

Antlia 2

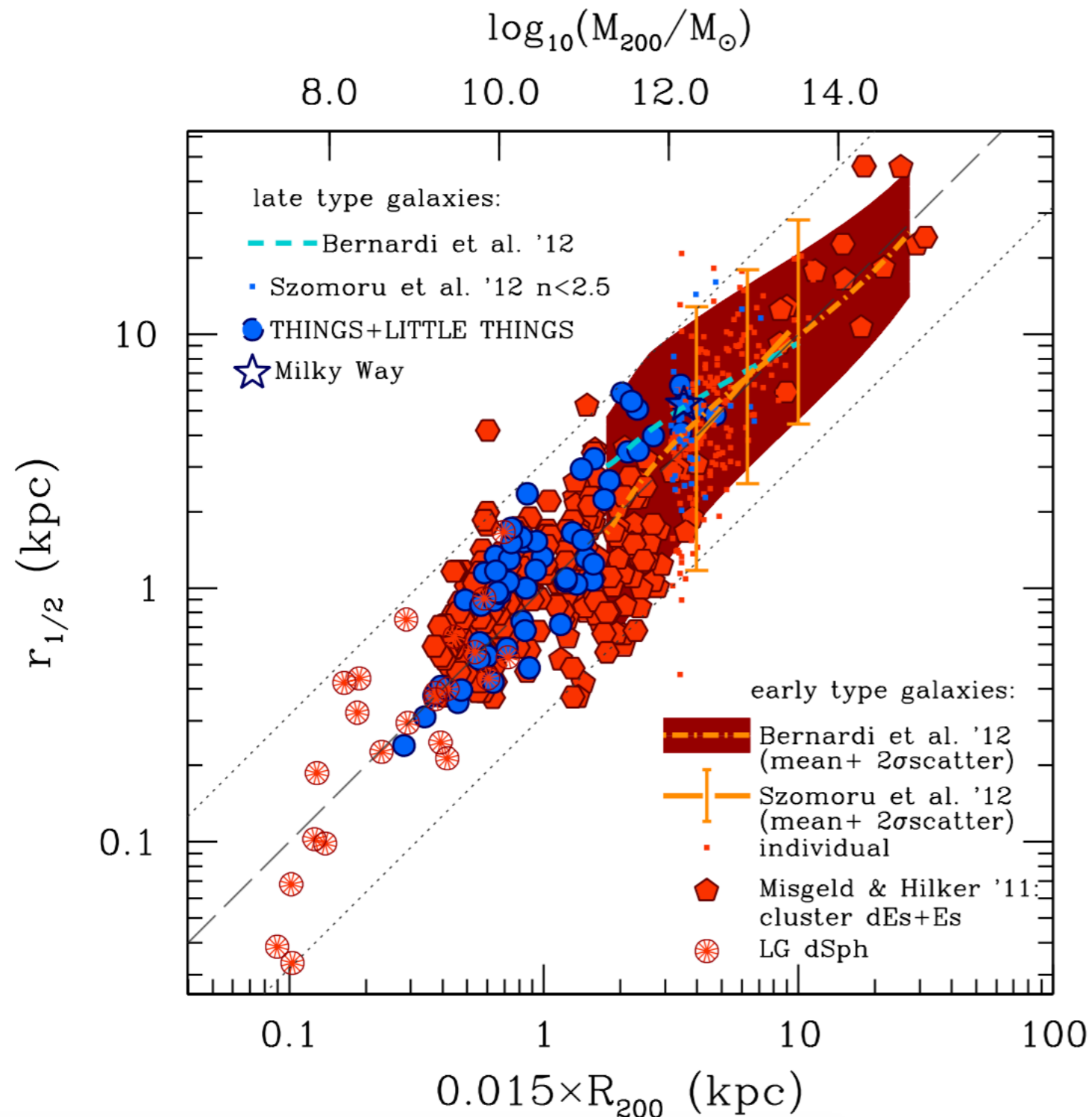
The hidden giant

Vasily Belokurov

Institute of Astronomy, Cambridge

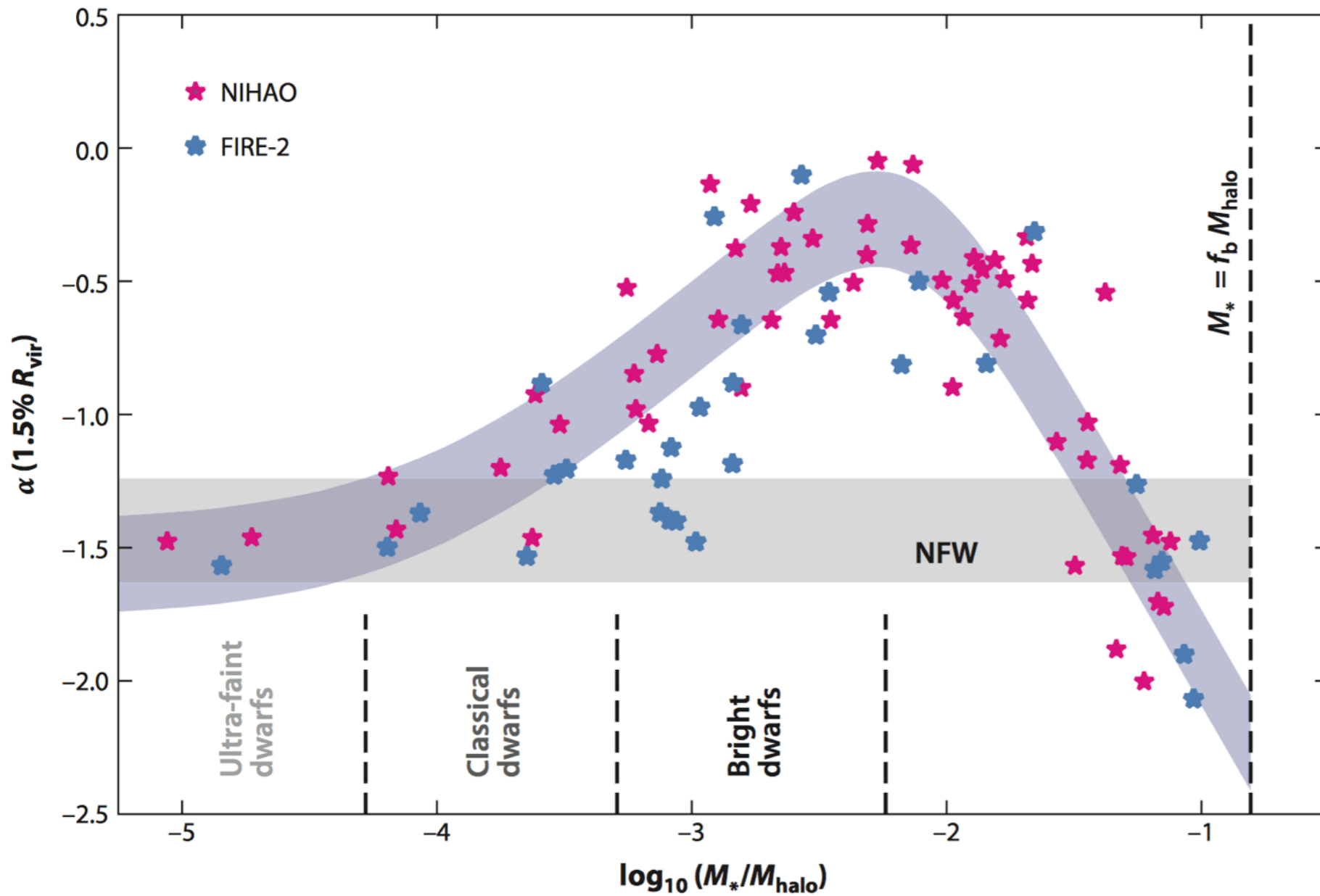
based on Torrealba et al. 2019

What controls the size of a (dwarf) galaxy?



based on:
size-luminosity
+
abundance matching
(both highly non-linear)

Stellar feedback?



Navarro et al 1996
Mashchenko et al 2008
Pontzen & Governato 2012
Zolotov et al 2012
Madau et al 2014
Di Cintio et al 2014
Brooks & Zolotov 2014
Read, Agertz & Collins 2016
...

Bullock & Boylan-Kolchin 2017

Gaia, the halo explorer

- relatively bright magnitude limit, but
- no weather
- perfect star/galaxy separation
- artifact rejection
- whole sky
- uniform(ish) quality
- astrometry



Prediction

Monthly Notices

of the

ROYAL ASTRONOMICAL SOCIETY

MNRAS **453**, 541–560 (2015)



