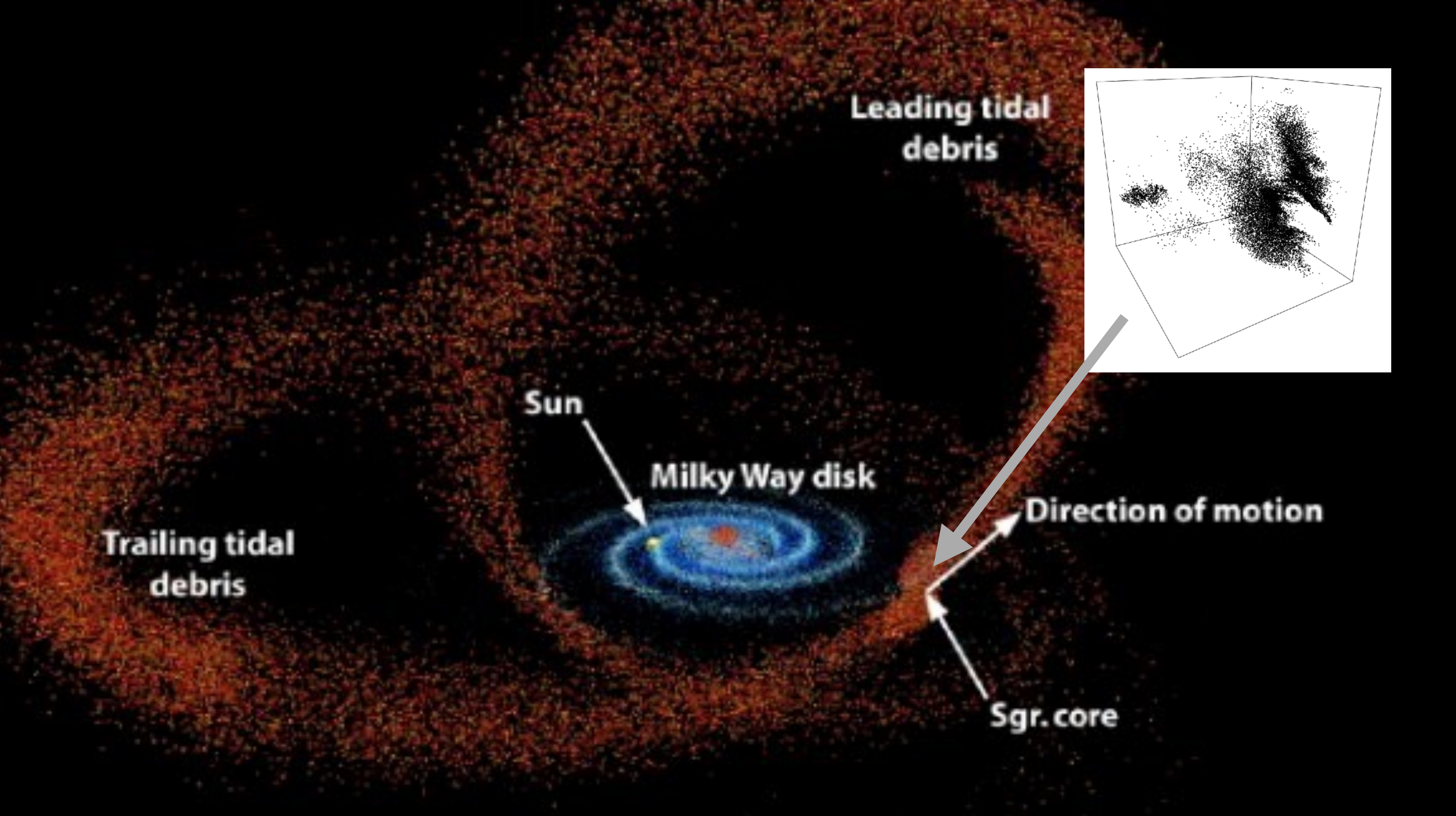
Sculptor multiple stellar populations & proper motions



Sculptor multiple stellar populations & proper motions



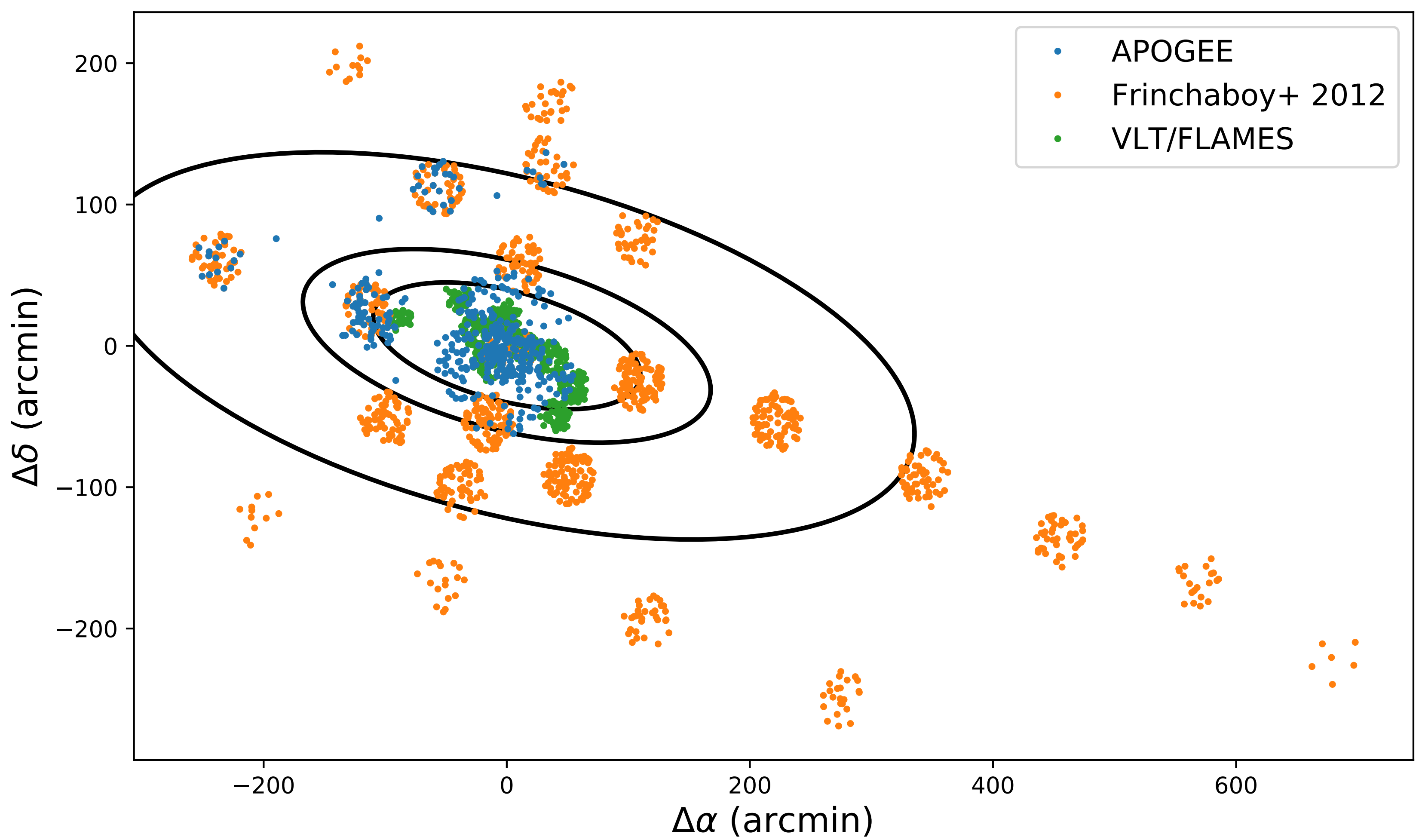
Require transverse velocity dispersions to ~ 1 km/s (LS, Frenk, White 2018)



