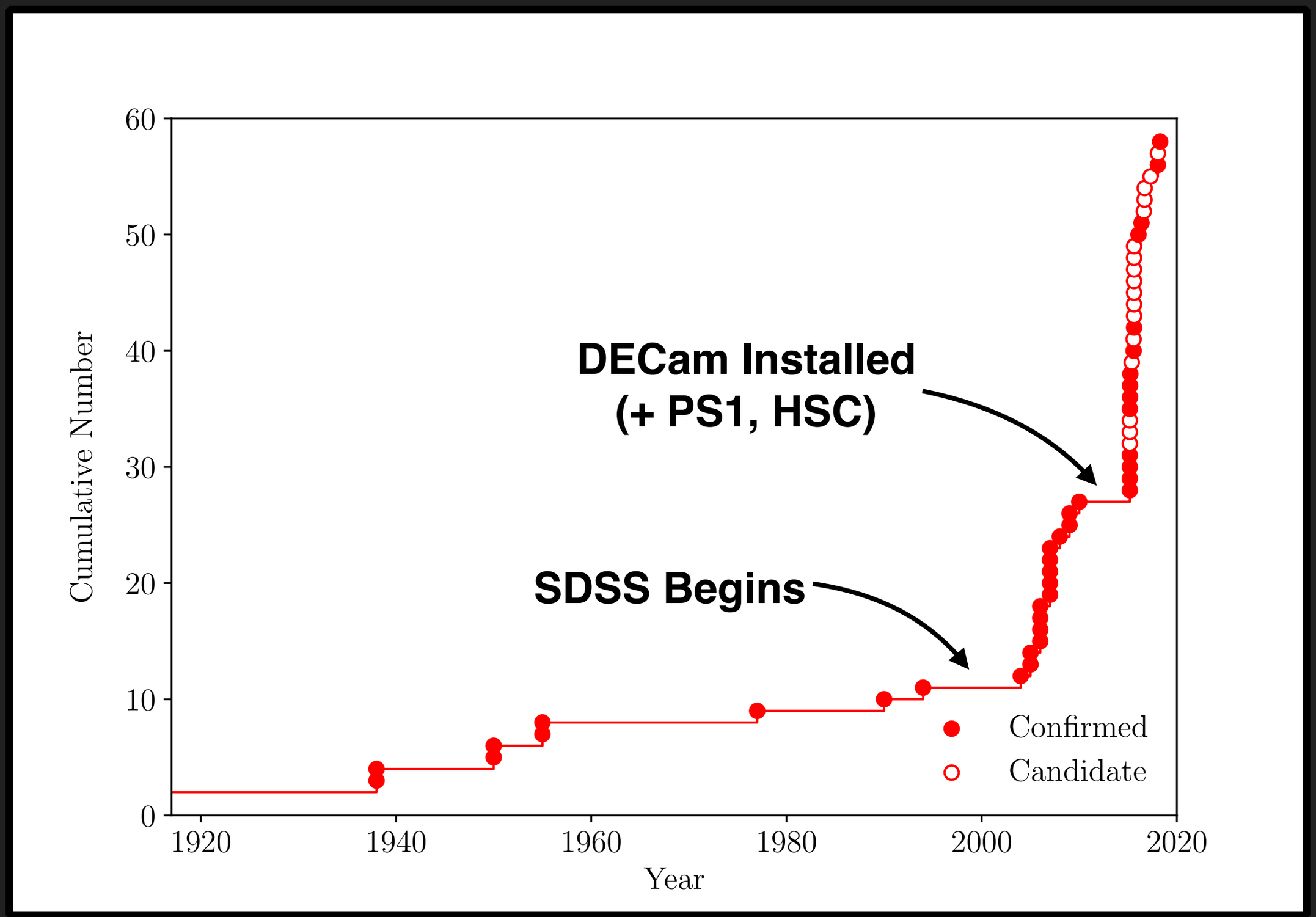
Searching for Magellanic Satellites with DECam

Alex Drlica-Wagner (Fermilab)

Near Field Cosmology Workshop

June 28, 2018

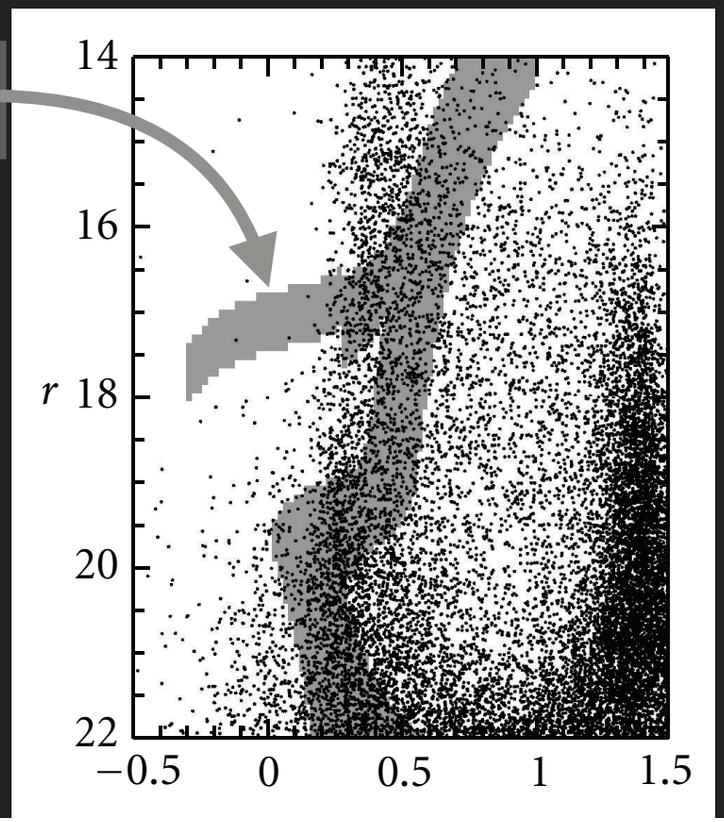
Dwarf Galaxy Discovery Timeline



Matched Filter Searches

Koposov et al. (2008)
Walsh et al. (2009)
Willman et al. (2010)
etc.