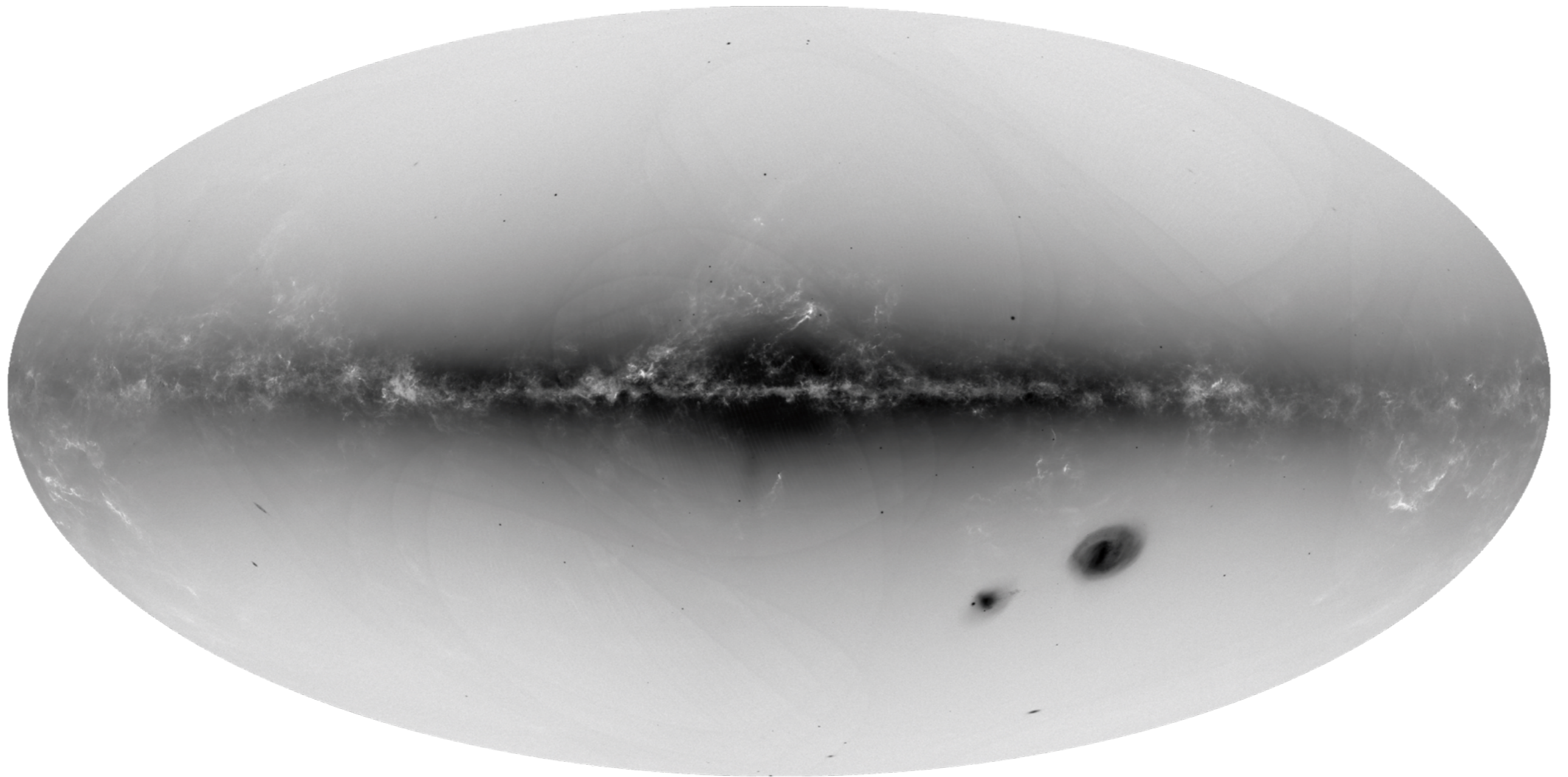
doi:10.1093/mnras/stv1622

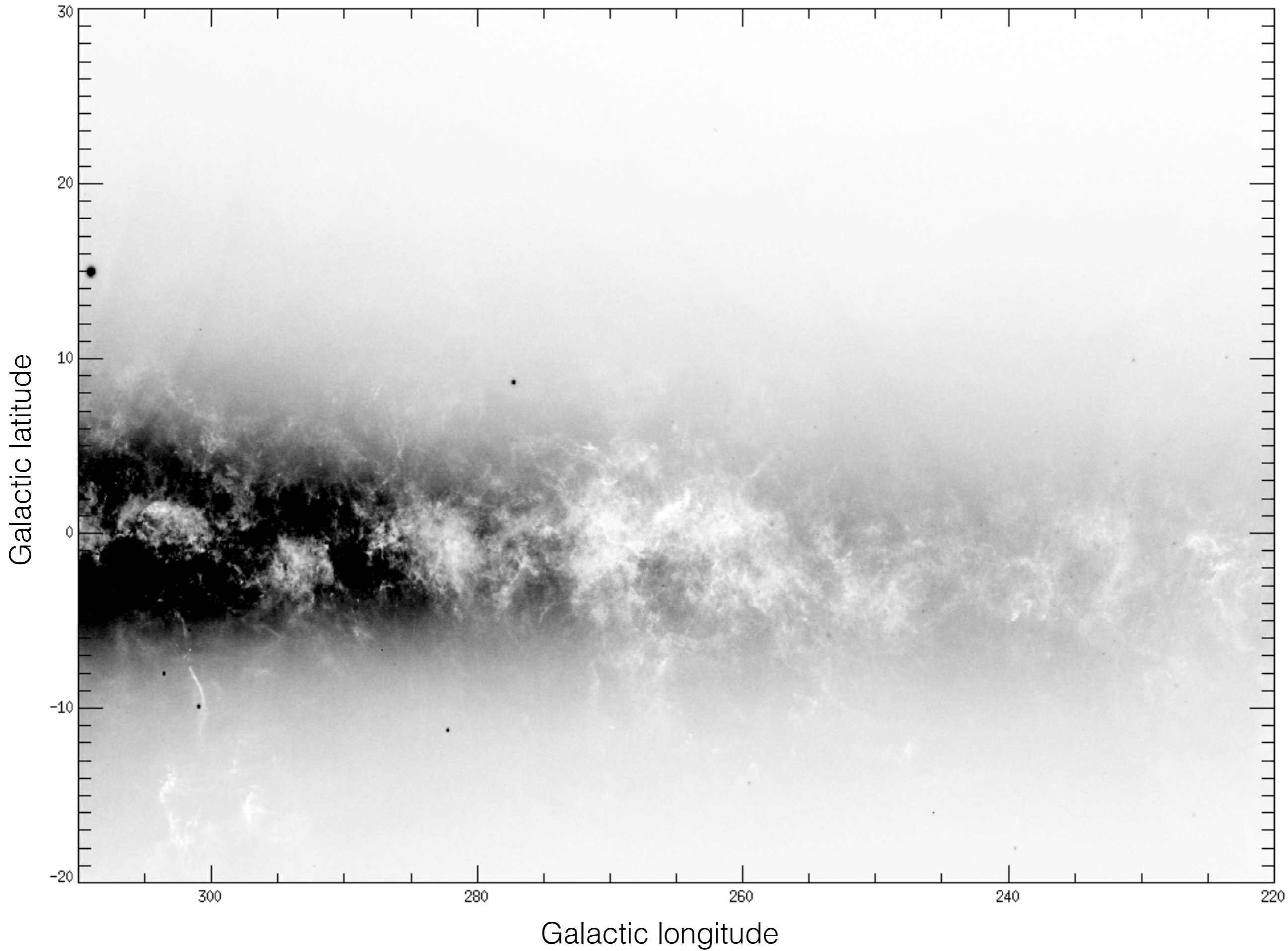
Detection of satellite remnants in the Galactic halo with *Gaia*– III. Detection limits for ultrafaint dwarf galaxies

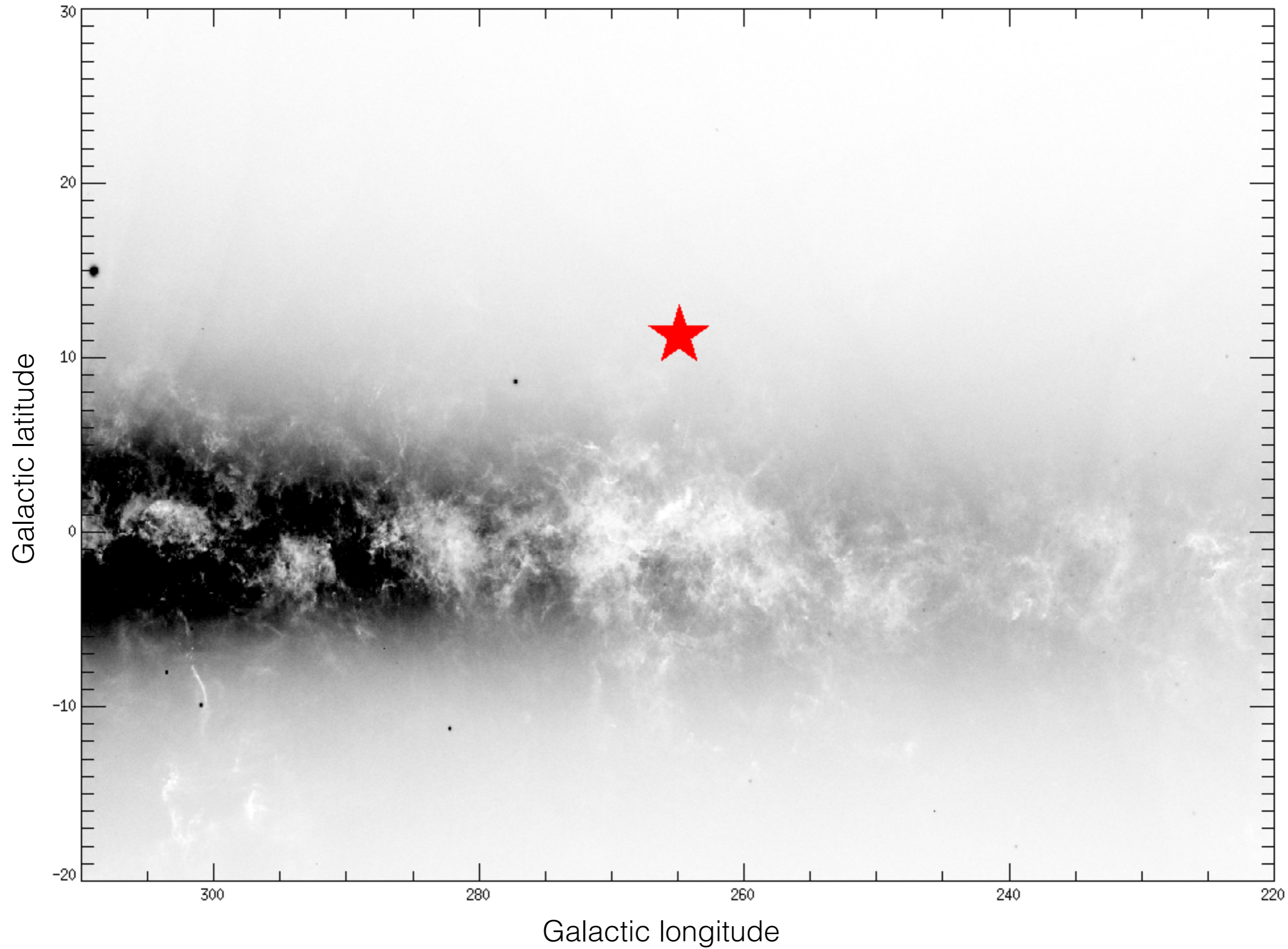
T. Antoja,¹★† C. Mateu,^{2,3} L. Aguilar,² F. Figueras,⁴ E. Antiche,⁴ F. Hernández-Pérez,³
A. G. A. Brown,⁵ O. Valenzuela,⁶ A. Aparicio,⁷ S. Hidalgo⁷
and H. Velázquez²

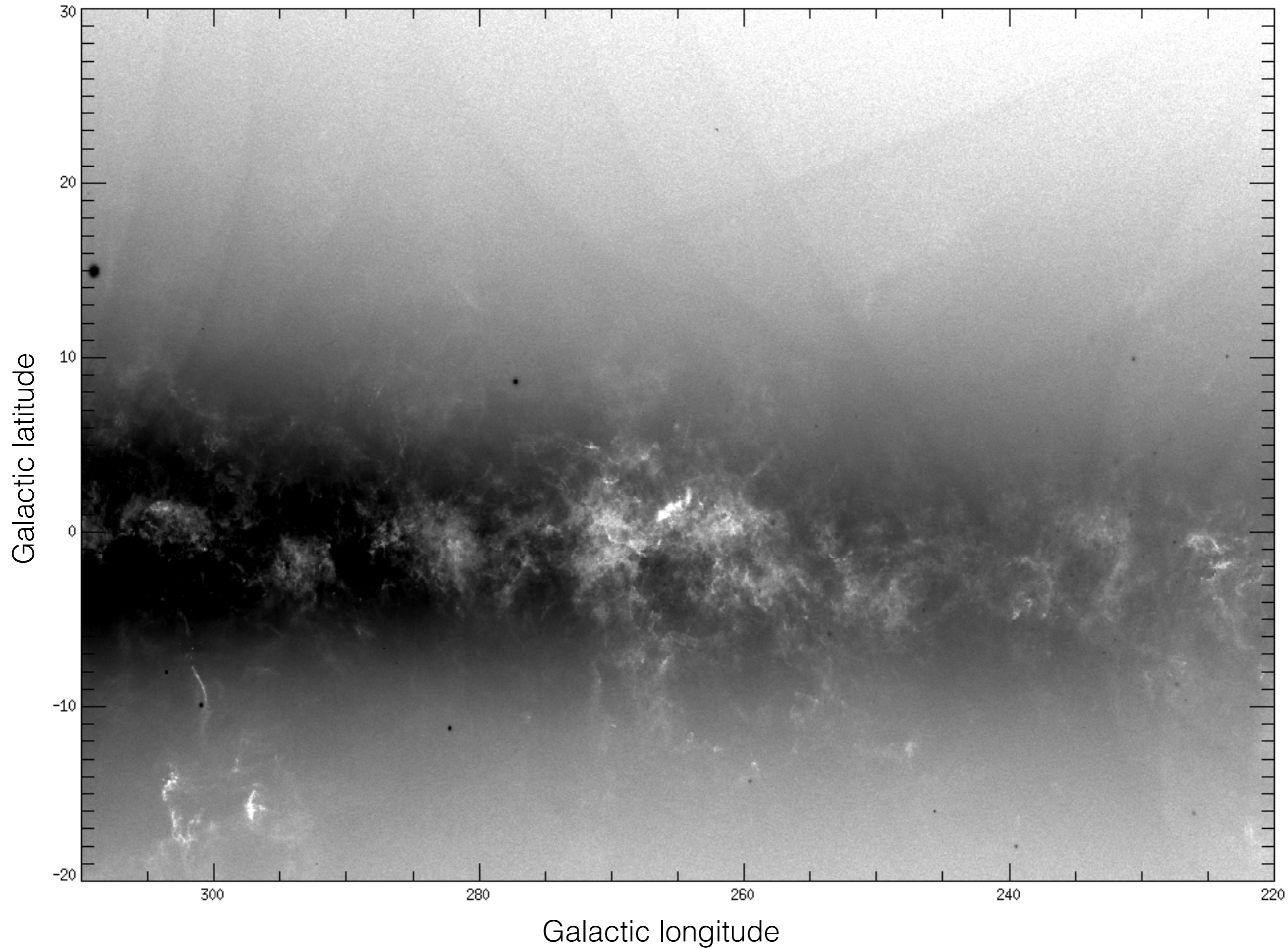
- “Our experiments suggest that *Gaia* will be able to detect UFDGs that are similar to some of the known UFDGs even if the limit of *Gaia* is around 2 mag brighter than that of SDSS, with the advantage of having a full-sky catalogue. We also see that *Gaia* could even find some UFDGs that have lower surface brightness than the SDSS limit”