Kinematics of the Sagittarius dwarf galaxy

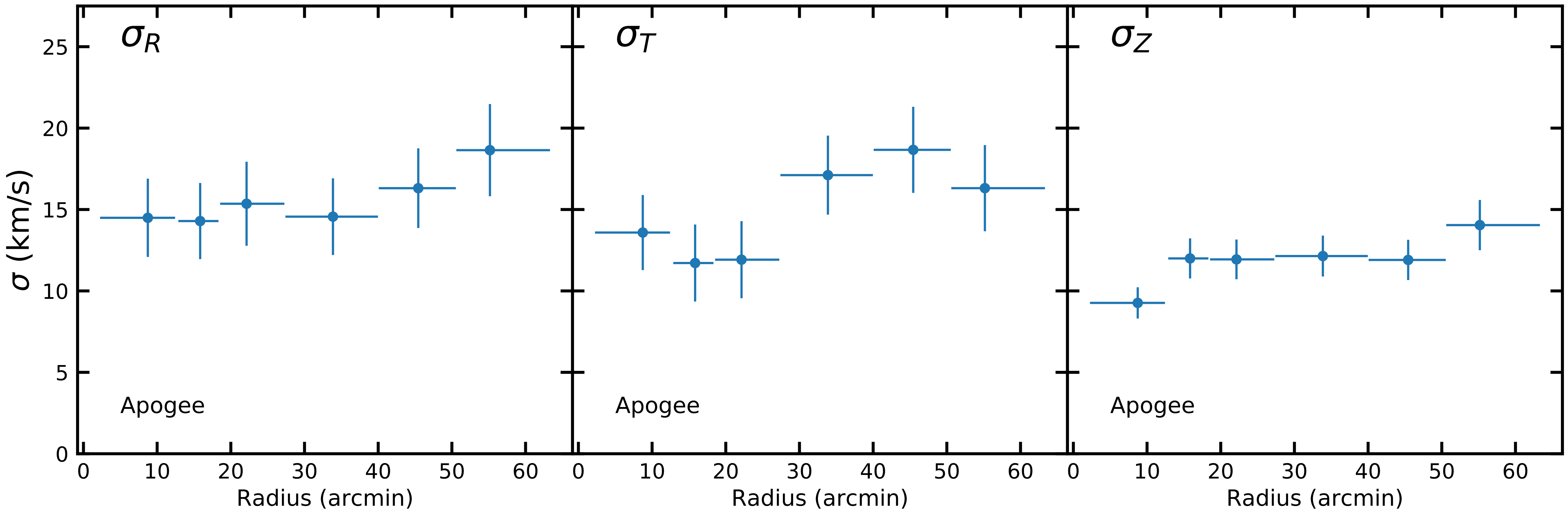
David R. Law
UCLA

Sagattarius velocity samples



- Several samples of velocity in the central core of Sagittarius (Majewski et al. 2012; Frinchaboy et al. 2012; McDonald et al. 2012)
- Evidence of a ``cold spot” in the center

Sagittarius velocity dispersion

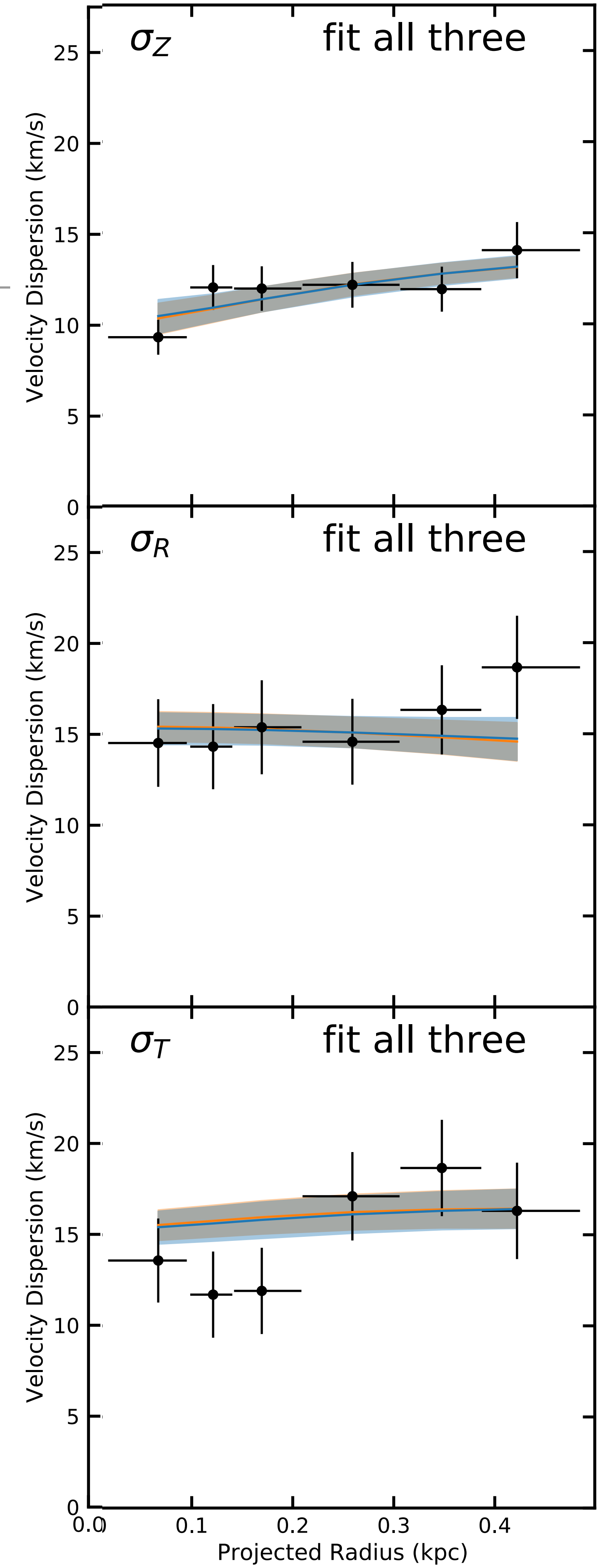


- To resolve the internal dispersion, need stars with tangential errors less than 12 km/s
- Sample contains Red Giant stars; Gaia PMs cross matched with previous spectroscopic samples
- F12 sample extends well beyond the core; equilibrium model likely not valid.

Andrew Pace & LS 2019

Sagittarius: NFW and Burkert fits

- Central region strongly dark matter-dominated (under equilibrium assumption)
- Assuming spherical jeans model, fits to entire data set unable to distinguish between core and cusp
- Circular orbits strongly preferred from combined data



