The Missing Satellites of the Magellanic Clouds

Testing LCDM Predictions on Small Scales

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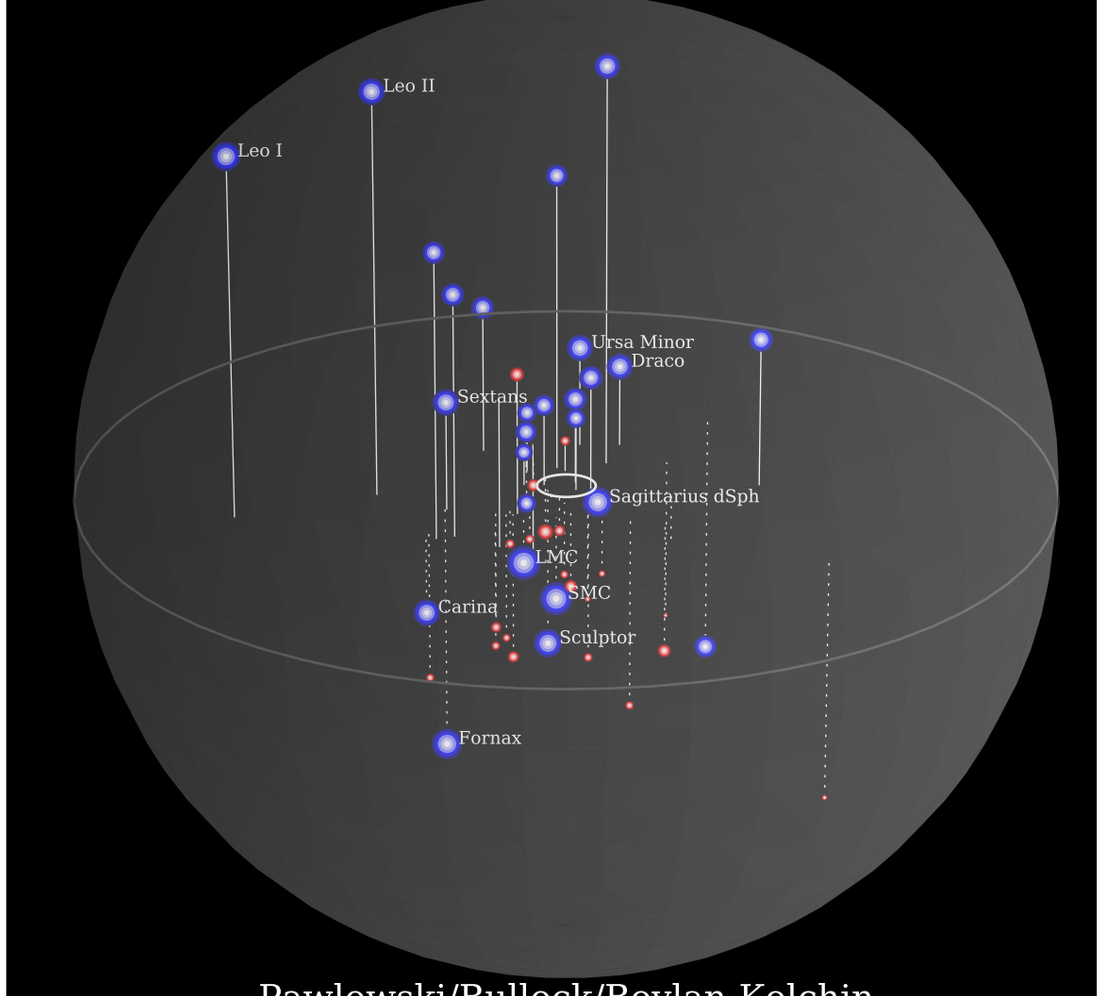
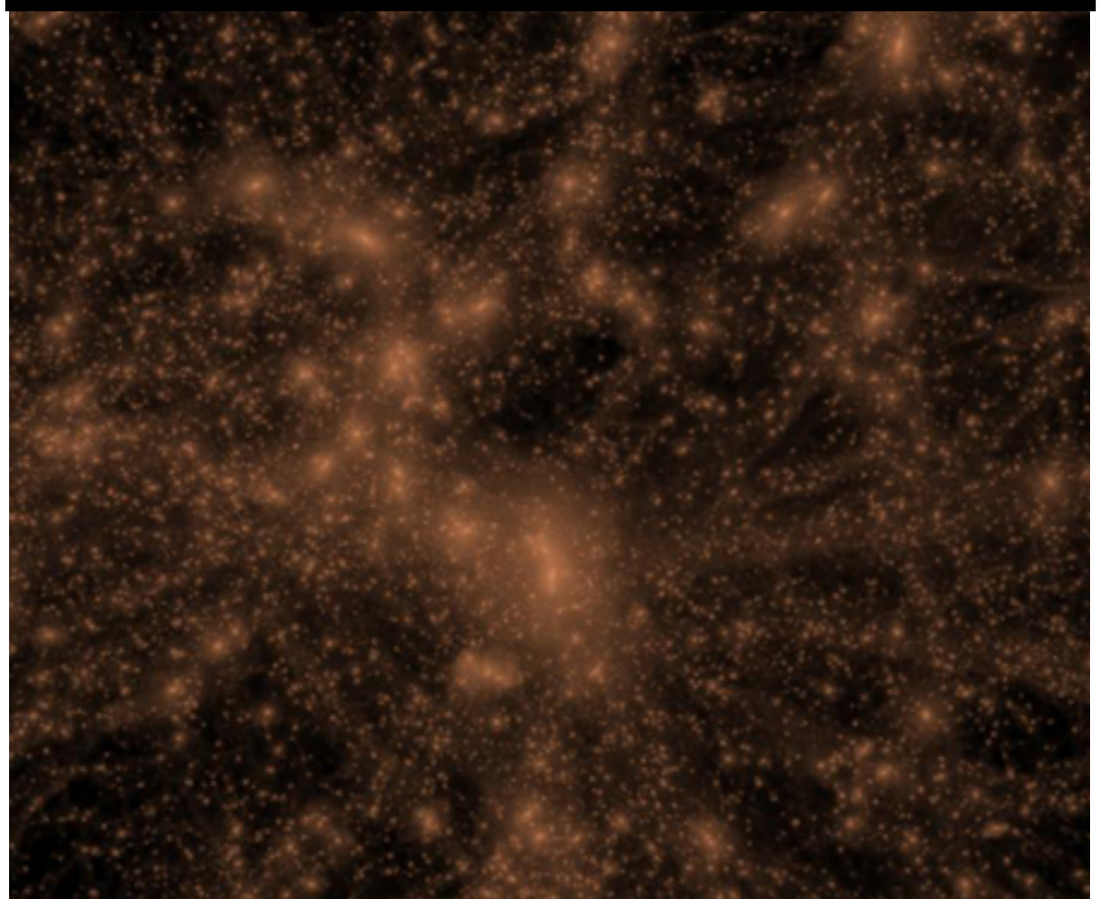
Ultra-Faint Intrigue