Gaia DR2

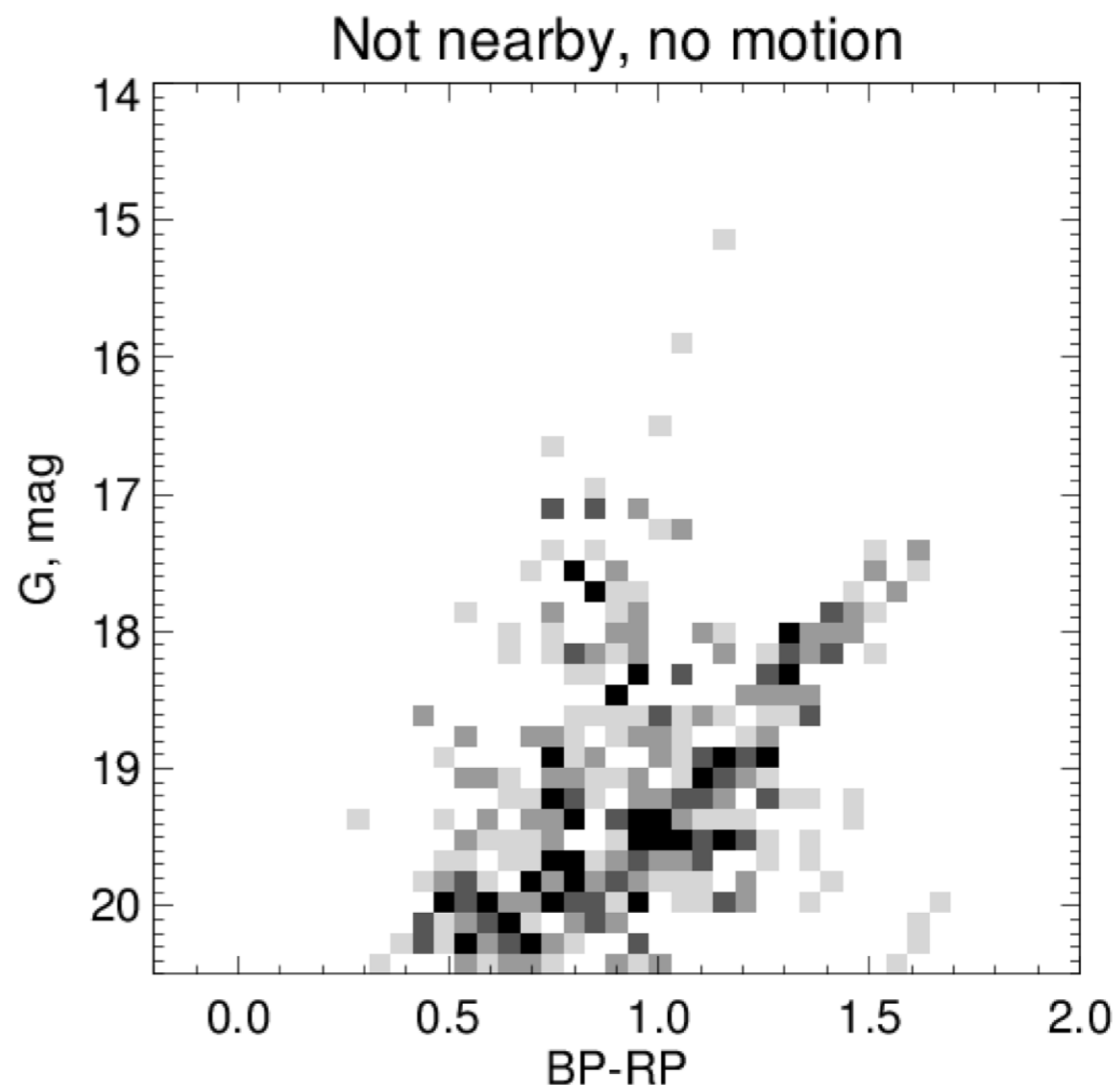
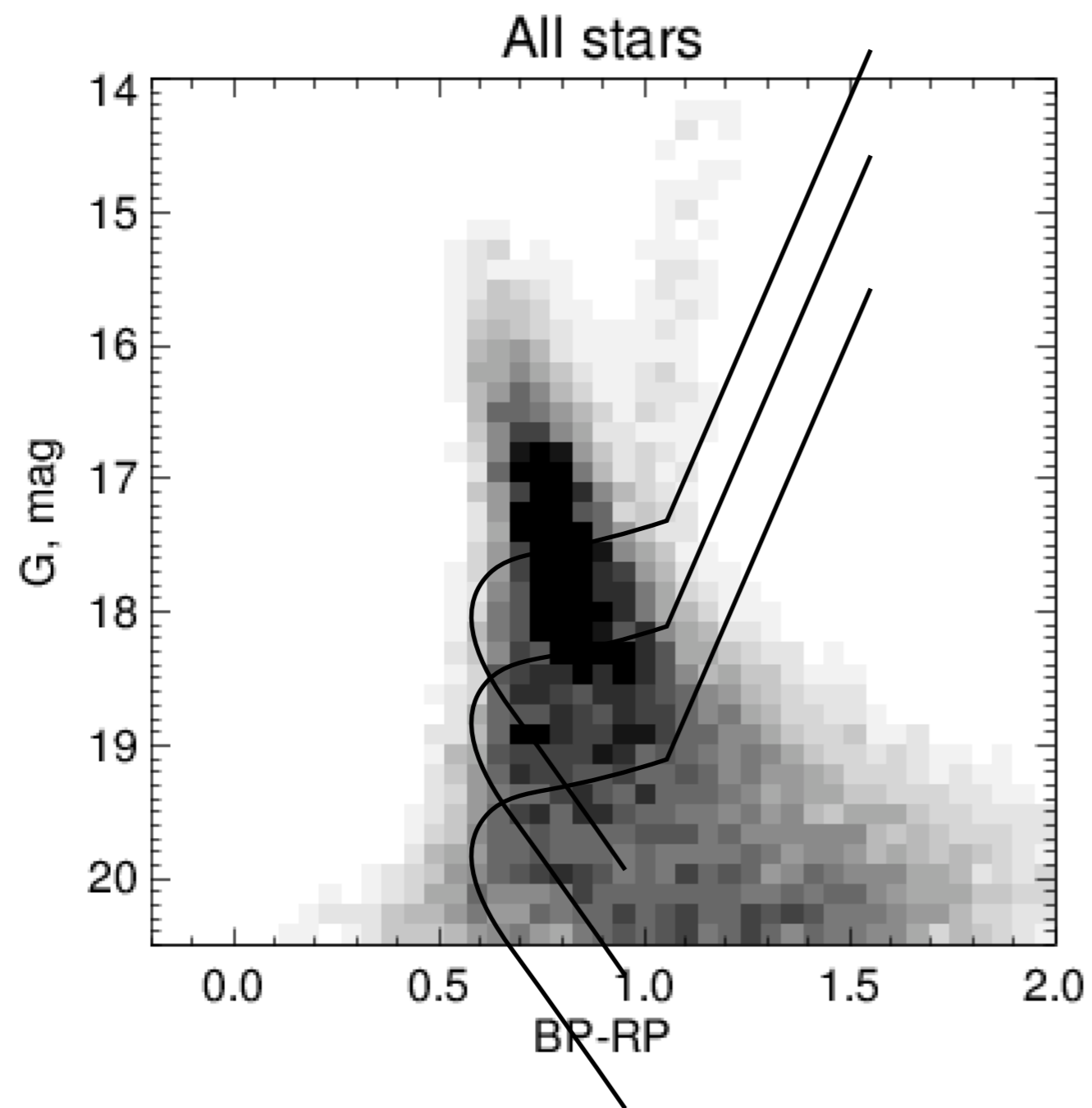




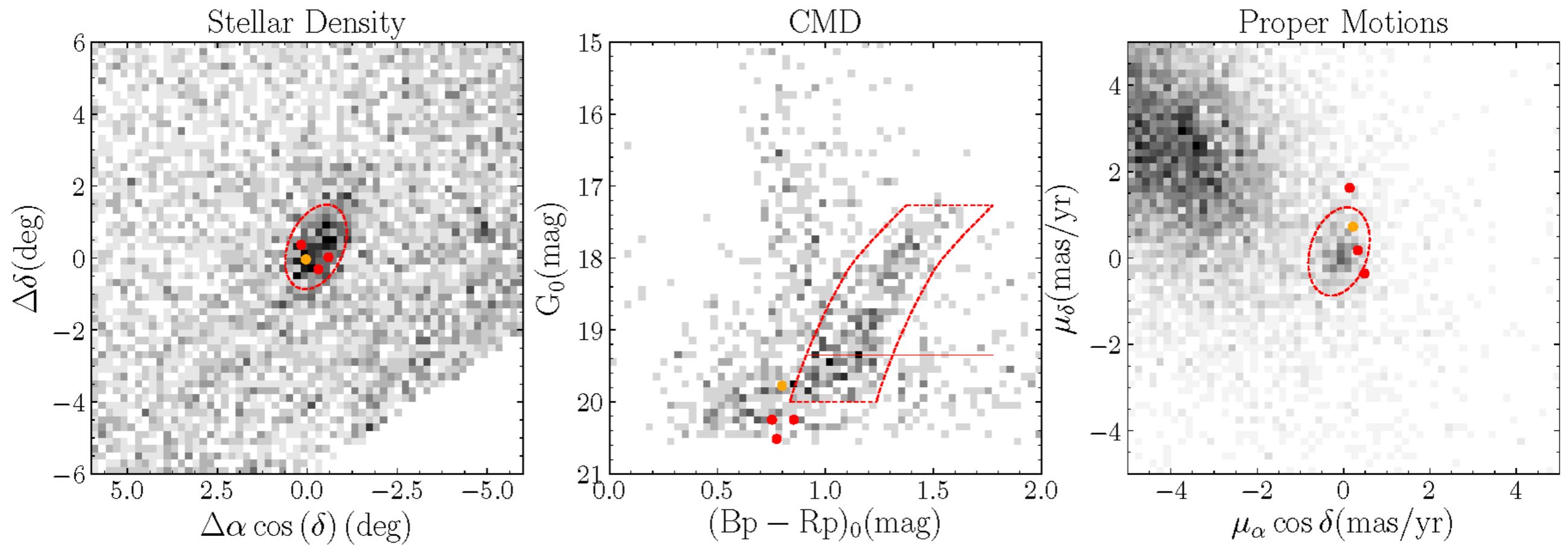




Gaia's magic

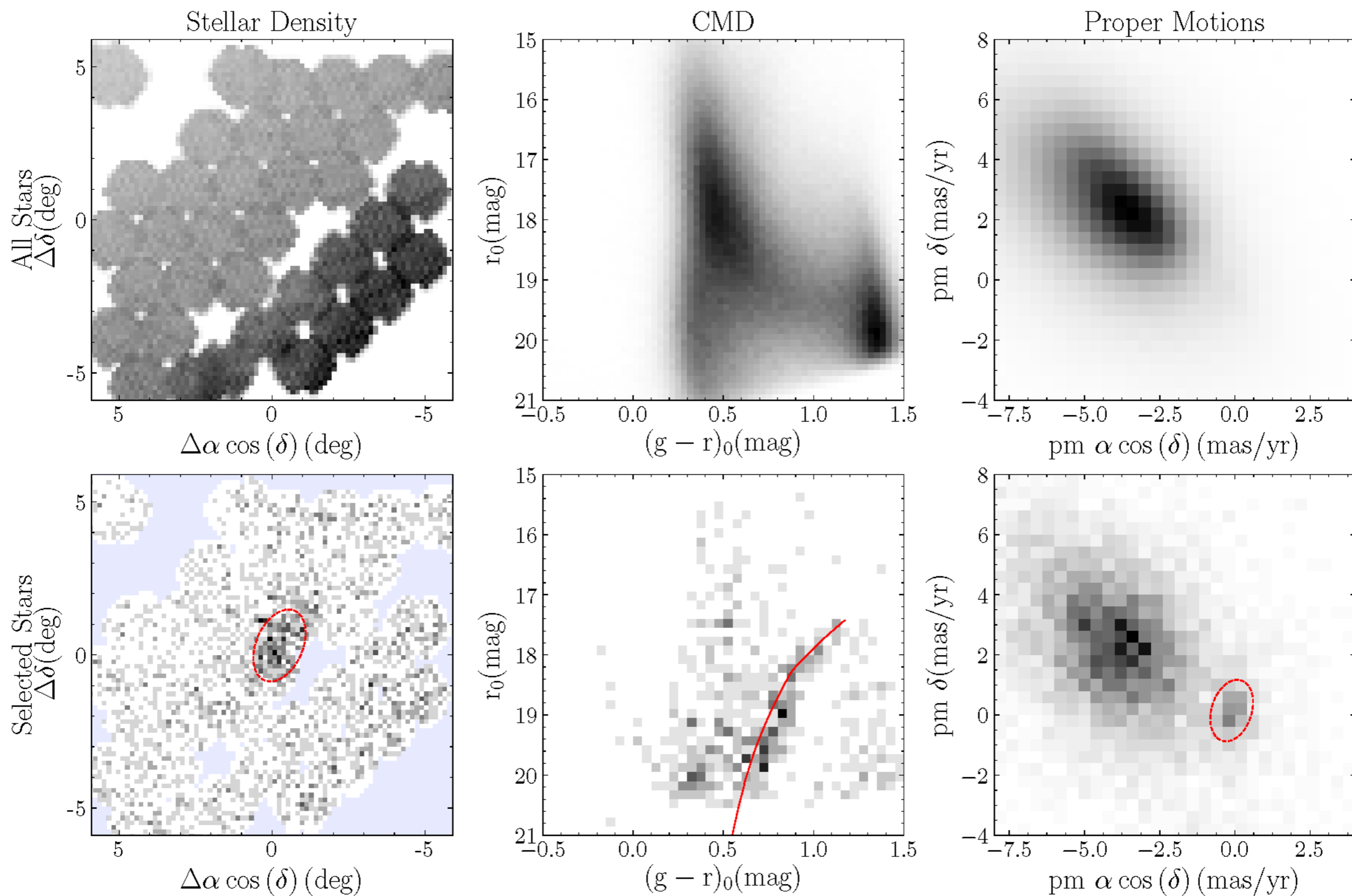


New satellite revealed by RR Lyrae



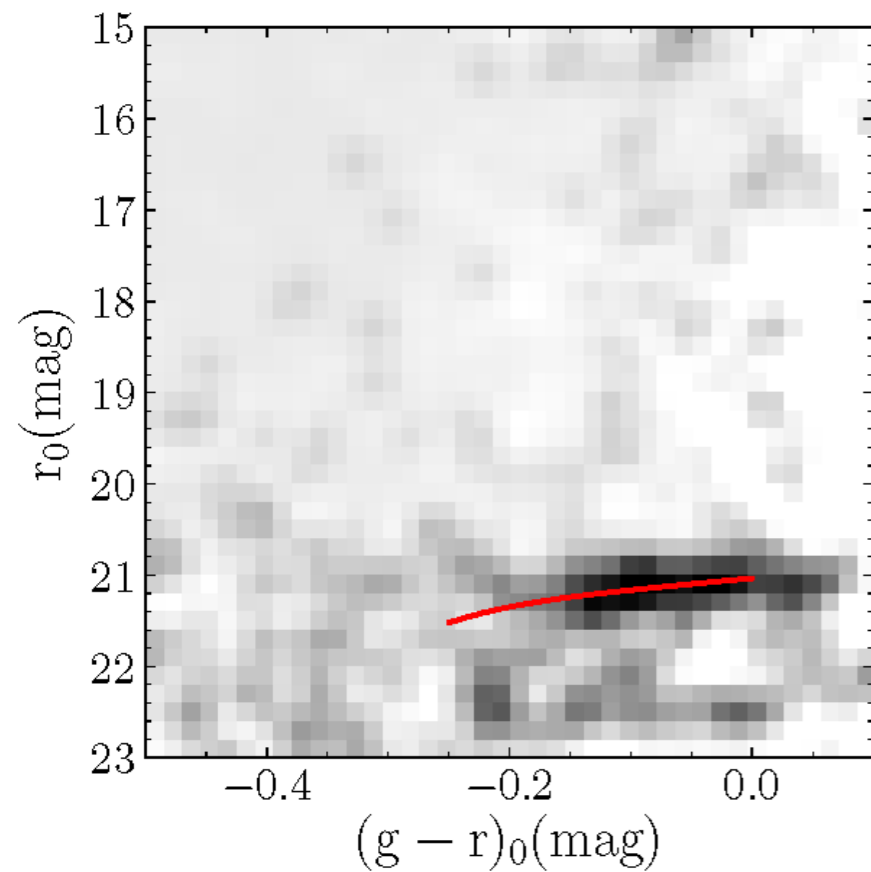
••• - RR Lyrae with distances $D > 70$ kpc

