The impact of the LMC's passage through the Milky Way halo

Julio Chanamé

The impact of the LMC’s passage through the Milky Way halo

Numerical simulations

Nico Garavito-Camargo et al. (2019)

Julio Chanamé

Observations + measurements

Manuel Cavieres et al. (2024)

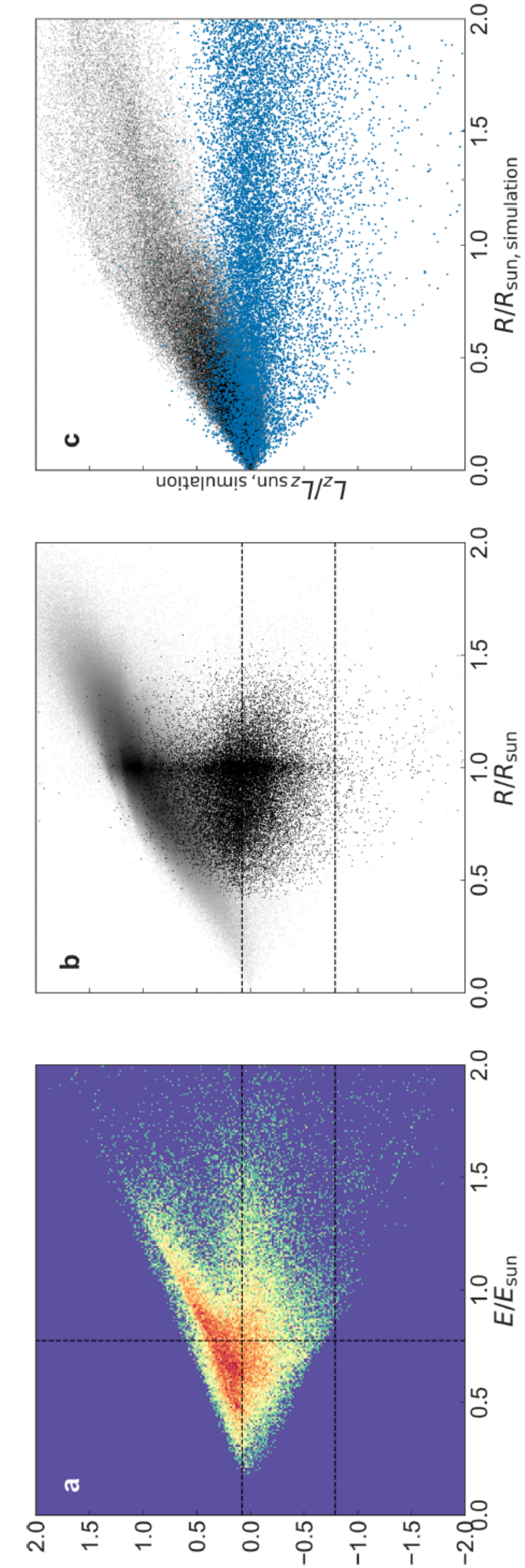
Accretion history of the Milky Way

OCTOBER 31, 2018

Astronomers discover the giant that shaped the early days of our Milky Way

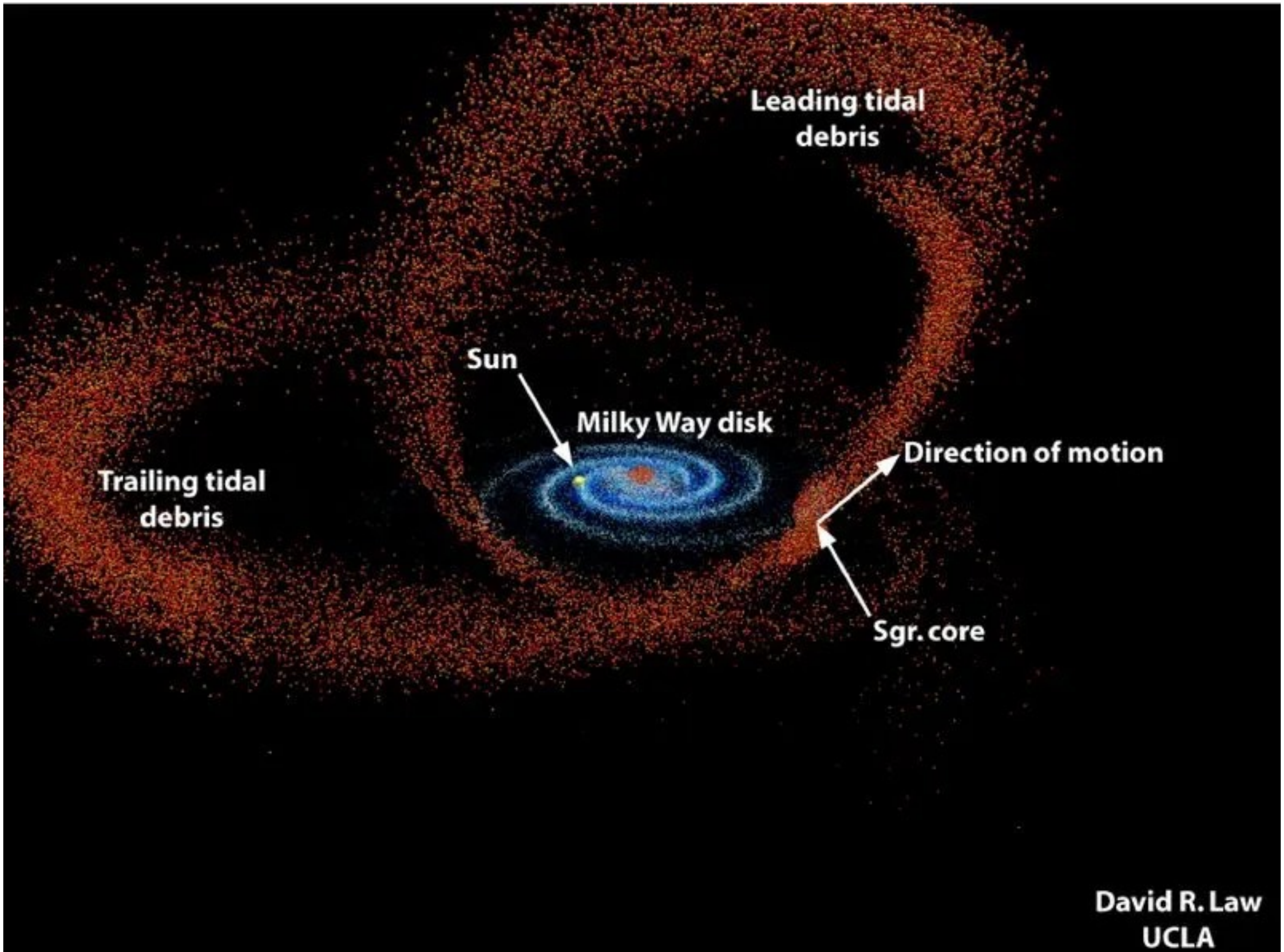
by University of Groningen

Artistic rendering of Enceladus being devoured by a Milky Way-like galaxy. Credit: René van der Woude, Mixr.nl



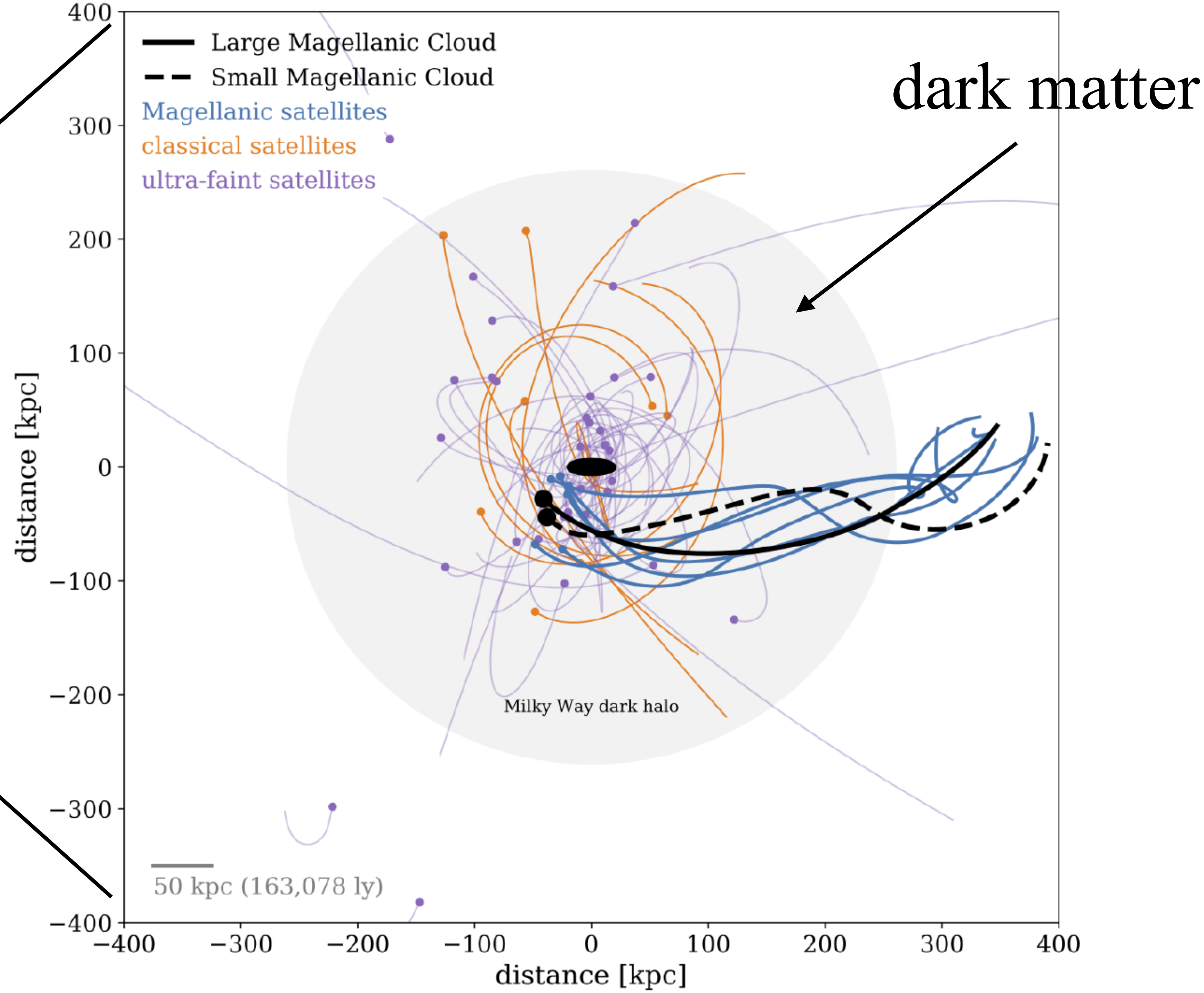
Helmi et al. (2018)

Accretion history of the Milky Way



The infalling Clouds

Watch the scale of the box!



Credit: Ekta Patel

The infalling Clouds

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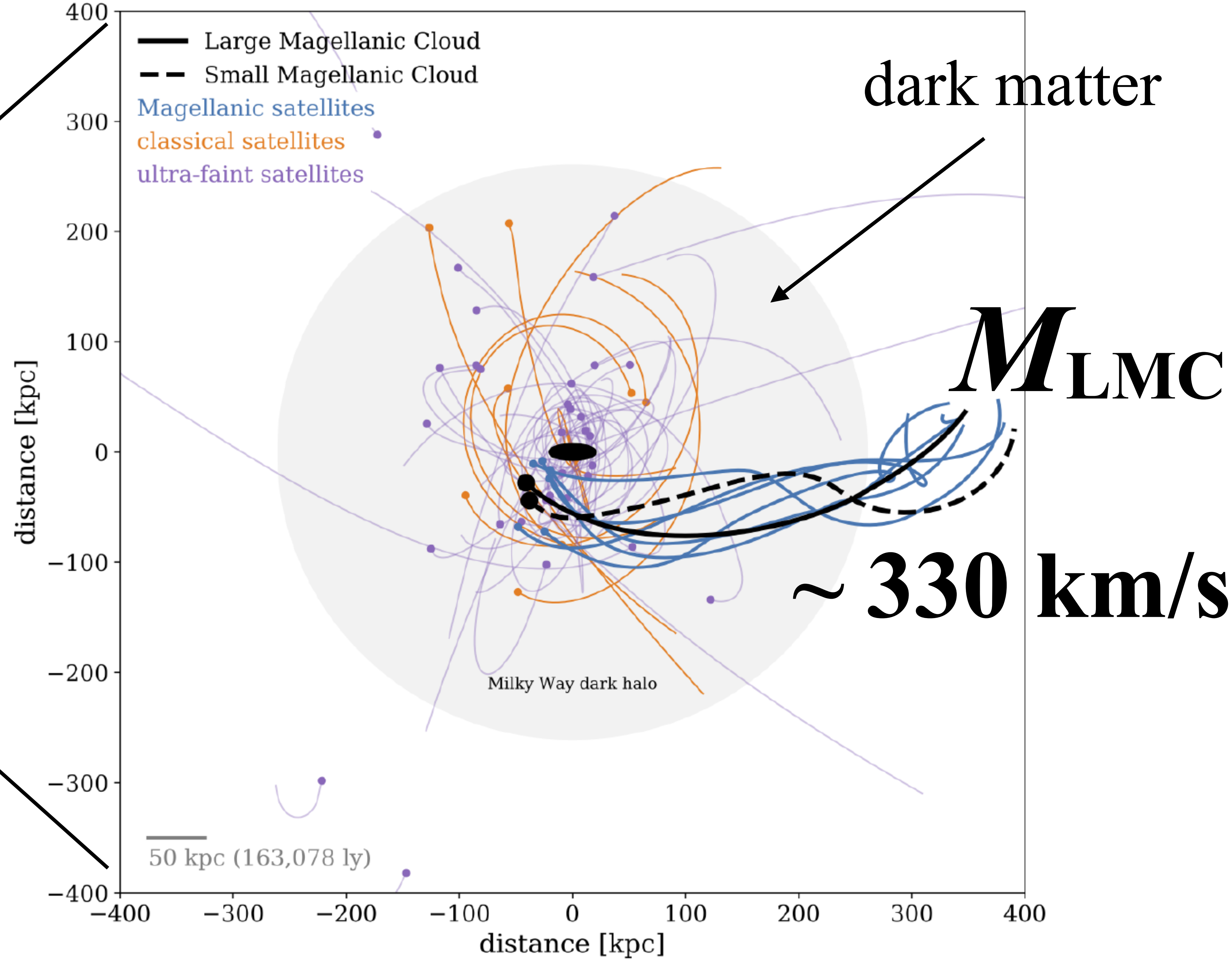