[$M_* \sim (0.1–1) \times 10^4\ M_\odot$; $M_{halo} \sim 10^8\ M_\odot$]

- How do galaxies populate the lowest mass halos?
  - Missing Satellites Problem (e.g., Klypin et al. 1999; Moore et al. 1999; see Nierenberg+ 2016 at higher z)
  - Low densities of dwarf galaxies: core vs. cusp, and Too Big to Fail (e.g. Boylan-Kolchin et al. 2011; Garisson-Kimmel et al. 2014; Ostriker et al. 2019)

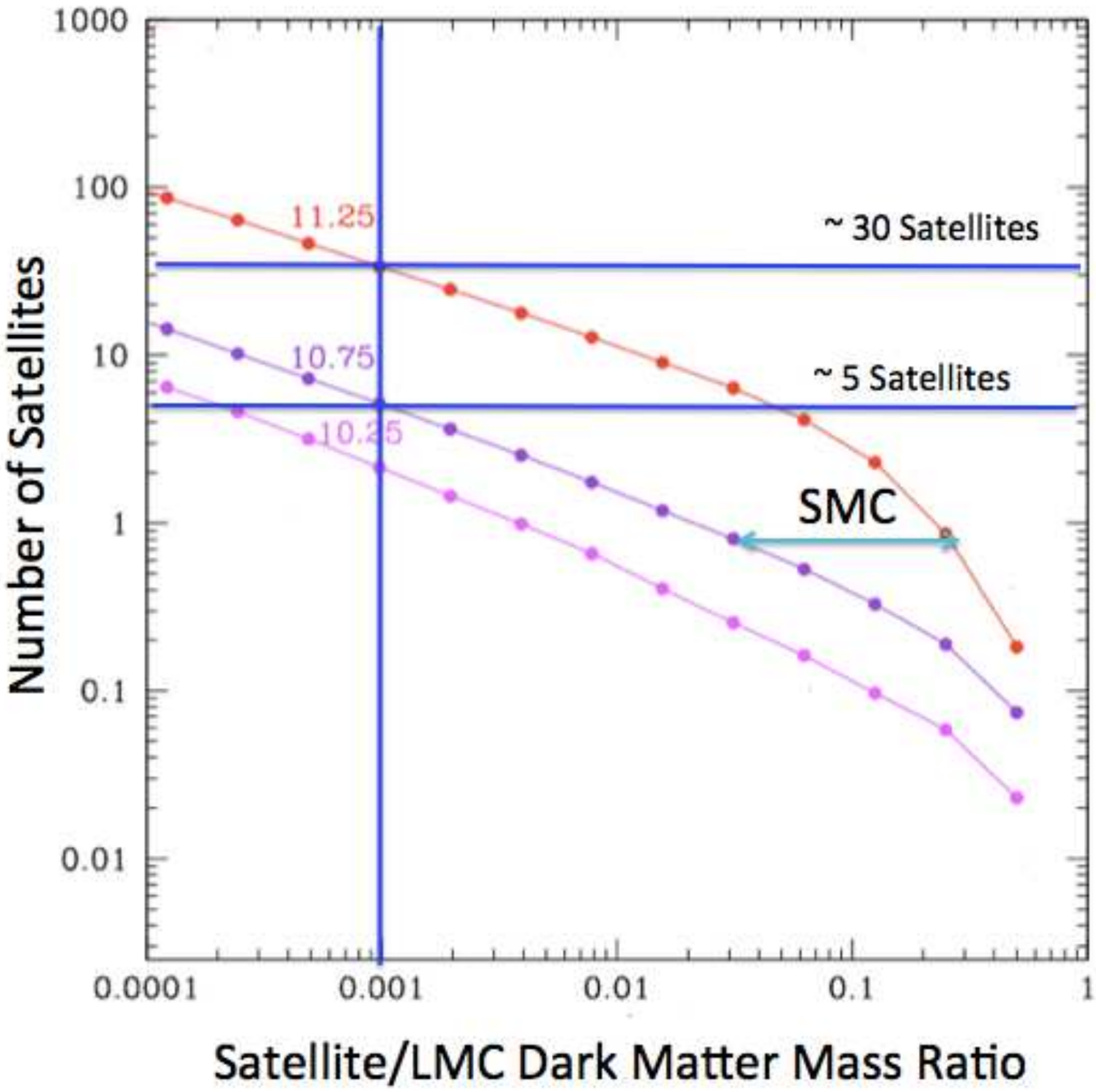


Pawlowski/Bullock/Boylan-Kolchin



Diemand et al.

How many Magellanic satellites does LCDM predict?