Archival deeper DECam imaging

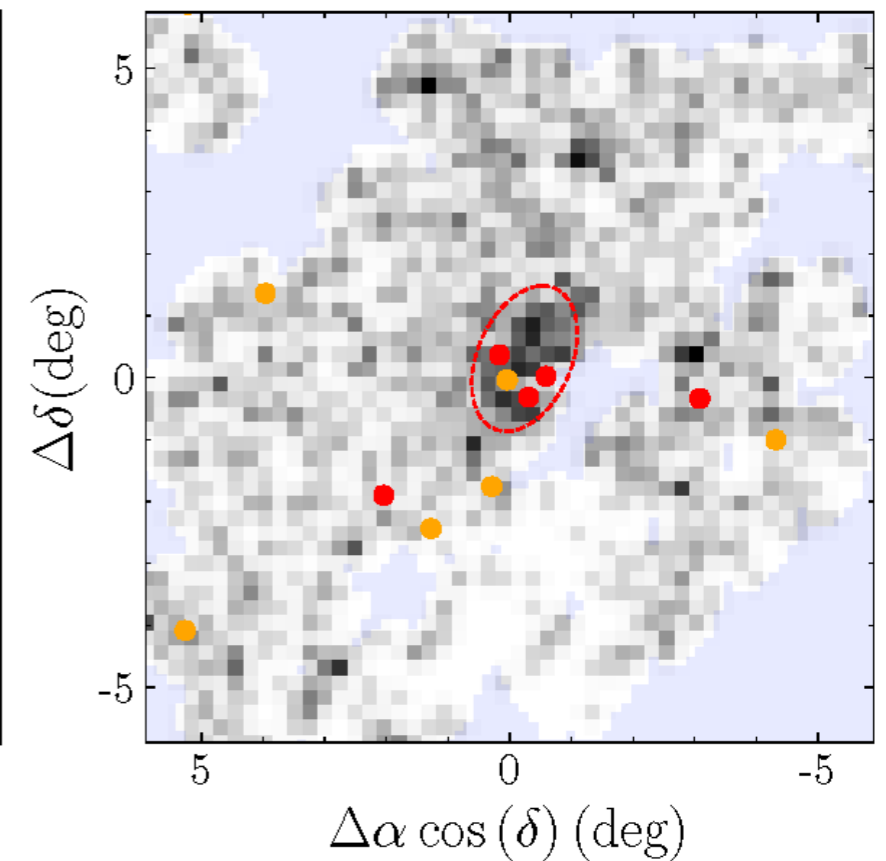
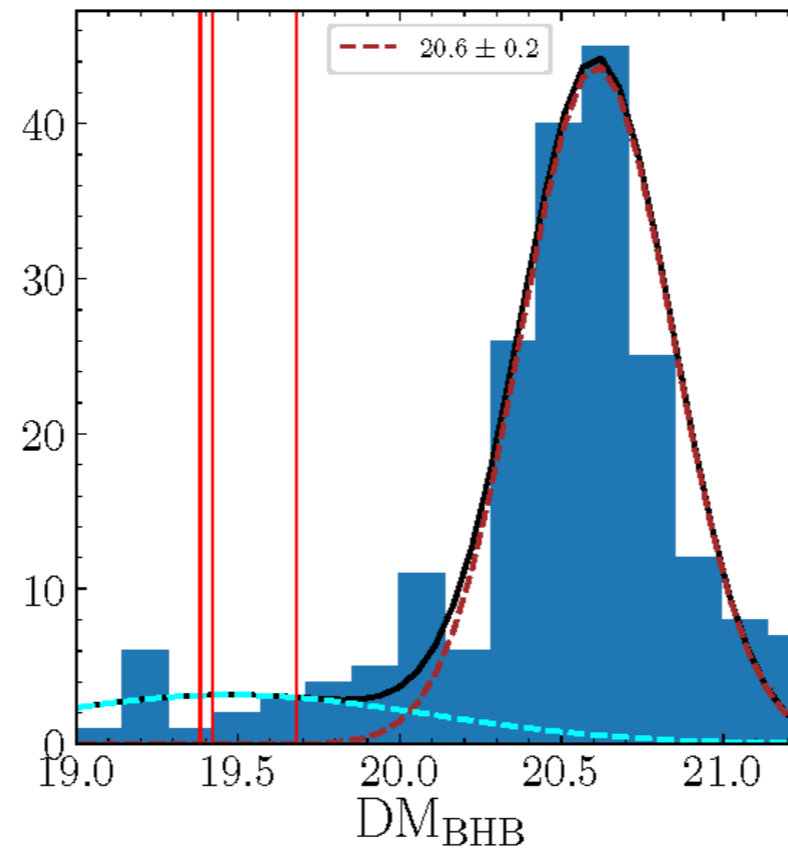


Distance to Antlia 2

Archival deeper DECam imaging



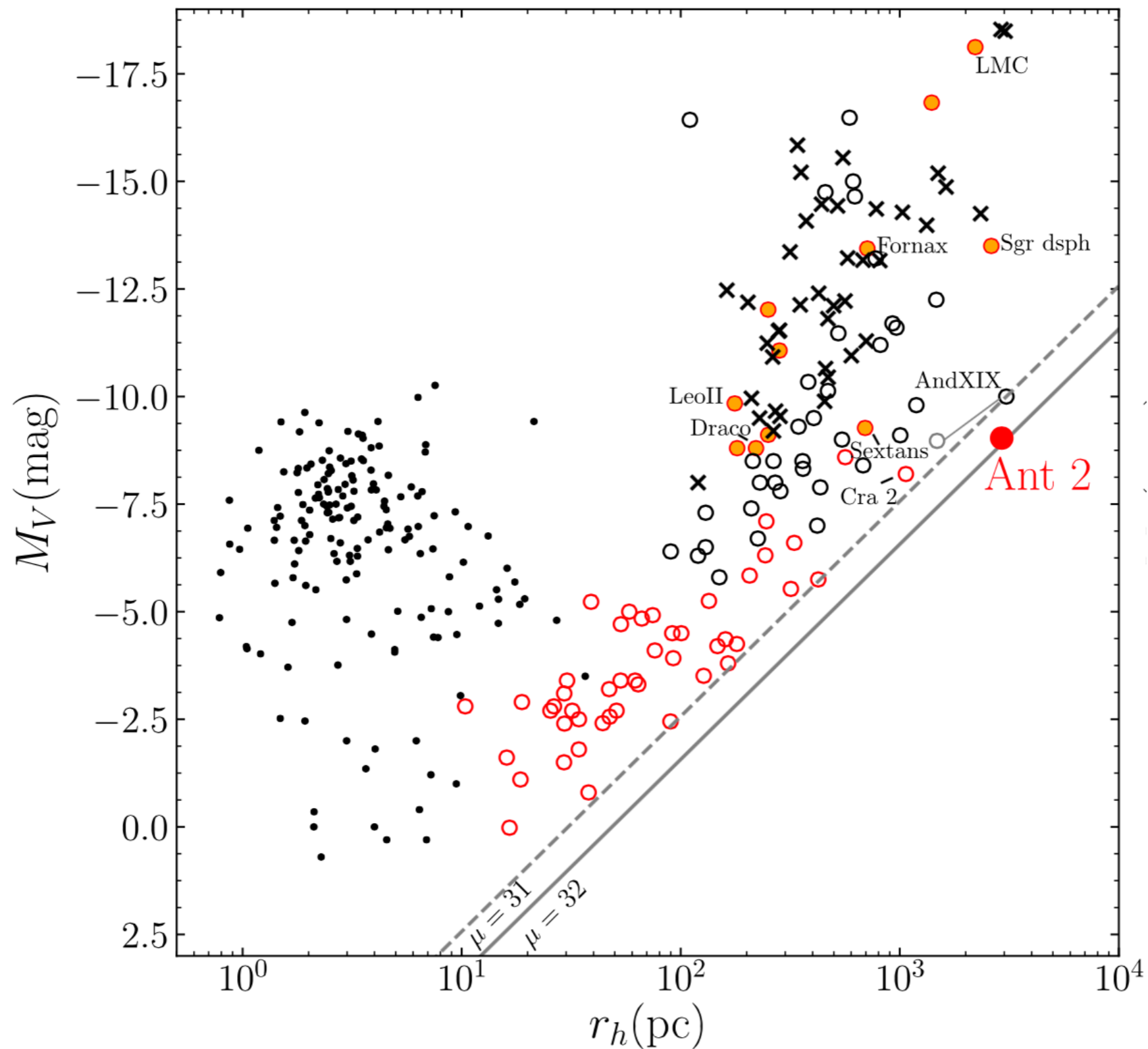
Blue Horizontal Branch
“standard candle”



 - distant RR Lyrae

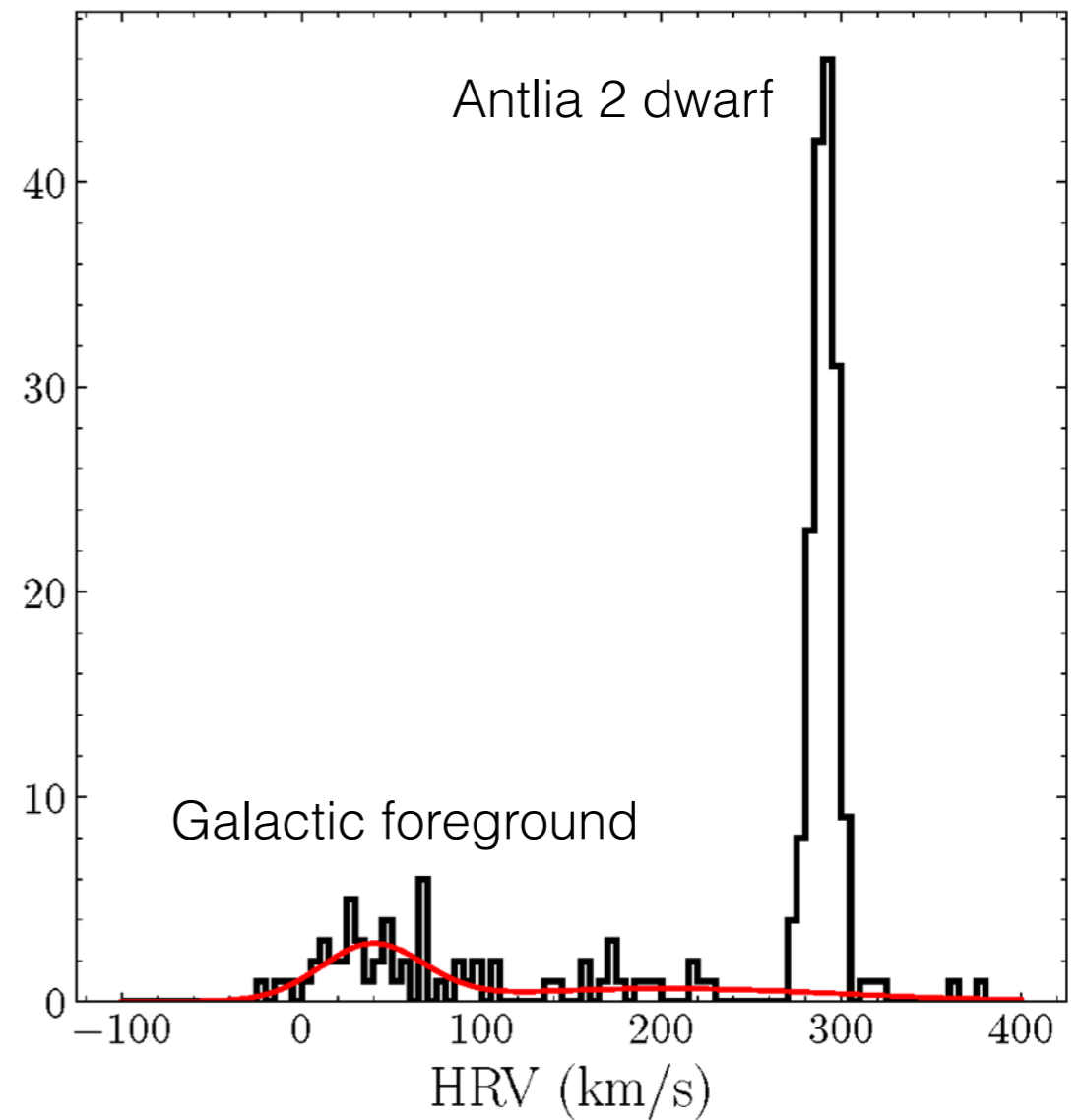
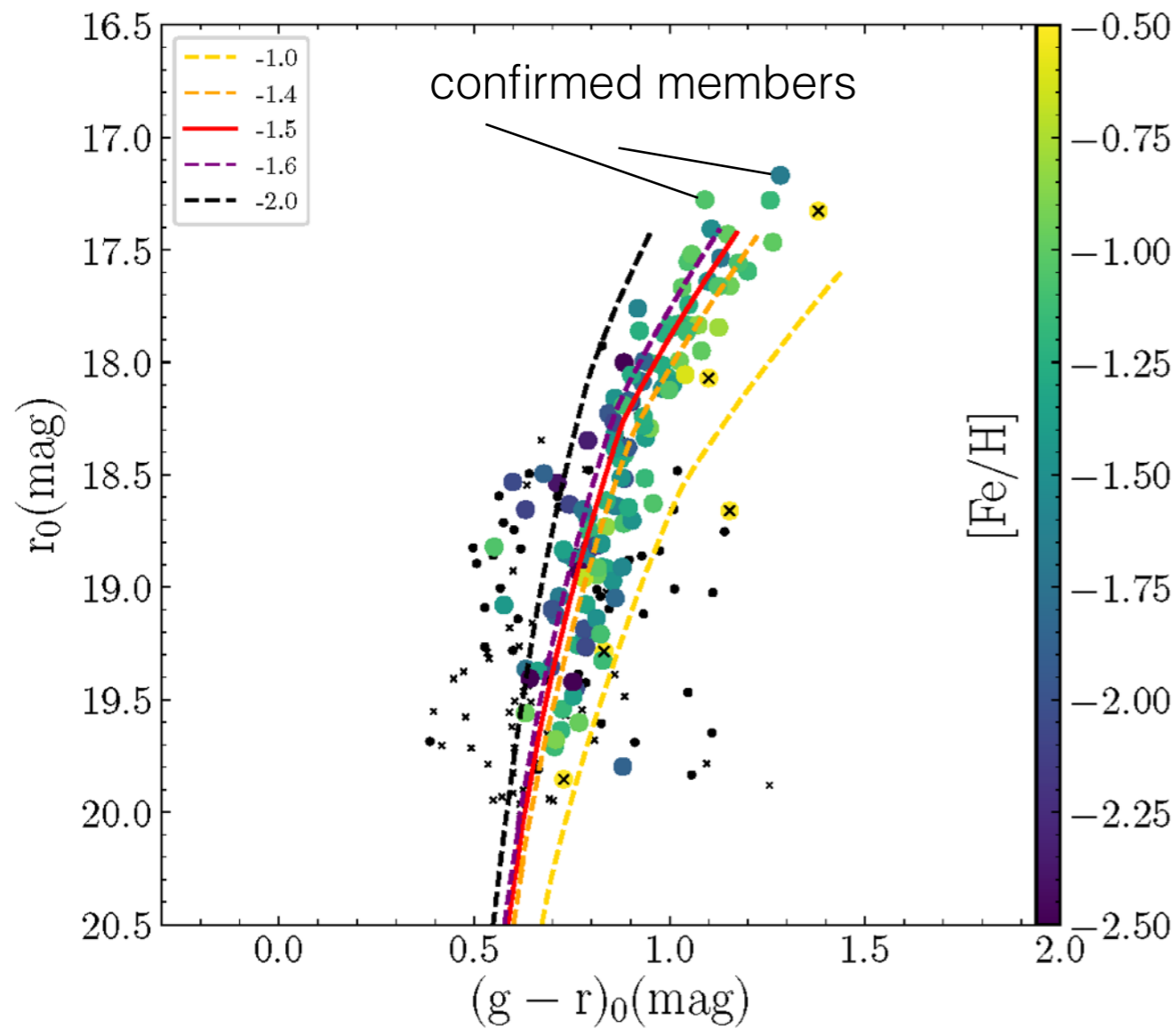
$D=130$ kpc