Andrew Pace & LS 2019

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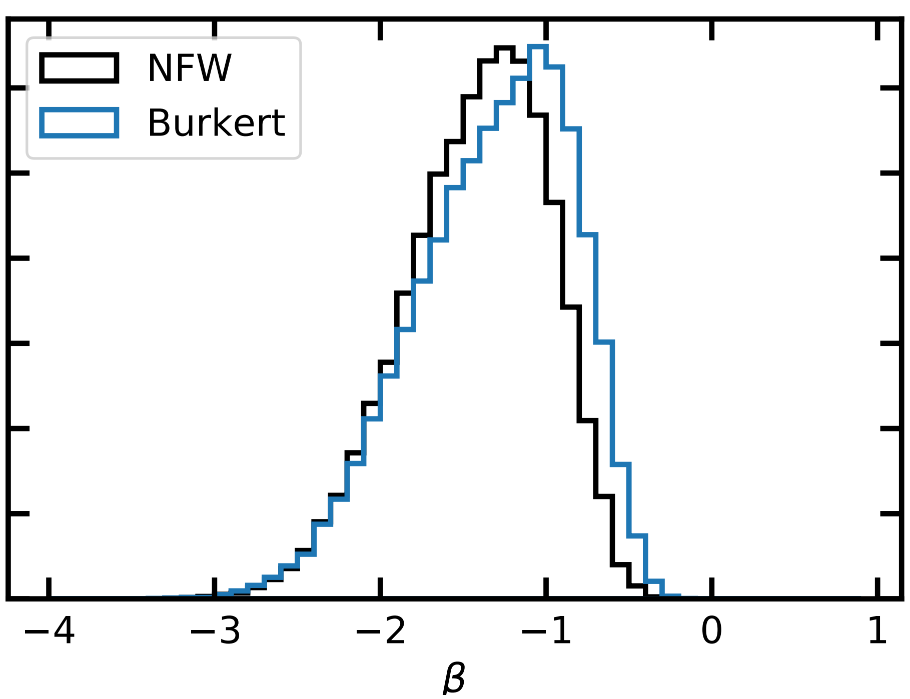
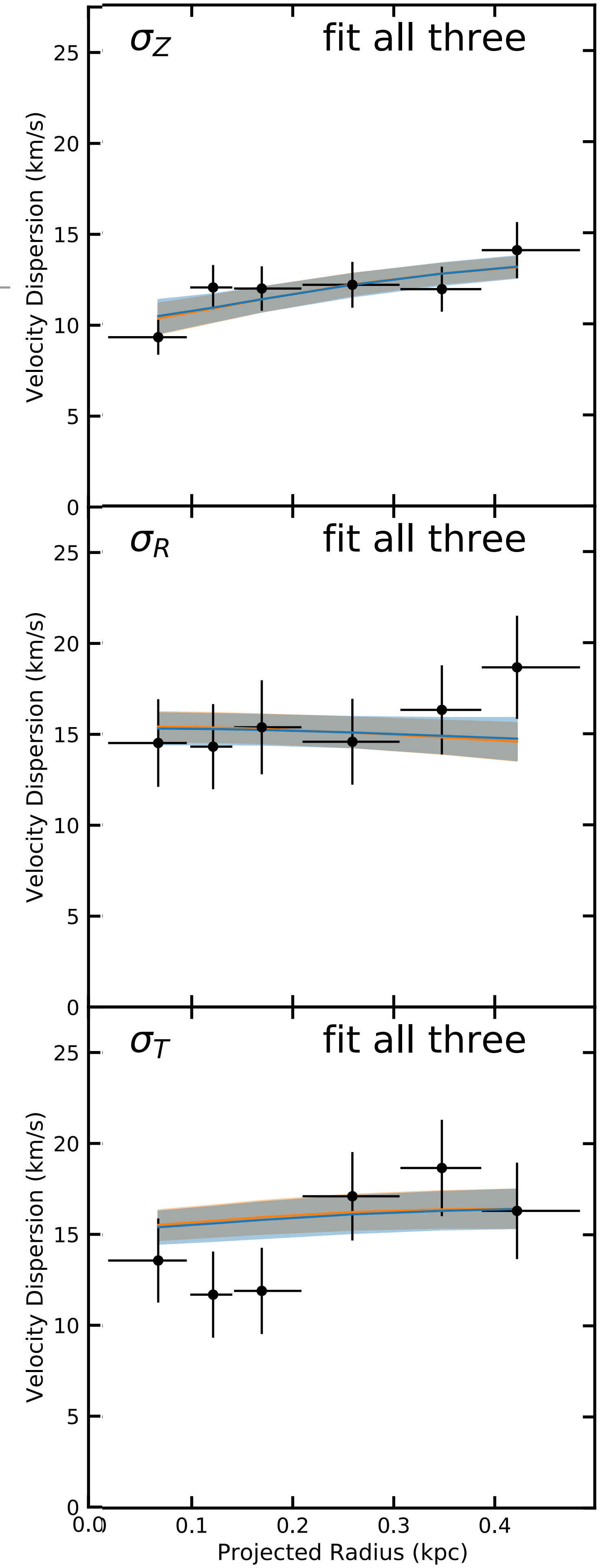
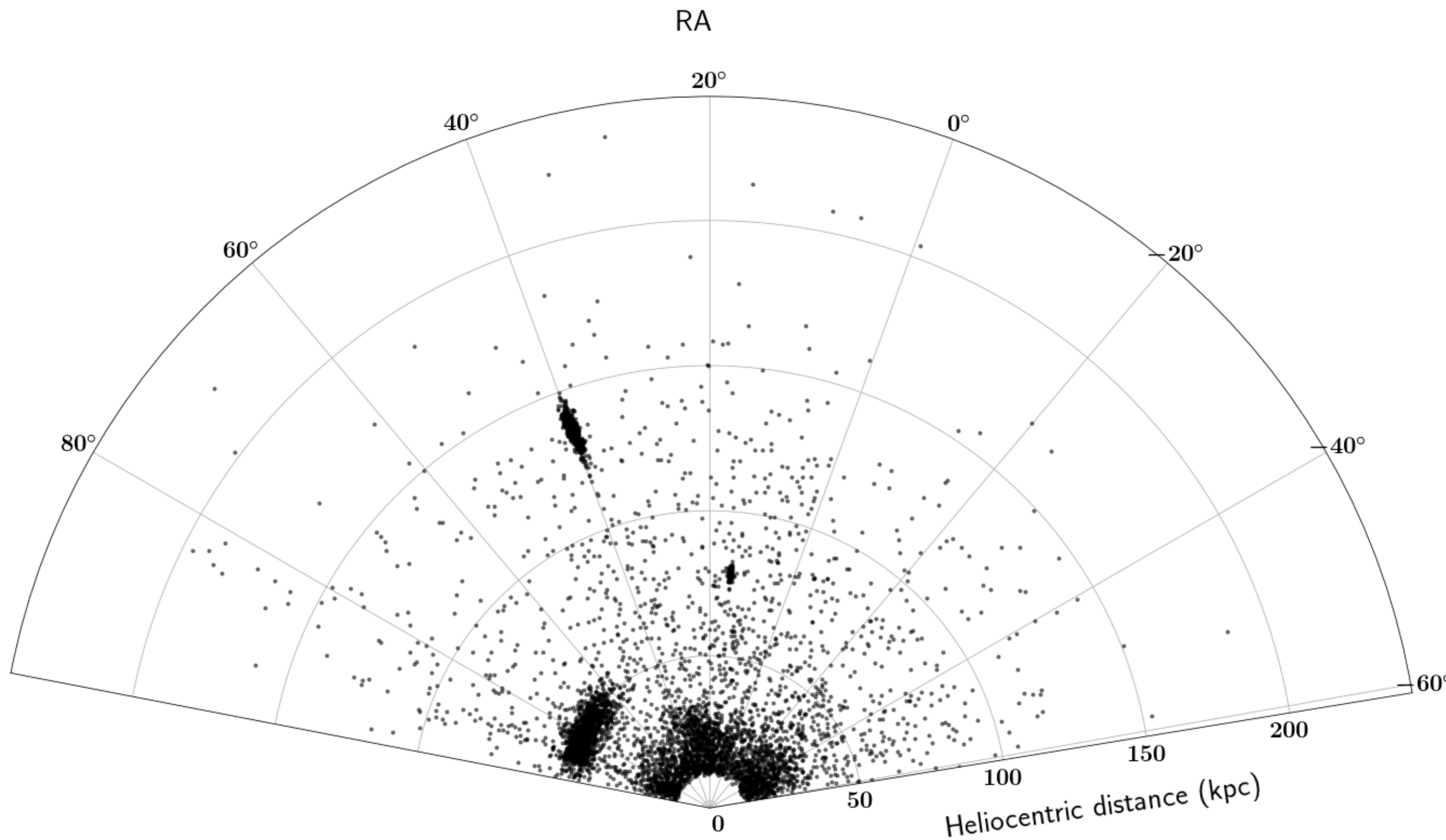