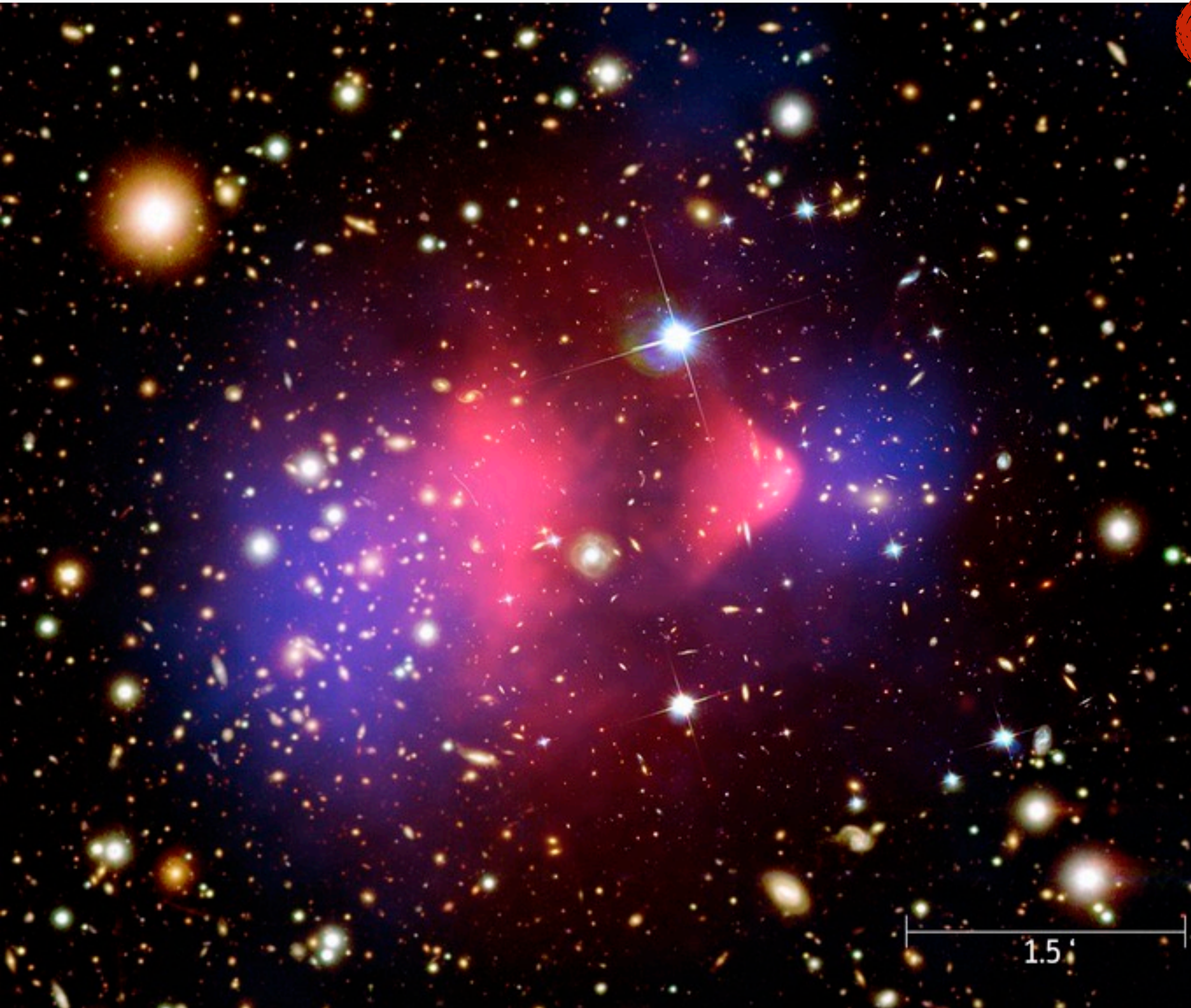
Credit: Ekta Patel

Scientific Visualization Studio

‹ 30081: Stereo Captures Eruption and CME

Chandra and the Bullet Cluster

Released Thursday, October 17, 2013



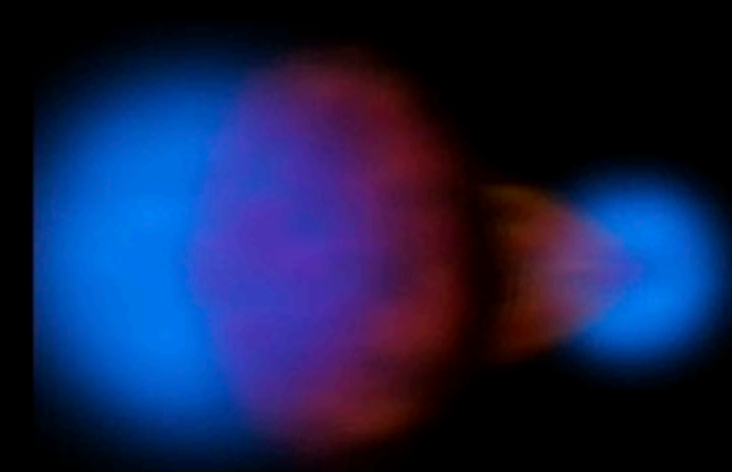
Direct Proof of Dark Matter

This composite image shows the galaxy cluster 1E 0657-56, also known as the "bullet cluster." This cluster was formed after the collision of two large clusters of galaxies, the most energetic event known in the universe since the Big Bang.

Hot gas detected by Chandra in X-rays is seen as two pink clumps in the image and contains most of the "normal," or baryonic, matter in the two clusters. The bullet-shaped clump on the right is the hot gas from one cluster, which passed through the hot gas from the other larger cluster during the collision. An optical image from Magellan and the Hubble Space Telescope shows the galaxies in orange and white. The blue areas in this image show where astronomers find most of the mass in the clusters. The concentration of mass is determined using the effect of so-called gravitational lensing, where light from the distant objects is distorted by intervening matter. Most of the matter in the clusters (blue) is clearly separate from the normal matter (pink), giving direct evidence that nearly all of the matter in the clusters is dark.

The animation below shows an artist's representation of the huge collision in the bullet cluster. Hot gas, containing most of the normal matter in the cluster, is shown in red and dark matter is in blue. During the collision the hot gas in each cluster is slowed and distorted by a drag force, similar to air resistance. In contrast, the dark matter is not slowed by the impact, because it does not interact directly with itself or the gas except through gravity, and separates from the normal matter.

Left: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.; Below: NASA/CXC/M.Weiss



The infalling Clouds

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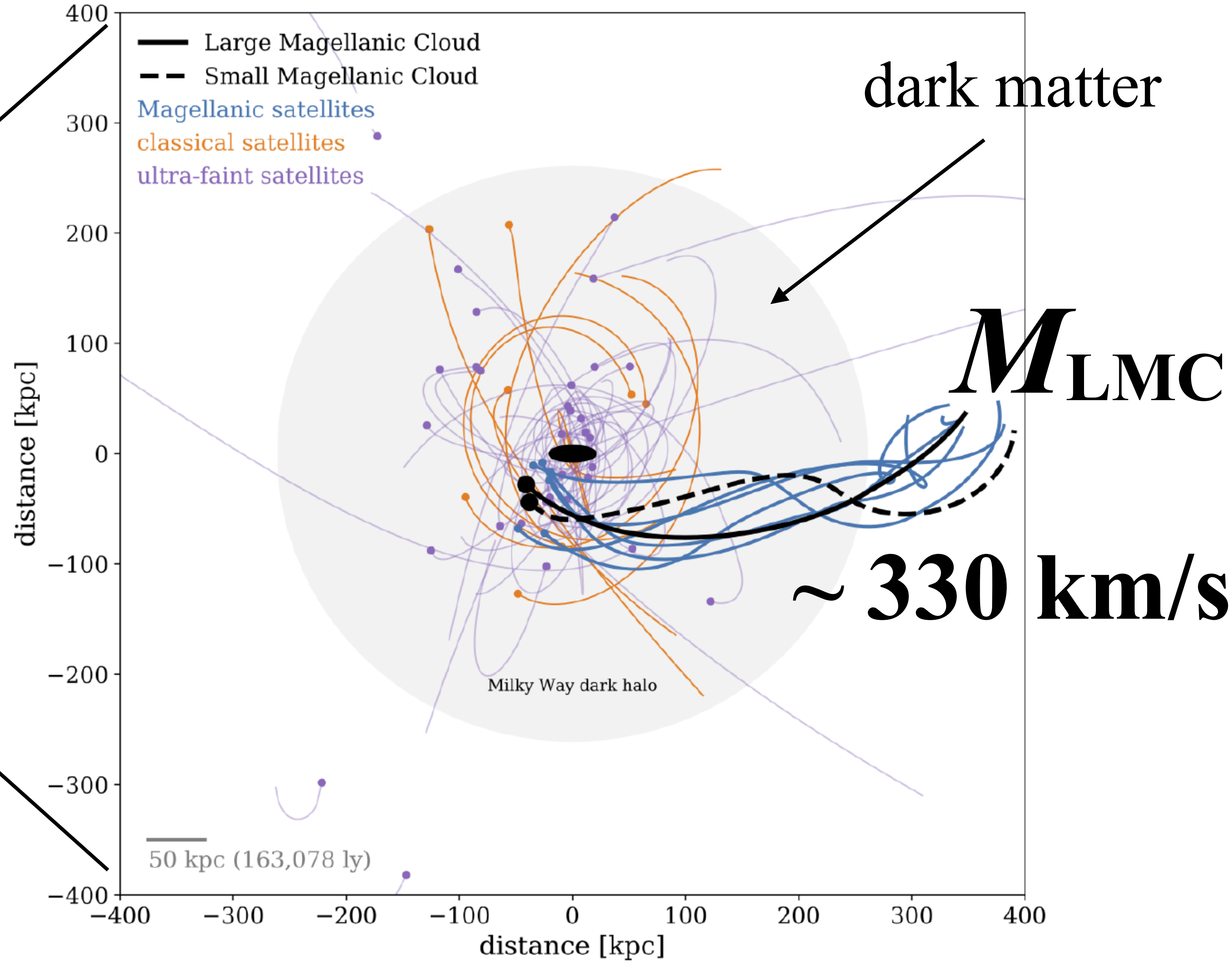
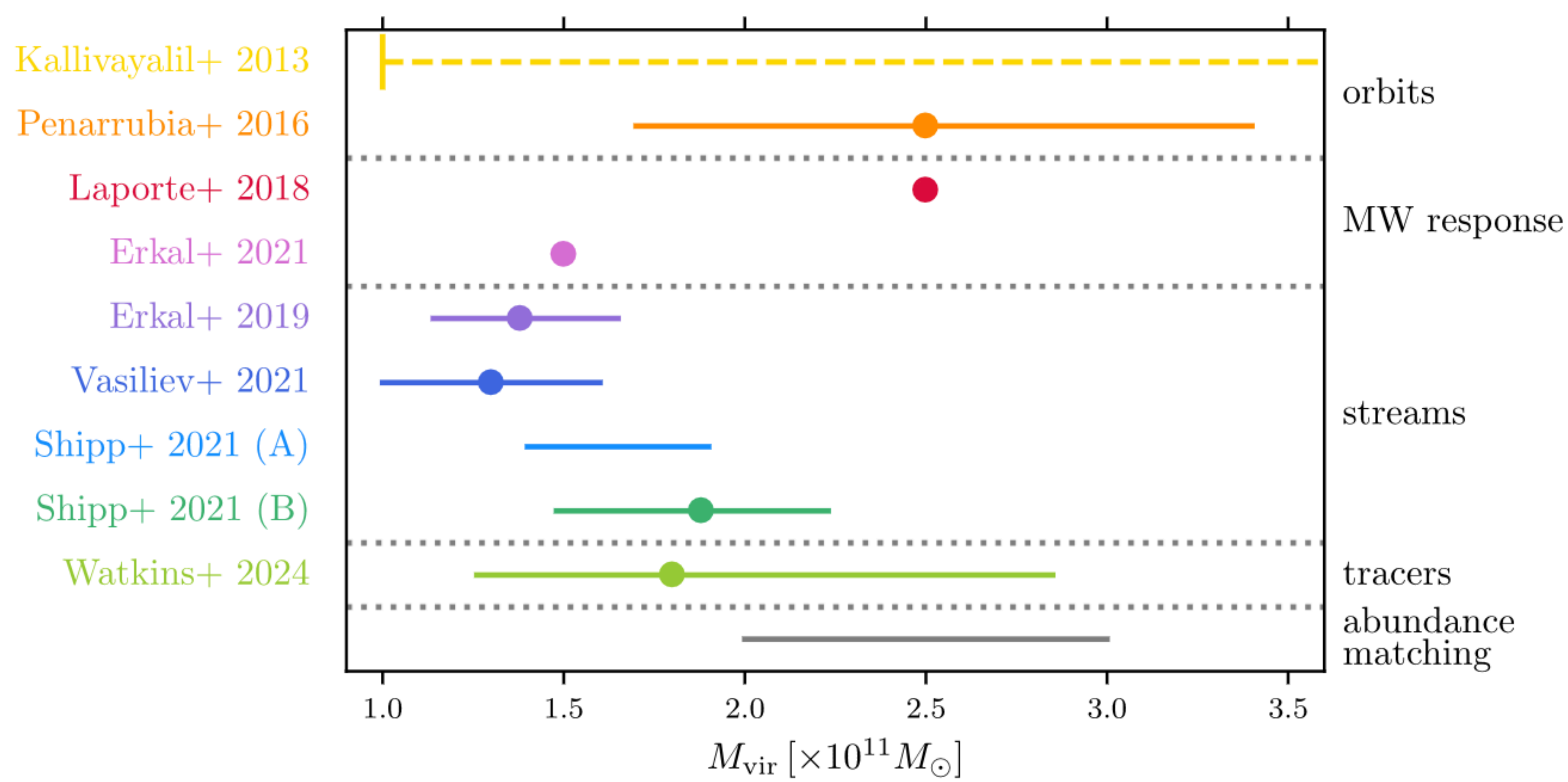


Credit: Ekta Patel

The response of the MW ?