Size and luminosity



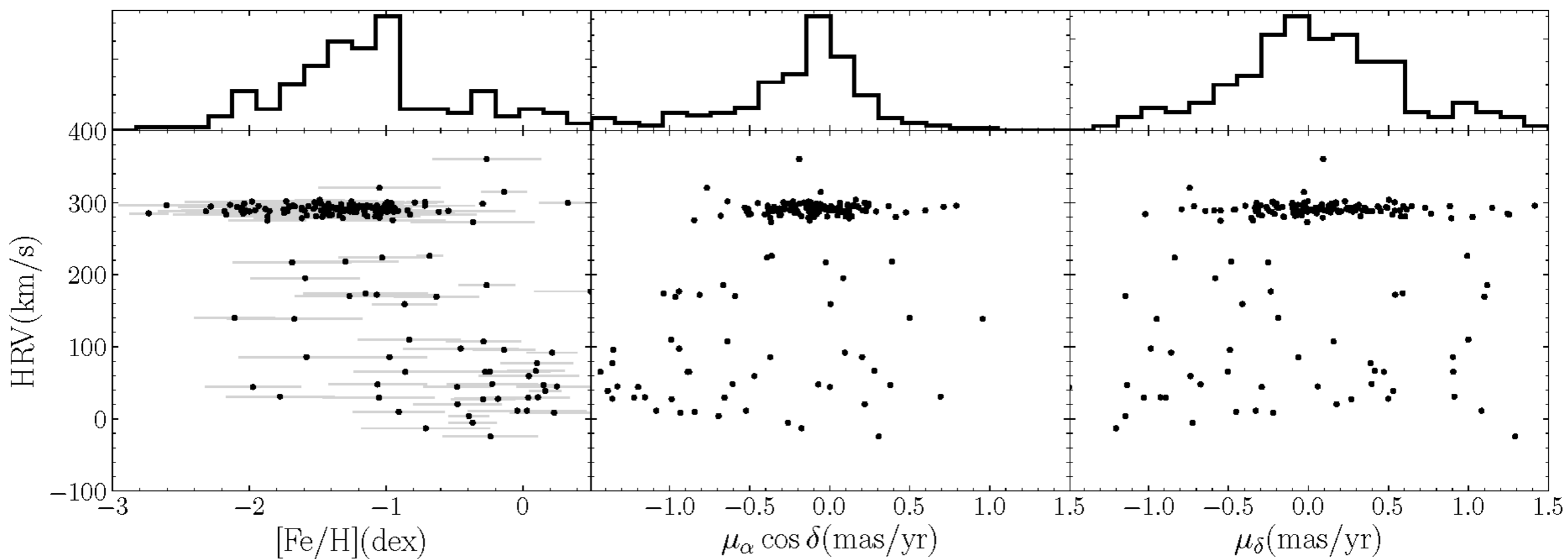
super
mega
ultra
diffuse!