Andrew Pace & LS 2019

RR Lyrae in Dark Energy Survey



Stringer et al. 2019

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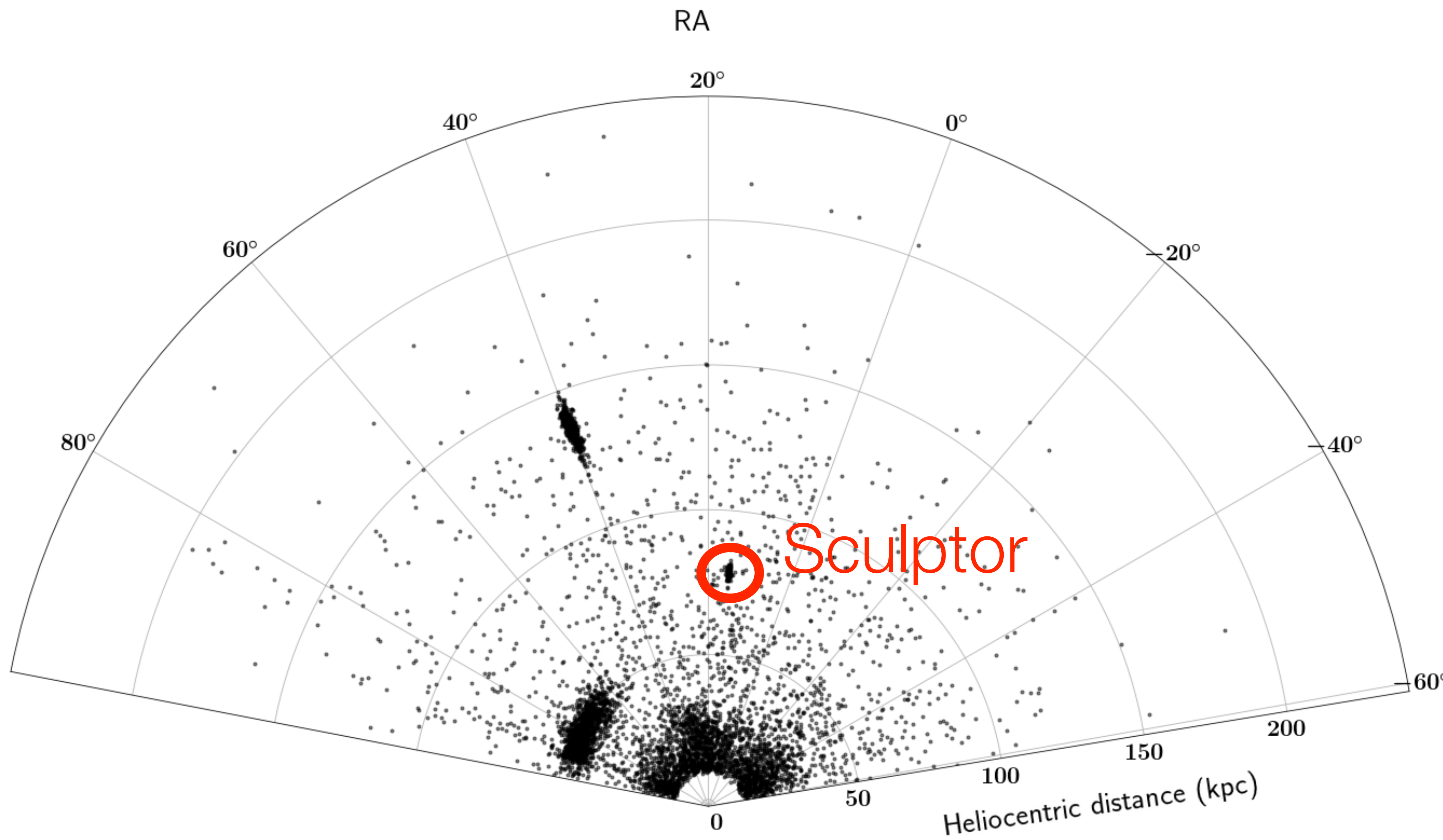