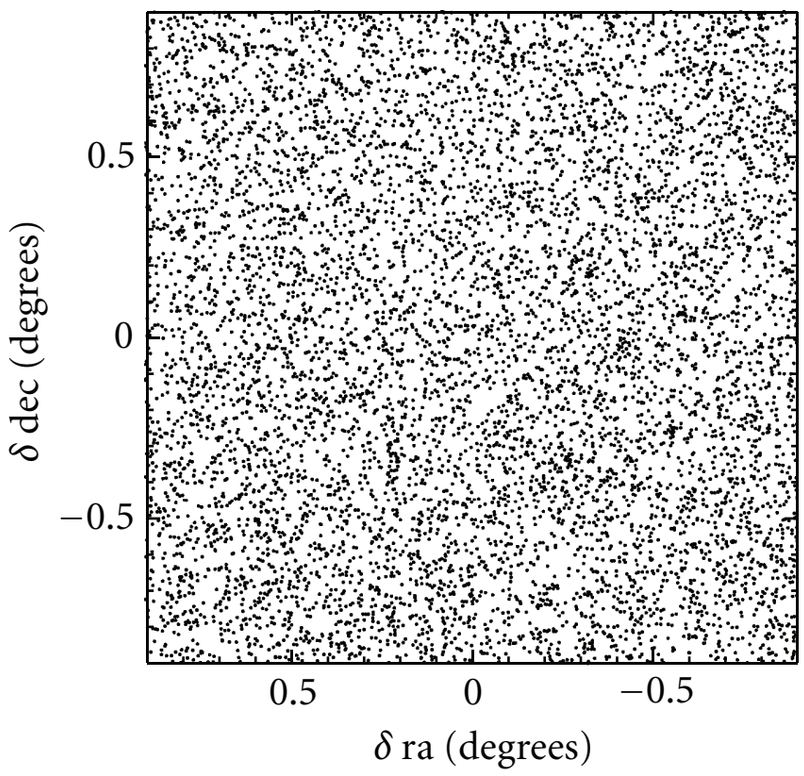
Stellar Isochrone

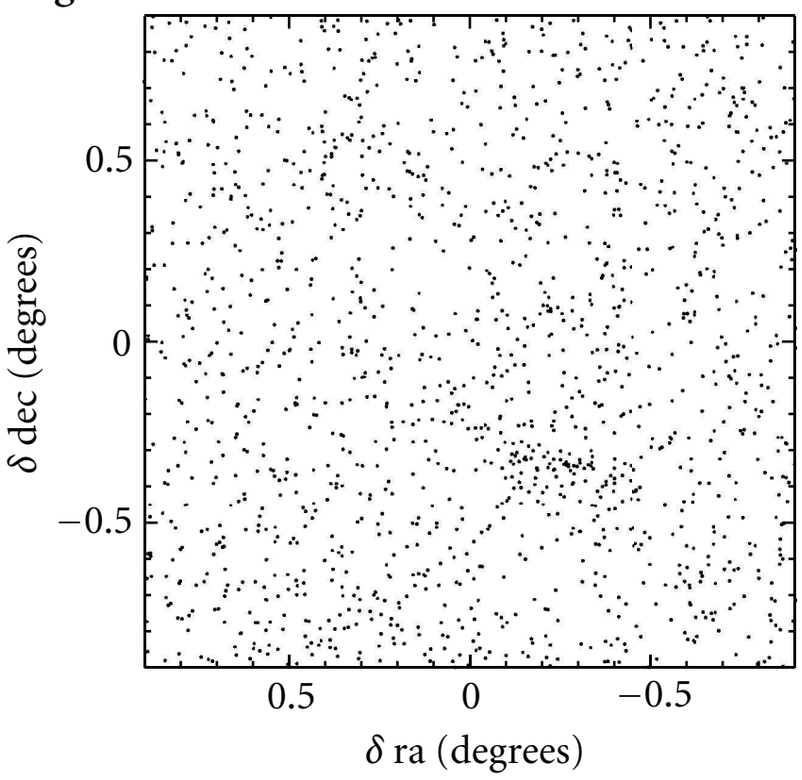


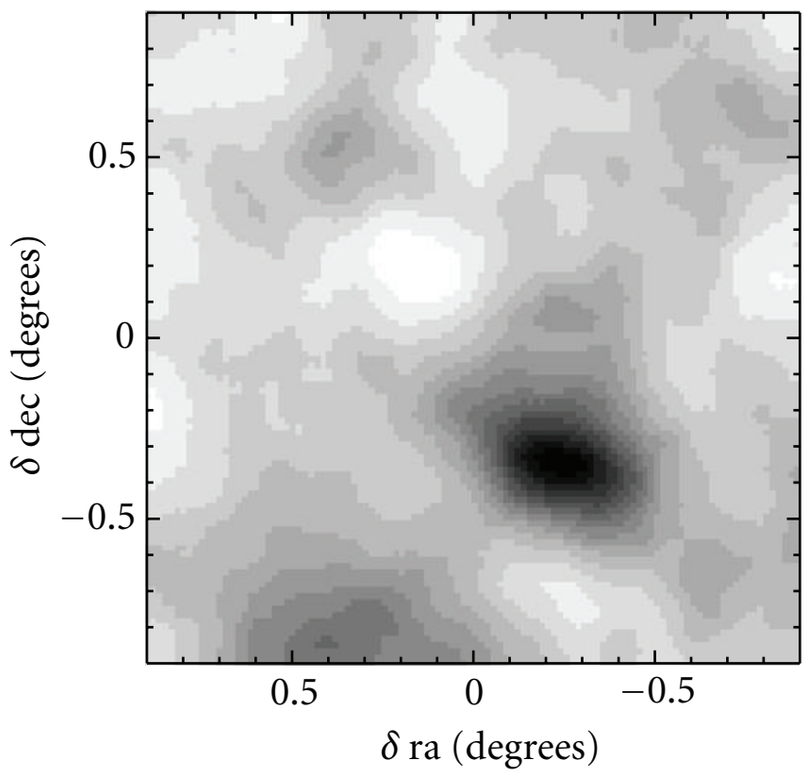
1) Start with a large catalog of stars

2) Apply a selection in color-magnitude space based on a stellar isochrone

3) Convolve with a spatial kernel

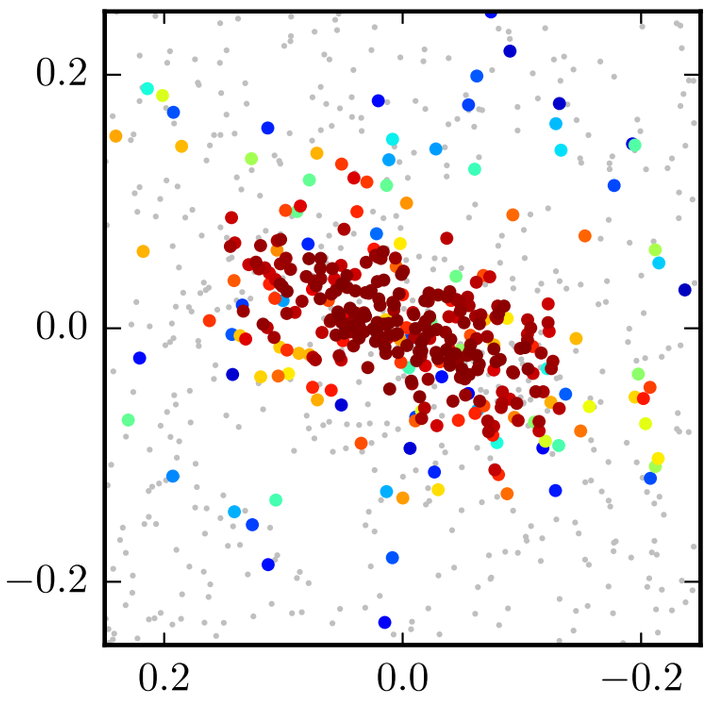




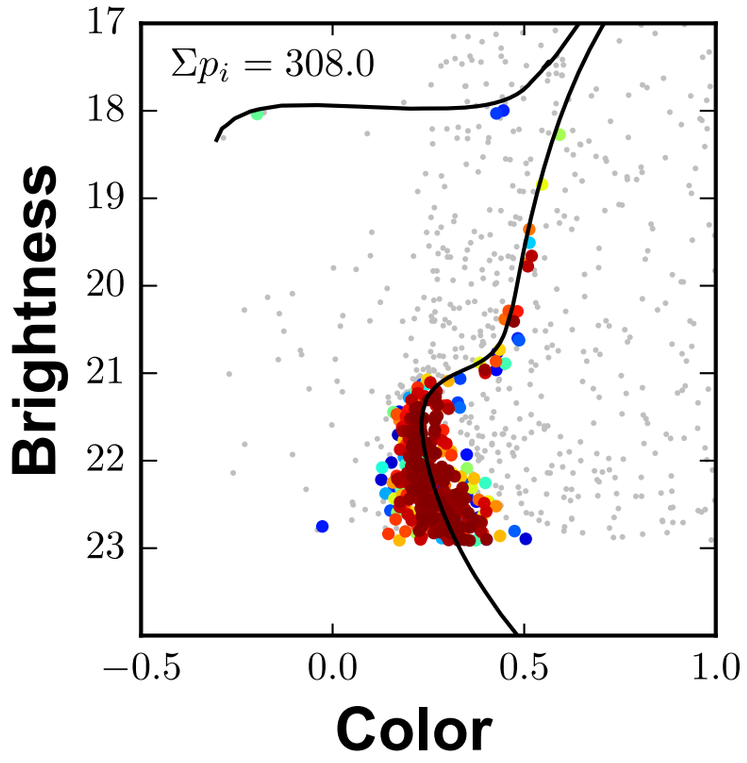


Maximum Likelihood Searches

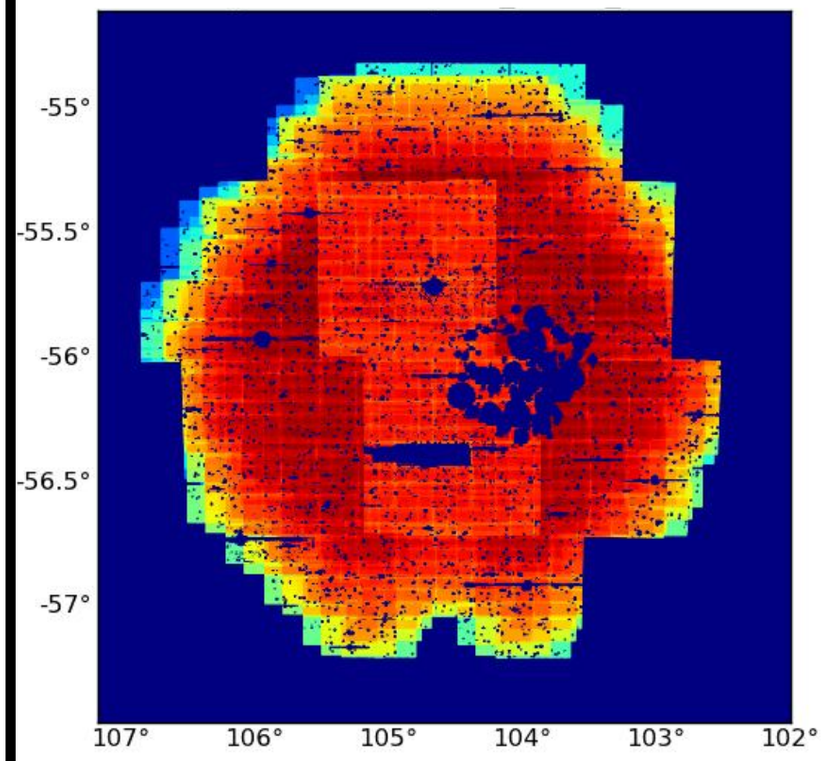
Spatial Model



Spectral Model



Survey Sensitivity



$$p_i = \frac{\lambda u_i}{\lambda u_i + b_i}$$

$$\lambda = \frac{1}{f} \sum_{i \in \text{Stars}} p_i$$

$$\log L = -\sum_{i \in \text{Stars}} \log(1 - p_i) - f\lambda$$

Combine spatial and spectral information

u_i **= signal probability**

b_i **= background probability**

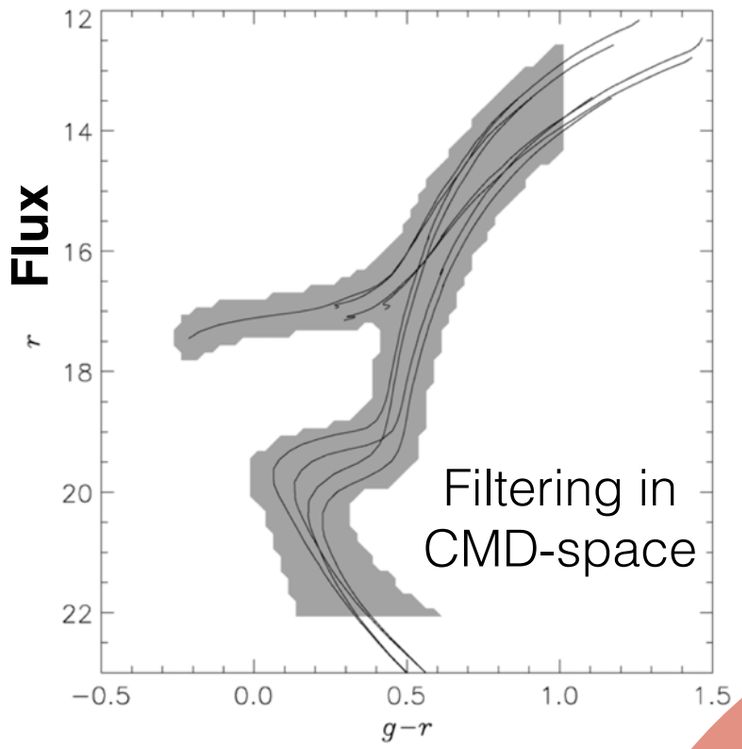
λ **= number of stars in the dwarf**

f **= observable fraction of stars**

Yields a membership probability for each star; important for spectroscopic targeting

Union of Search Strategies

Walsh et al. 2009, AJ, 137, 450



Visual inspection of images and catalogs

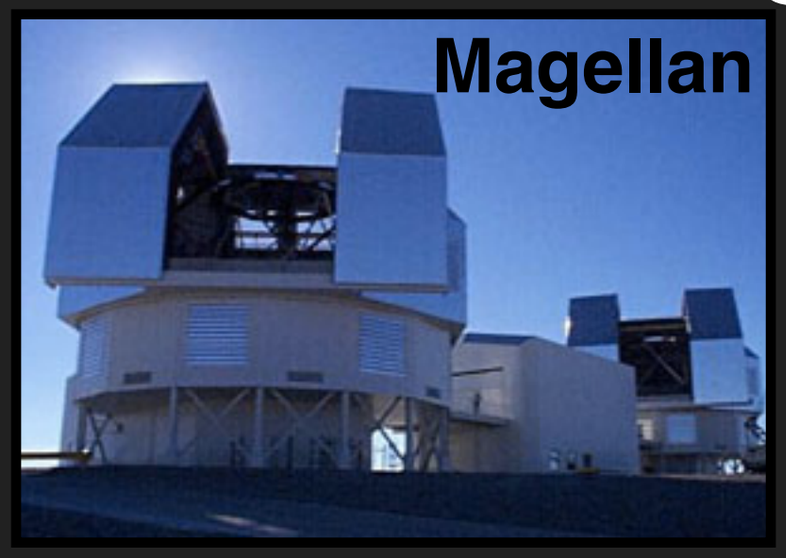
Simple filter

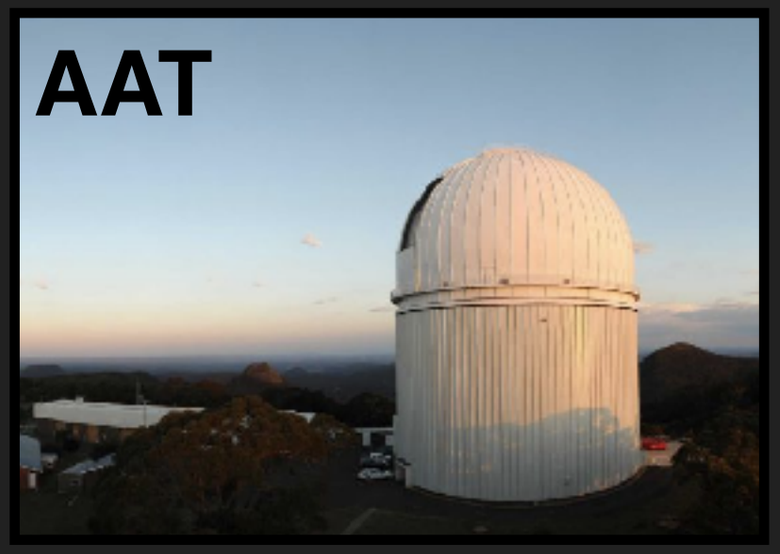
Matched-filters + Maximum-likelihood

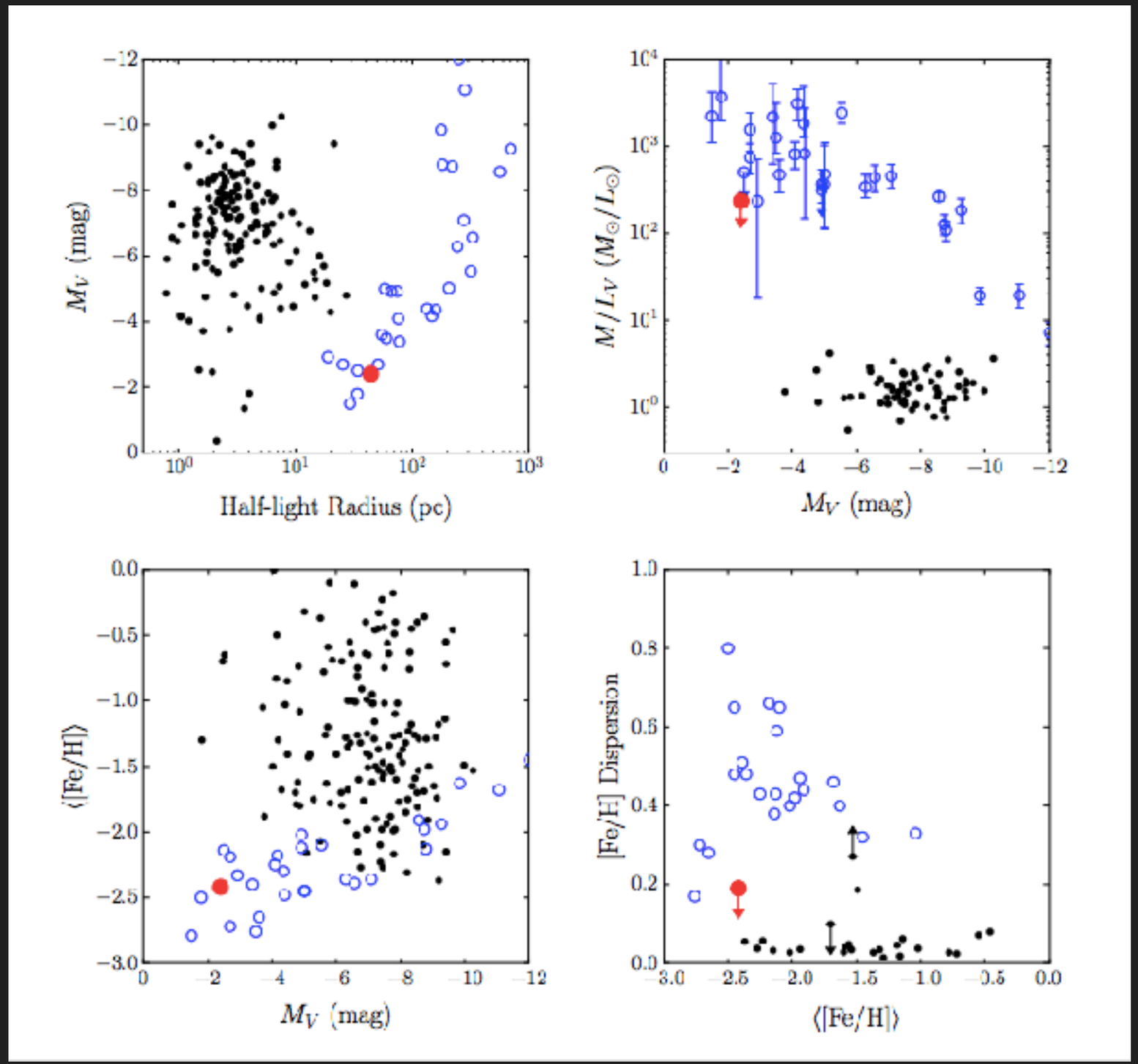
$$\log \mathcal{L} = -f\lambda + \sum_i (1 - p_i)$$