Spectroscopic Follow-up

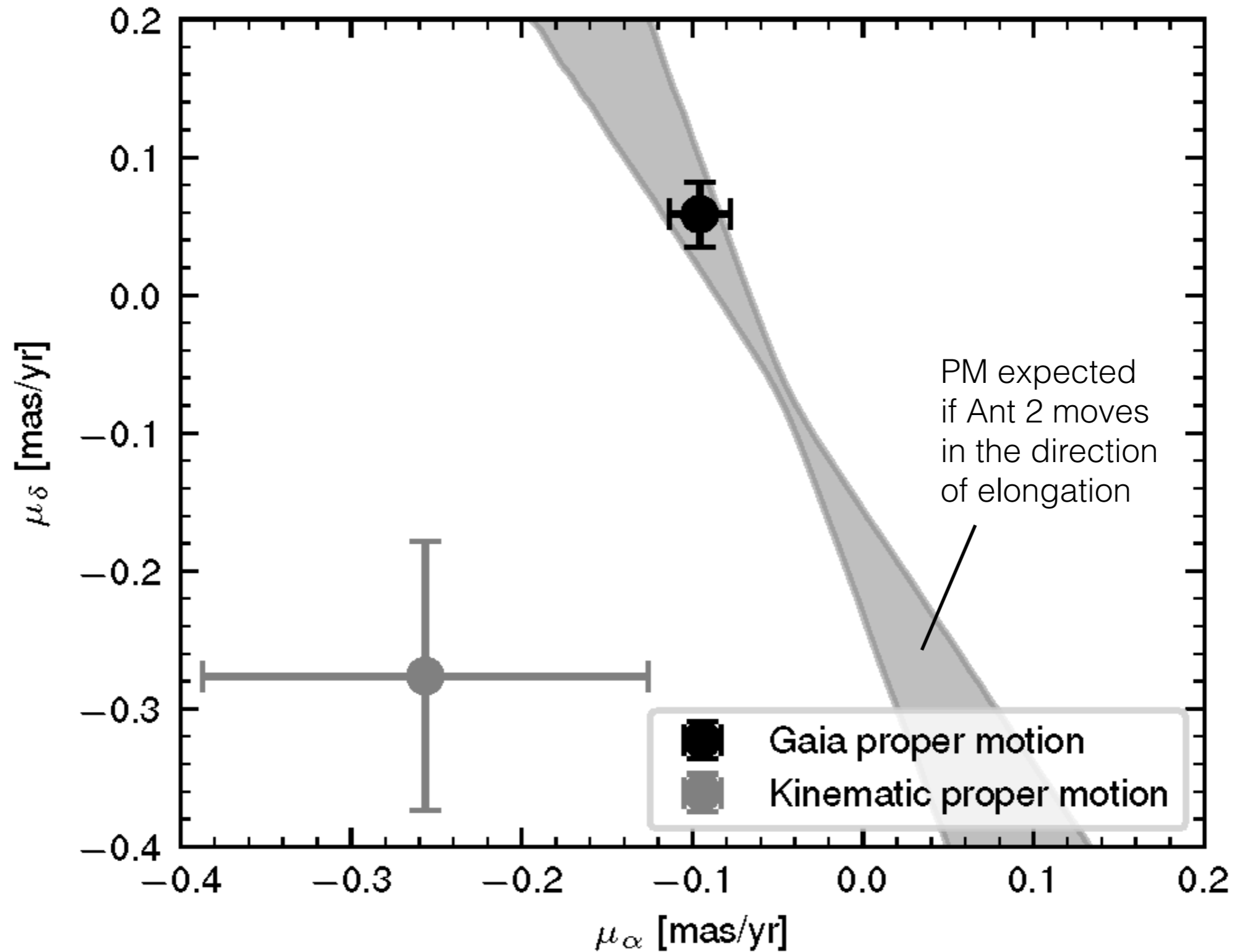


line-of-sight velocity

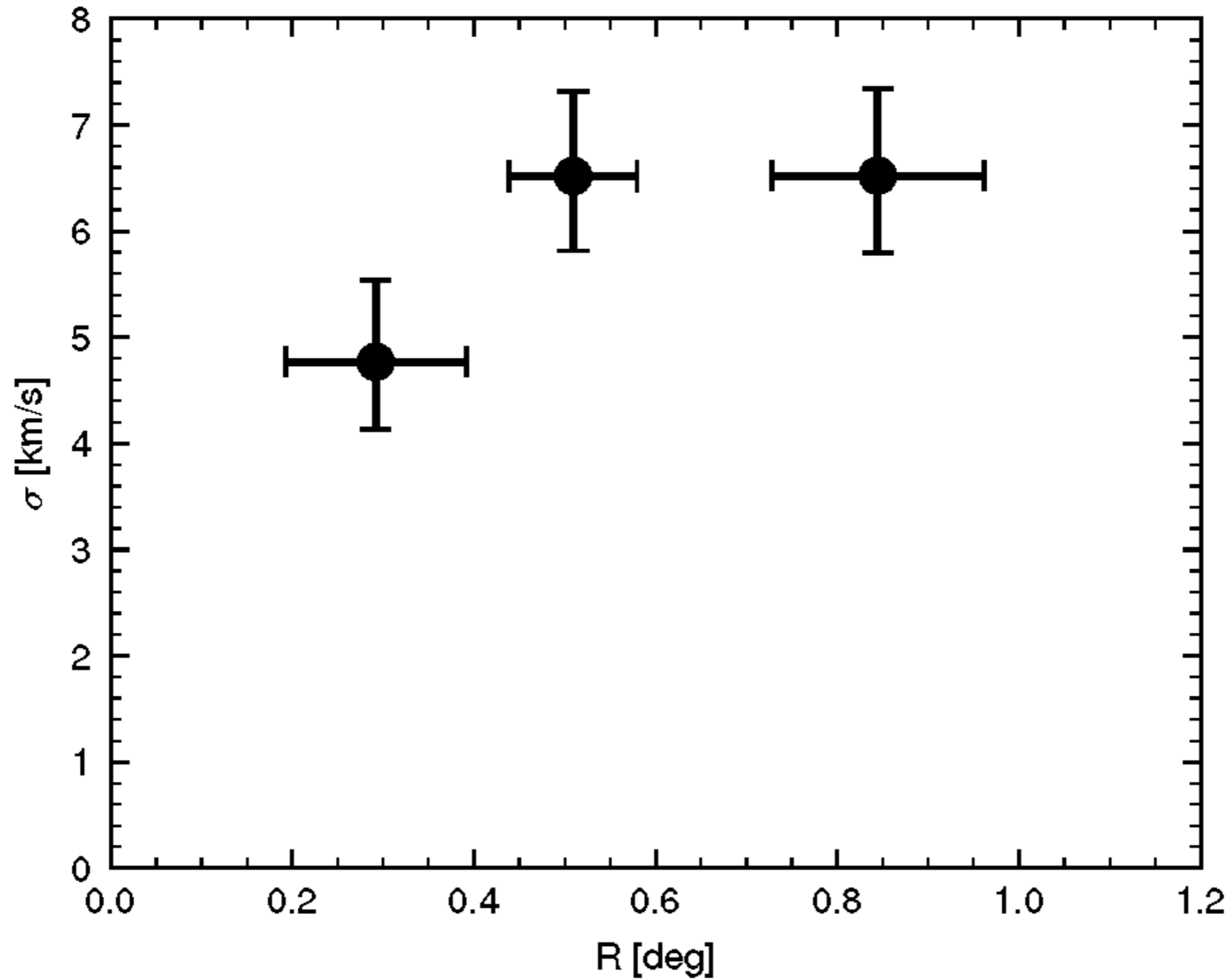
3D motion + metallicity



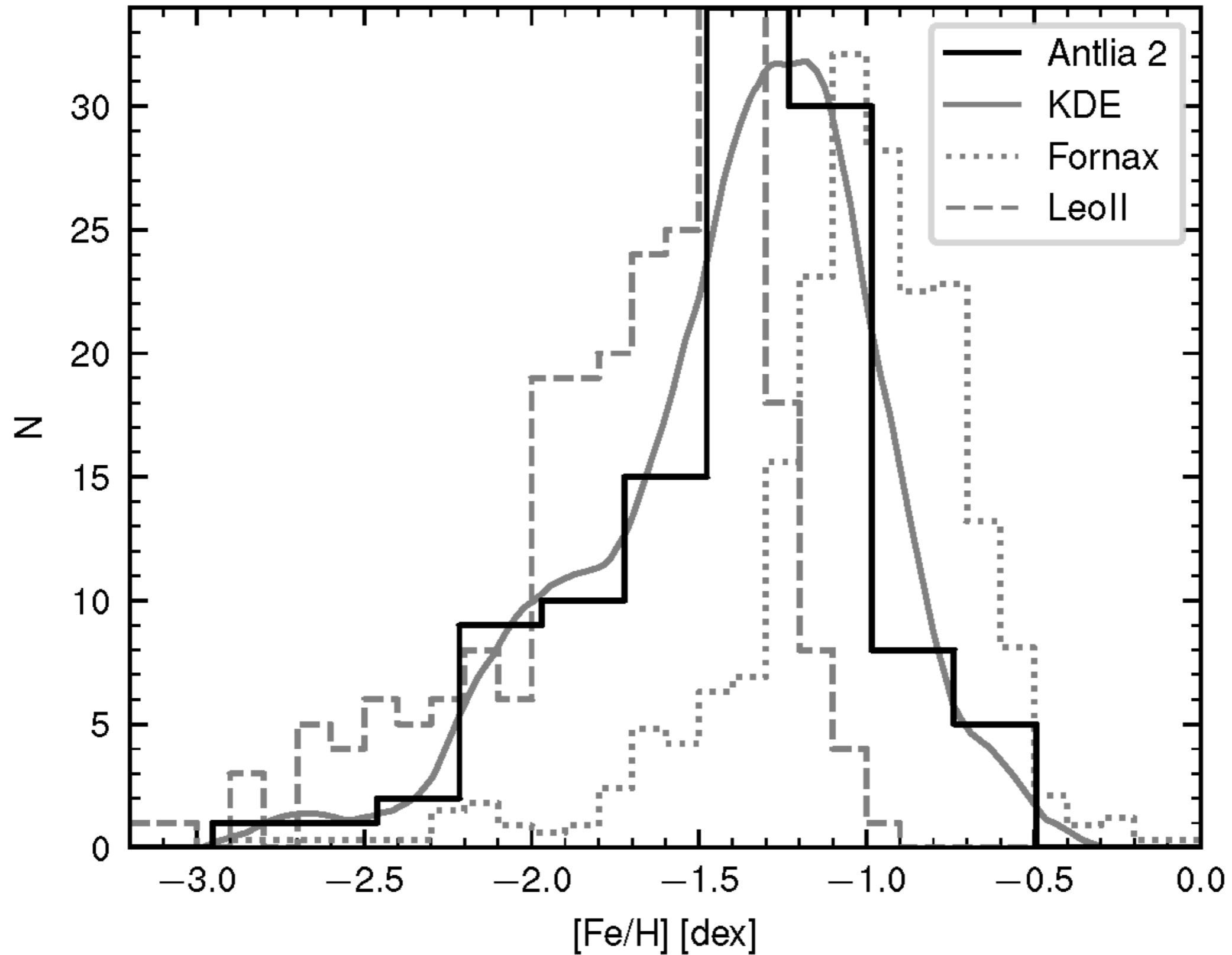
Kinematics



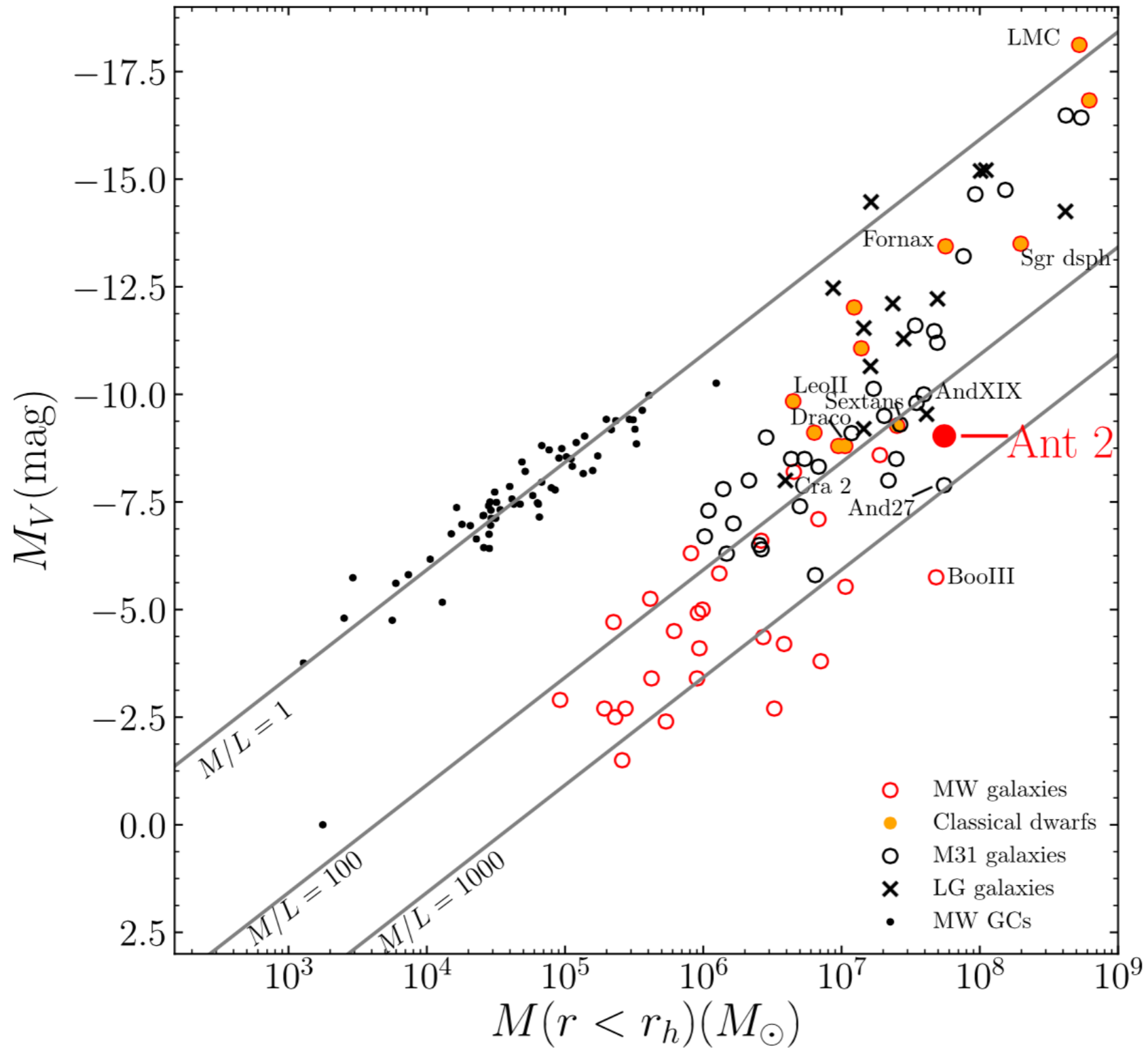
Kinematics



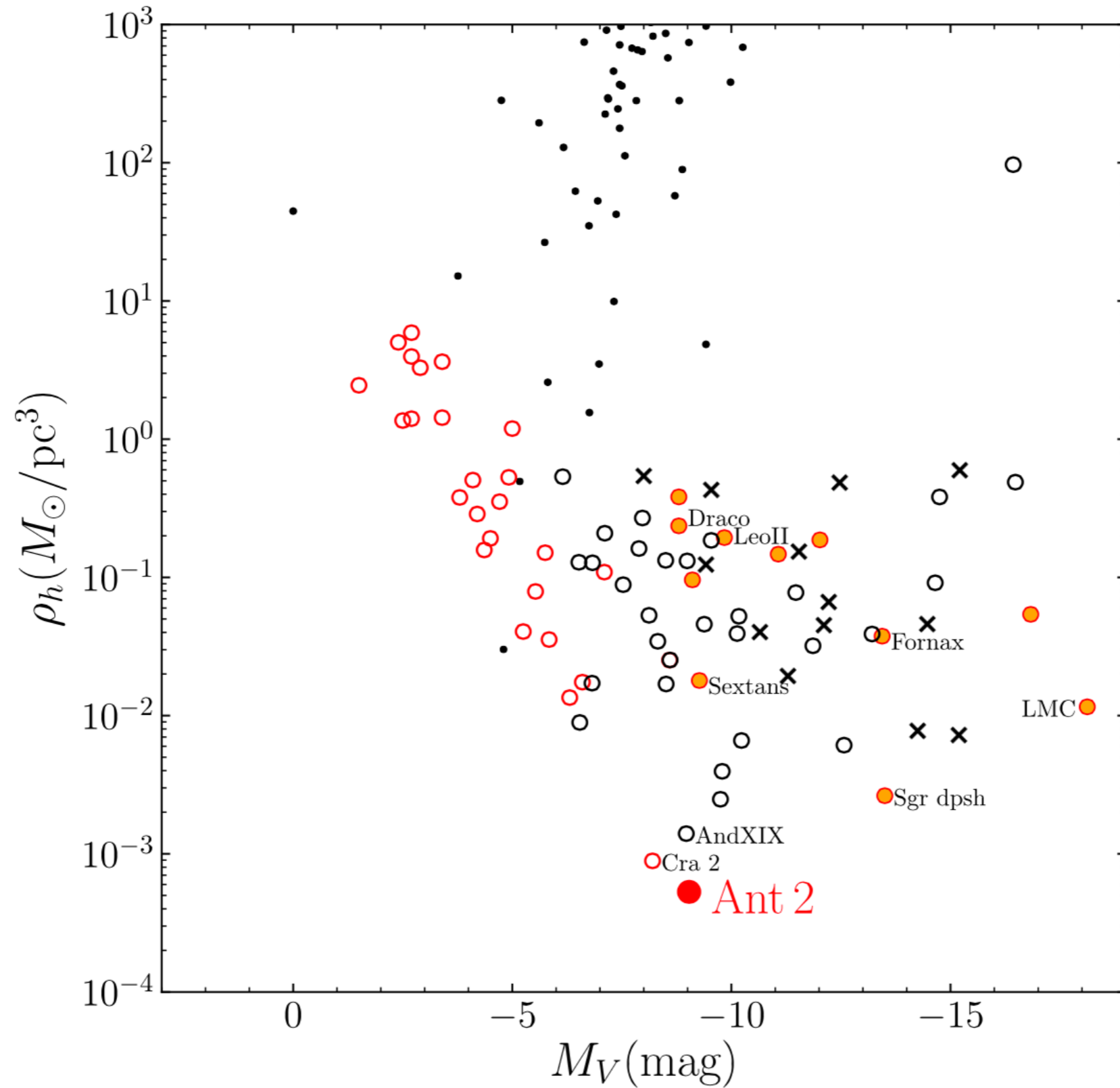
Metallicity distribution