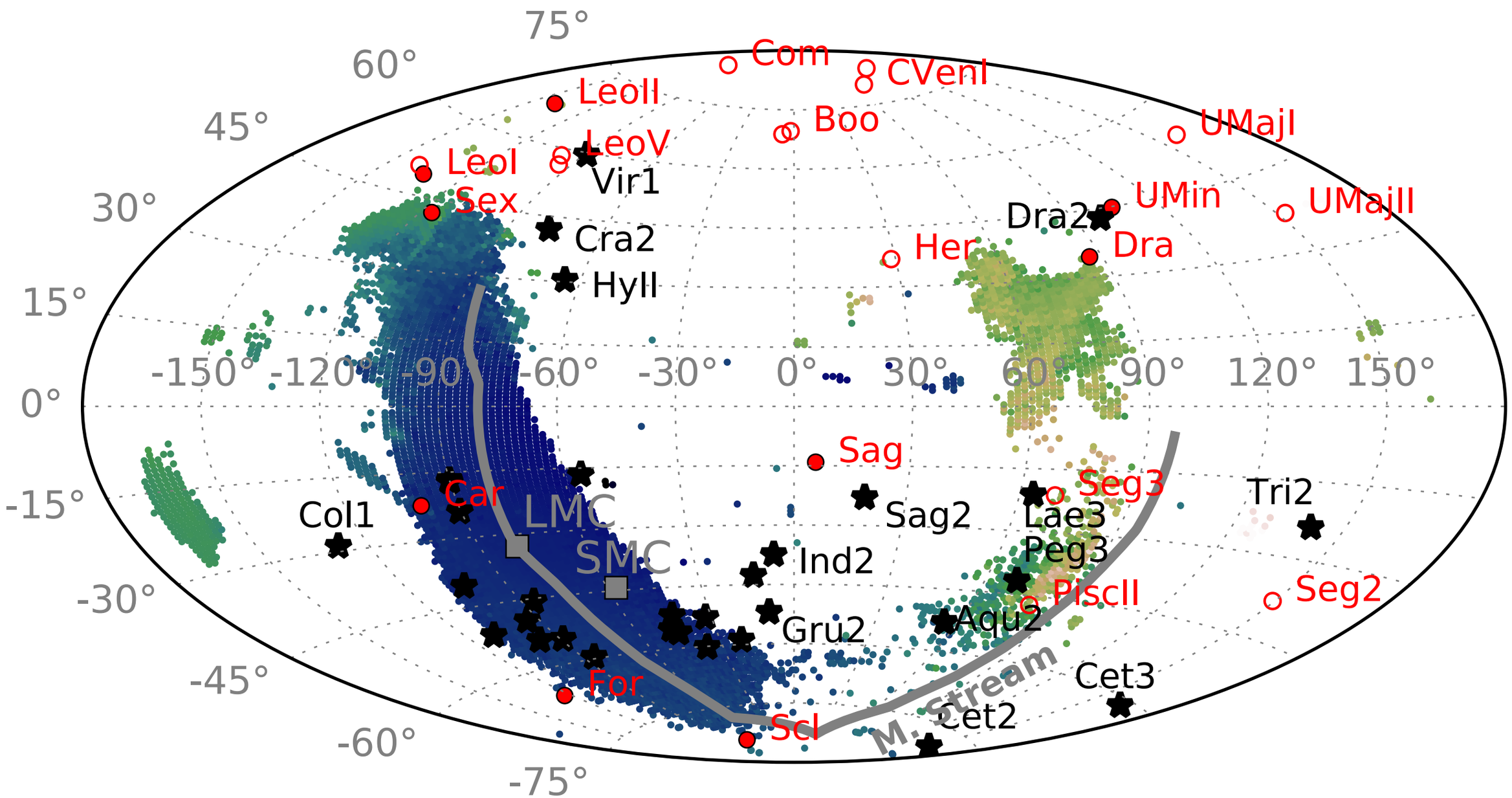
Sales et al. 2013

Dooley+17: 2-12 UFDs with $M_* > 10^4\ M_\odot$

Group infall: Wetzel et al. 2015; Deason et al. 2015: ~30% of $M_* \sim 10^5\ M_\odot$ satellites of Milky Way hosts fell in as a group

(see also Guo et al. 2011, D'Onghia & Lake 08, Li & Helmi 2008)