Stringer et al. 2019

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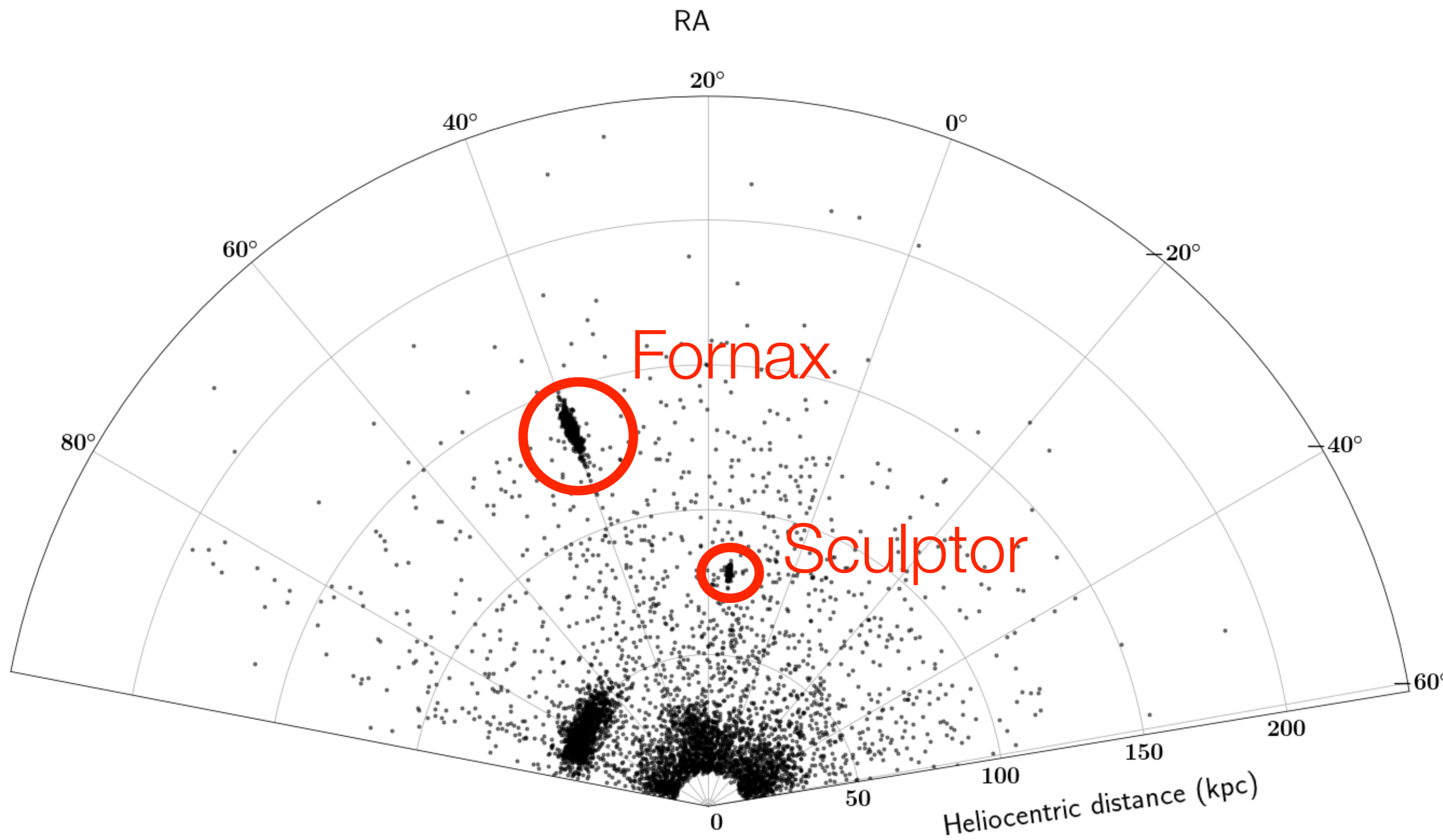
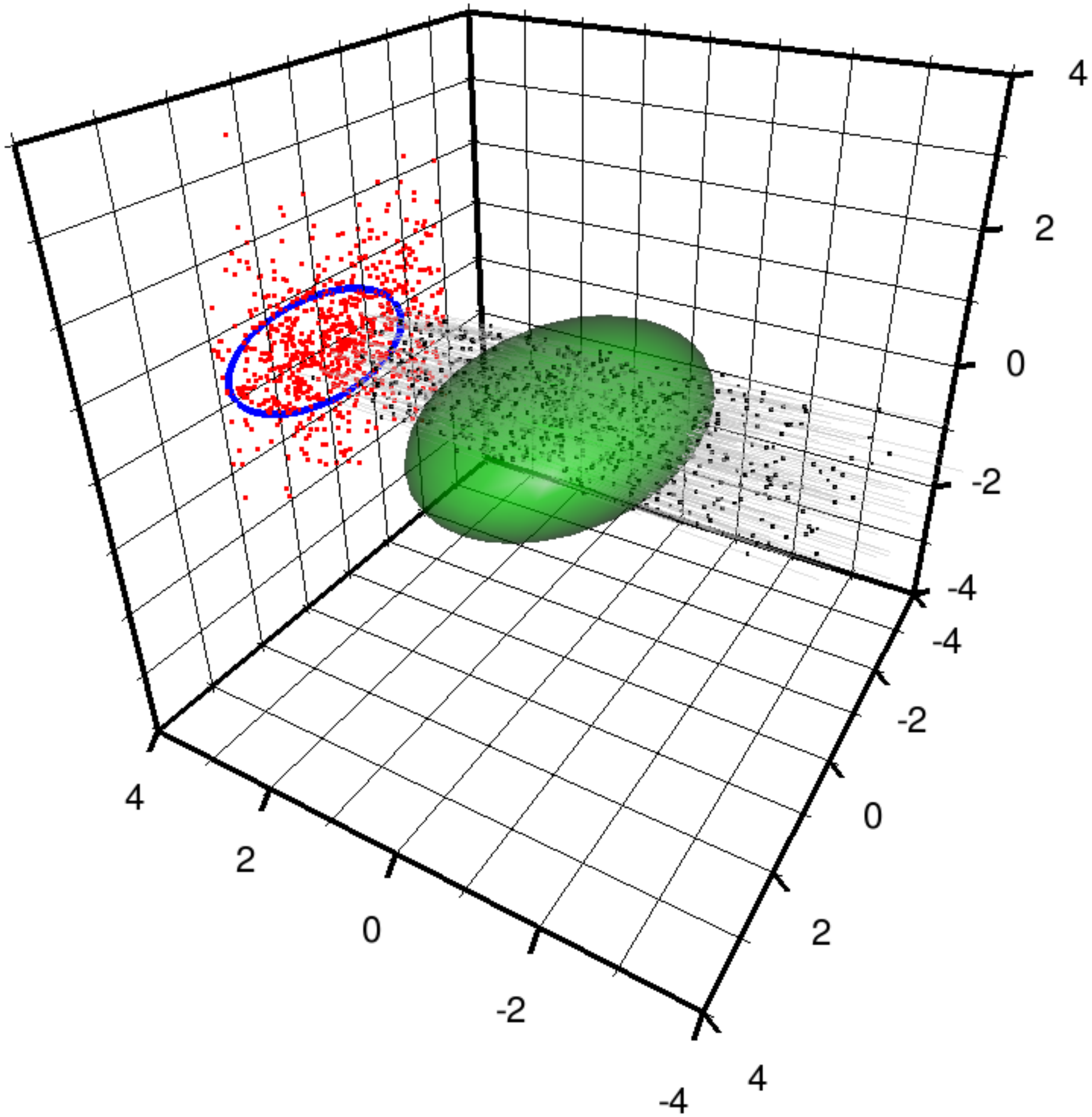