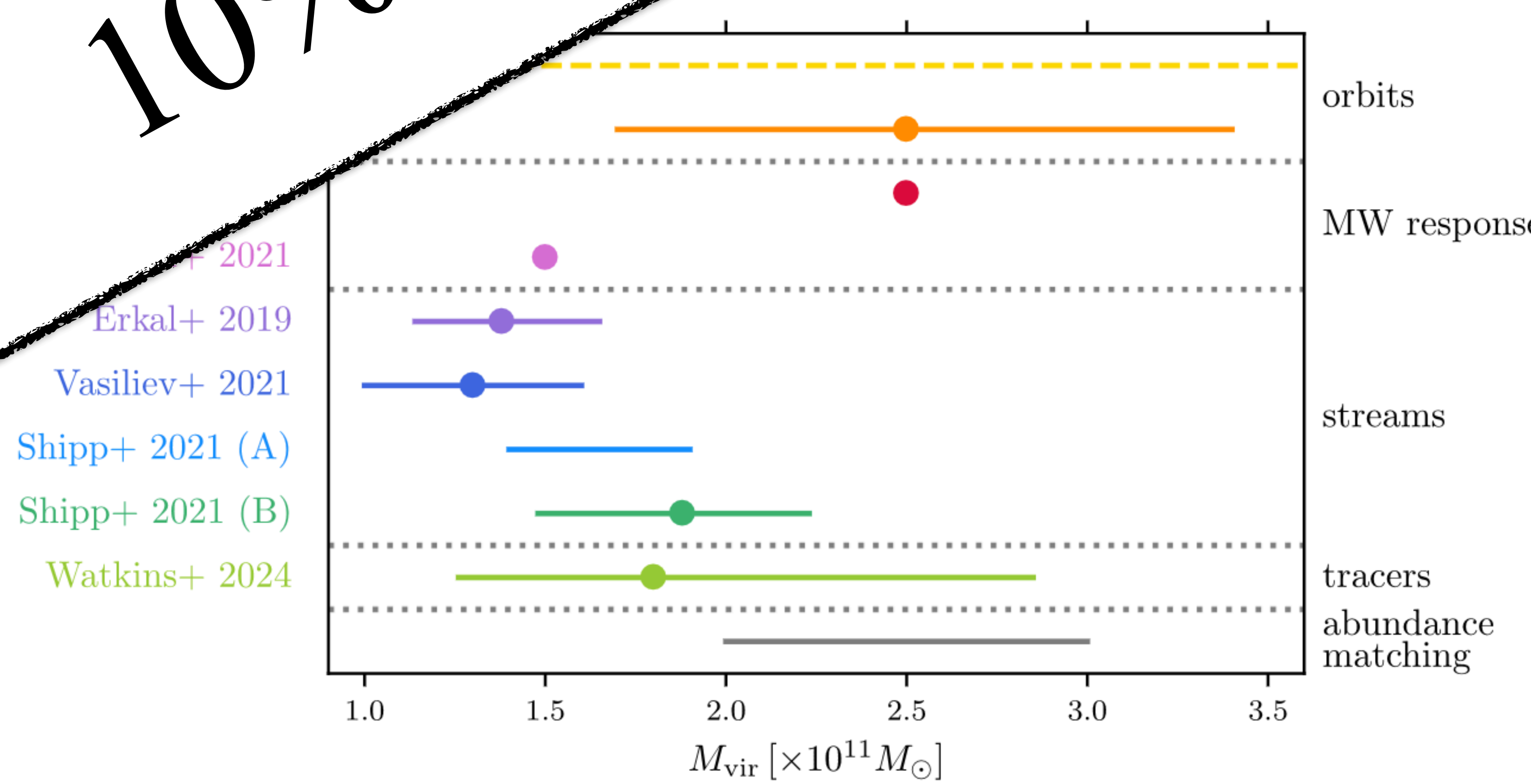
M_{LMC}



Watkins, van der Marel, & Bennet (2024)

The response of the MW ?

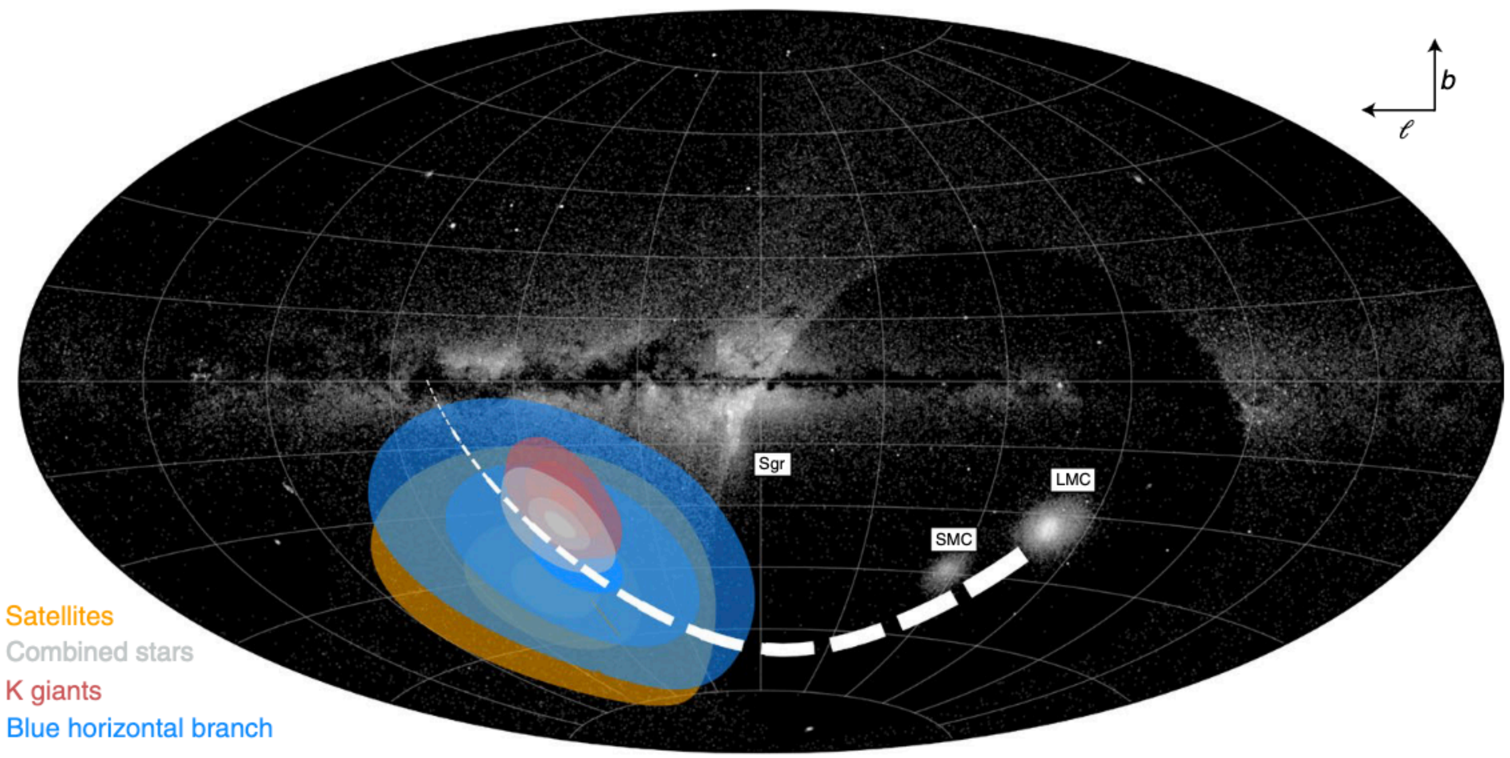
$M_{LMC} = 10\% — 25\% \; M_{MW}$



Watkins, van der Marel, & Bennet (2024)

The response of the MW ?

- Reflex motion of MW disk wrt. halo (Gómez et al. 2015)



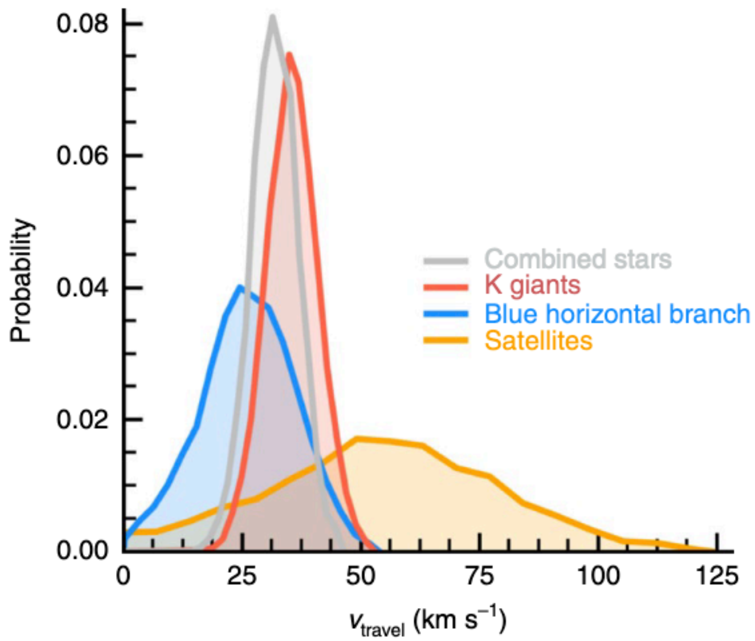


Fig. 2 | Measured velocity of the MW disk with respect to halo stars located at Galactocentric distances *r* > 40 kpc (red and blue curves), the combined sample (silver curve) and satellites (orange curve). We find that the three distinct samples of halo tracers (K giant stars, BHB stars and satellites) return consistent values within statistical uncertainties.

Petersen & Peñarrubia (2021)

The response of the MW ?

- Reflex motion of MW disk wrt. halo (Gómez et al. 2015)
- Equilibrium assumption bias MW mass measurems. (Erkal et al. 2020)

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- Warp of MW disk (Laporte et al. 2018)

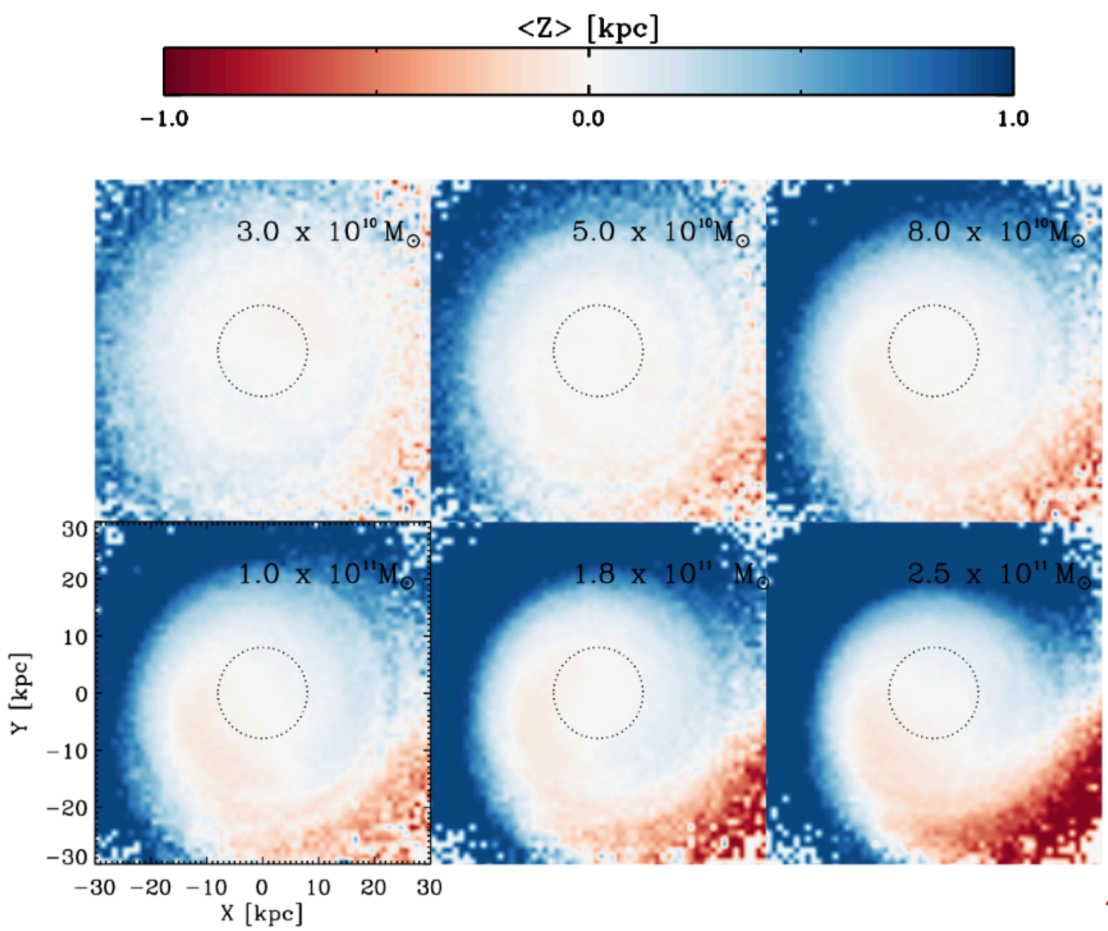
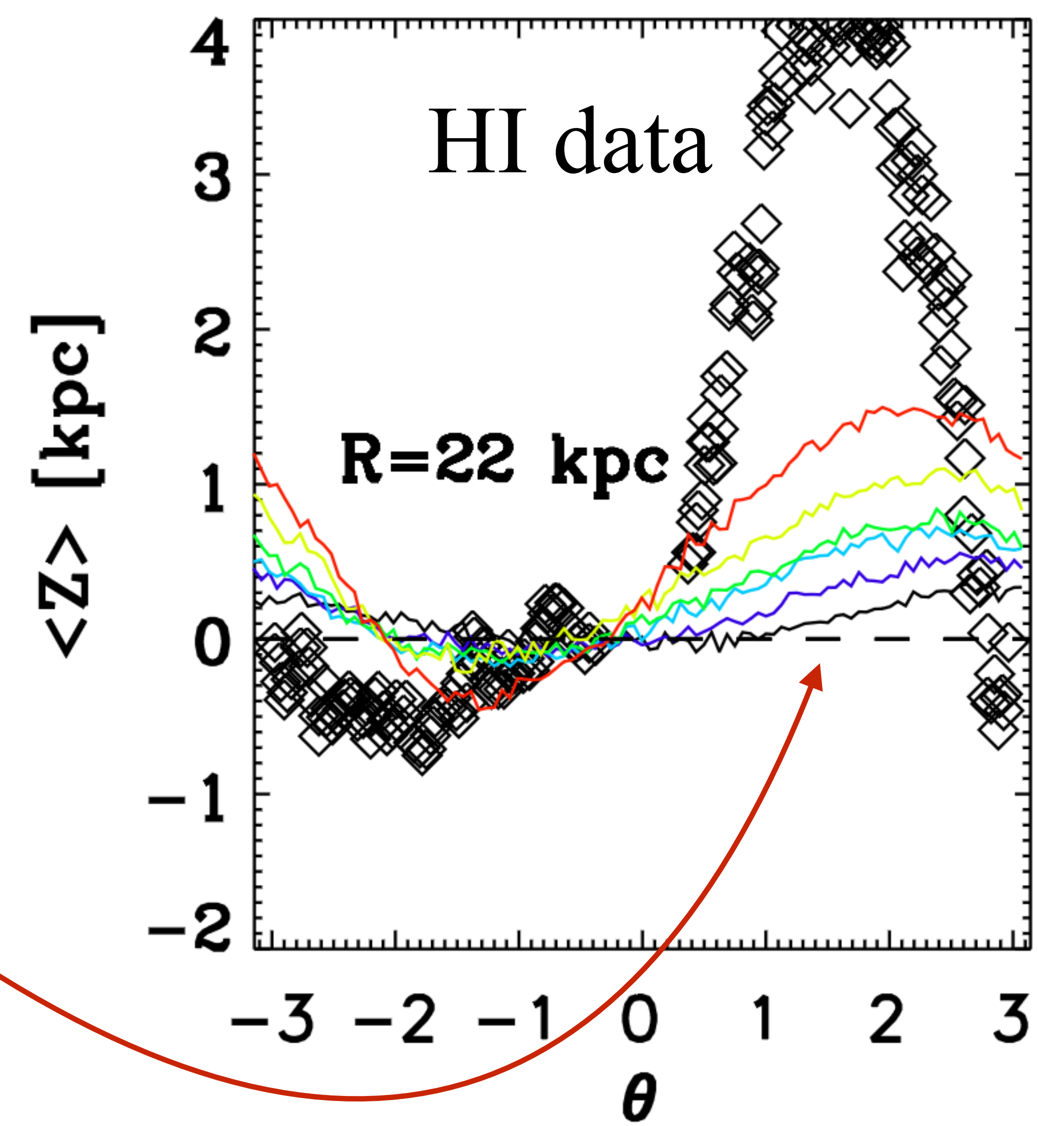


Figure 6. Mean disc height maps for all six realizations. The solar circle at $R \sim 8.0$ kpc is denoted by the dashed circle. For the more massive models, a warp in the stars can already be discerned within the solar neighbourhood.