Bechtol et al. 2015, ApJ, 807, 50 Luque et al. 2015, arXiv:1508.02381

Confirming & Classifying Satellites

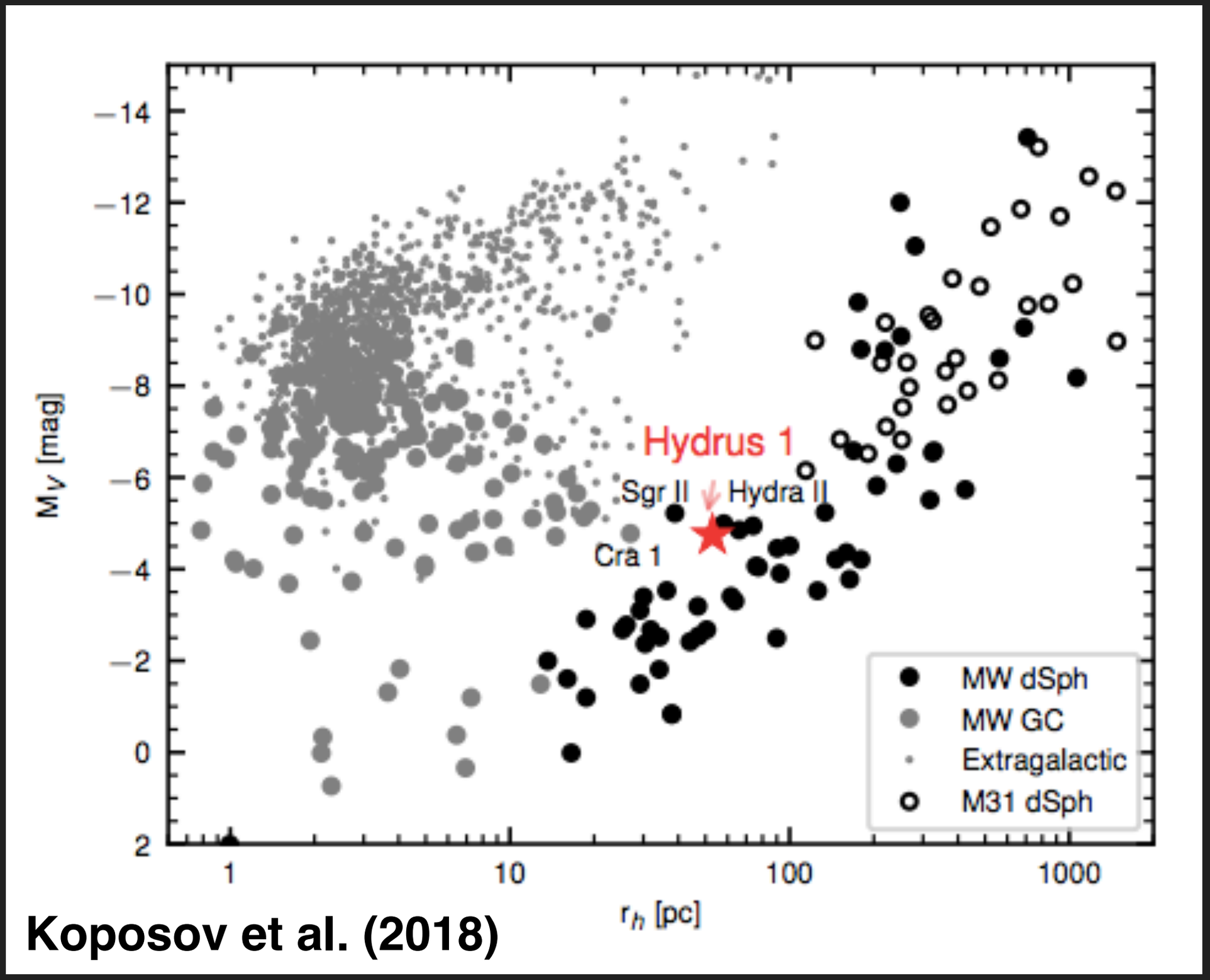






Simon et al. (2016)

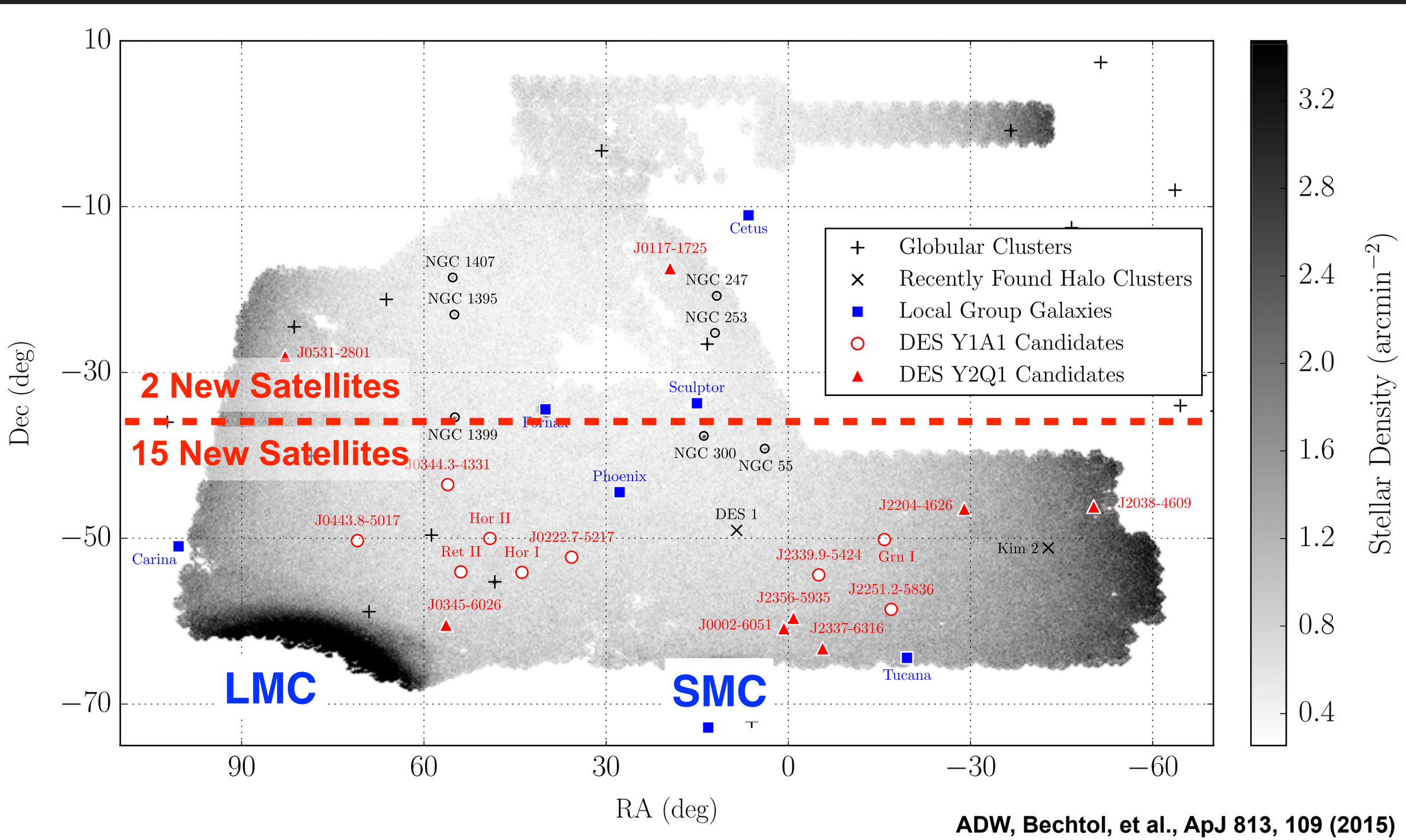
Classification Without Spectroscopy



Koposov et al. (2018)

Anisotropy in the DES Footprint

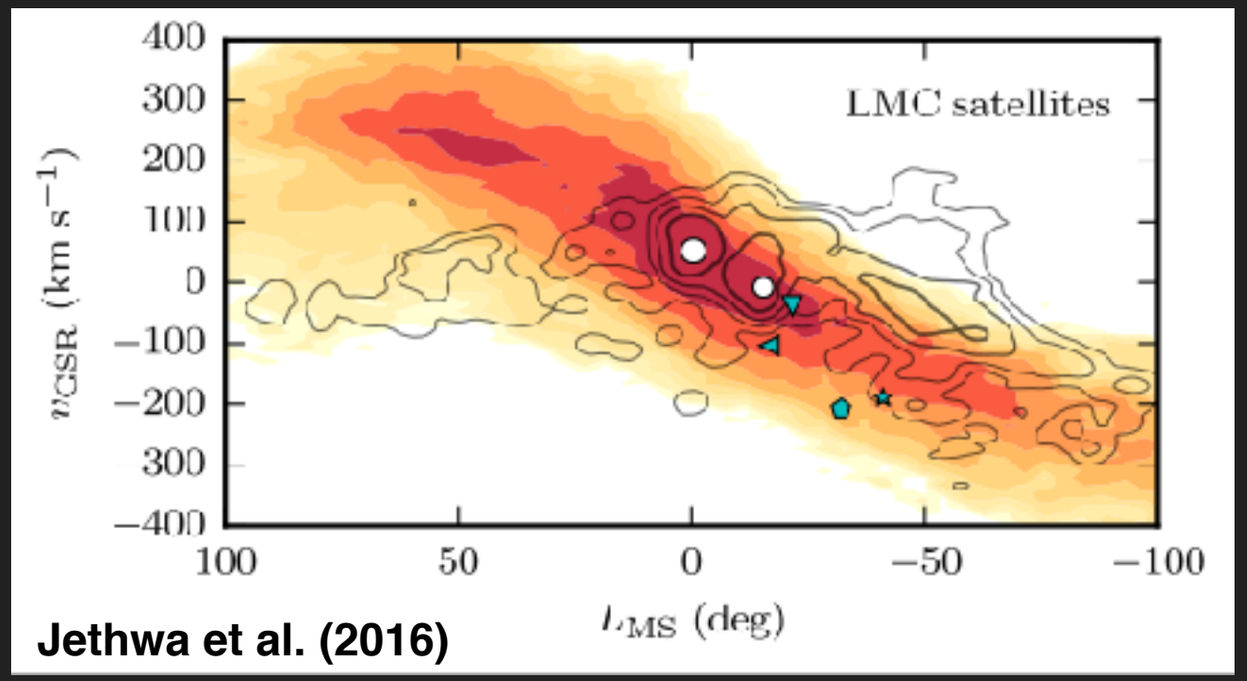
THE DARK ENERGY SURVEY



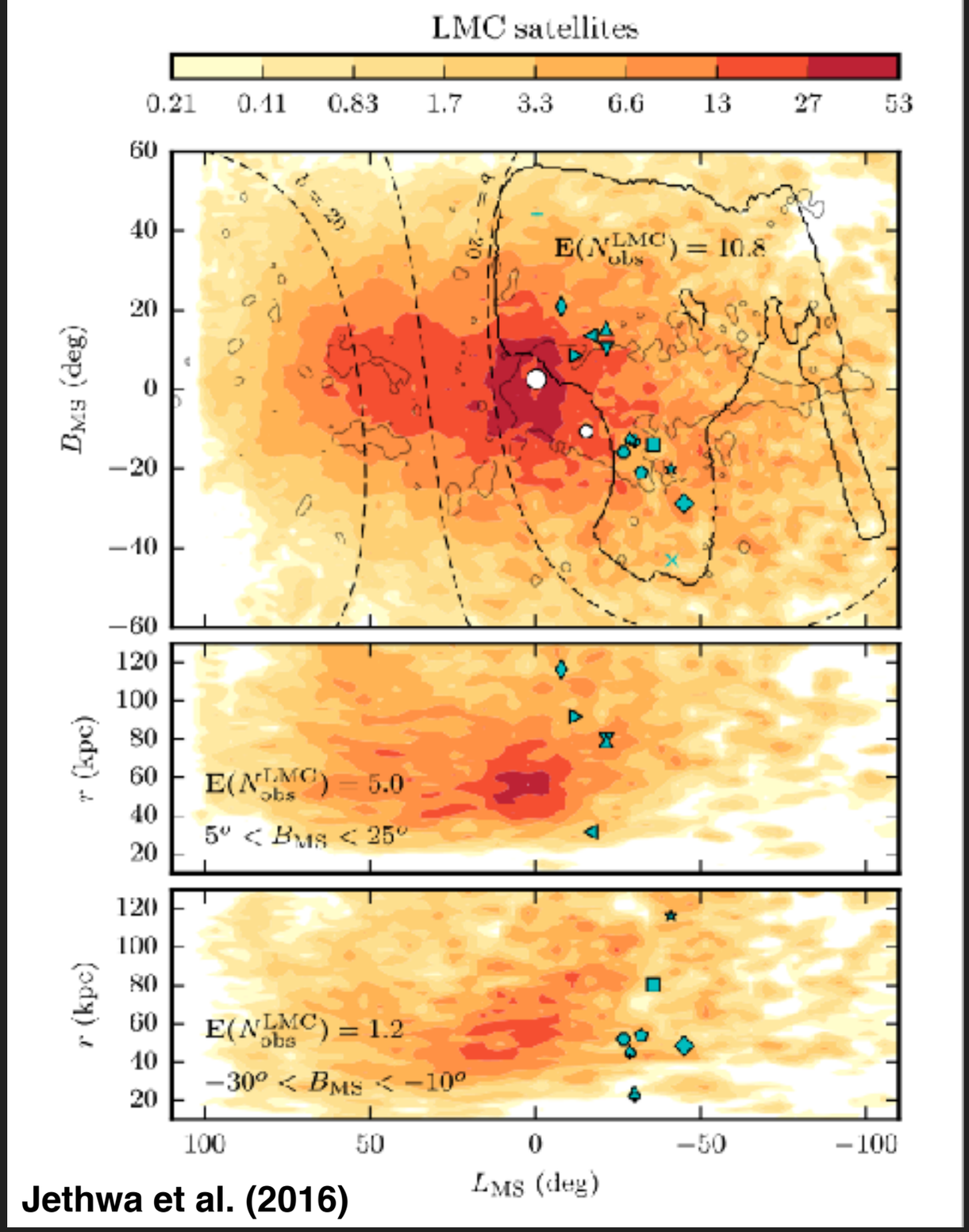
ADW, Bechtol, et al., ApJ 813, 109 (2015)