Mass-luminosity



Luminosity-density

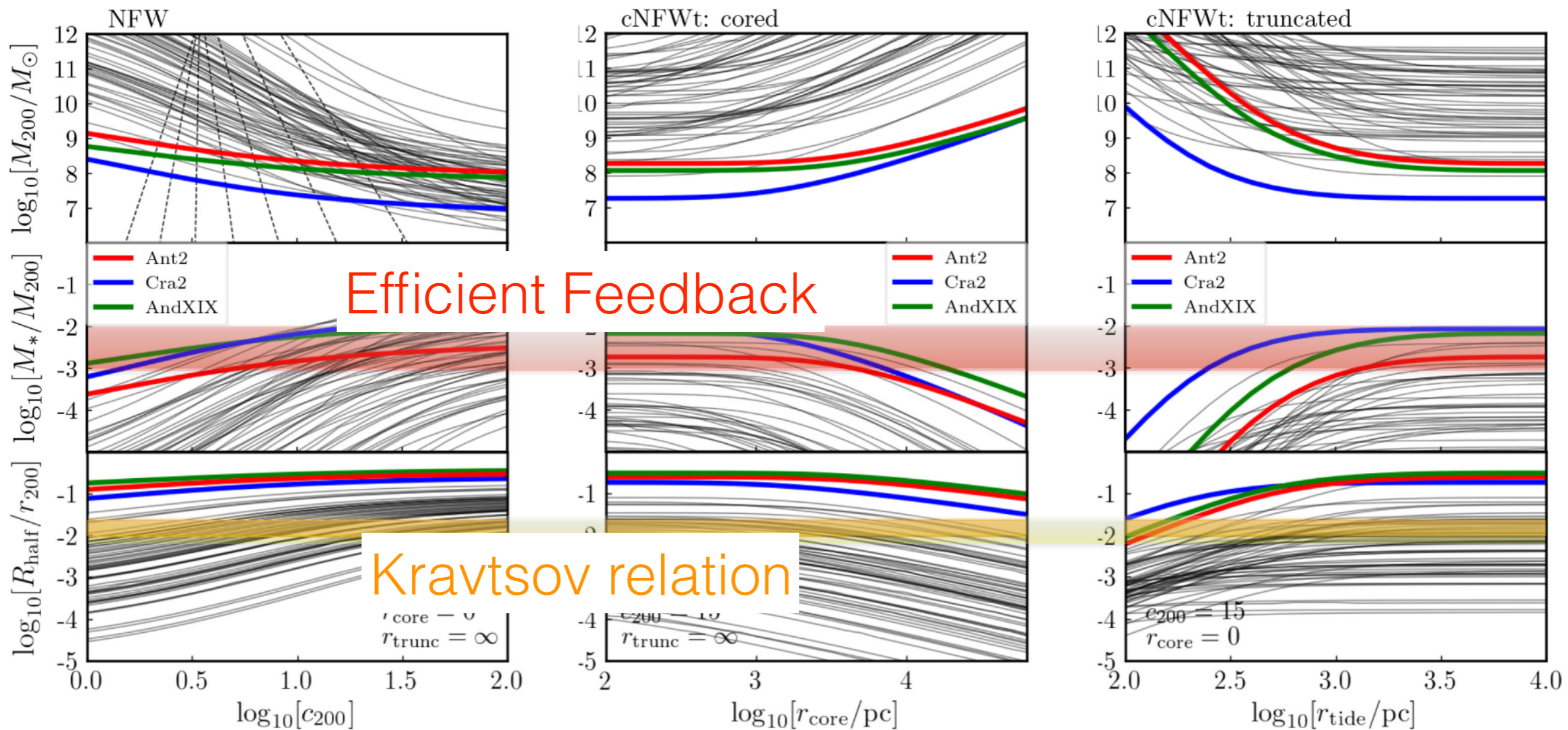


Fluffy dwarfs

NFW

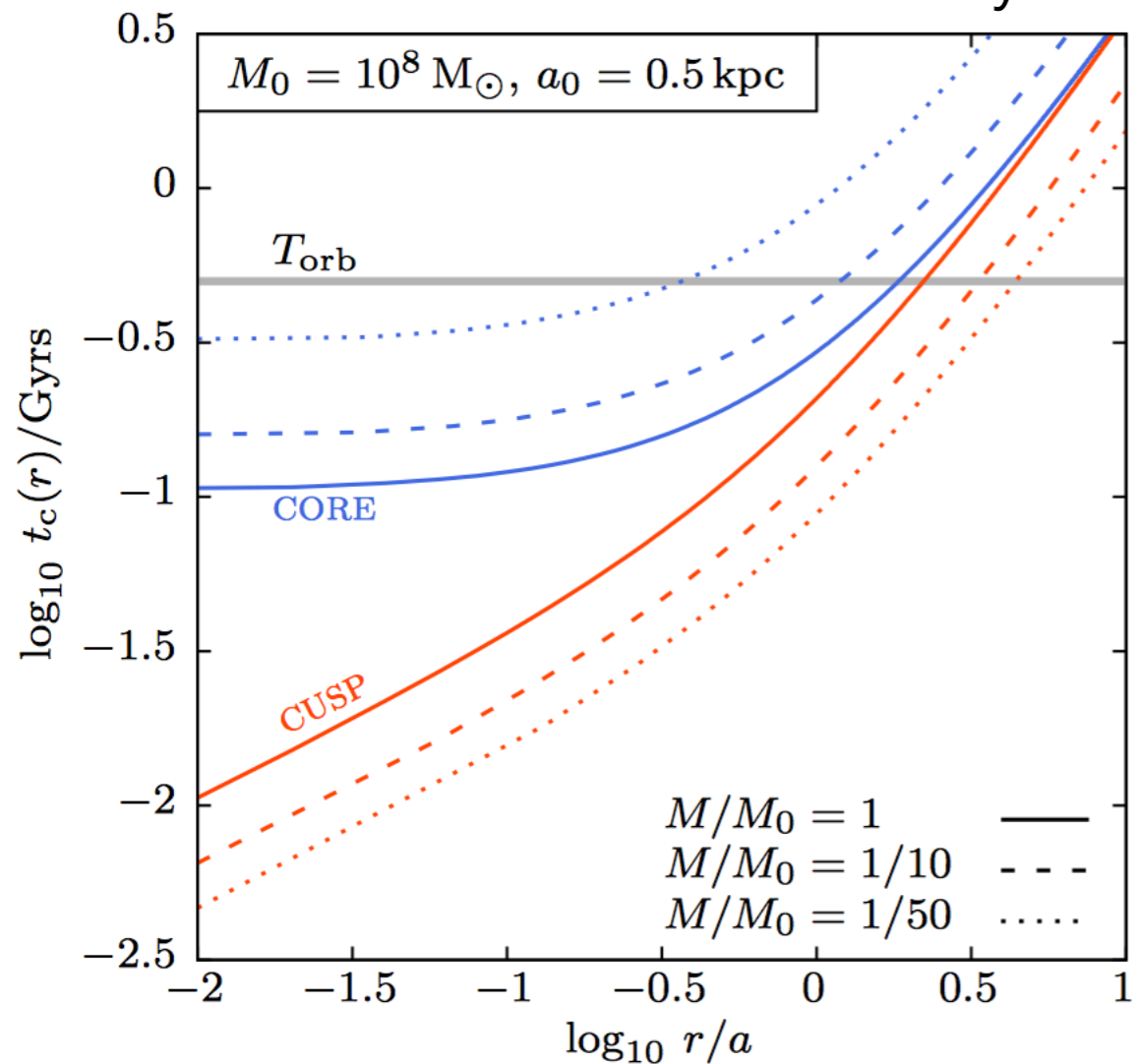
cored NFW

truncated NFW

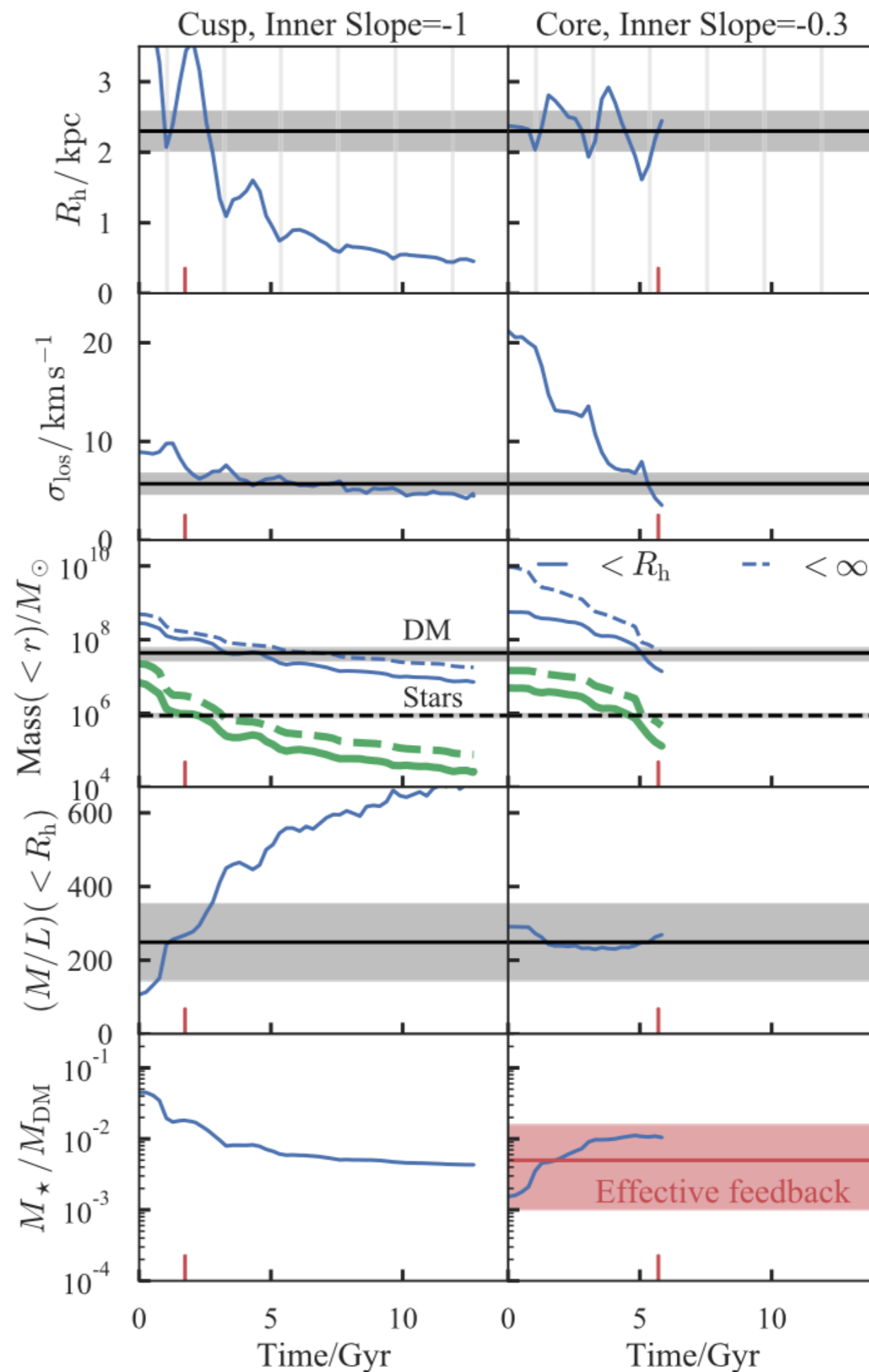


Can tidal stripping play a role?

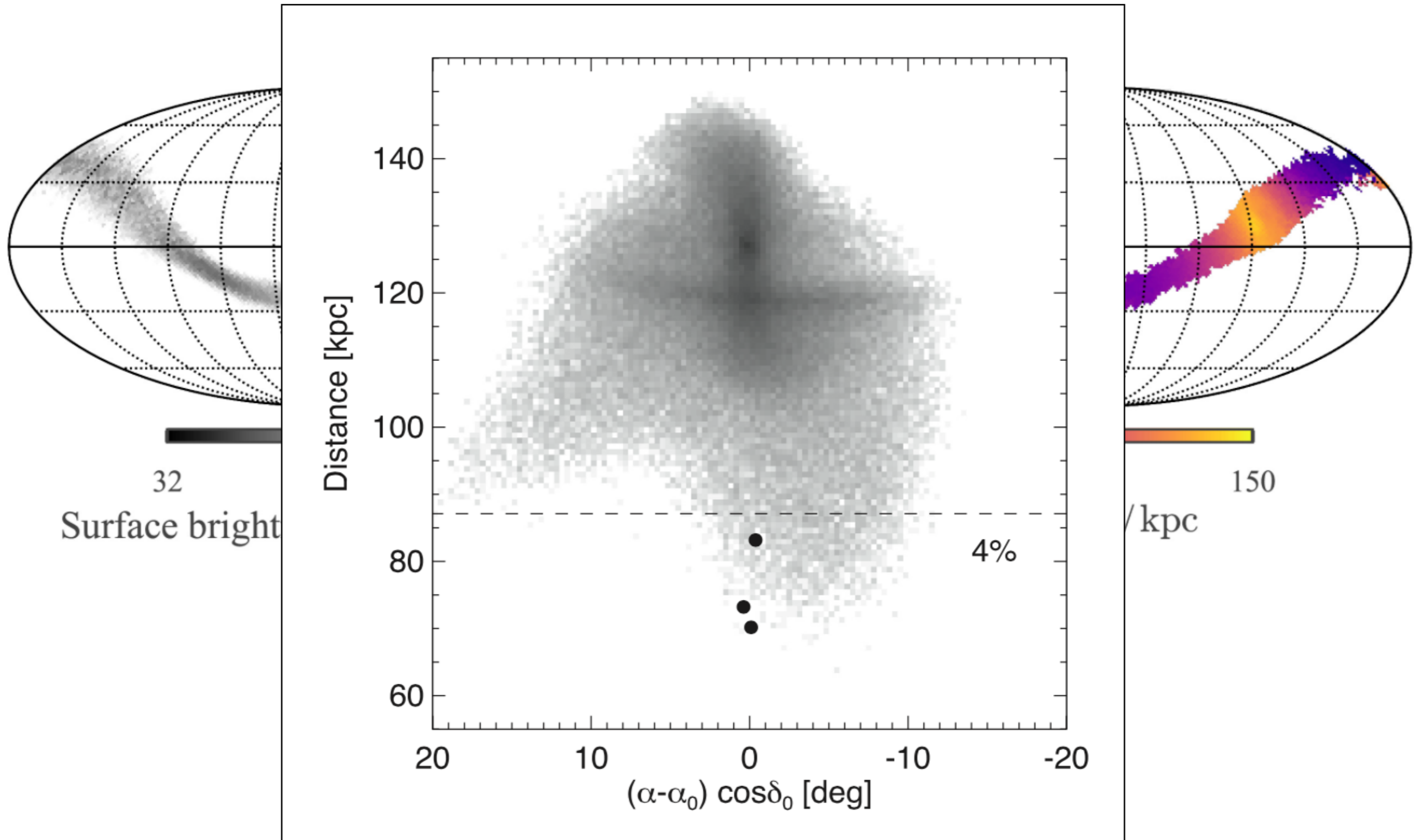
Cuspy and cored haloes react to tides differently