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- Warp of MW disk (Laporte et al. 2018)
- Orbital evolution of streams will feel all this

(Law & Majewski 2010; Vera-Ciro & Helmi 2013; Koposov et al. 2019; ……)

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  (Law & Majewski 2010; Vera-Ciro & Helmi 2013; Koposov et al. 2019; ……)

- Stellar and dark matter wake (Garavito-Camargo et al. 2019)

The Astrophysical Journal, 884:51 (29pp), 2019 October 10 https://doi.org/10.3847/1538-4357/ab32eb

CrossMark

Hunting for the Dark Matter Wake Induced by the Large Magellanic Cloud

Nicolas Garavito-Camargo[1], Gurtina Besla[1], Chervin F. P. Laporte[2,8], Kathryn V. Johnston[3], Facundo A. Gómez[4,5], and Laura L. Watkins[6,7]
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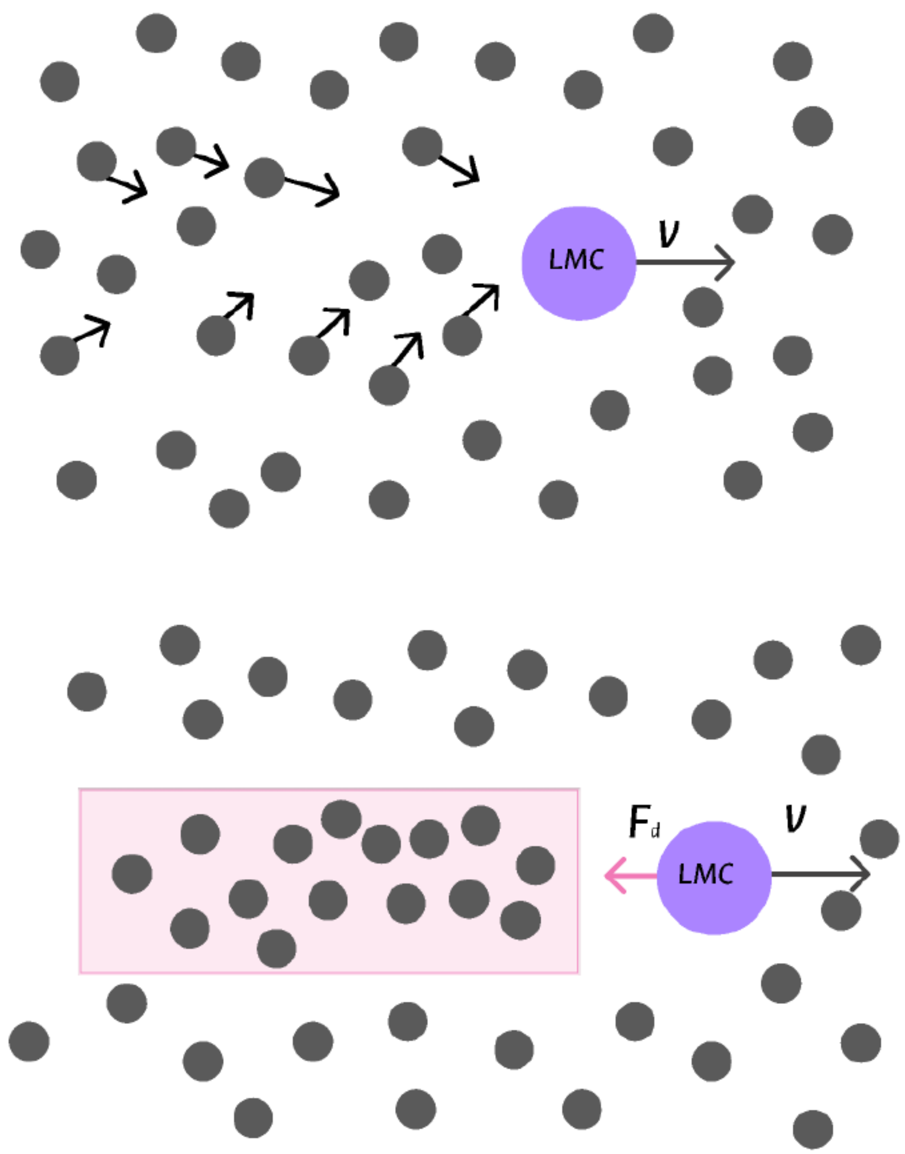
Received 2019 February 13; revised 2019 July 3; accepted 2019 July 7; published 2019 October 11