Magellanic Treasure Map

- Rewind the infall of the LMC+SMC
- Populate the LMC with a population of satellites
- Run forward to predict current distribution of satellites



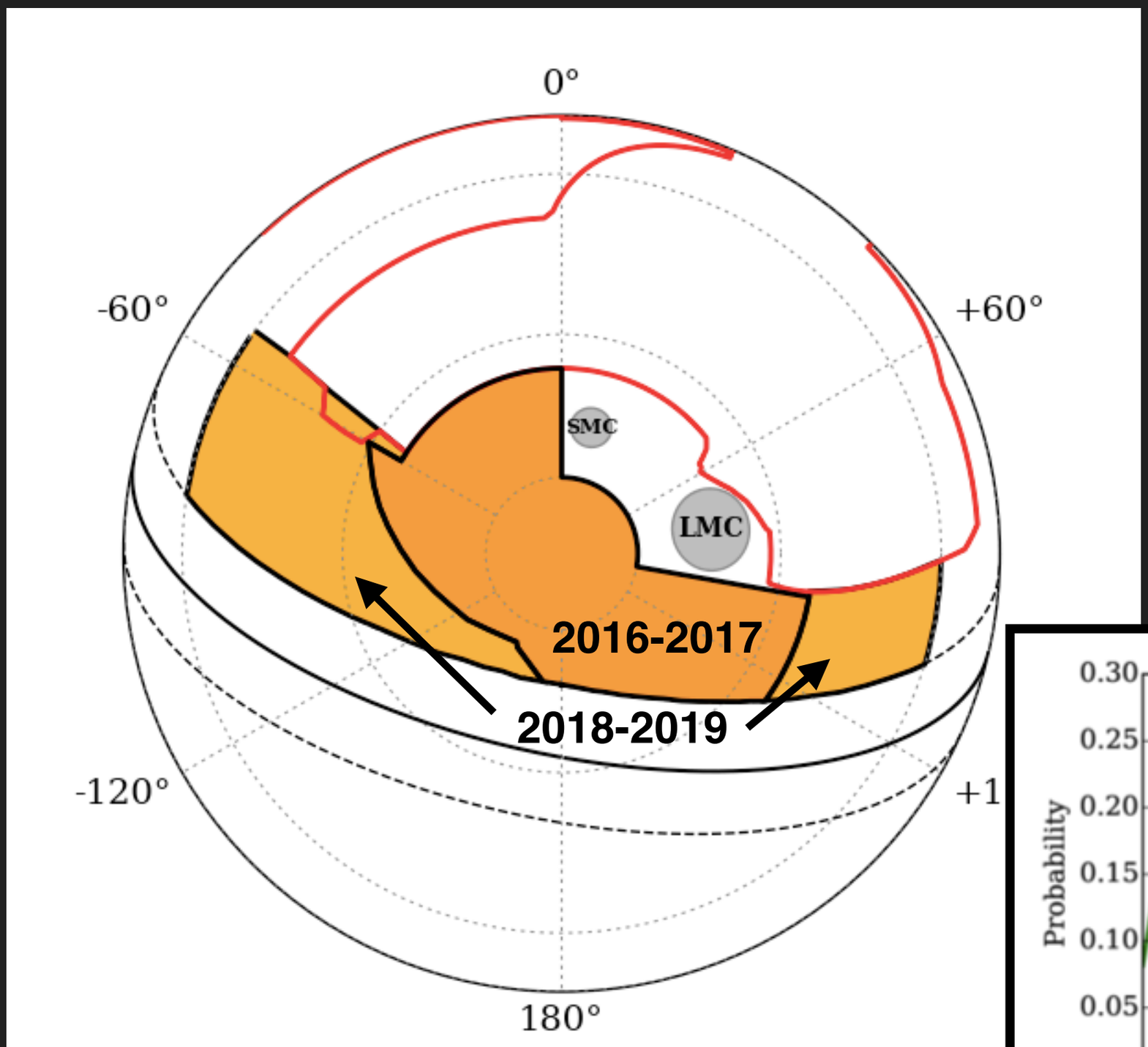
Jethwa et al. (2016)



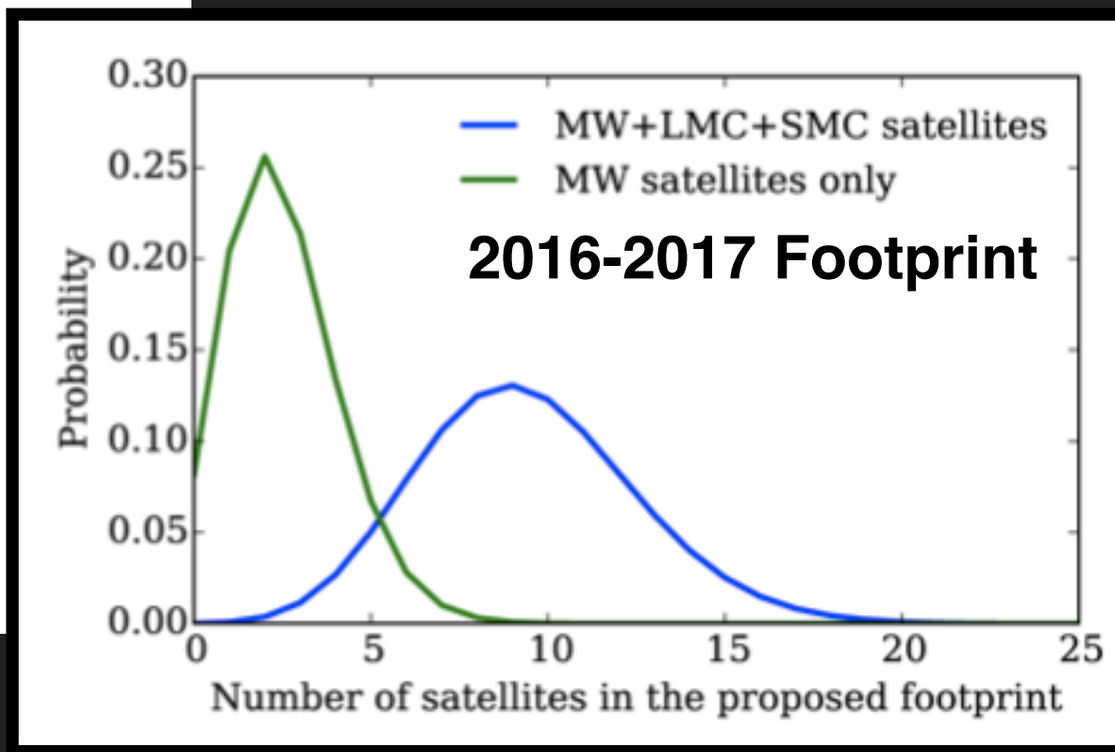
Jethwa et al. (2016)

Magellanic Satellites Survey (MagLiteS)

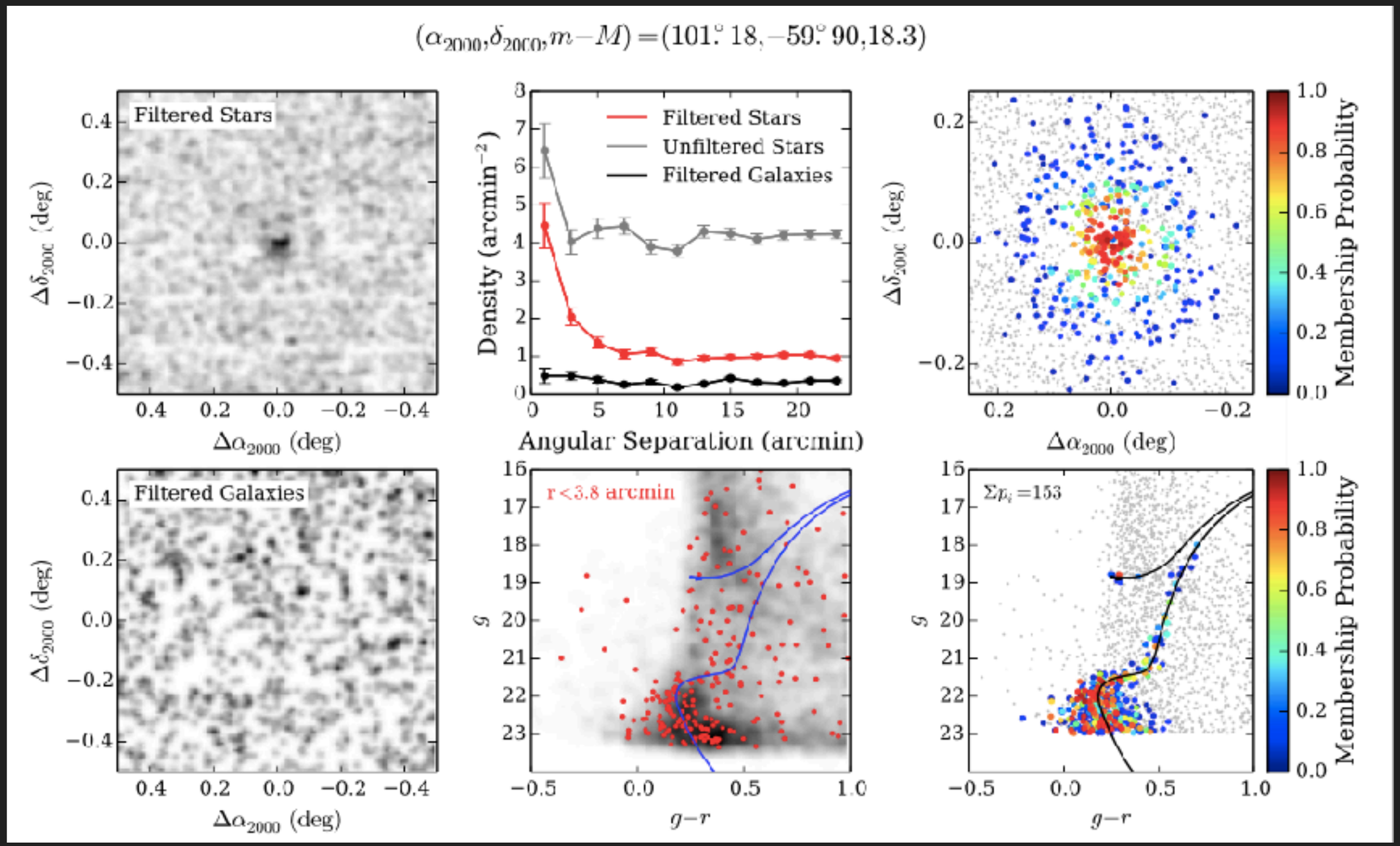
PI: Keith Bechtol



- 3x90s in g,r-band
- g,r ~ 23.5 mag
- Area ~ 2200 deg^2
- 22 nights in 2016-2019