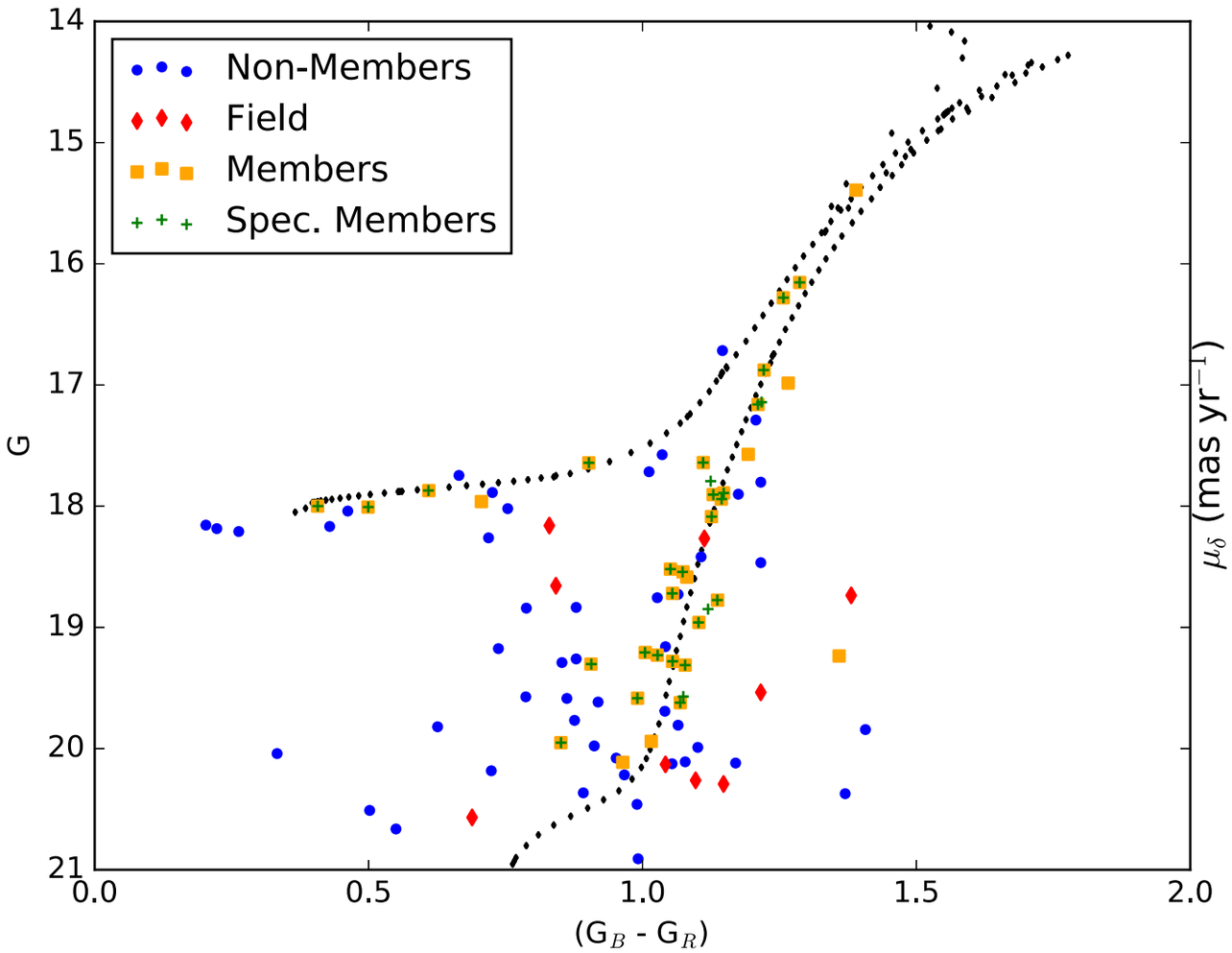
The Infalling LMC system

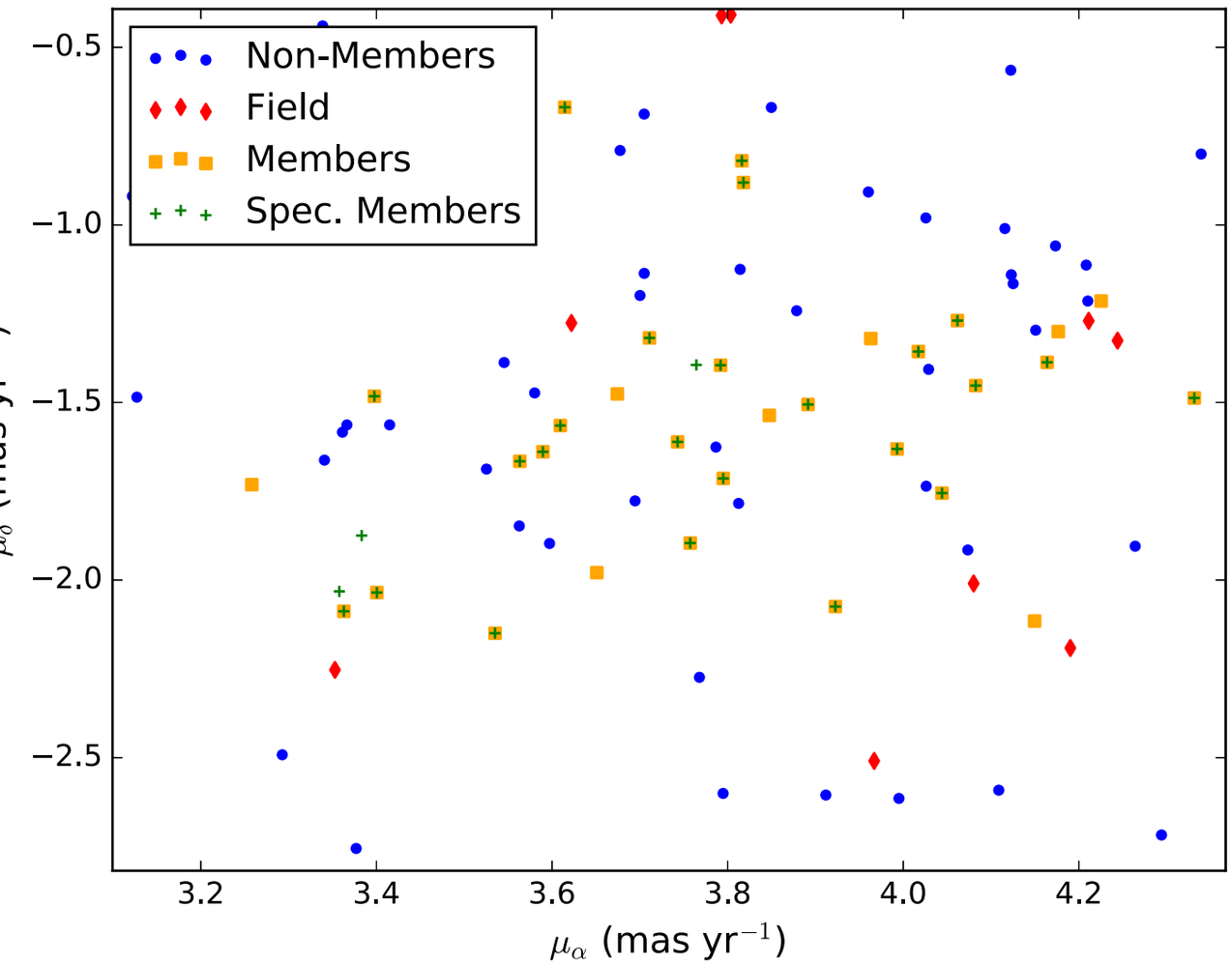


NK et al. 2018; Sales et al. 2017

See also: Jethwa et al. 2016; Yozin and Bekki 2015; Deason et al. 2015

Gaia DR2 PMs of Ultra-faints: Hydrus 1