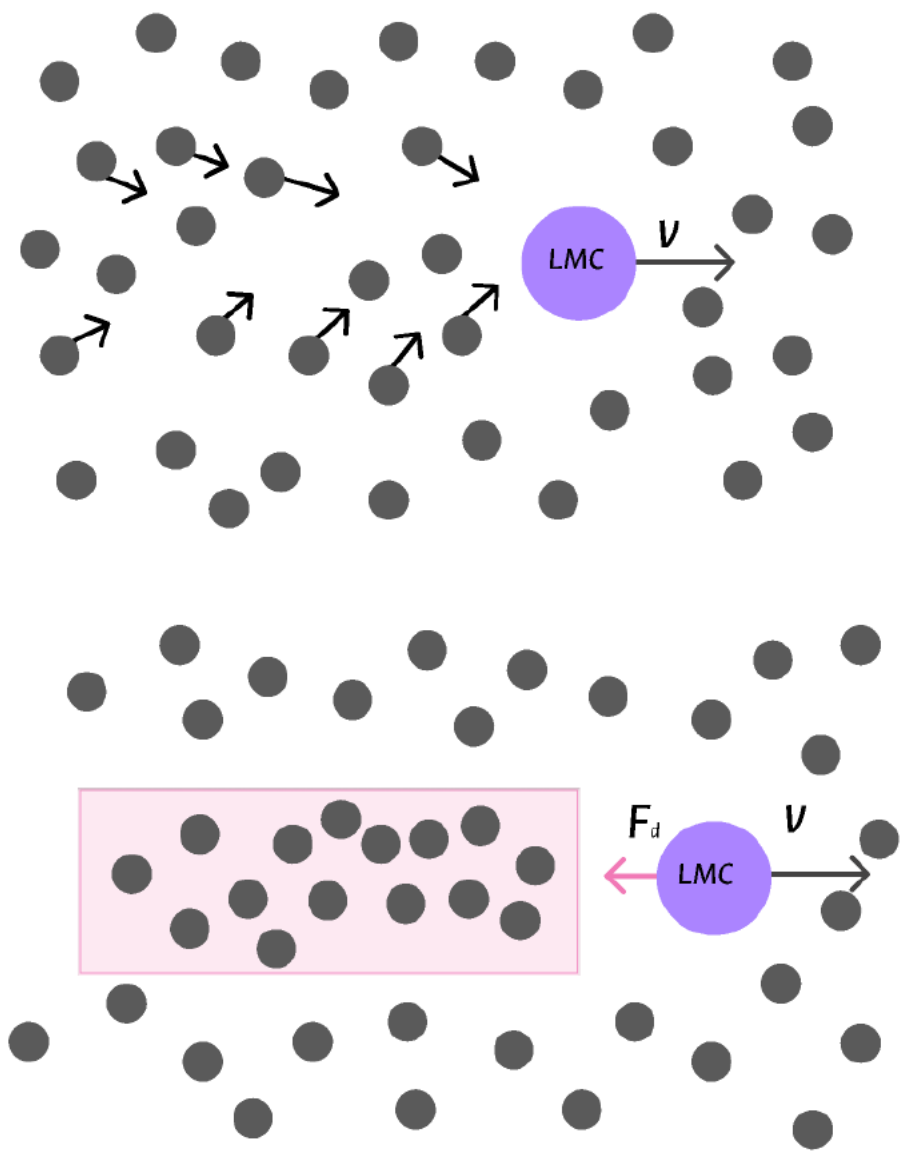
The Magellanic dark matter wake

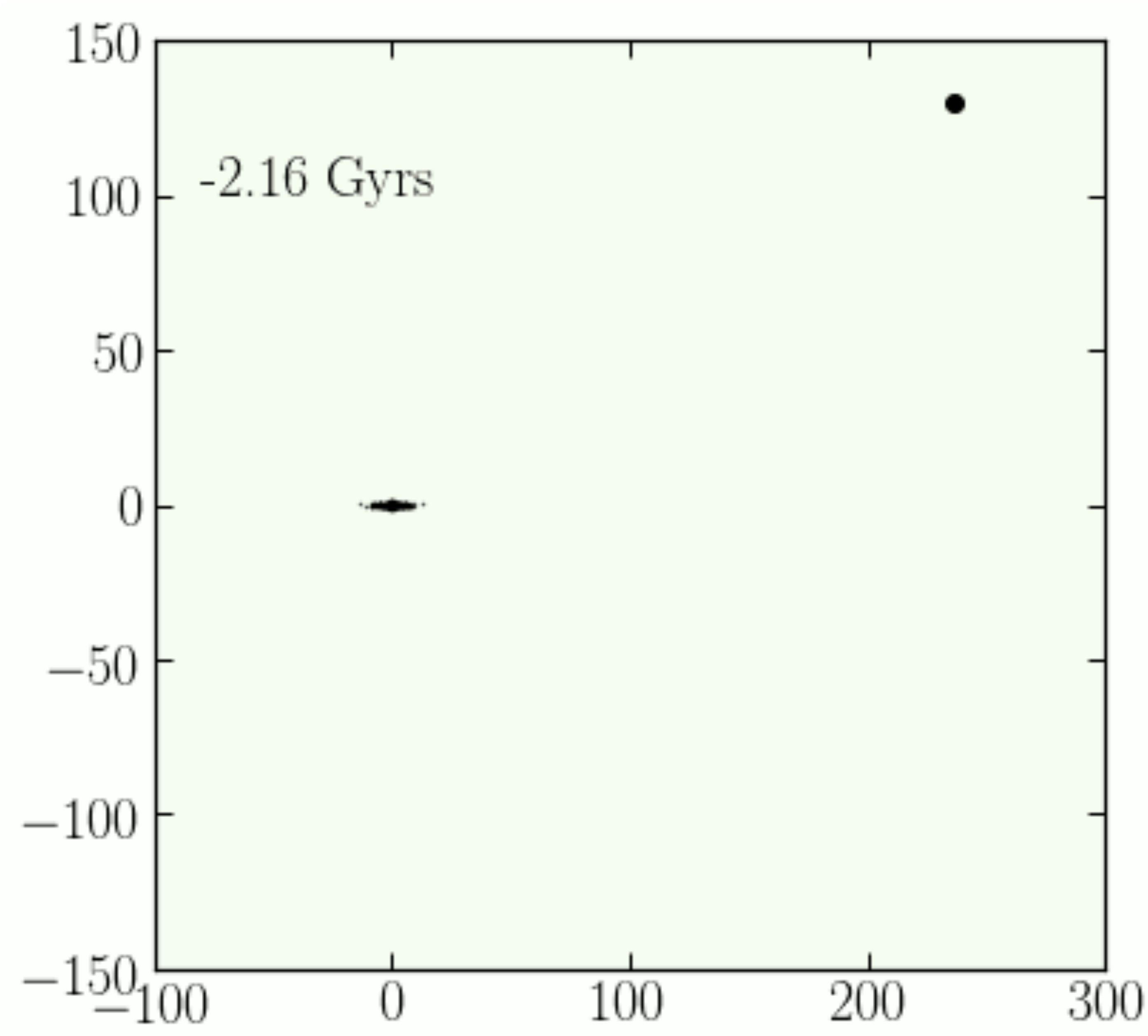
Dynamical friction Wake



The Magellanic dark matter wake

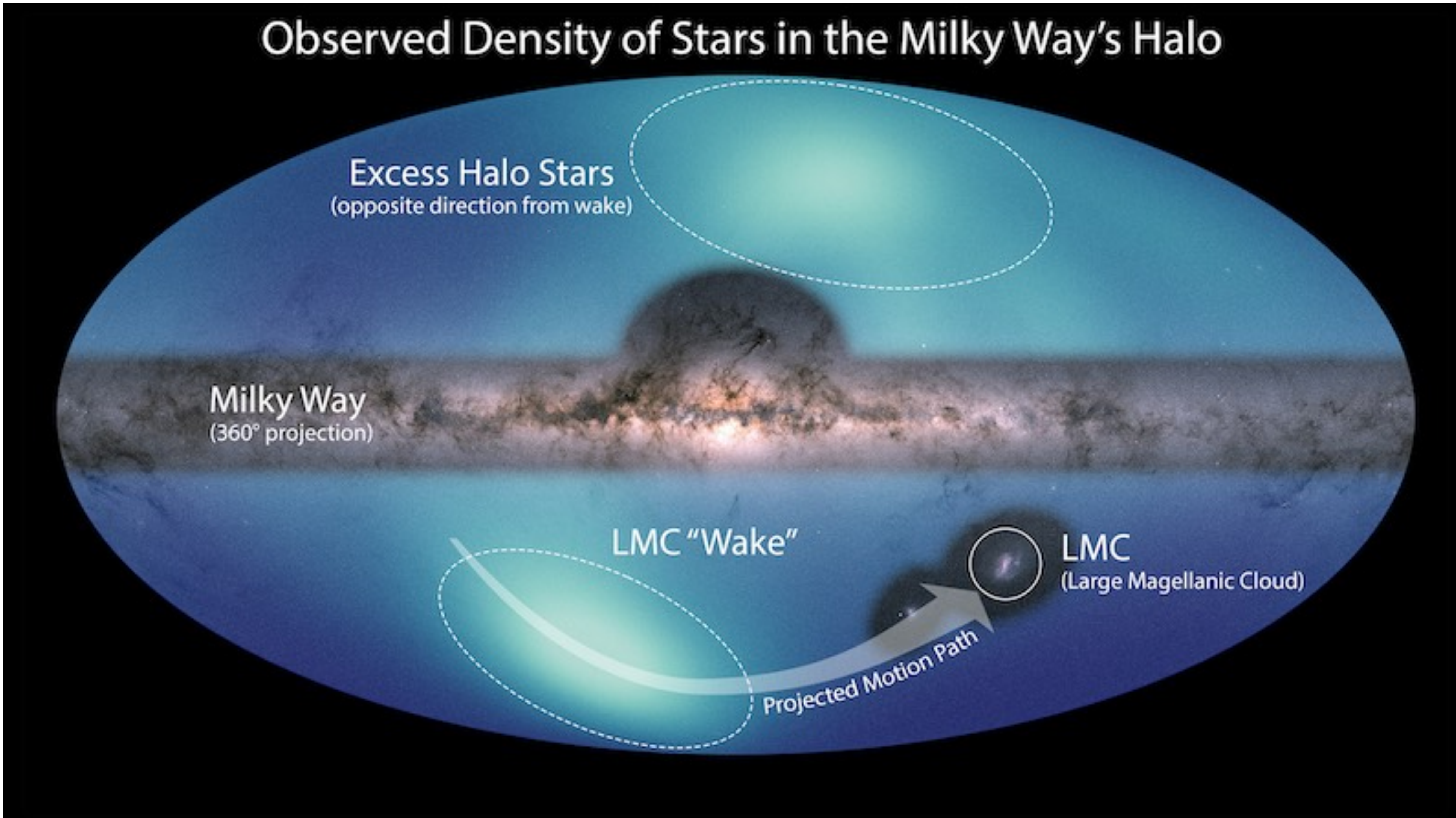
Dynamical friction Wake





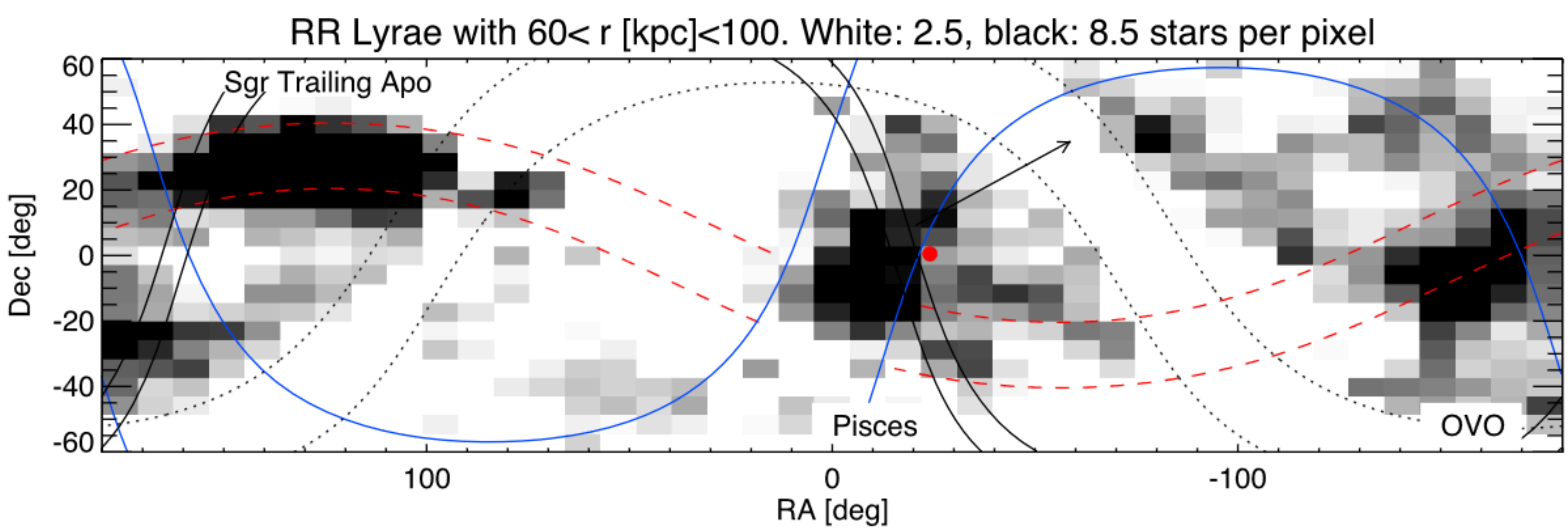
Credits: Nico Garavito-Camargo

The Magellanic dark matter wake



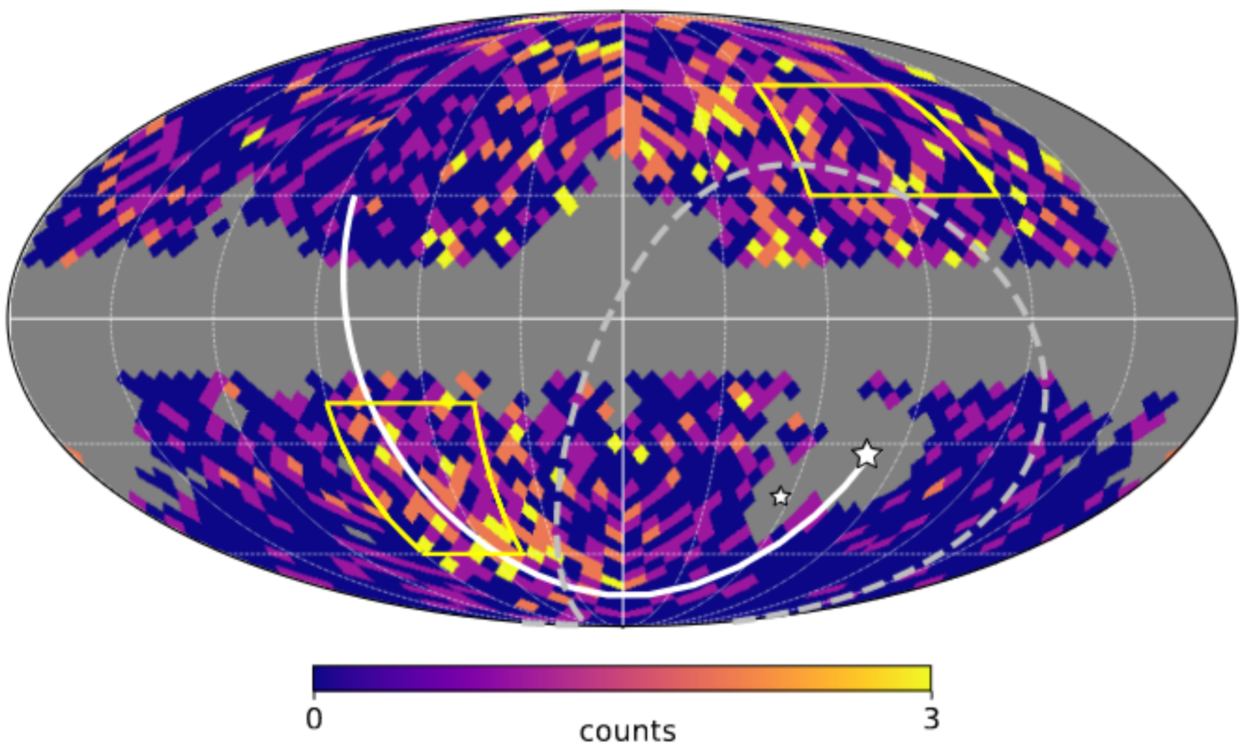
Observational evidence for the wake

Pisces Plume/overdensity (Belokurov et al. 2019)



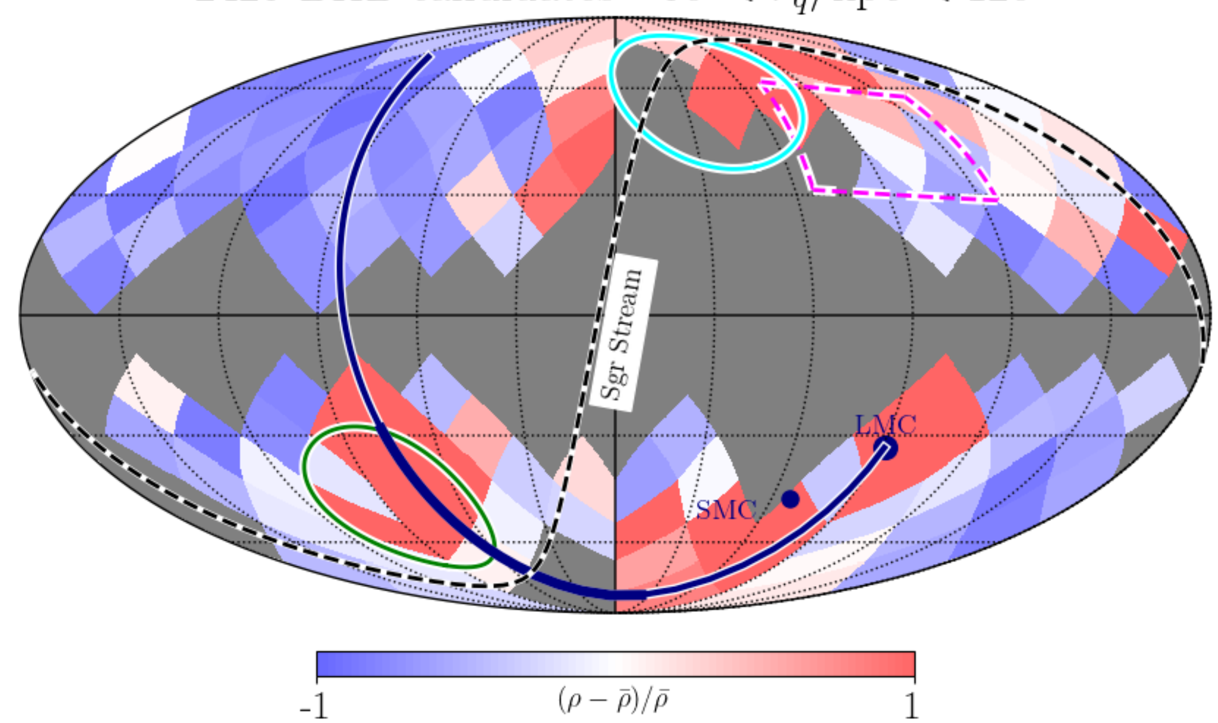
Observational evidence for the wake

1301 giant stars at 60 kpc< R_{gal} < 100 kpc



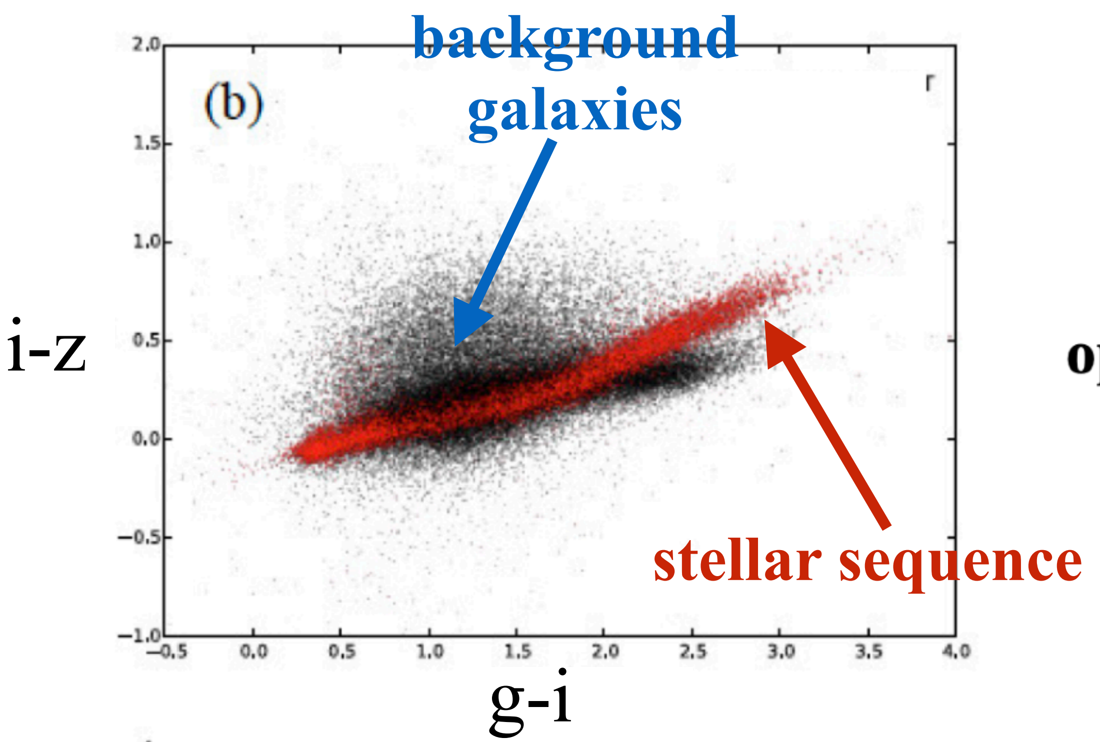
Conroy et al. (2021)

2425 BHB candidates - $50 < r_q/\mathrm{kpc} < 120$



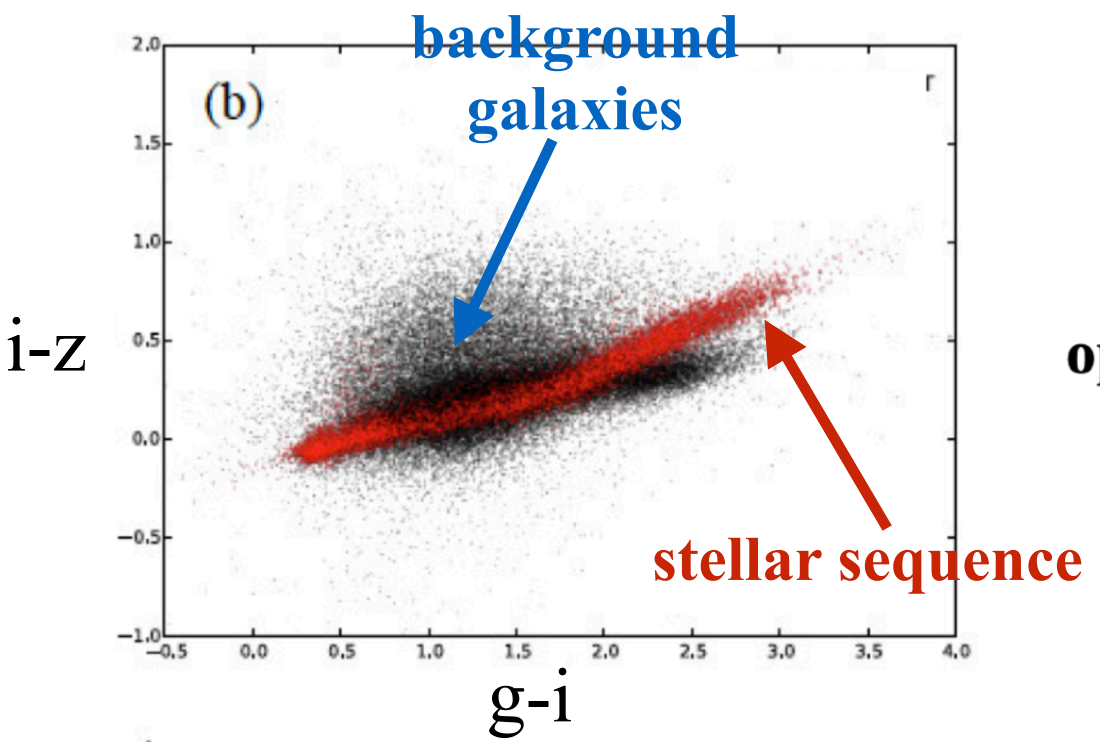
Amarante et al. (2024)