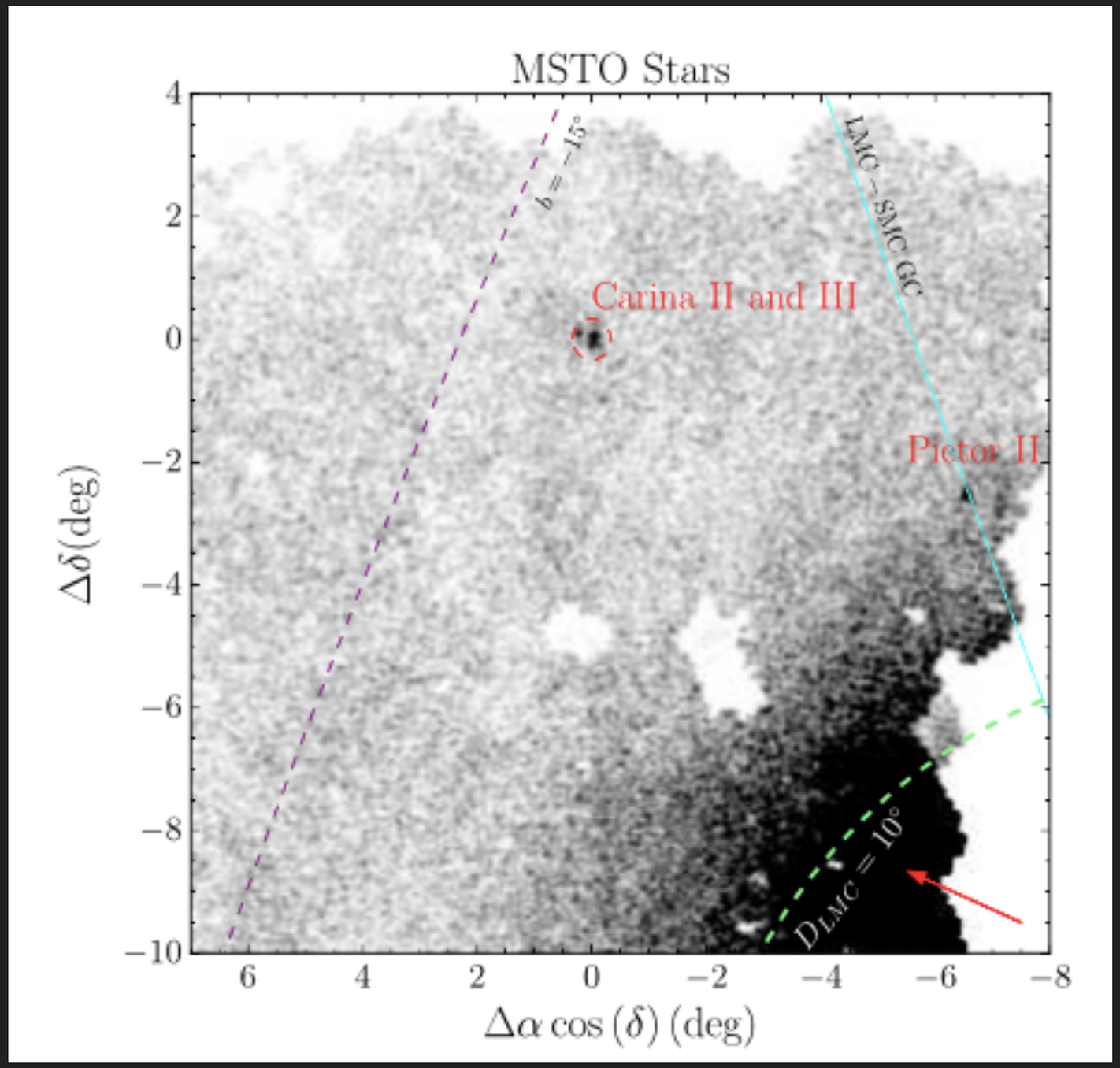


Pictor II

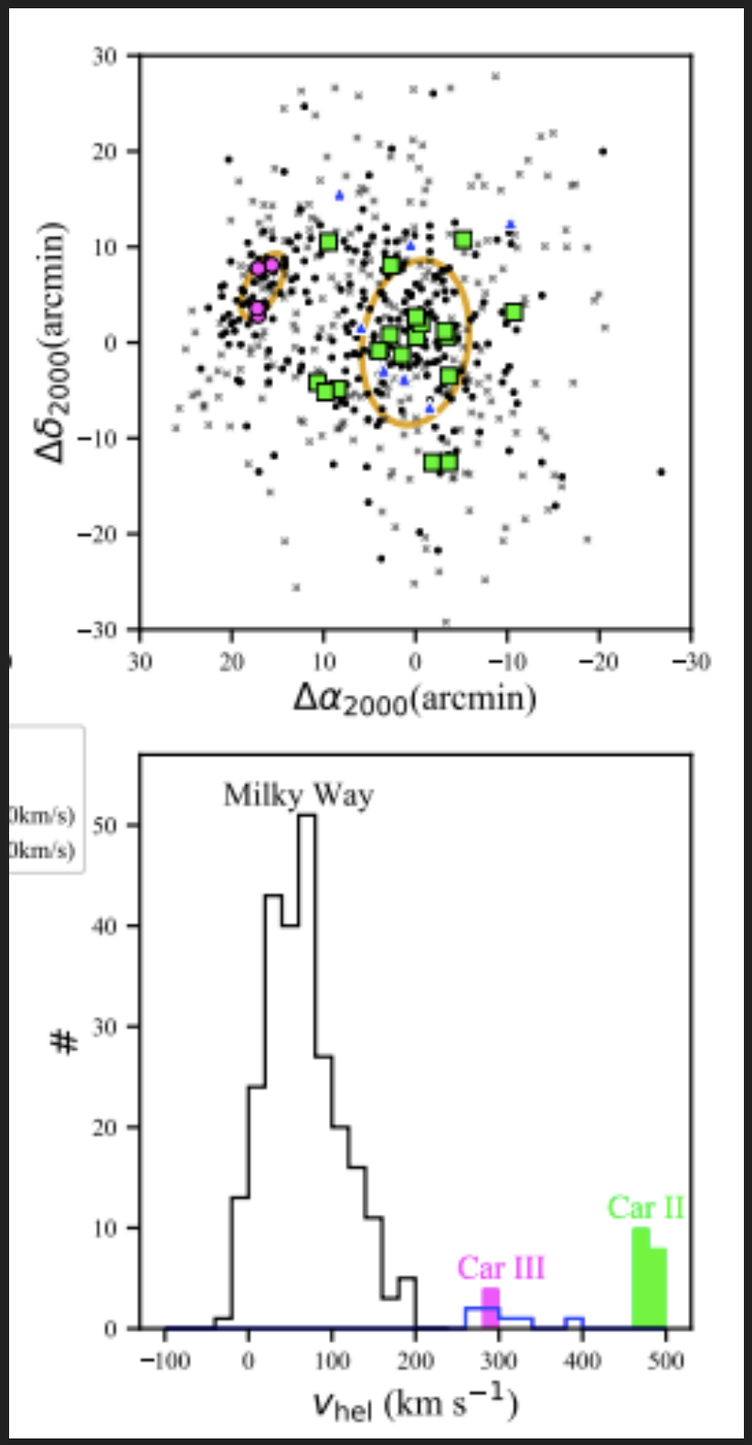


ADW et al. (2016)

Carina II & Carina III

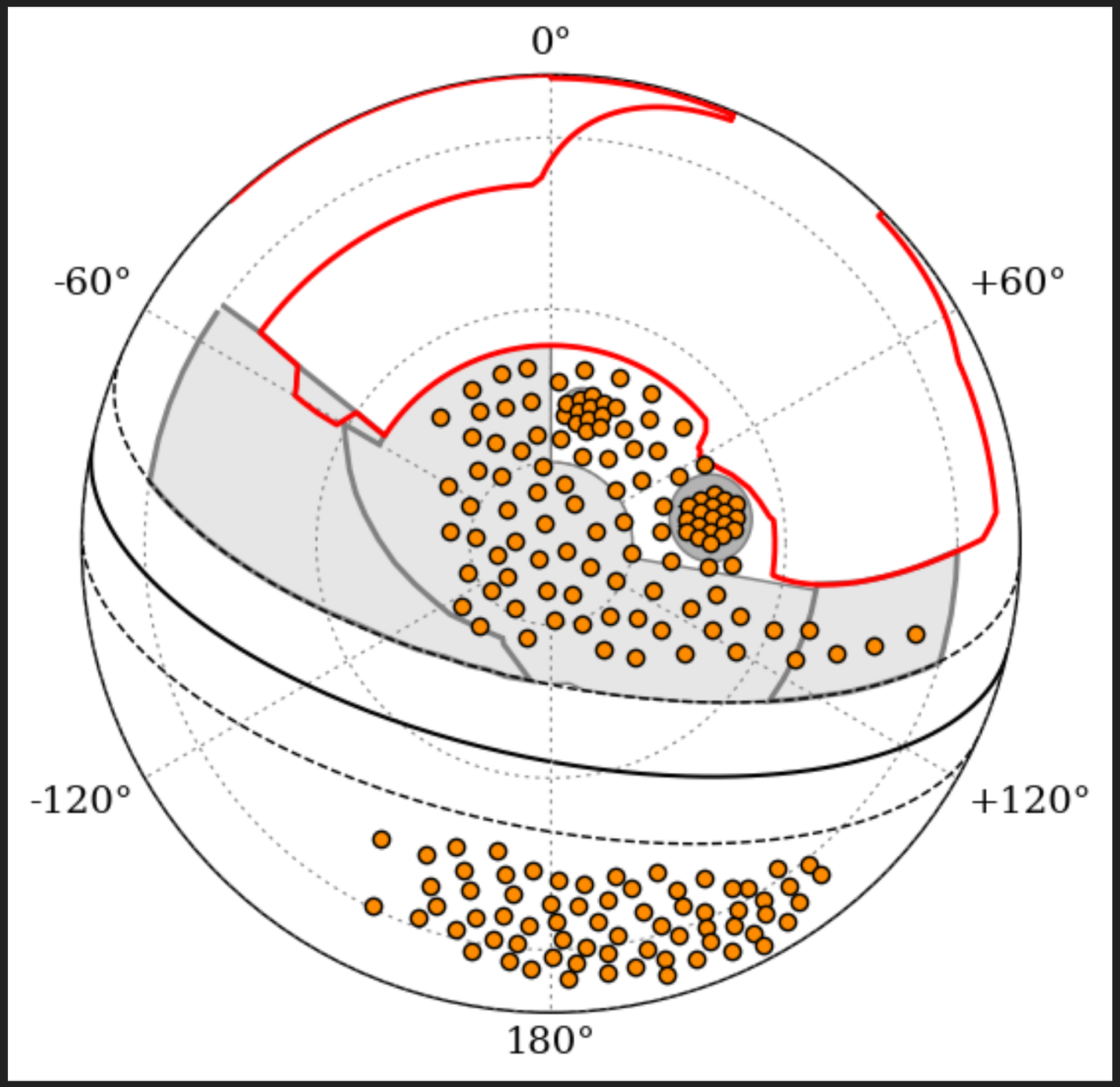


Torrealba et al. (2018)



Li et al. (2018)

Survey of the Magellanic Stellar History (SMASH)



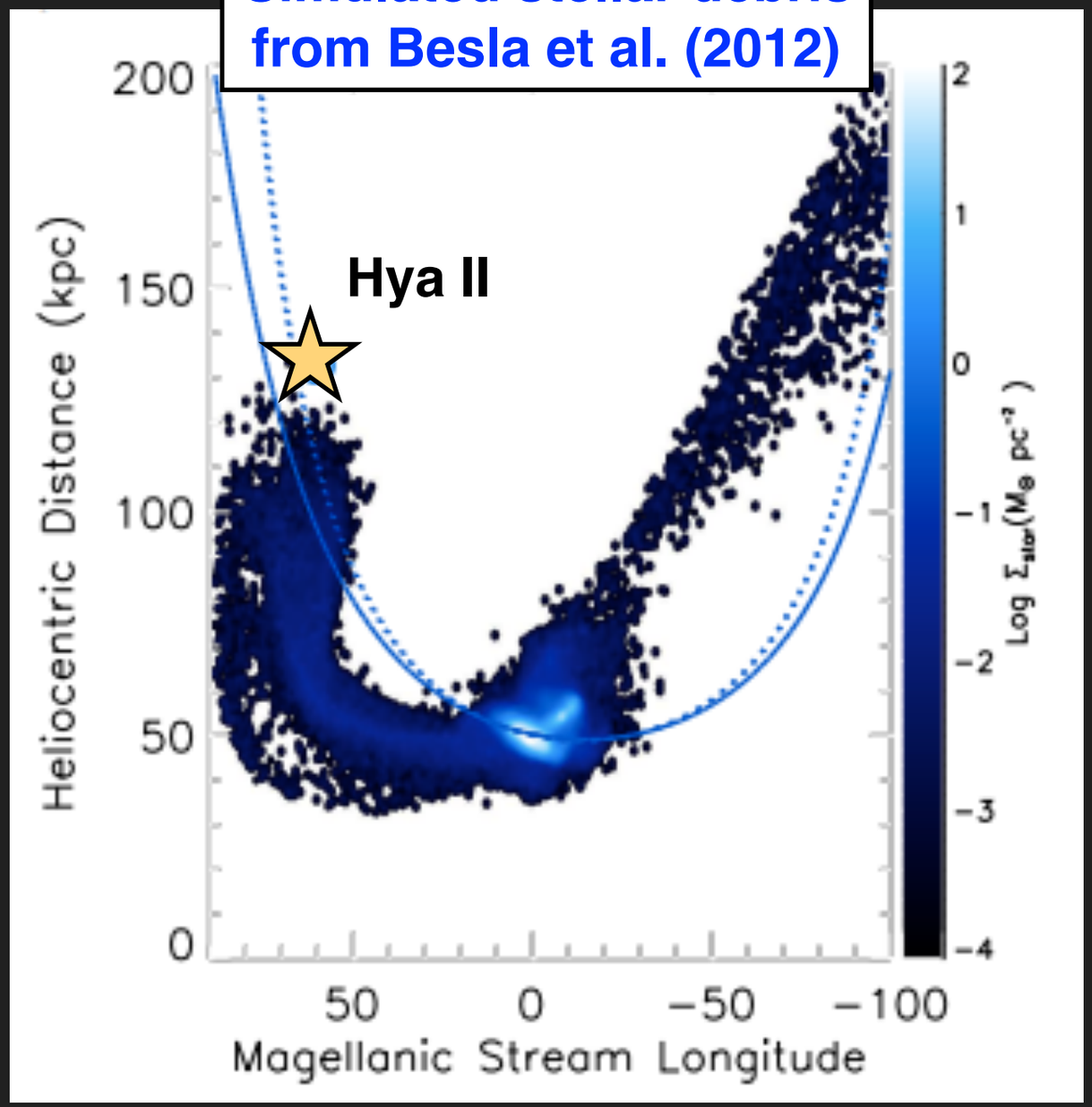
PI: David Nidever

See Yumi Choi's talk yesterday

- ~57 nights allocated between 2012-2016
- 480 deg^2 sparsely distributed over ~2400 deg^2
- ugriz ~ 24 mag