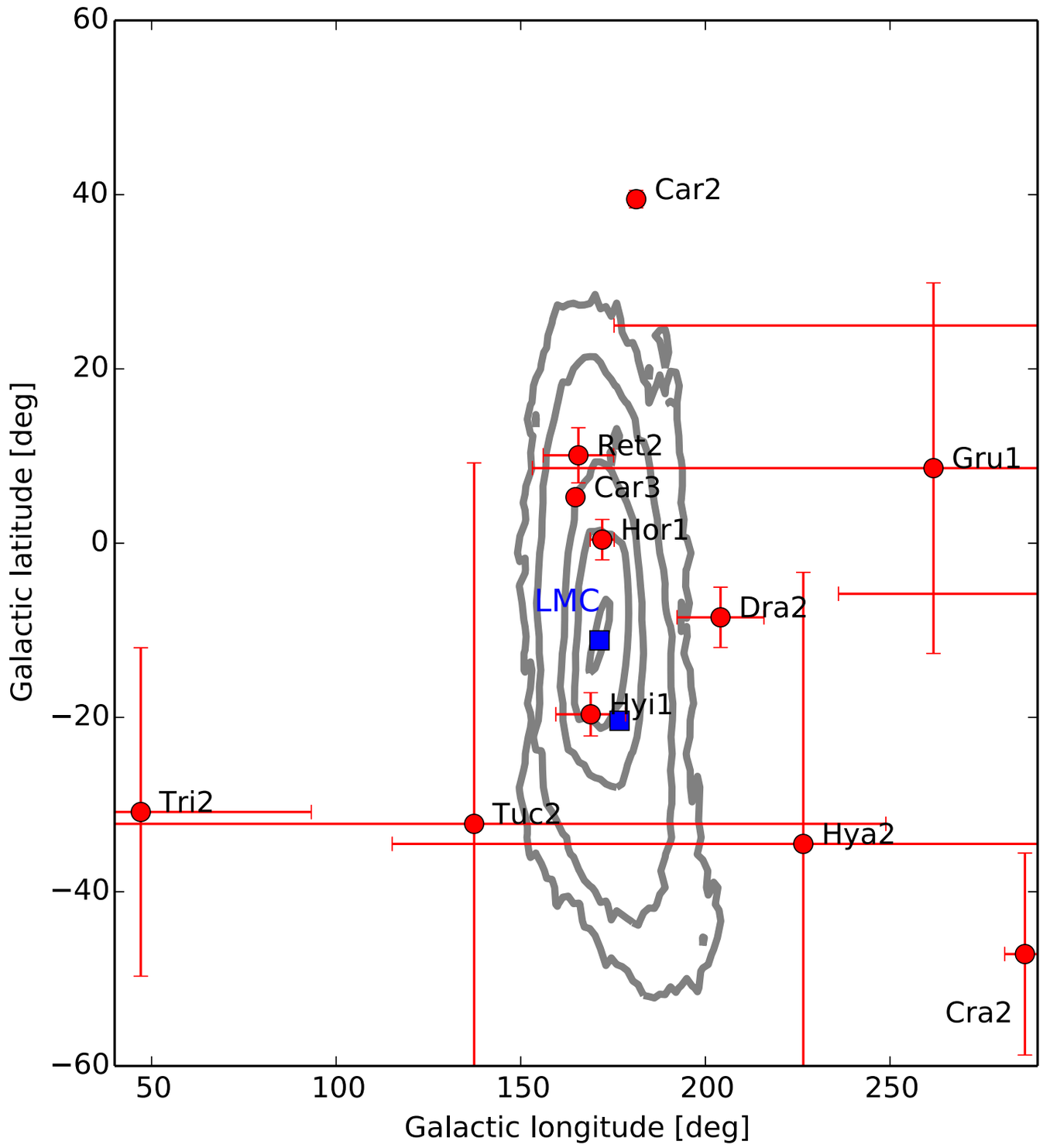




NK et al. 2018

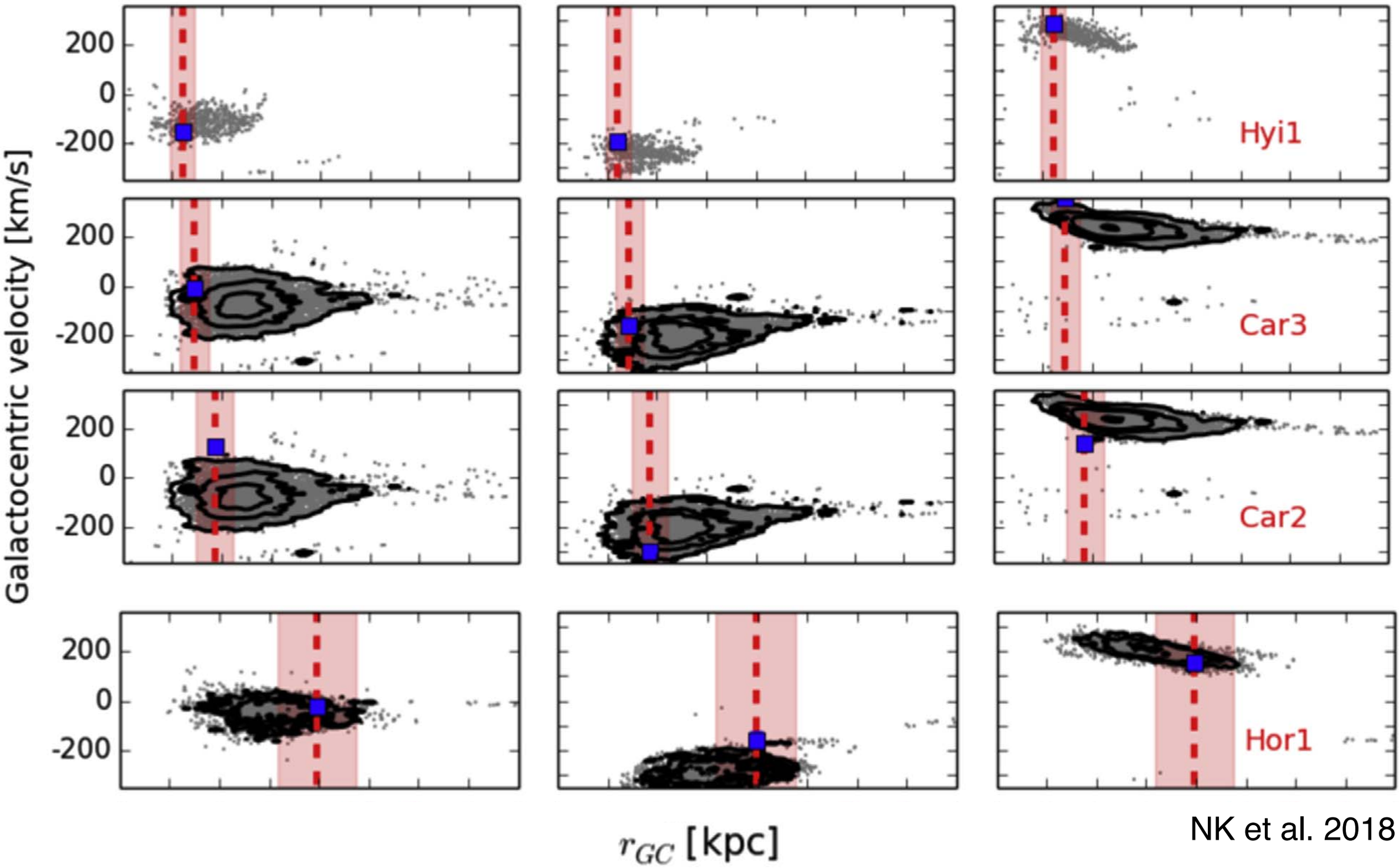
DR2 UFD PMs from spectroscopic samples: Simon 2018; Fritz et al. 2018
Adding photometric information: NK et al. 2018; Pace & Li 2018; Massari & Helmi 2018