Going very deep into the halo…
has its complications



only optical data

Going very deep into the halo… has its complications



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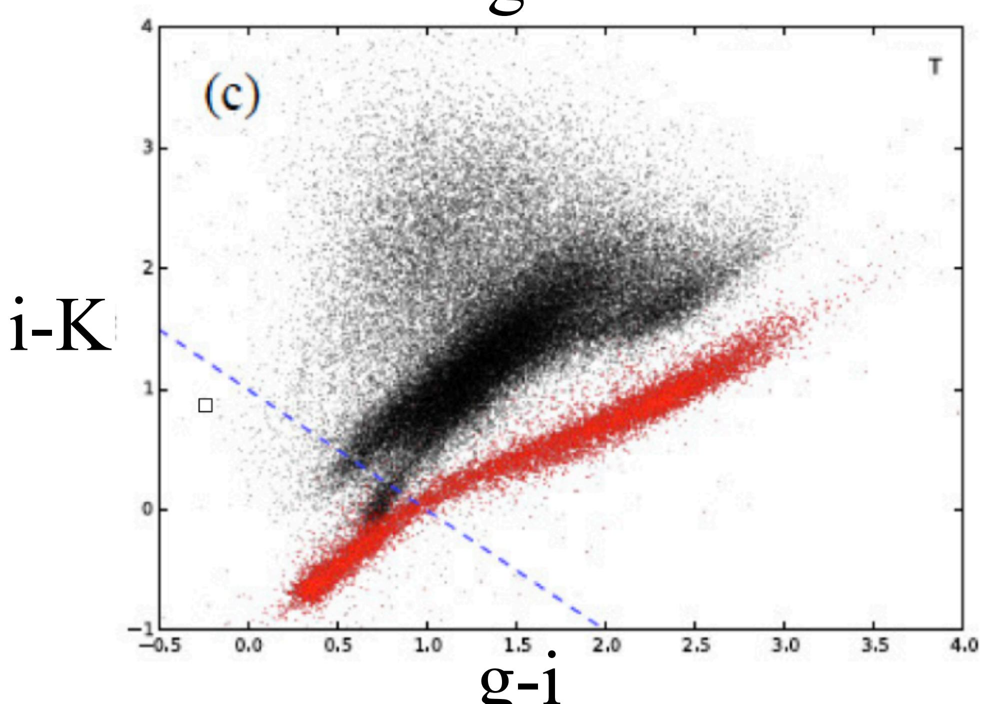

optical + K-band

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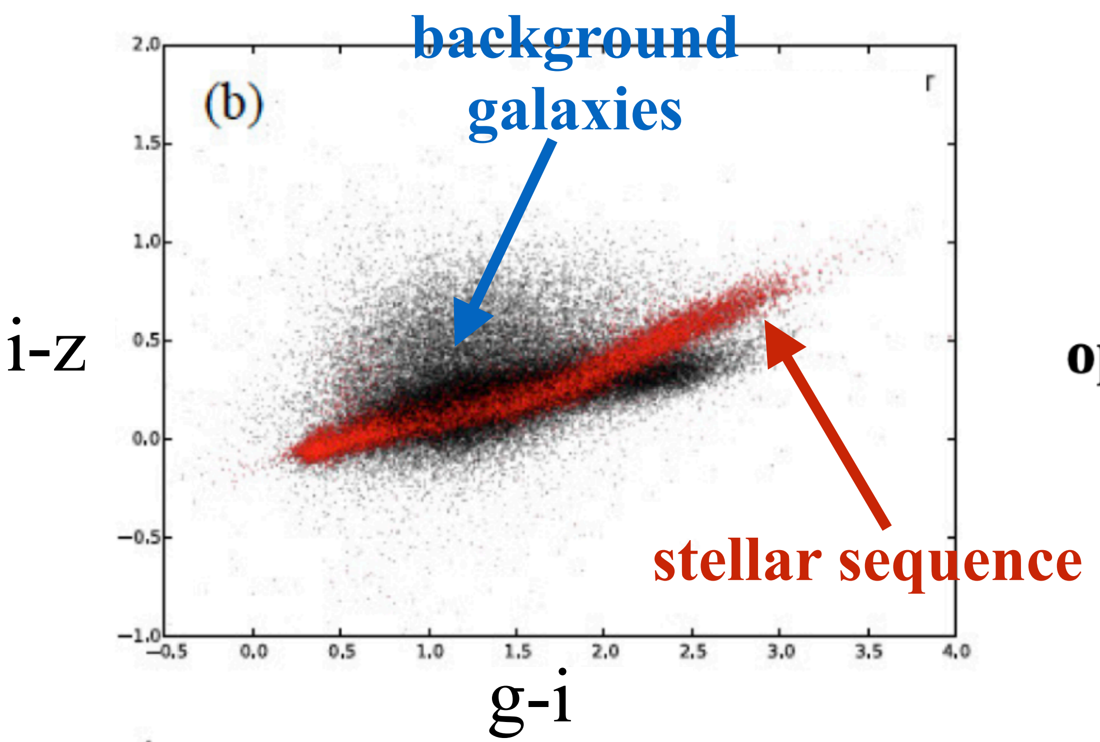
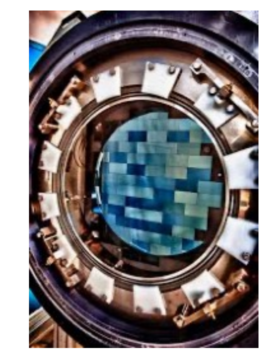
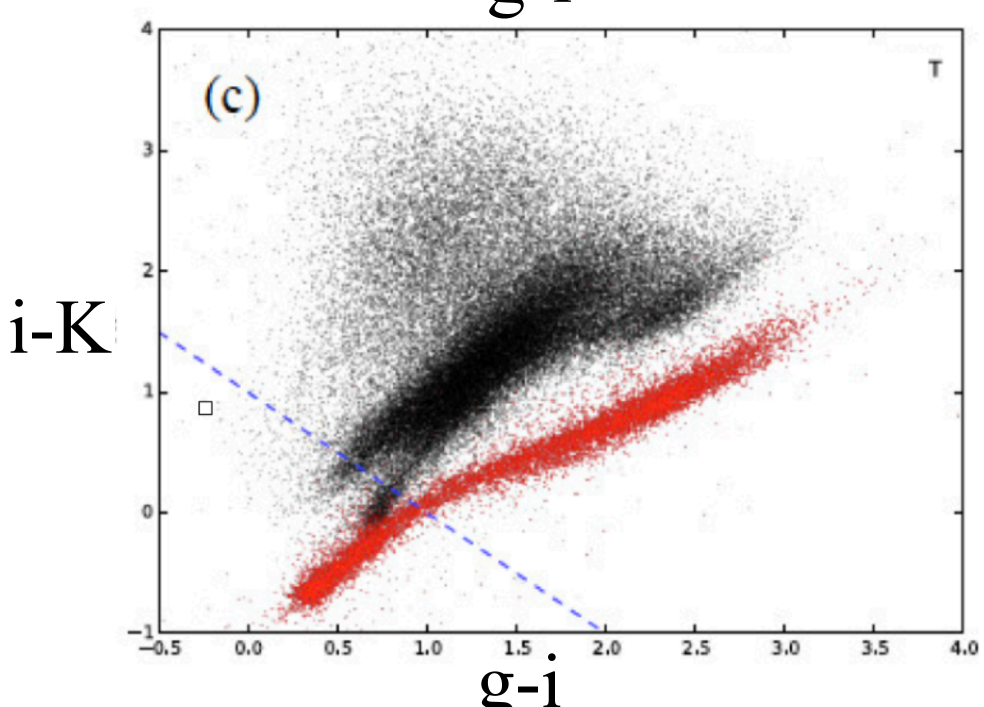


only
optical data





optical
+
K-band

arXiv > astro-ph > arXiv:2410.00114

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[Submitted on 30 Sep 2024]

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Manuel Cavieres, Julio Chanamé, Camila Navarrete, Yasna Ordenes-Briceño, Nicolás Garavito-Camargo, Gurtina Besla, Maren Hempel, Katherina Vivas, Facundo Gómez

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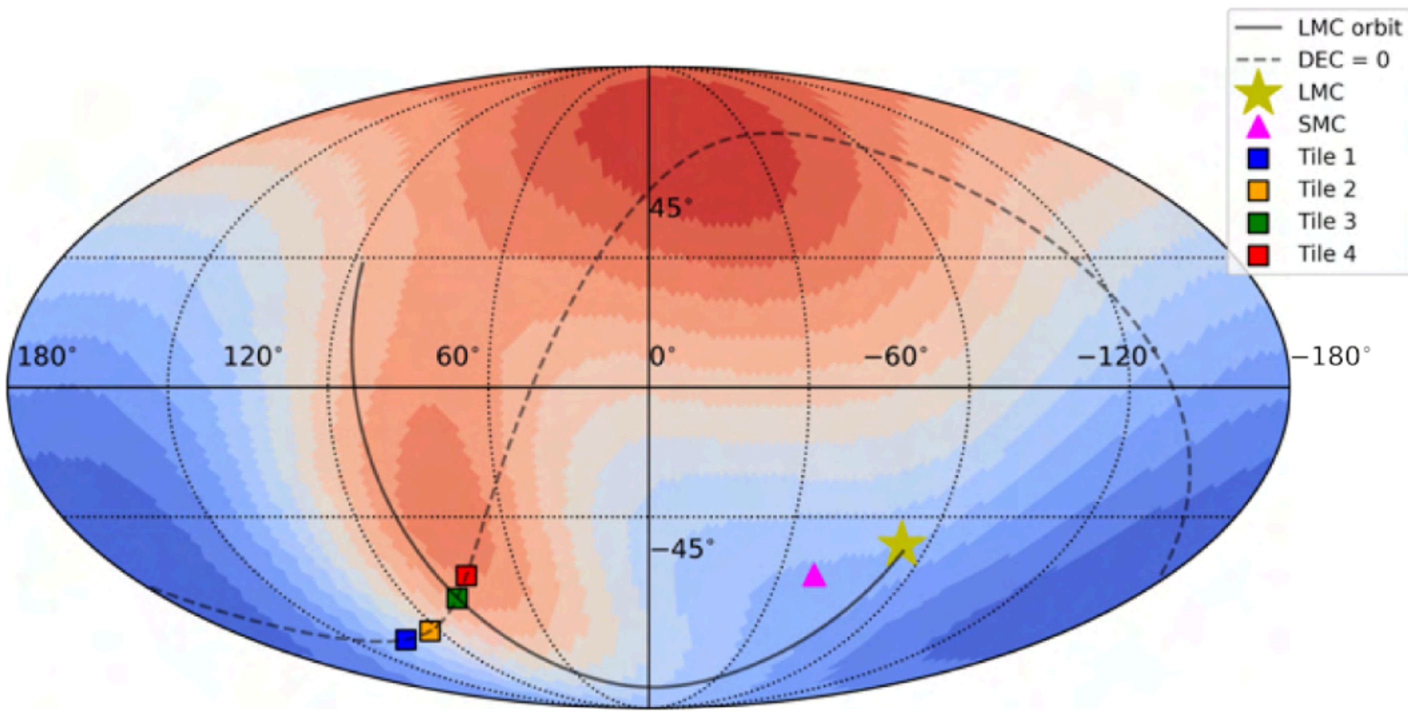

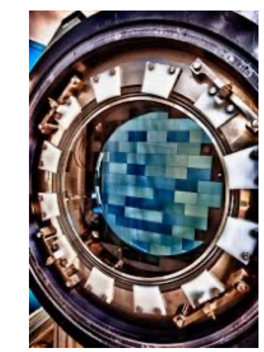

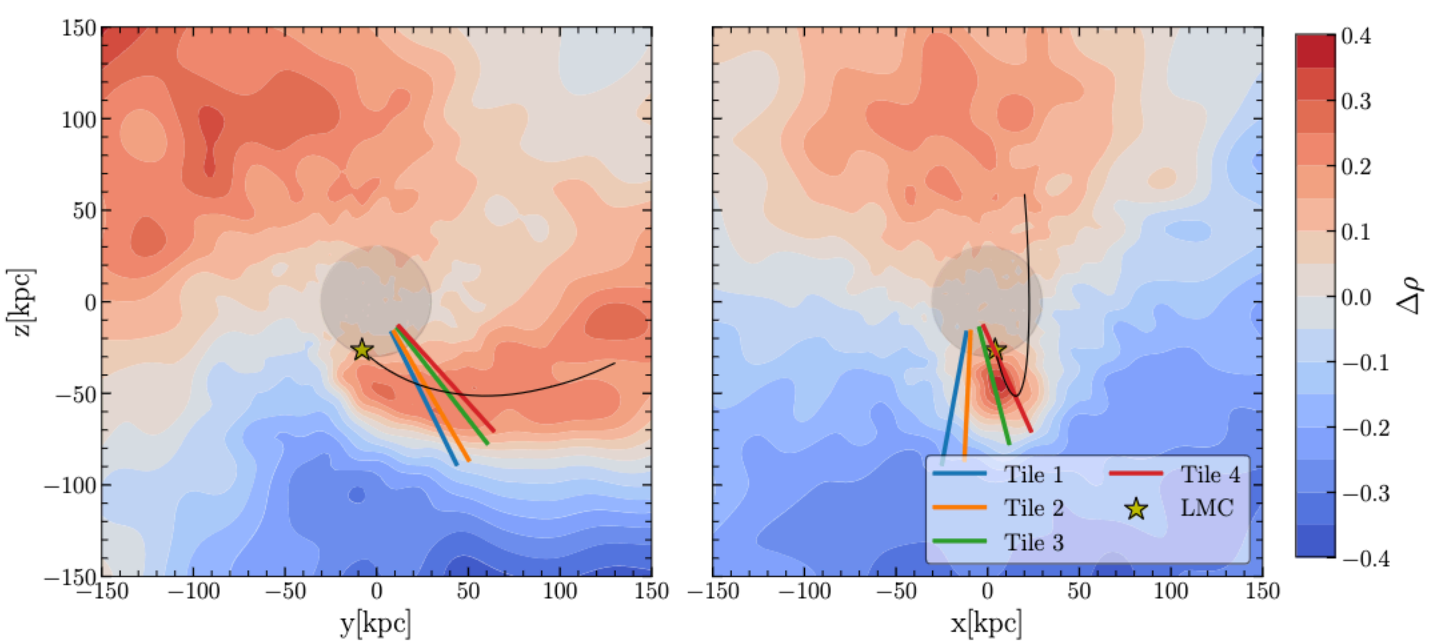

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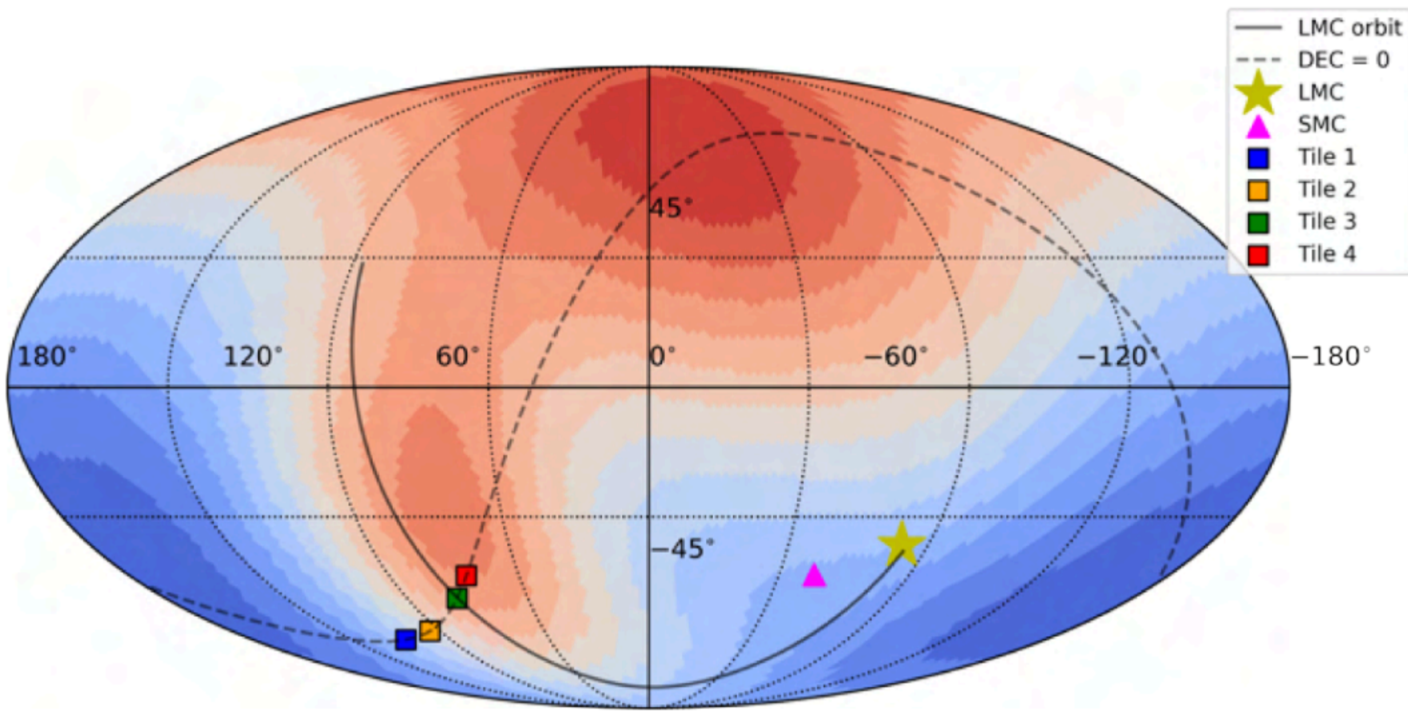