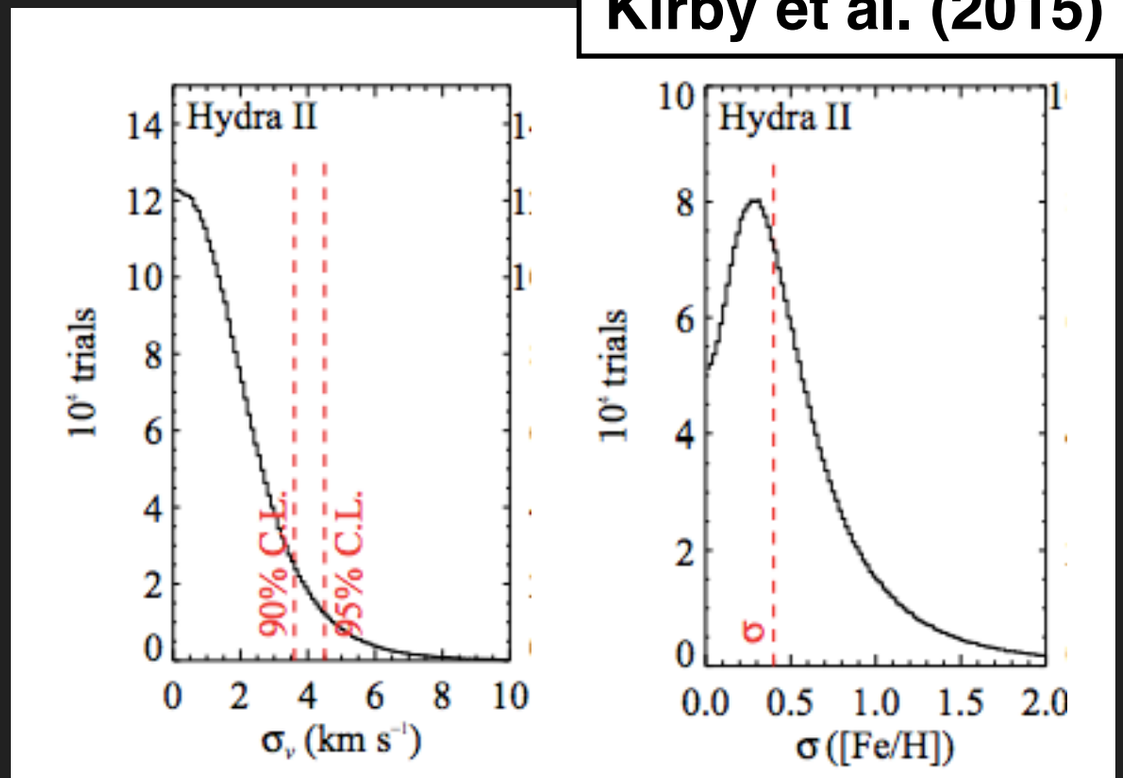
Hydra II

Simulated stellar debris from Besla et al. (2012)



Martin et al. 2015

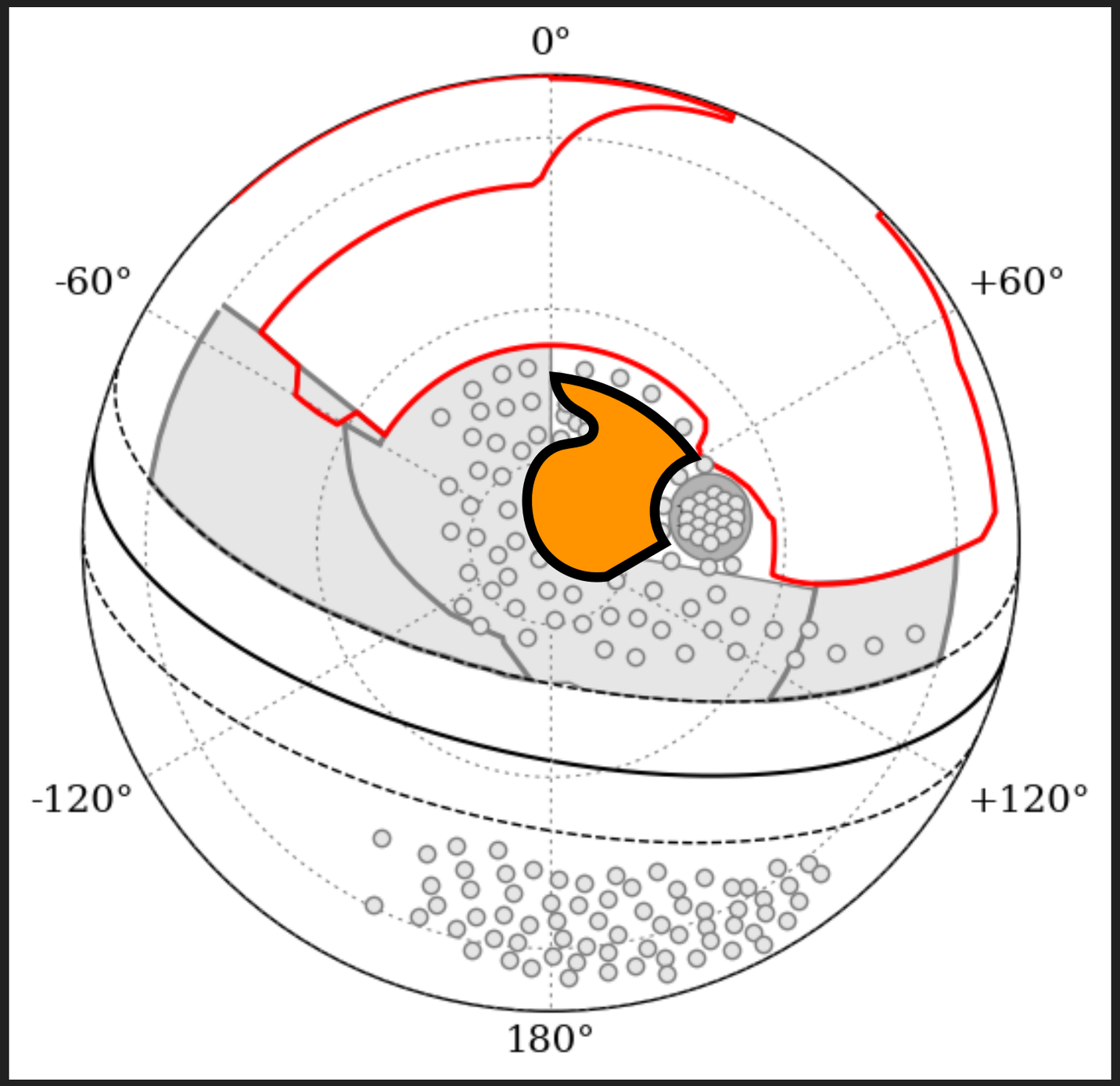
Kirby et al. (2015)



Unresolved velocity dispersion; marginally resolved metallicity dispersion

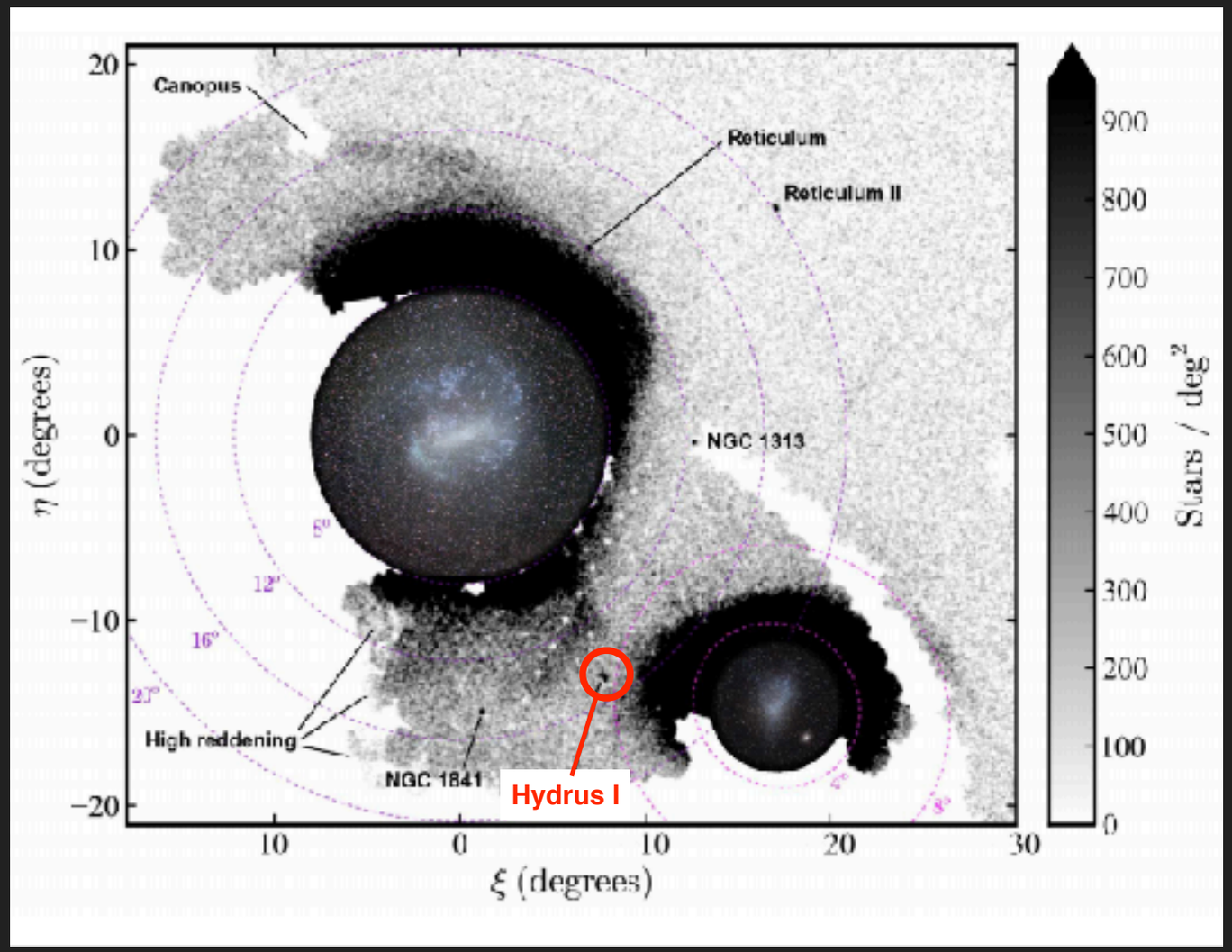
Magellanic Periphery Survey

PI: Dougal Mackey

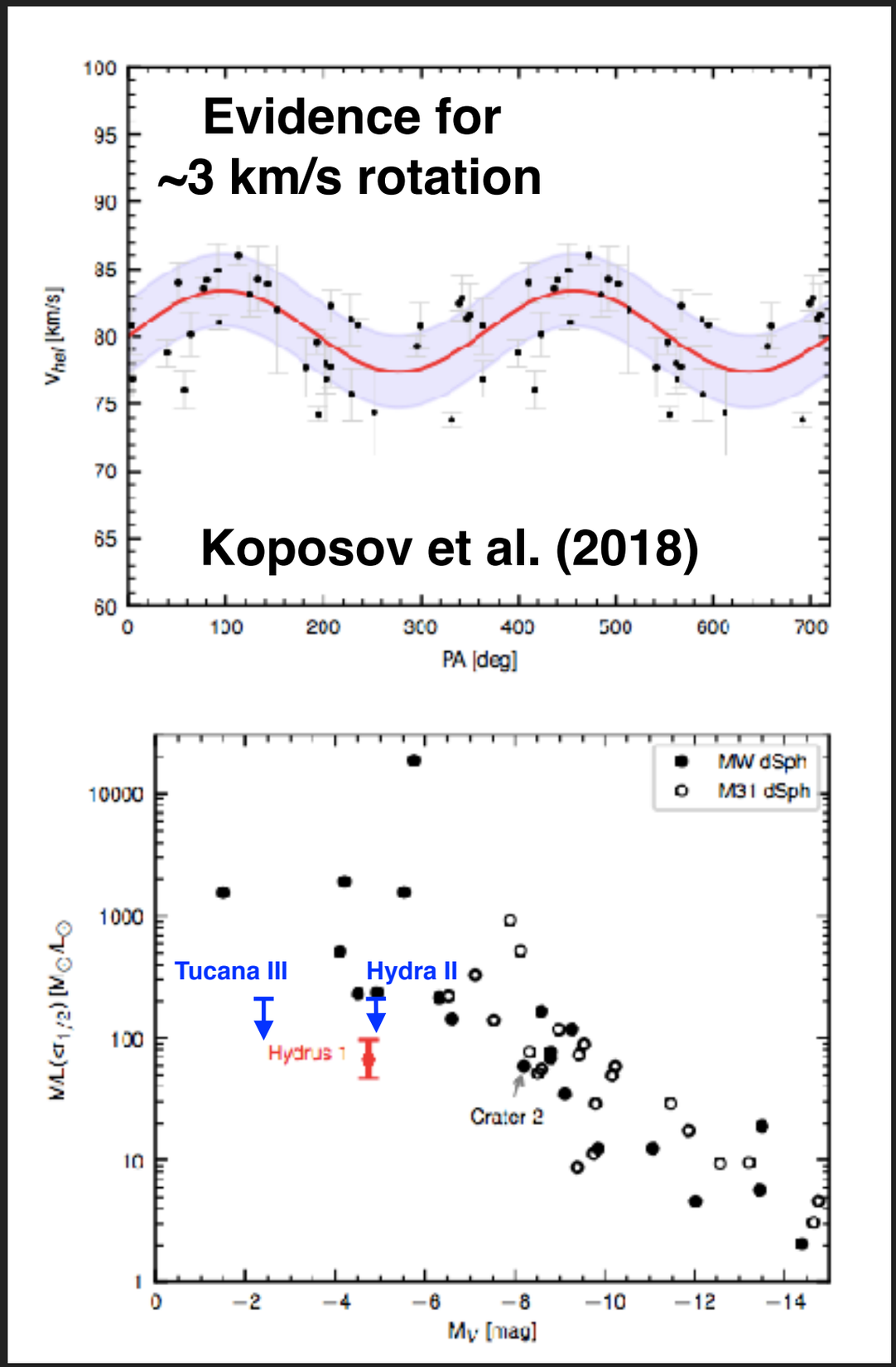


- Contiguous observation in the bridge between the LMC & SMC
- 4 nights in 2016-2017
- ~440 deg^2
- g,r ~ 23.5 mag