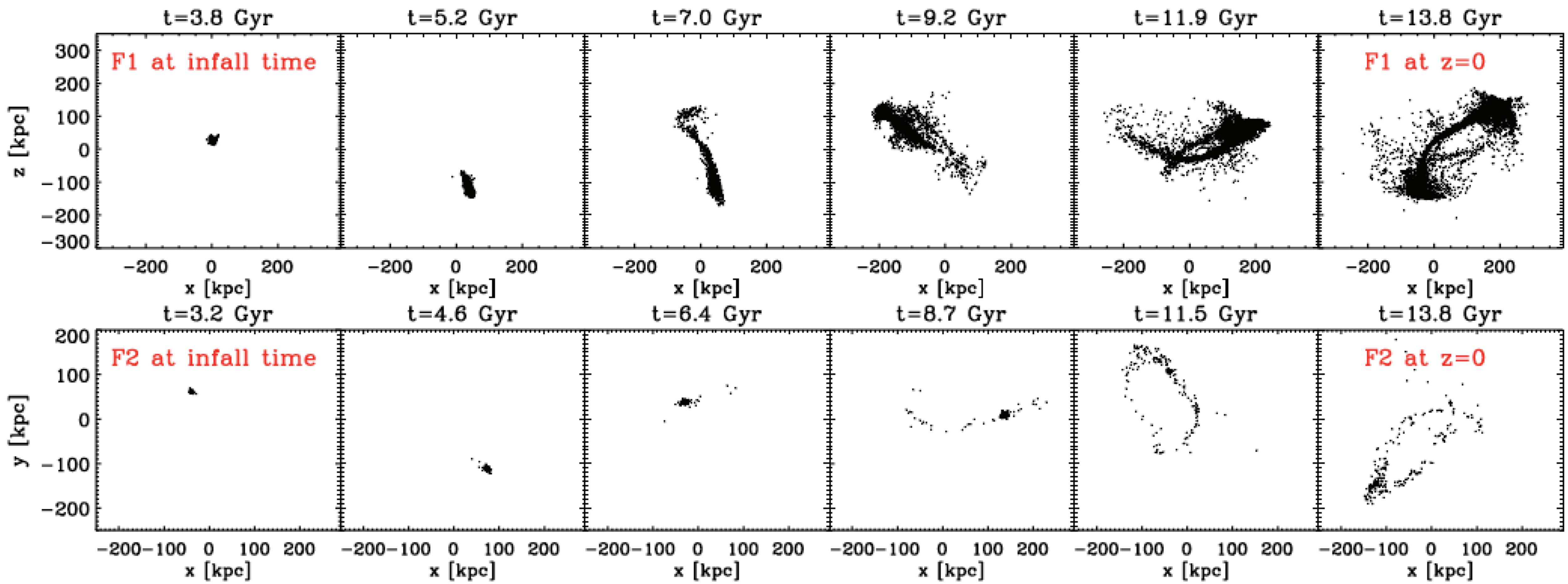
Stringer et al. 2019

RR Lyrae in the core of Sagittarius



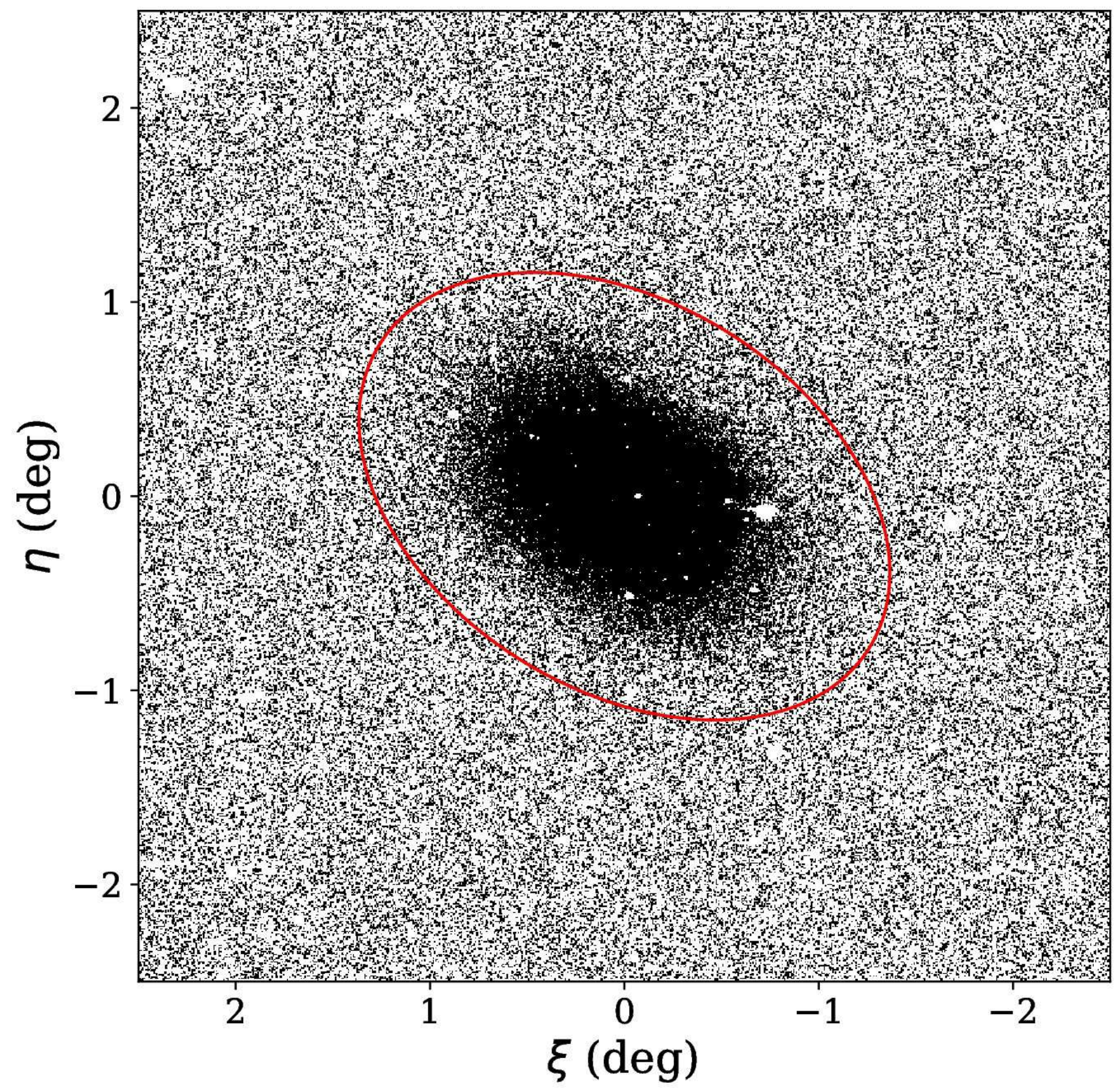
Peter Ferguson et al. 2019

Orbits of dwarfs in simulations



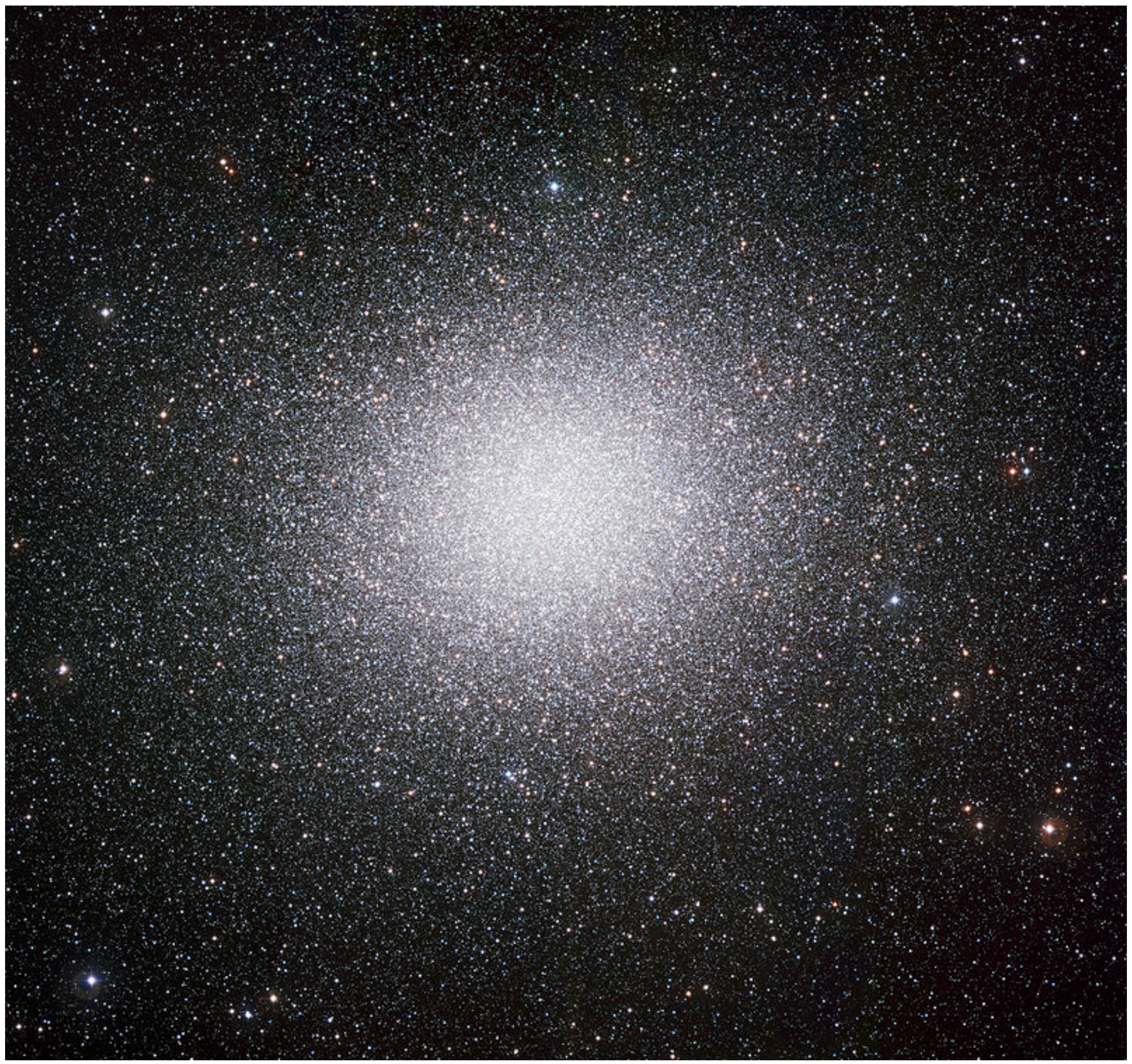
- Fornax analogues in APSOTLE show a range tidal disruption possibilities (Mei-Yu Wang, Azi Fattahi et al. 2017)
- Difficult to match the kinematics & the orbital dynamics simultaneously
- Best model: Stream with surface brightness ~ 32 mag/arcsec^2 (DES, LSST?)