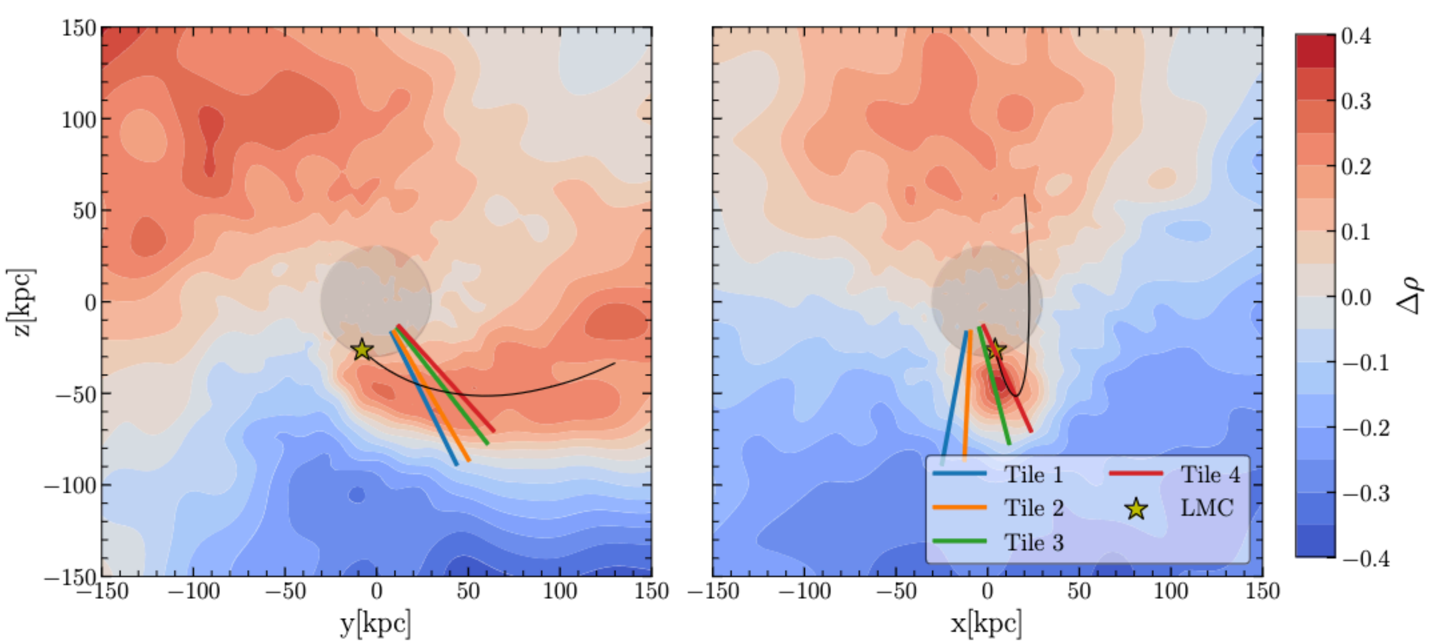

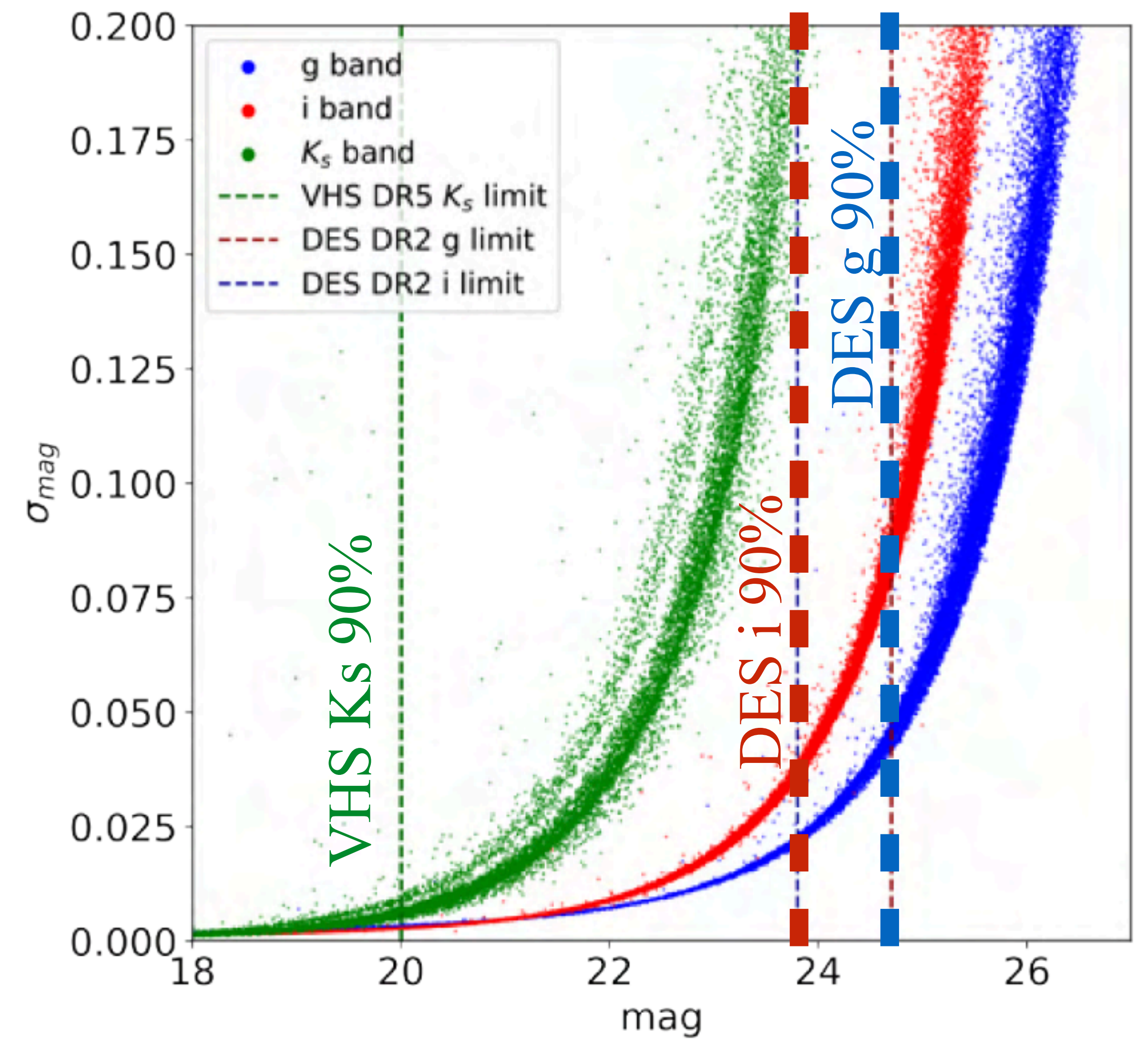

Figure 2. Photometric uncertainties of point sources in our VIRCAM/DECam stacked images as a function of magnitude. K_s band uncertainties are shown in green, g and i-band uncertainties are presented in blue and red. The 90% limiting magnitude for current surveys that present coverage of the region are shown as vertical dashed lines in green for the K_s band VHS survey; blue and red for the g and i band limits in DES DR2.

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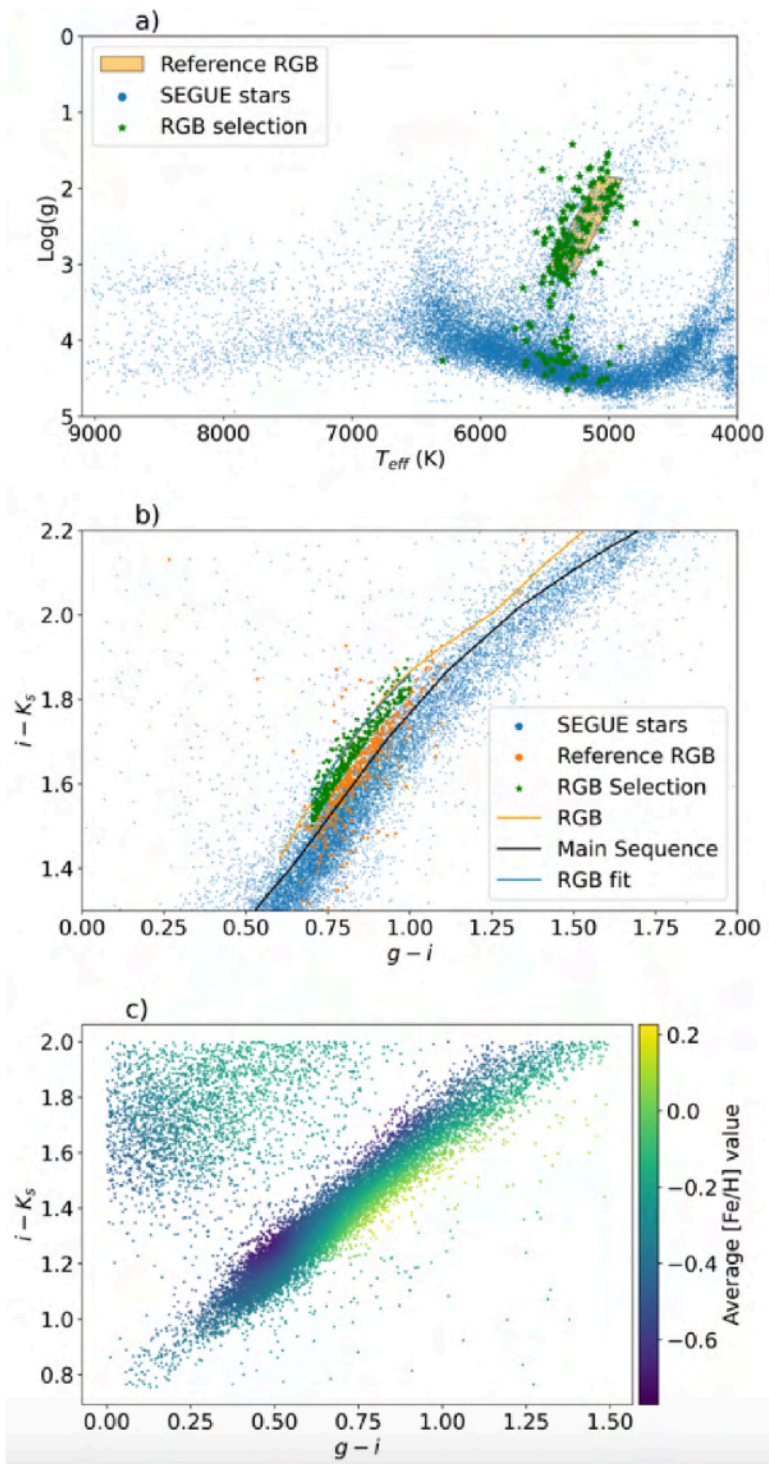
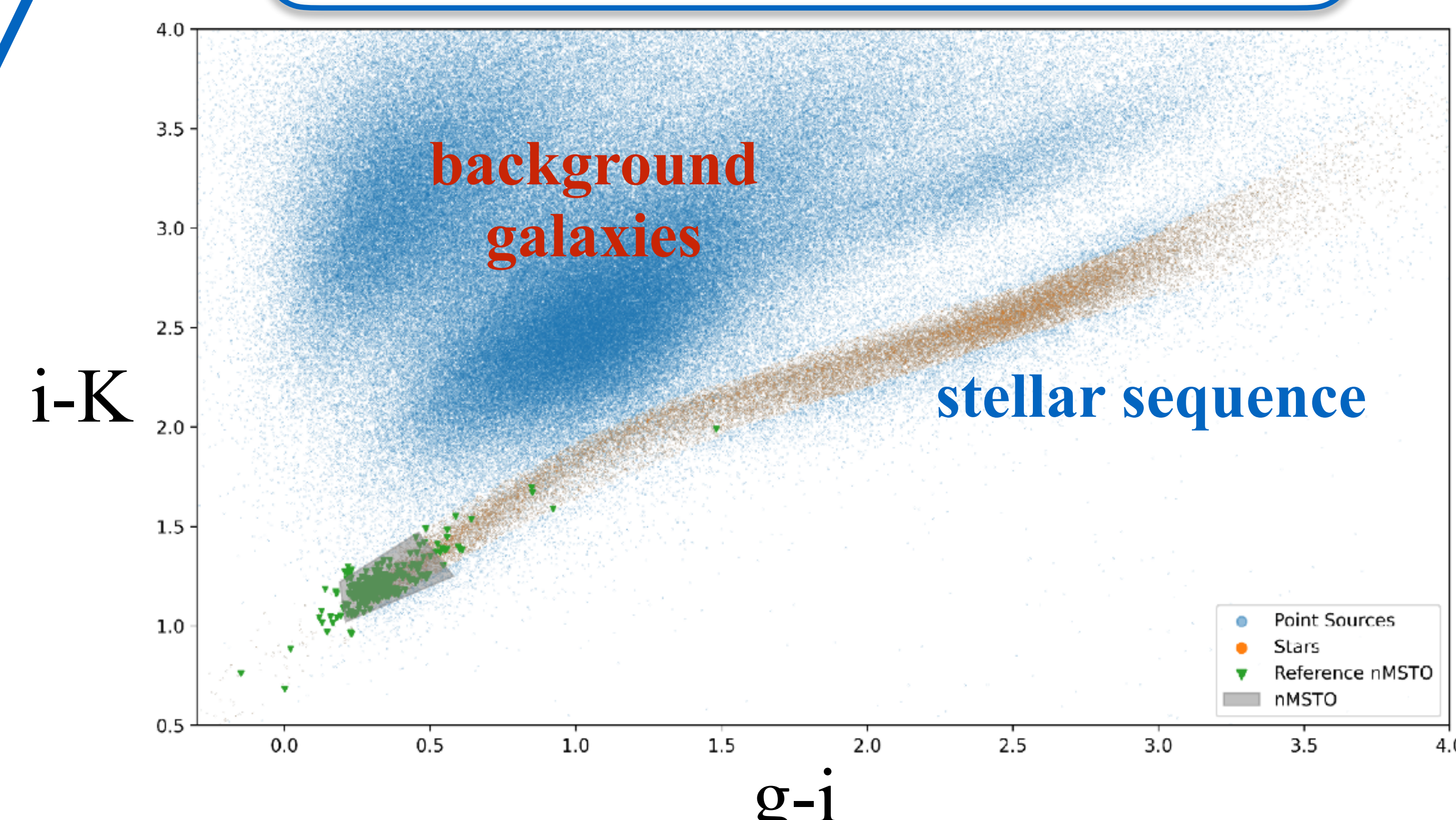
K-giant selection