Orbital Poles of successfully measured systems



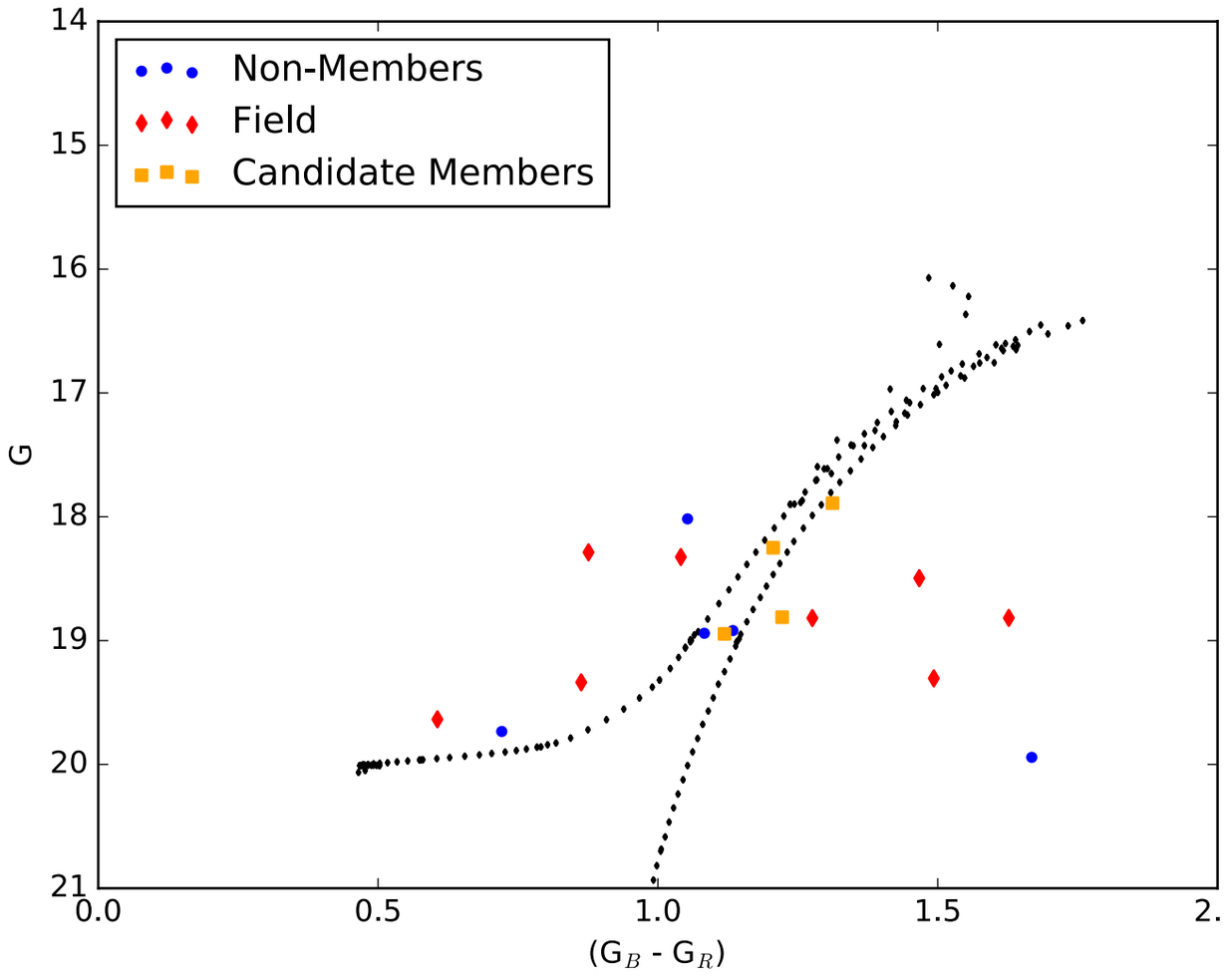
NK et al. 2018

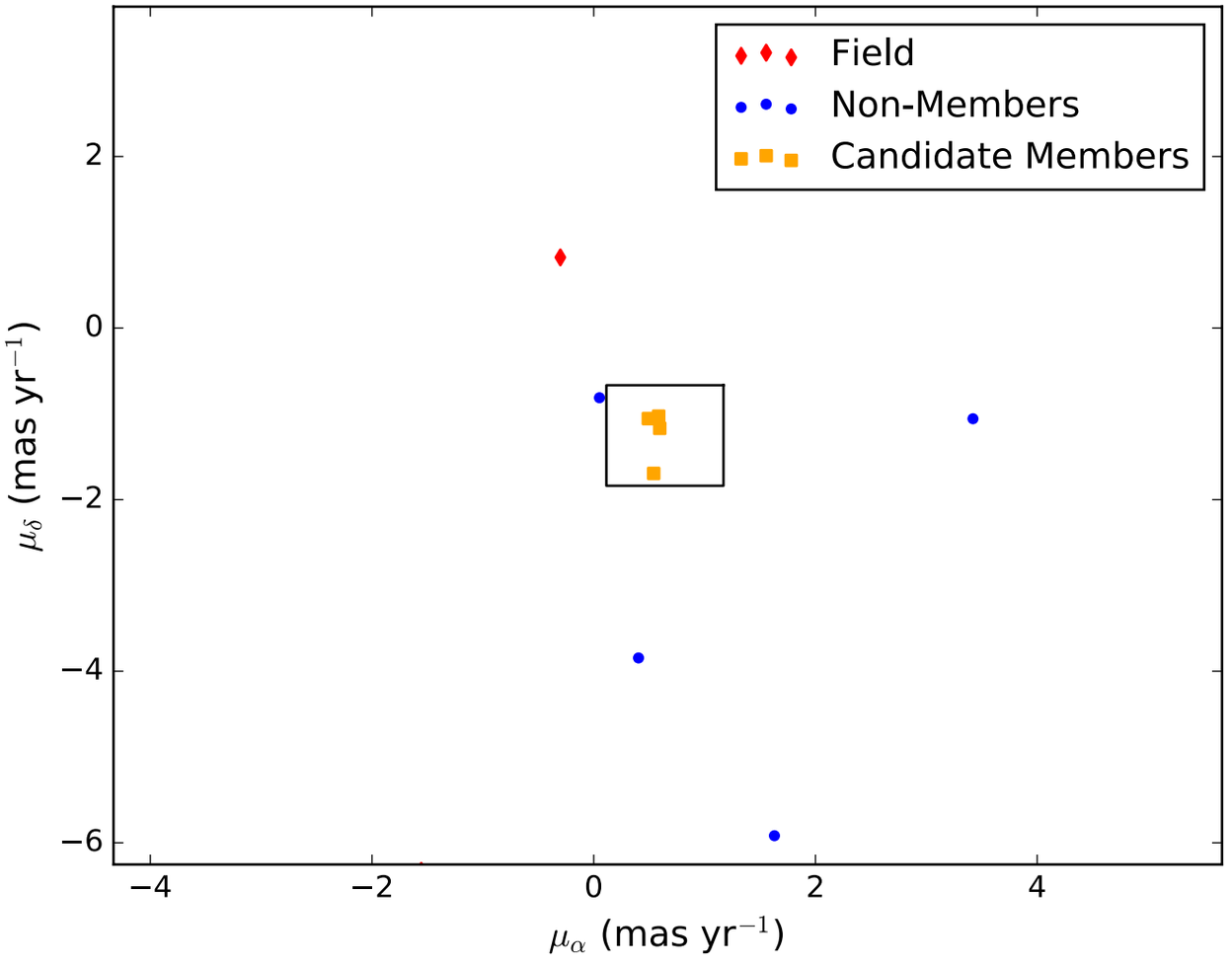
Velocities and Distances



NK et al. 2018

Predictions for galaxies without PMs: Phx2

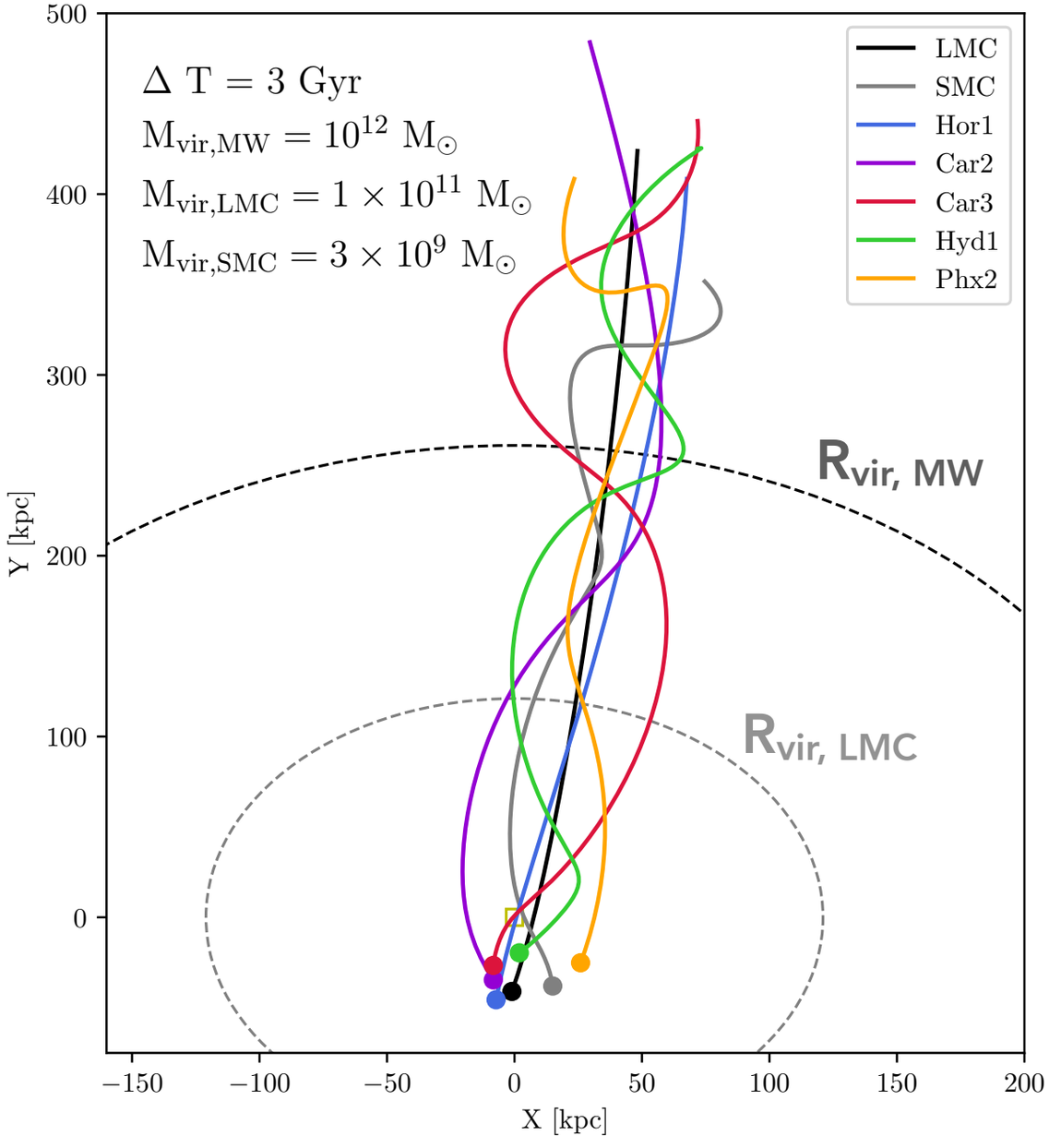


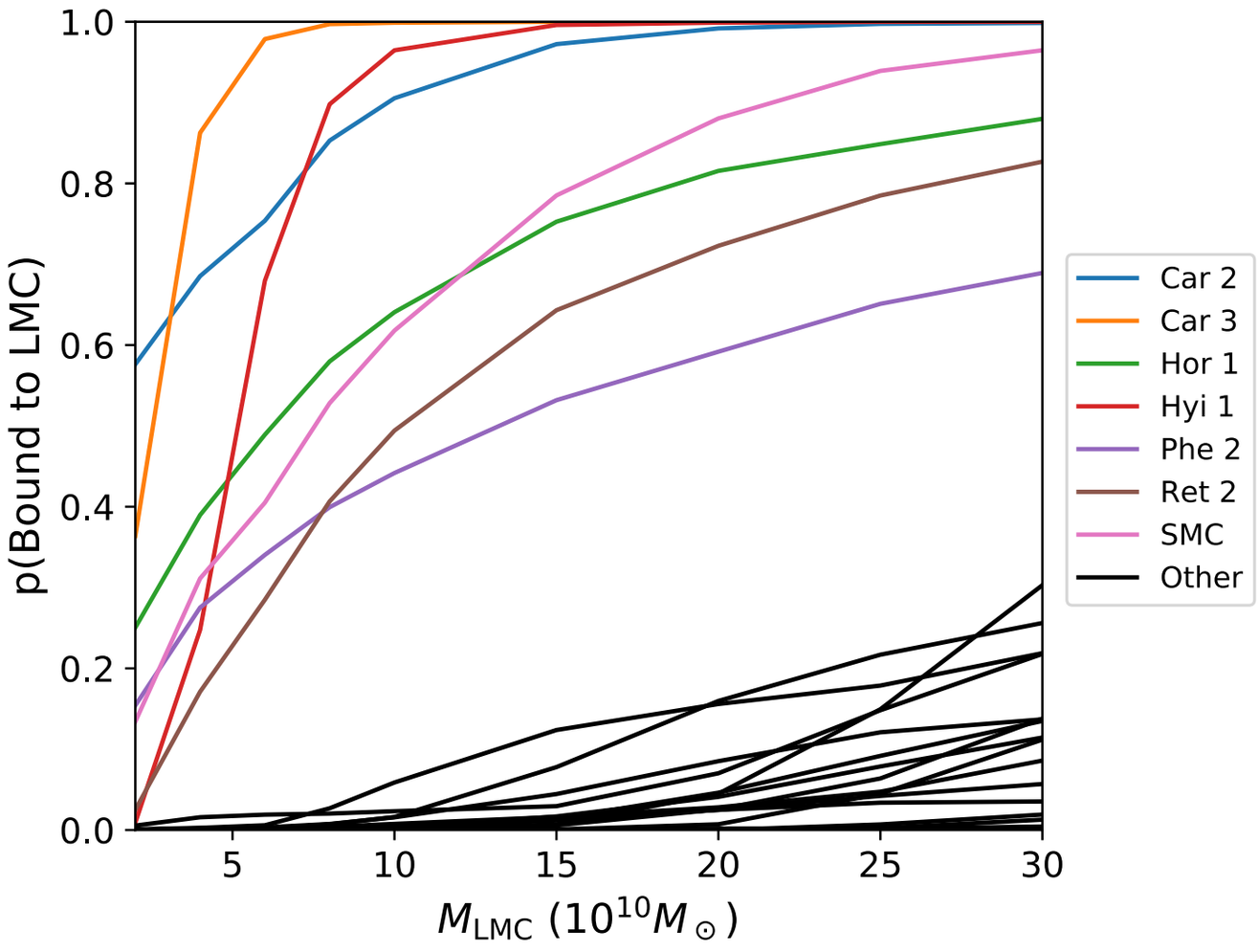


NK et al. 2018; see also Pace & Li 2018