Stellar streams around dwarf galaxies?



Fornax: Wang et al. (DES Collaboration) 2018

Omega Centauri



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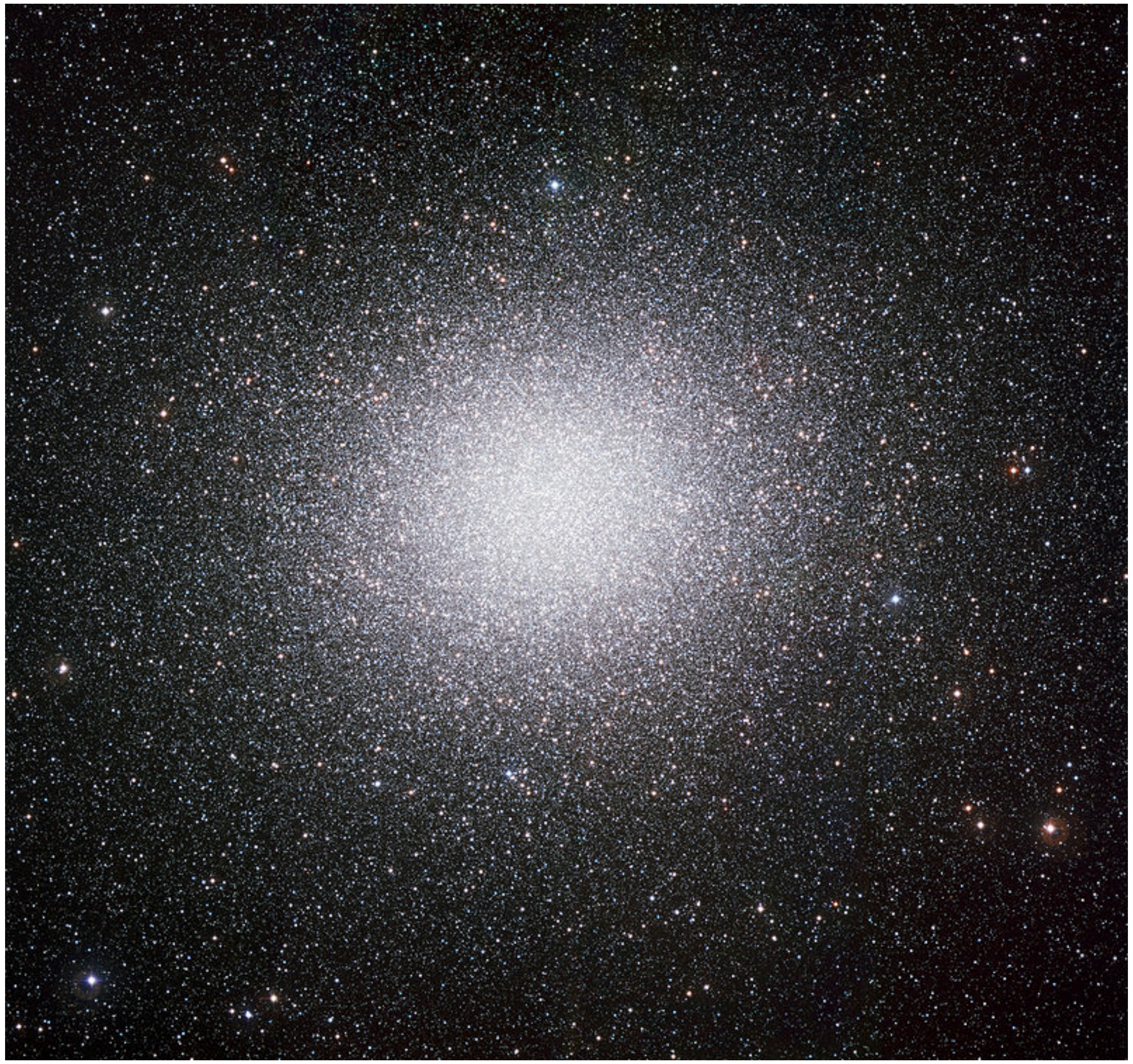