near-MS turnoff selection



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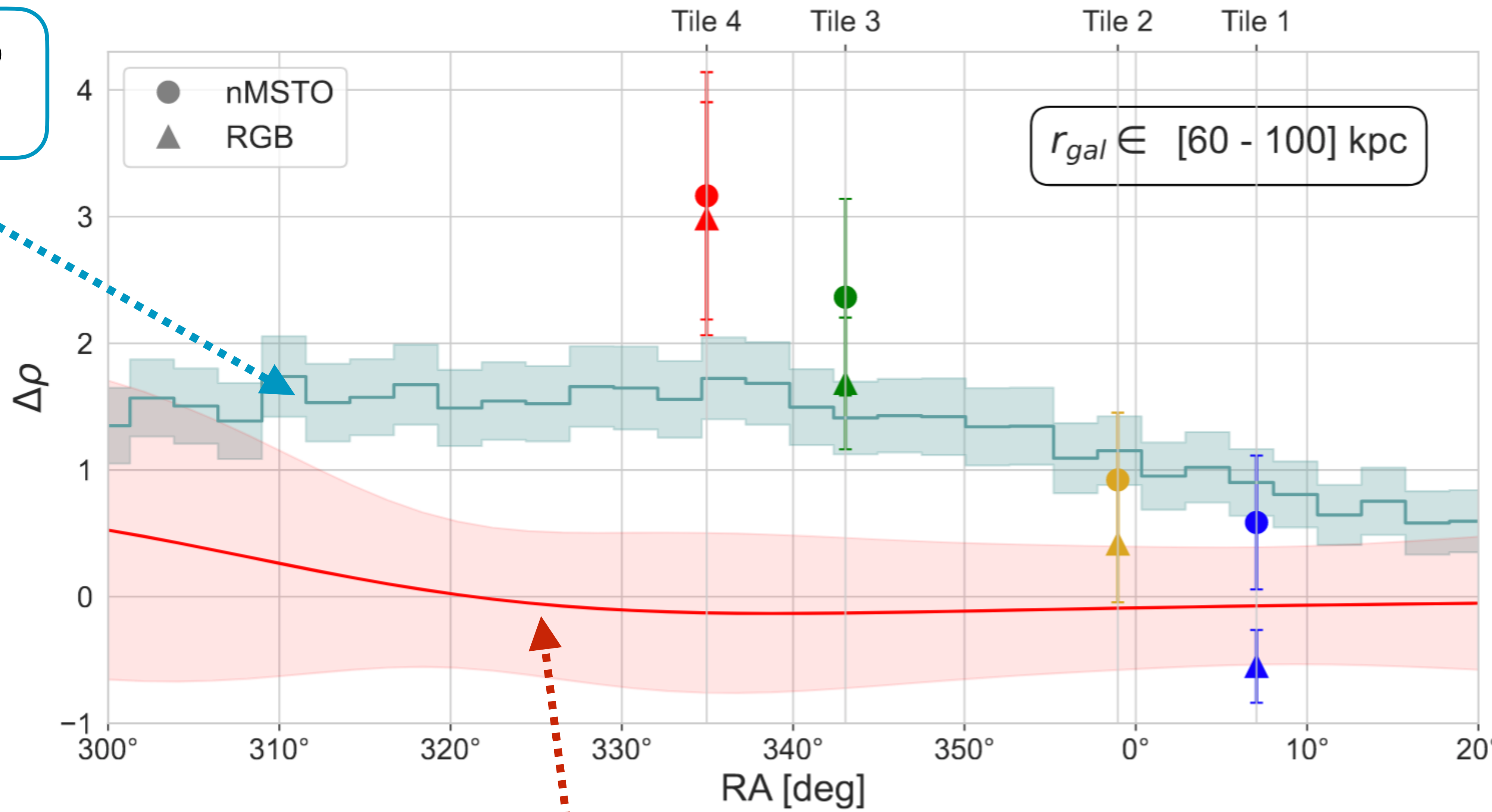
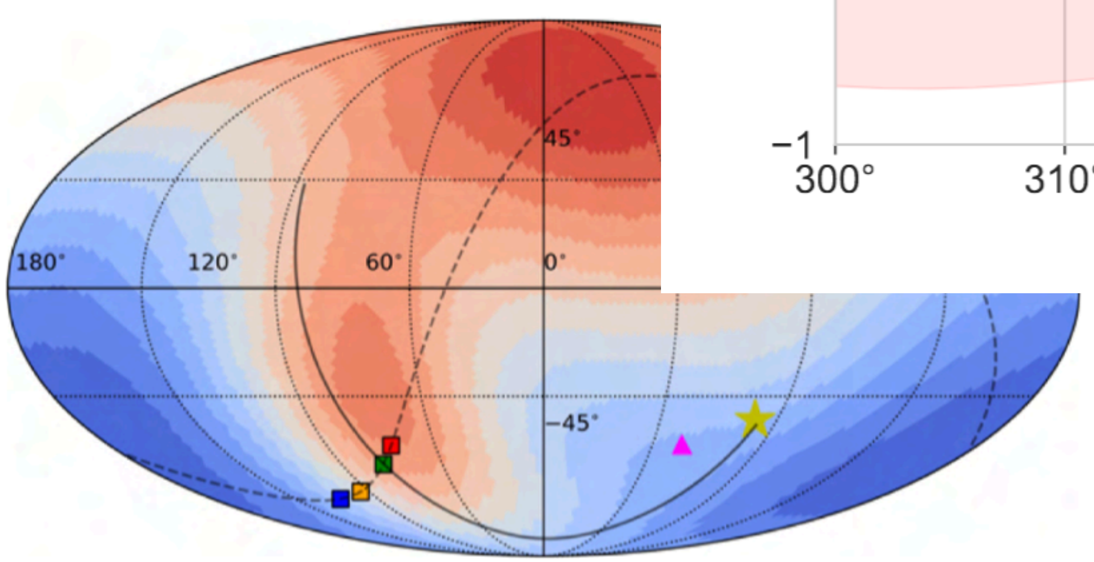
Garavito-Camargo+2019
LMC ~ 2.5 x 10^{11} $M_{\odot}$





Bullock & Johnston (2005)
average

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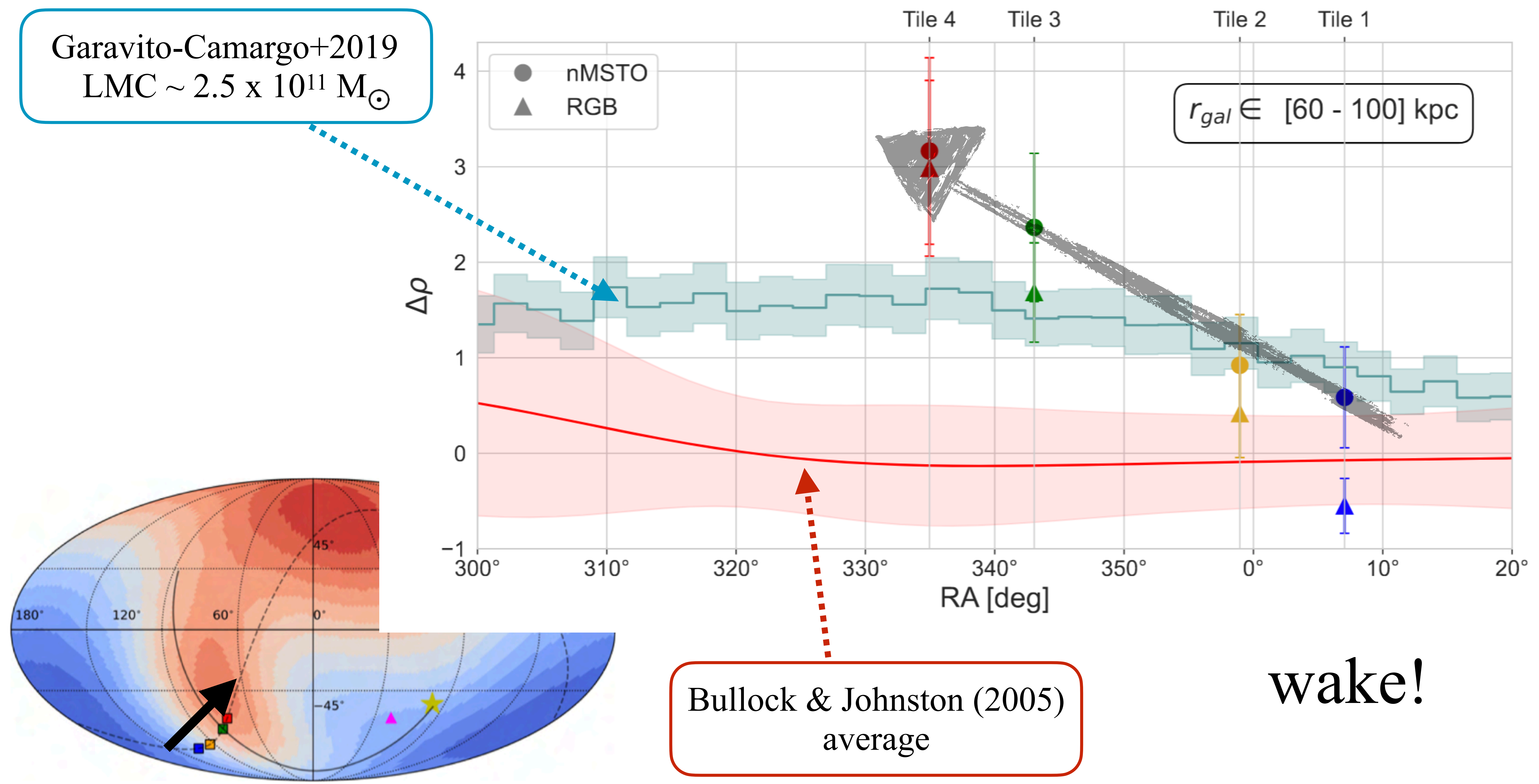

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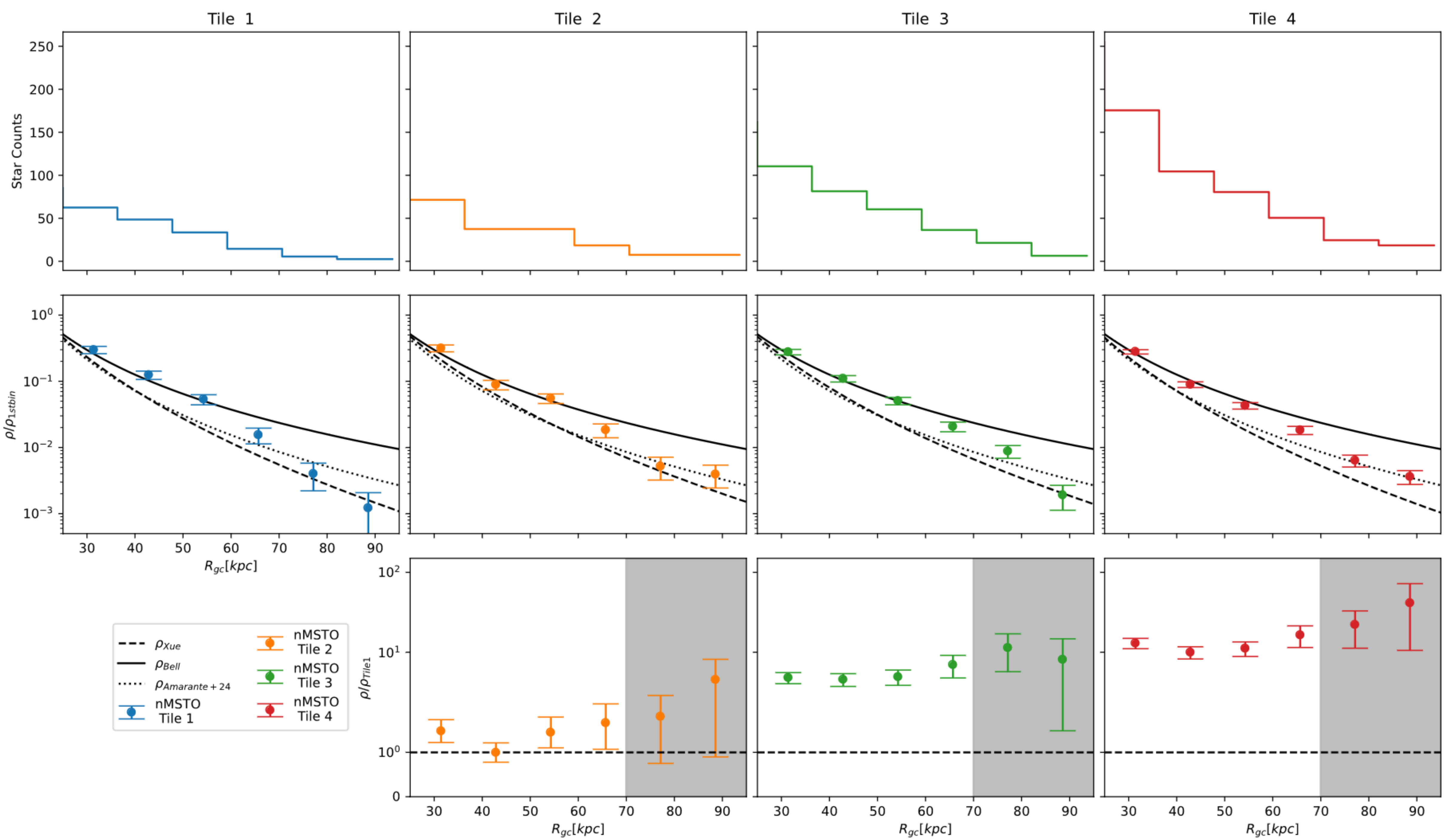

The impact of the LMC's passage through the Milky Way halo

- The mass of the LMC is a significant fraction of that of the MW
- It cannot be ignored — the MW has already responded to its infall

- We have detected a clear overdensity in the distant stellar halo at the predicted location/distance of the LMC wake.
- The measured density contrast suggests an even more massive LMC, or maybe a different orbit, than tried in current models of the wake.
- There may be contamination from unidentified sources.

- The MW-LMC interaction provides a near-field "Bullet cluster"-like experiment to pin down with precision the properties of the Local Group, and maybe even help distinguish between dark matter models.
- Upcoming all-sky kinematics of very faint halo stars should constrain all this phenomena with greater detail (Rubin/LSST).