Hydrus I

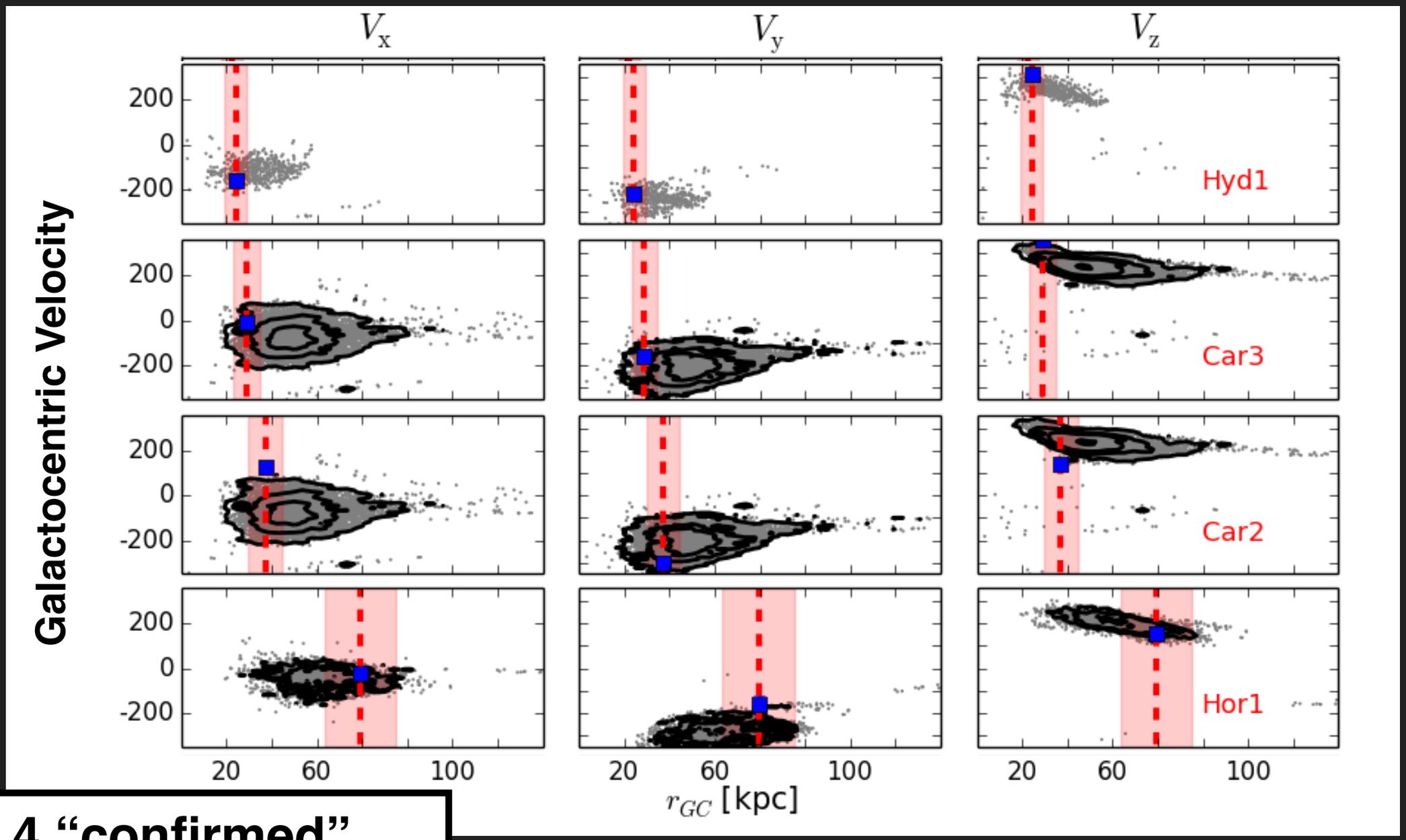


Mackey et al. (2018)



Adding Gaia Proper Motions

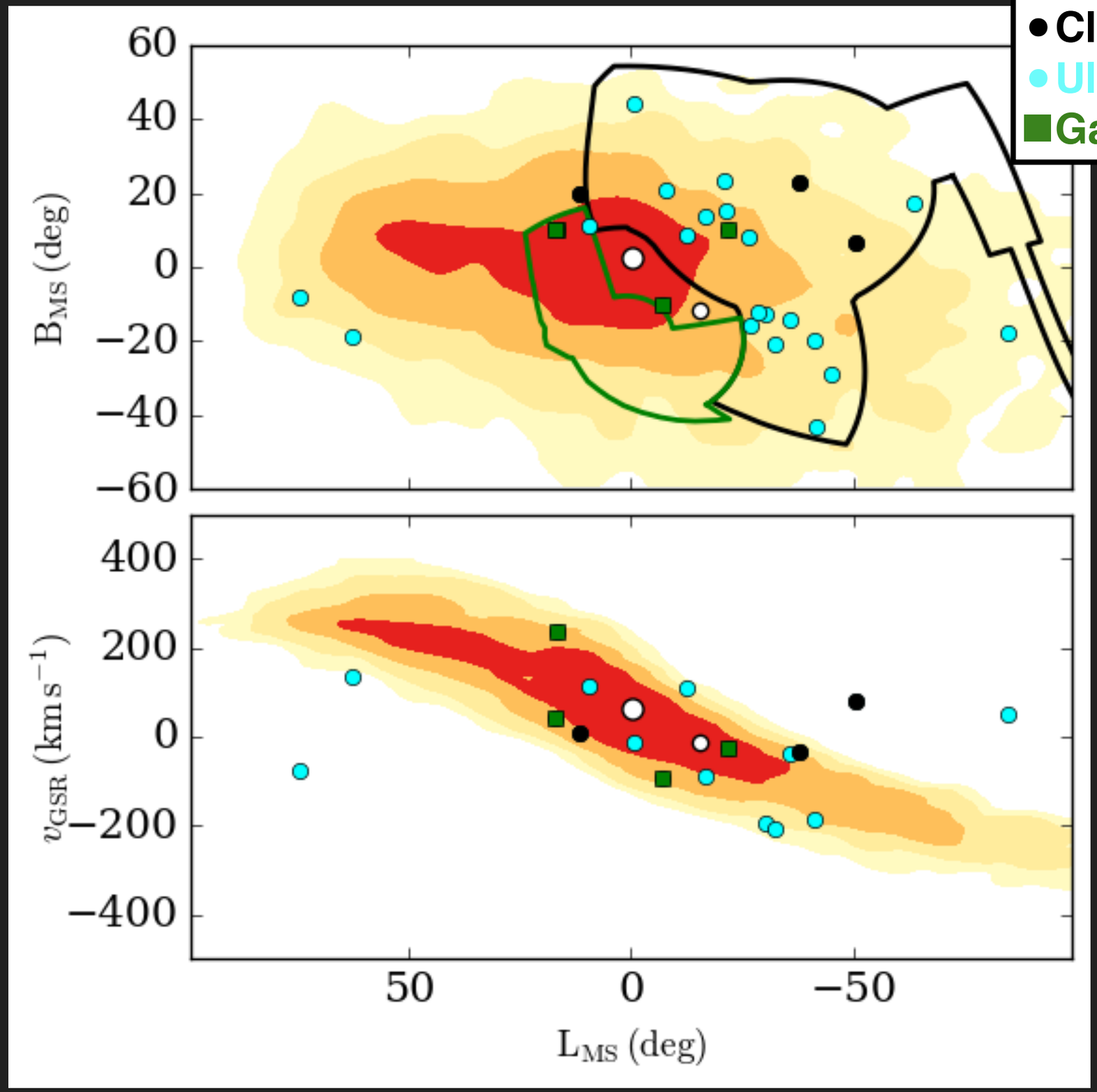
Compare 6D phase space to LMC-analog debris in Aquarius simulation (a la Sales et al. 2011, 2017)



4 “confirmed” Magellanic satellites

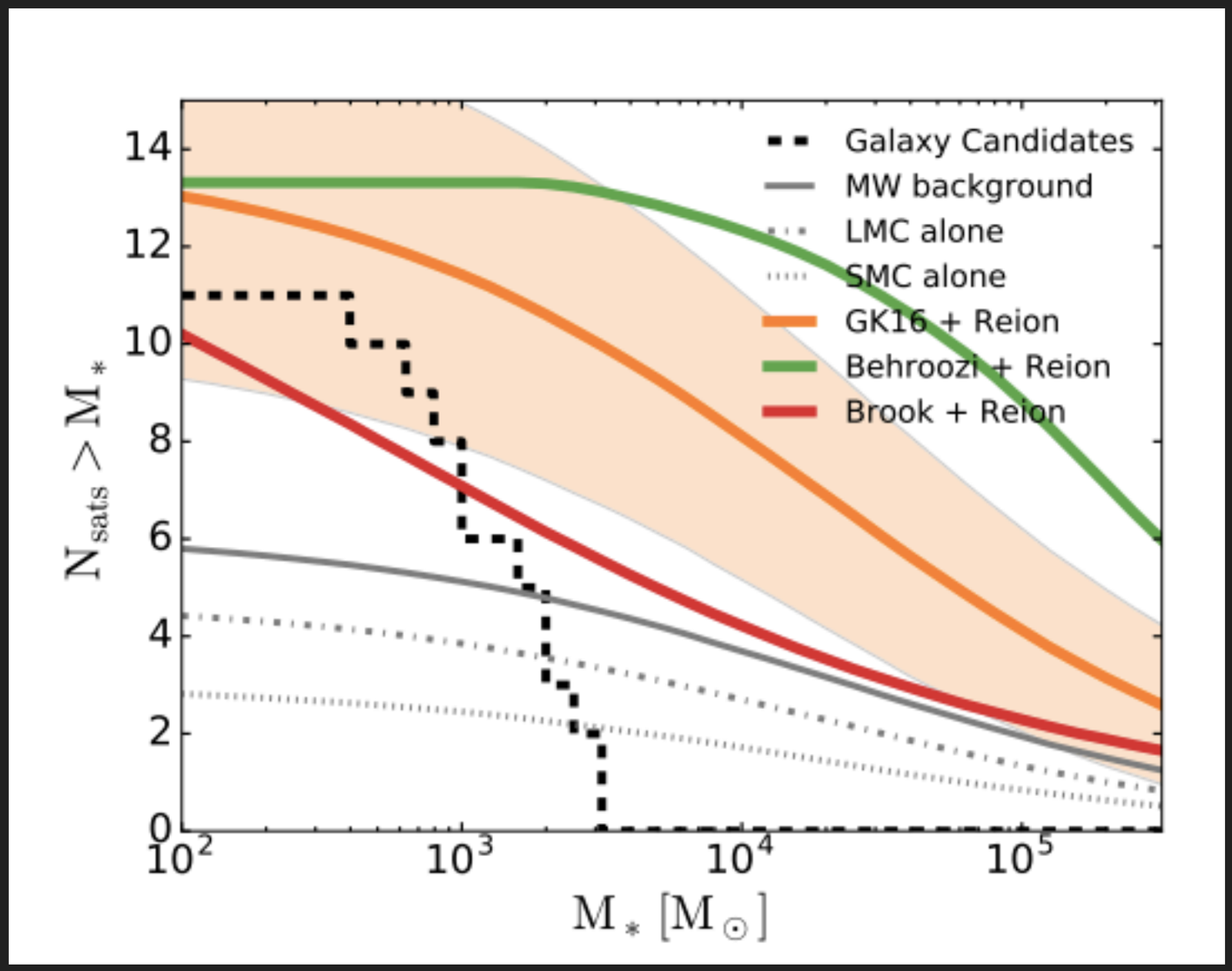
Kallivayalil et al. (2018)

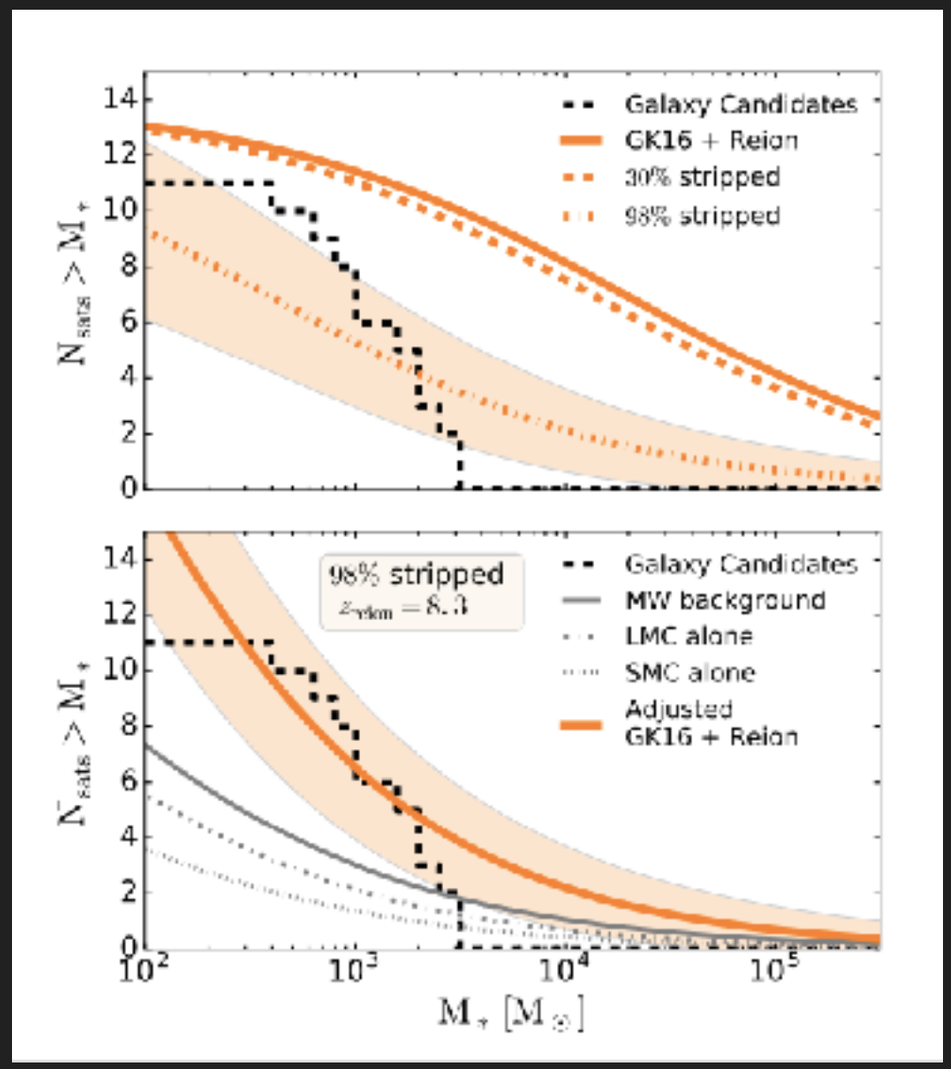
Magellanic Treasure Map



Missing Satellites of the LMC?