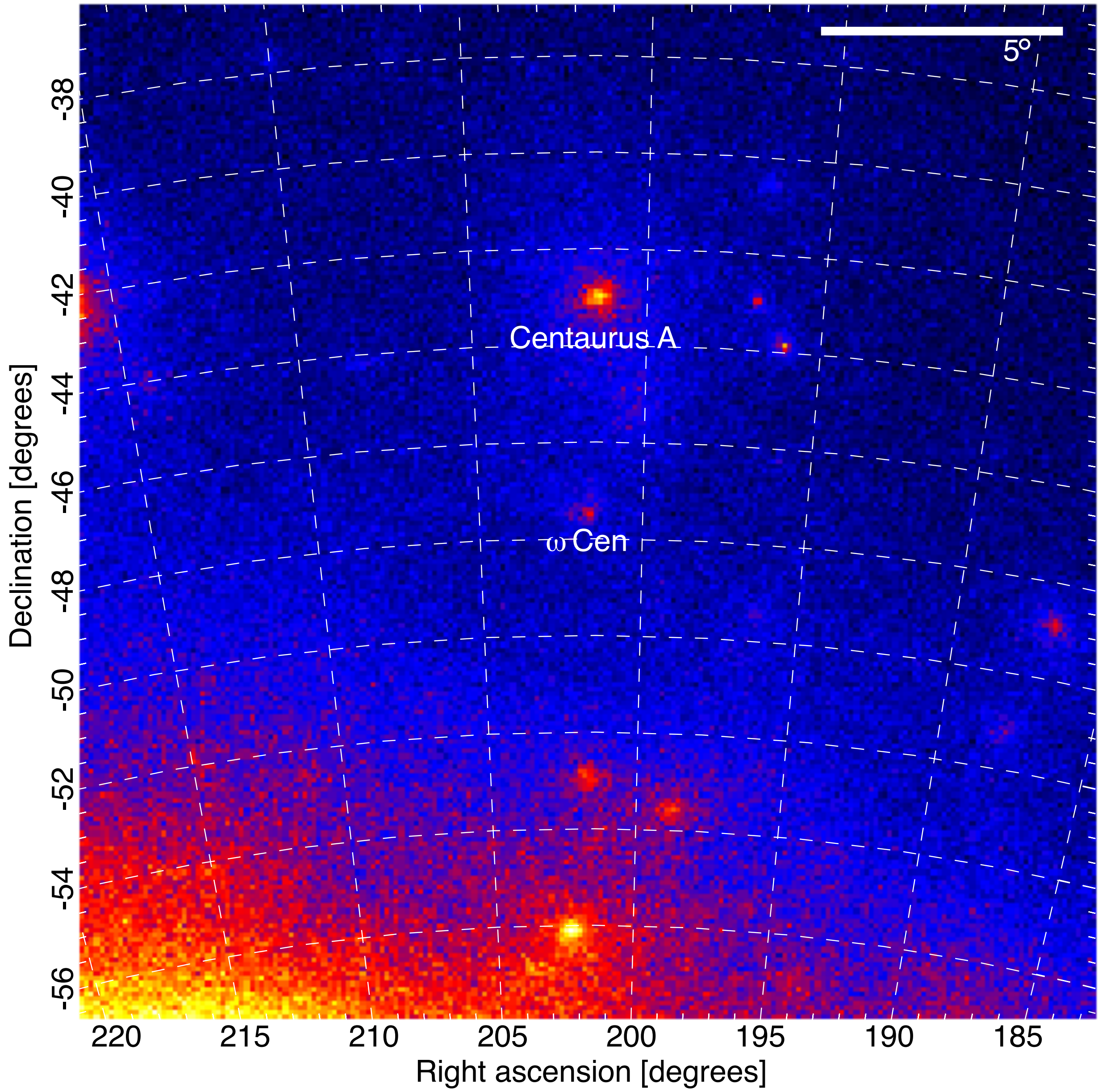

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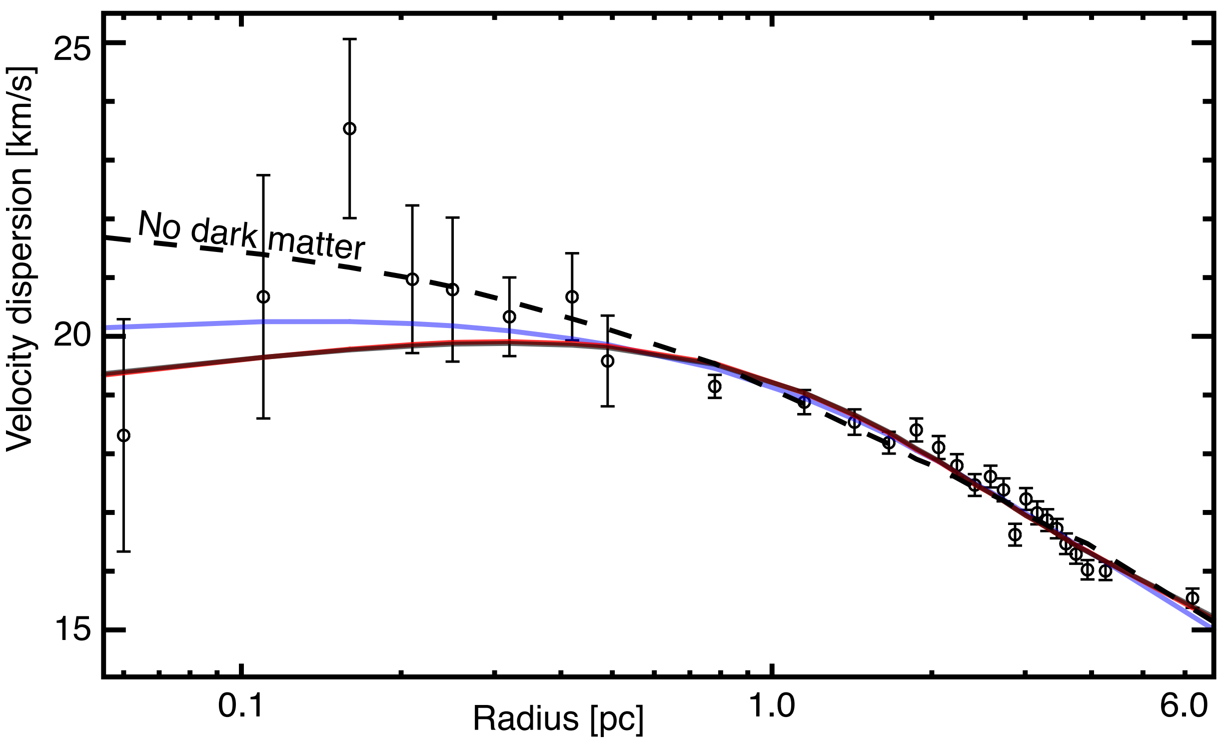
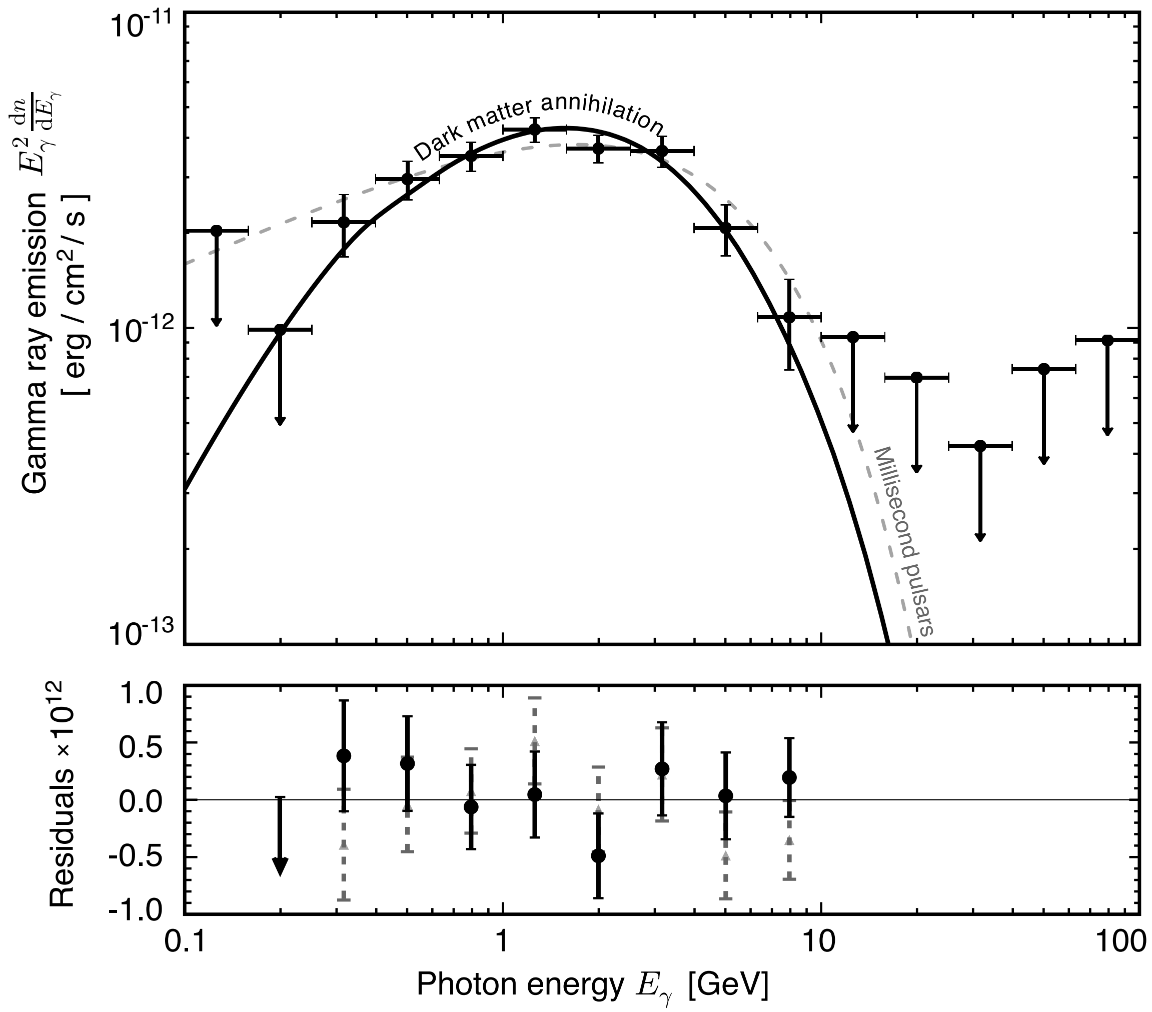


Brown et al. 2019



- Best fit dark matter spectrum: 31 GeV
- Sensitivity to much lower annihilation cross sections that dSphs or Galactic center
- Deeper radio observations

Reynosa-Cordova et al. 2019

In the upcoming years

- Obtain velocity dispersions from Gaia DR3?
- 6D view of Sagittarius and other dSphs?
- Revisit possibility of dark matter in globular clusters