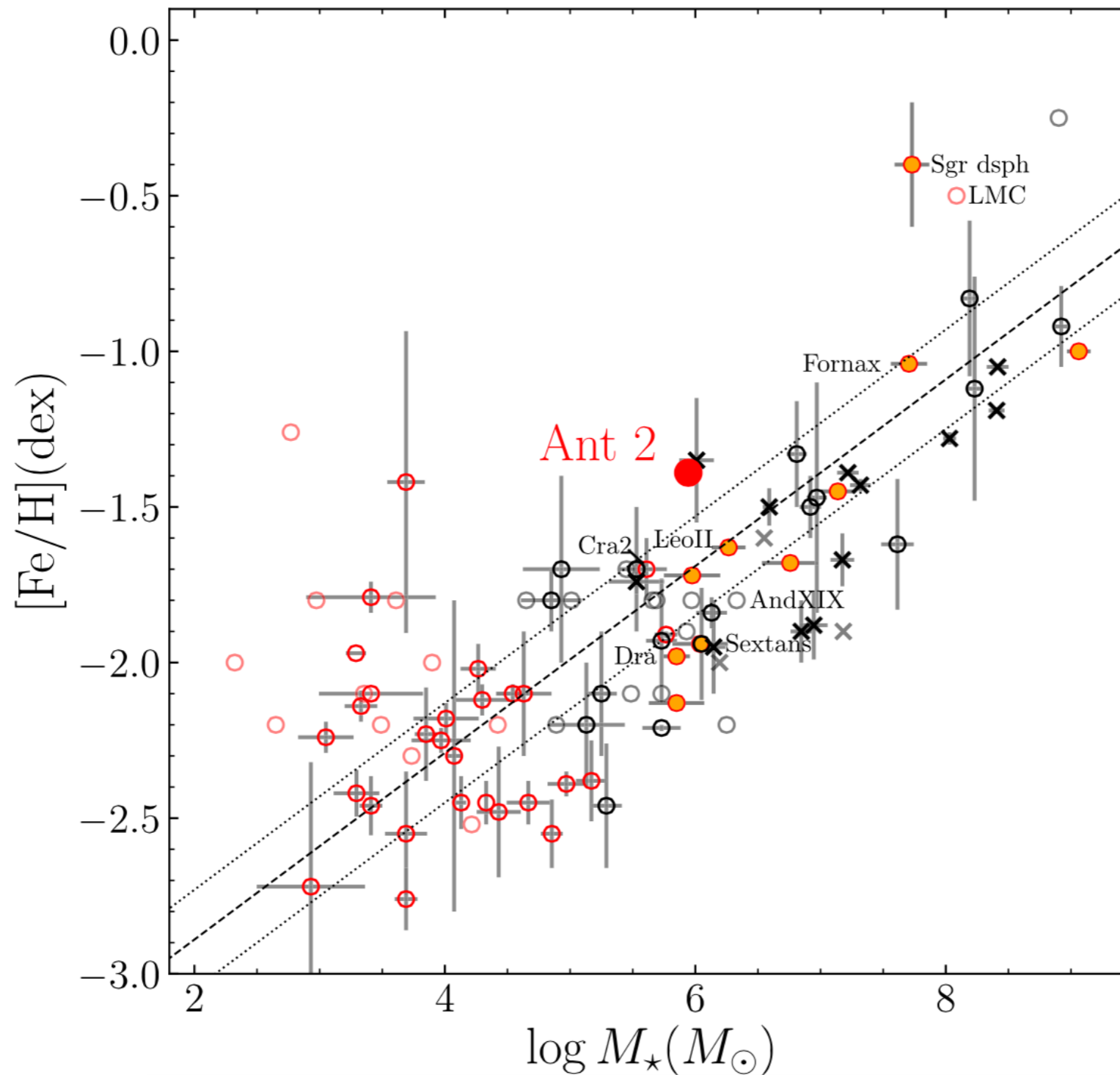
Errani & Peñarrubia 2019



(predicted) Tidal debris



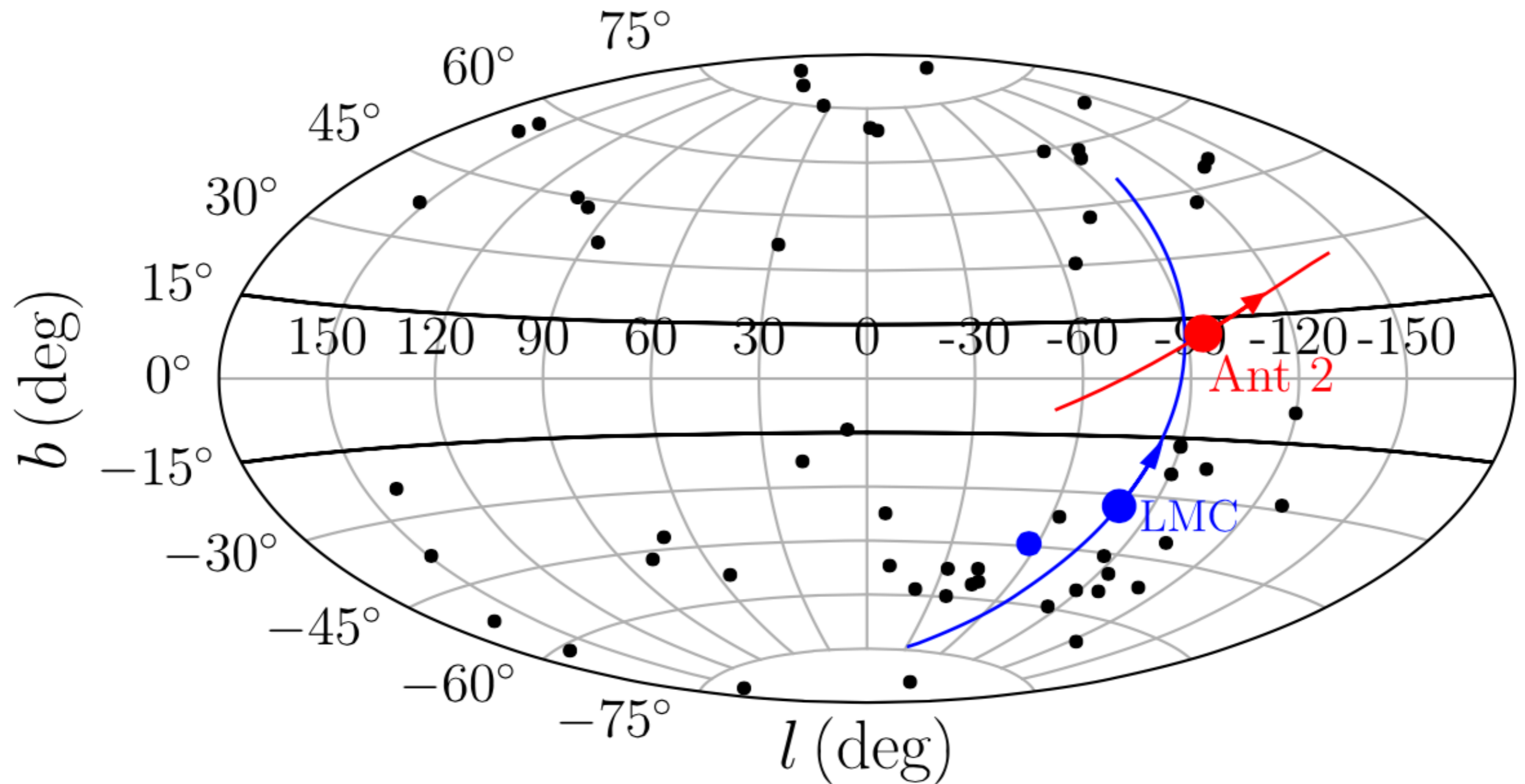
Stellar mass - metallicity



not too
much tidal
stripping?

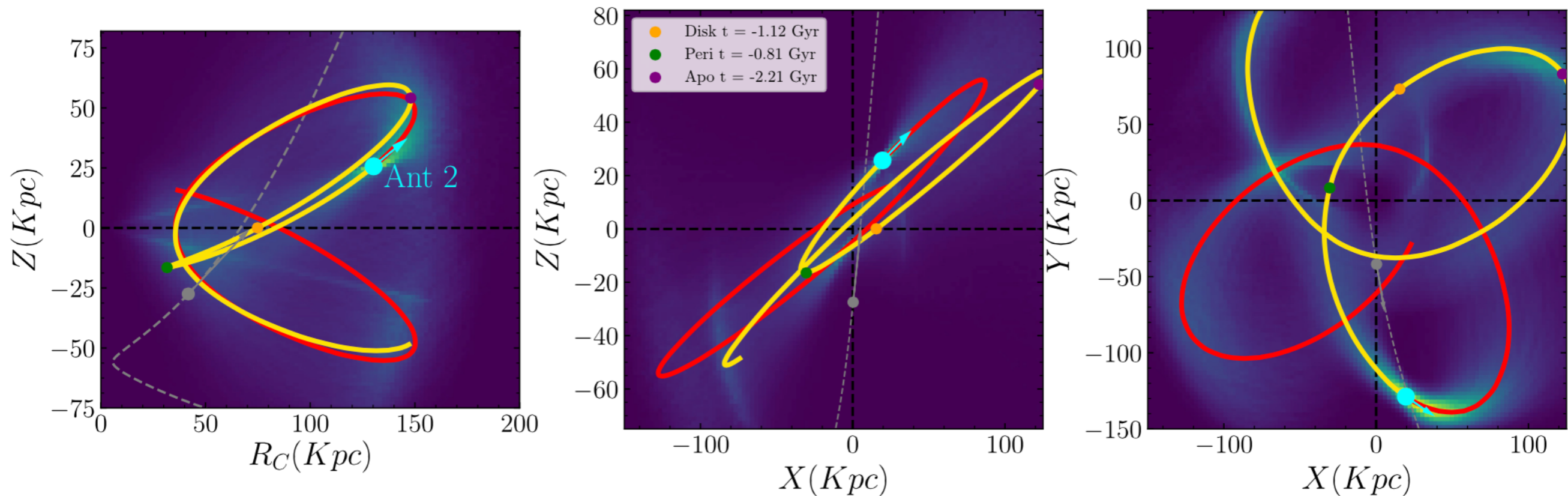
a-la Kirby et al 2013

Antlia 2 and the LMC



LMC changes Ant 2 orbit

Peri-centre shifts from 37 kpc to 27 kpc
if massive LMC is included
(Erkal & Belokurov 2019)



future orbit, past orbit, LMC orbit

Formation pathways?

- Strong feedback - clues in SFH/MDF?
- Dwarf merging - clues in SFH/MDF?
- Born cored - clues anywhere?

Conclusions

- *Gaia* can detect super mega ultra diffuse galaxies
- There may be a (much) larger scatter in luminosity at fixed size than previously assumed
- Ant 2 is difficult to stuff into a cuspy halo
- Even a cored halo requires plenty of tidal stripping
- Giant clouds of tidal debris predicted
- Unclear if the cored halo is consistent with feedback-induced conditions

Low surface brightness Universe

- Are **And XIX**, **Cra 2** and **Ant 2** the tip of the iceberg?
- If yes, our predictions for LSST detection efficiency (with resolved stellar pops) at large distances are **too pessimistic**
- Last week Gaia finished its 5 year-long mission... and started its second life, also 5 years long

The END

Table 1. Properties of the Antlia 2 dwarf.

Property	Antlia 2 dwarf	Unit
α (J2000)	143.8868 ± 0.05	deg
δ (J2000)	-36.7673 ± 0.10	deg
l	264.8955 ± 0.05	deg
b	11.2479 ± 0.10	deg
$(m - M)$	20.6 ± 0.11	mag
D_{\odot}	132 ± 6	kpc
r_h	1.27 ± 0.12	deg
r_h	2920 ± 311	pc
$1 - b/a$	0.38 ± 0.08	
PA	156 ± 6	deg
M_V	-9.03 ± 0.15	mag
$\langle \mu \rangle(r < r_h)$	31.9 ± 0.3	mag arcsec ⁻²
[Fe/H]	-1.36 ± 0.04	dex
$\sigma_{[\text{Fe}/\text{H}]}$	0.57 ± 0.03	dex
rv_{helio}	290.7 ± 0.5	km s ⁻¹
rv_{gsr}	64.3 ± 0.5^b	km s ⁻¹
σ_{rv}	5.71 ± 1.08	km s ⁻¹
$\mu_{\alpha} \cos \delta$	-0.095 ± 0.018^a	mas yr ⁻¹
μ_{δ}	0.058 ± 0.024^a	mas yr ⁻¹
$M(r < r_h)$	5.5 ± 2.2	$10^7 M_{\odot}$
$M(r < 1.8r_h)$	13.7 ± 5.4	$10^7 M_{\odot}$
M_{\star}	8.8 ± 1.2	$10^5 M_{\odot}$
M/L_V	315 ± 130	M_{\odot}/L_{\odot}

^aDoes not consider systematic uncertainties (see text).

^bDoes not consider LSR uncertainties.