Hard to solve with just reionization, stellar stripping, or lower halo mass threshold for star formation





Dooley et al. (2017)

A combination of late reionization and stellar stripping get closer…

Conclusions

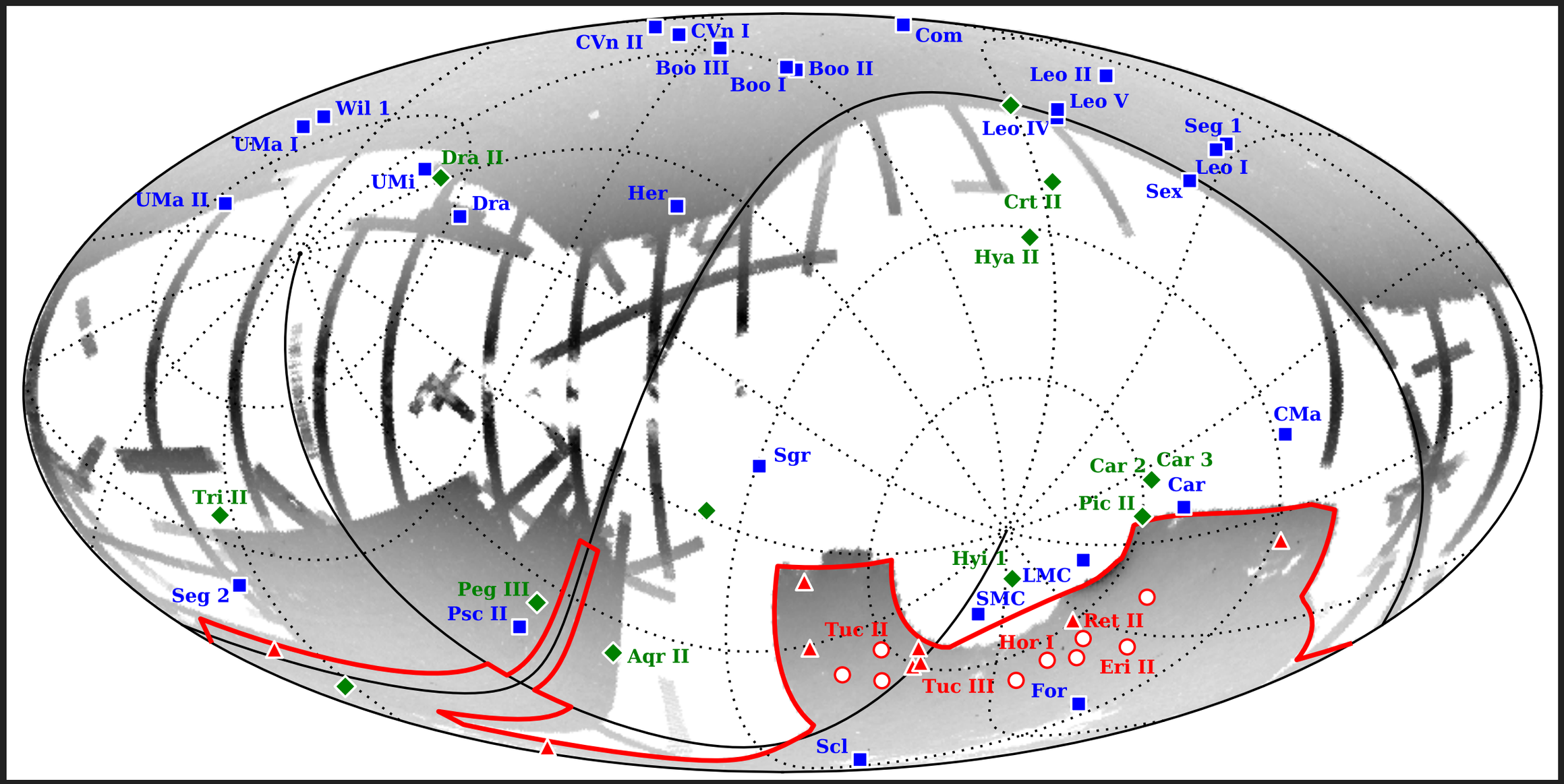
- Various authors predict 4 - 12 observed satellites could have originated with the Magellanic Clouds.
- Total contribution of Magellanic satellites between 1% - 30% of total Milky Way satellite population.
- Satellite distribution can be used to estimate properties of the LMC (mass, accretion time, etc.)
- Lack of *bright* ($M^* > 10^4\ M_\odot$) Magellanic satellites compared to predictions from simulations?

Backup

Incomplete Reference List

- Bechtol et al. (2015) [1503.02584]
- Koposov et al. (2015) [1503.02079]
- Drlica-Wagner et al. (2015) [1508.03622]
- Martin et al. (2015) [1503.06216]
- Deason et al. (2015) [1504.04372]
- Drlica-Wagner et al. (2016) [1609.02148]
- Simon et al. (2016) [1610.05301]
- Torrealba et al. (2018) [1801.07279]
- Dooley et al. (2017) [1703.05321]
- Nidever et al. (2017) [1701.00502?]
- Mackey et al. (2018) [1804.06431]
- Koposov et al. (2018) [1804.06430]
- Kallivayalil et al. (2018) [1805.01448]

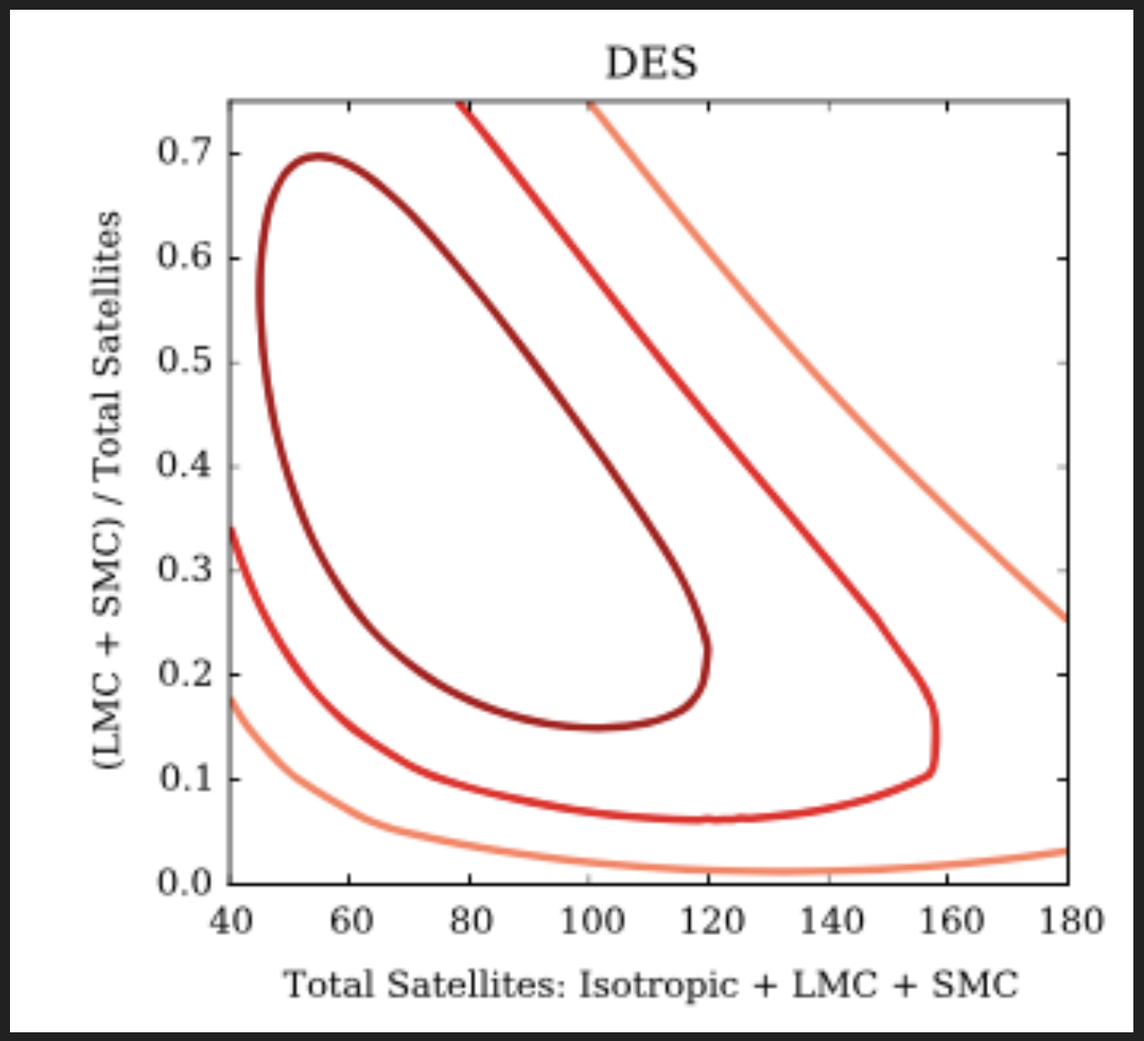
Sky Coverage



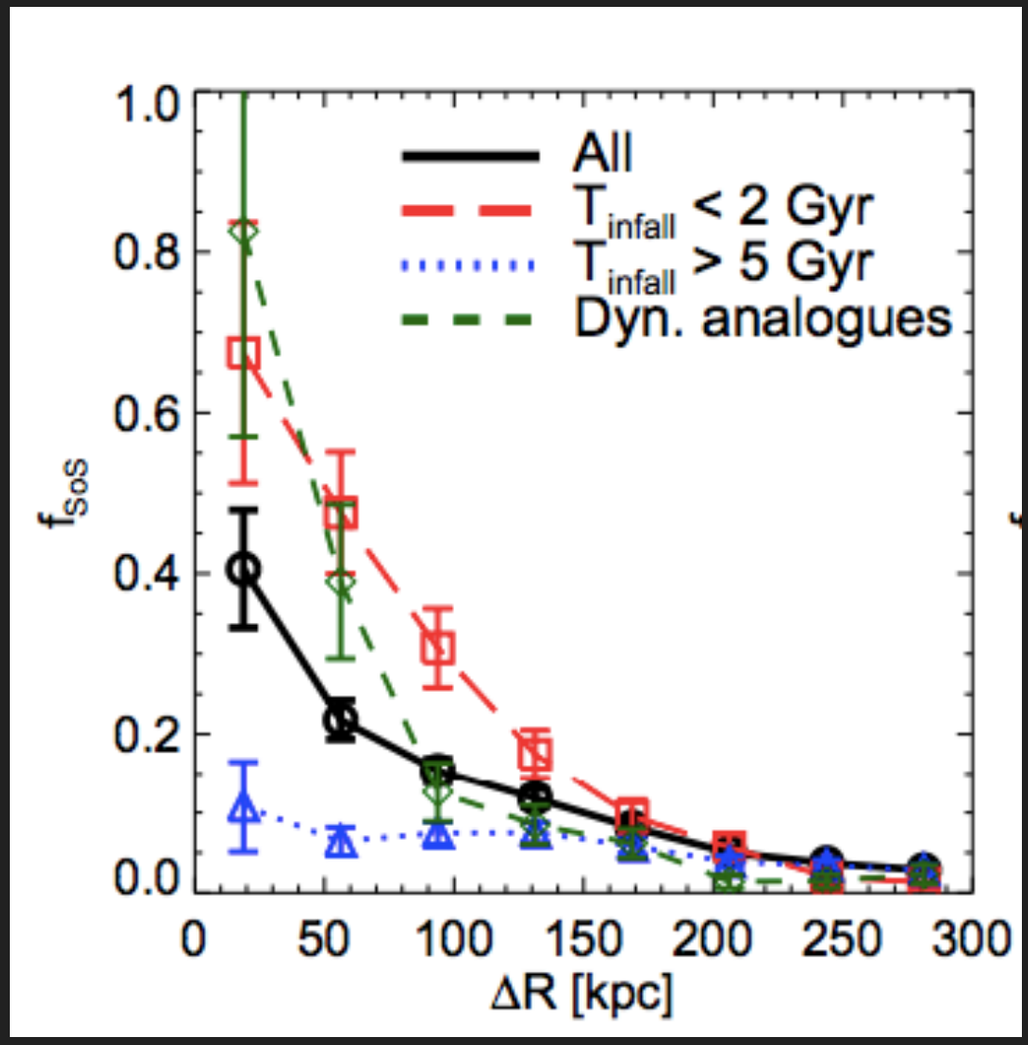
Fraction of satellites originating with the LMC

- Drlica-Wagner et al. (2015): ~30%
- Deason et al. (2015): 1%-25%
- Jethwa et al. (2016): 33%
- Sales et al. (2017): 5%
- Dooley et al. (2015): 15%-25%

Fraction of LMC Satellites



ADW, Bechtol et al. (2015)



Deason et al. (2015)