- Newly measured RV from Fritz et al. 2018

Orbital modeling of satellites associated with the MCs

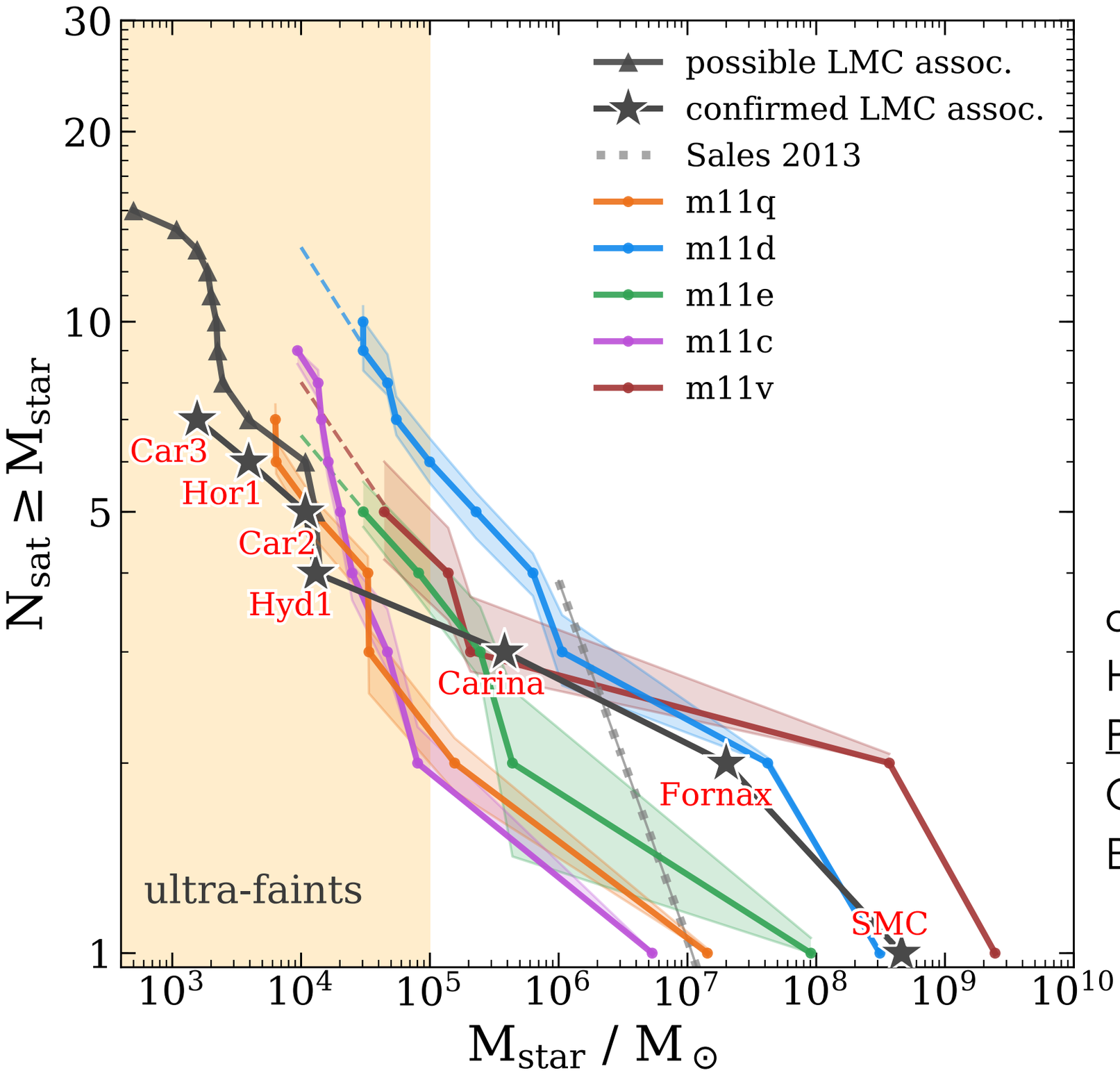




Patel+19, in prep.

Erkal & Belokurov 2019

Consistent with LCDM?



Jahn et al. 2019
- See also Munshi et al. 2019

dSphs: new Gaia DR2 PMs;
Helmi et al. 2018
Pardy et al 2019: case for
Carina and Fornax
But see Erkal & Belokurov 2019

Conclusions

- Proper motions are key in enabling near-field cosmology: mass and origin.
- We conclude that four ultra-faint systems Hor1, Car2, Car3, and Hyi1) are members of the Magellanic Cloud system.
- Another 4 galaxies (Phx2, Dra2, Hya2 and Ret 2) are highly likely members.
- Carina and Fornax are two dSphs that may be associated with the LMC system.
- Consistent with LCDM LMC mass systems?