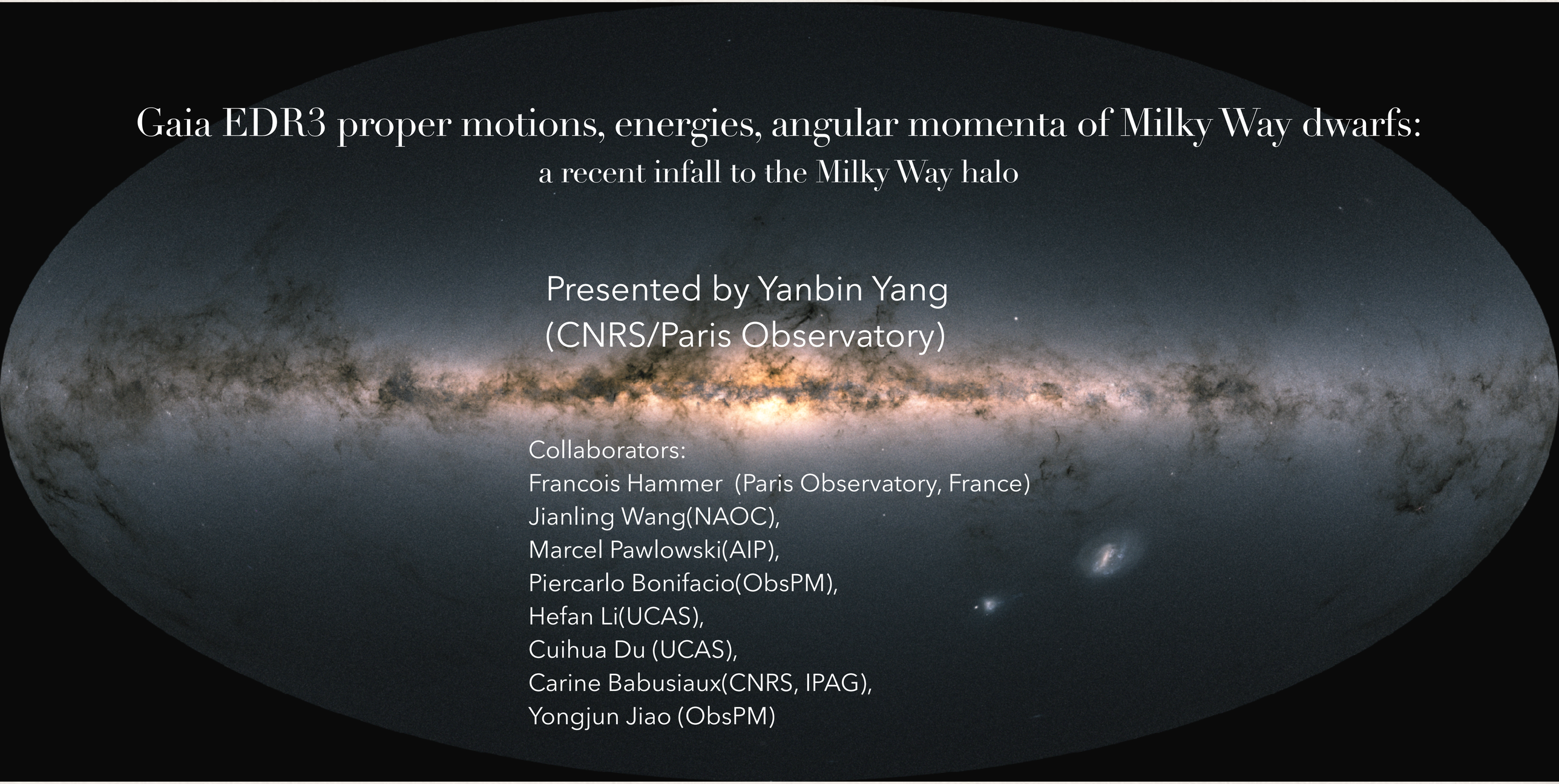


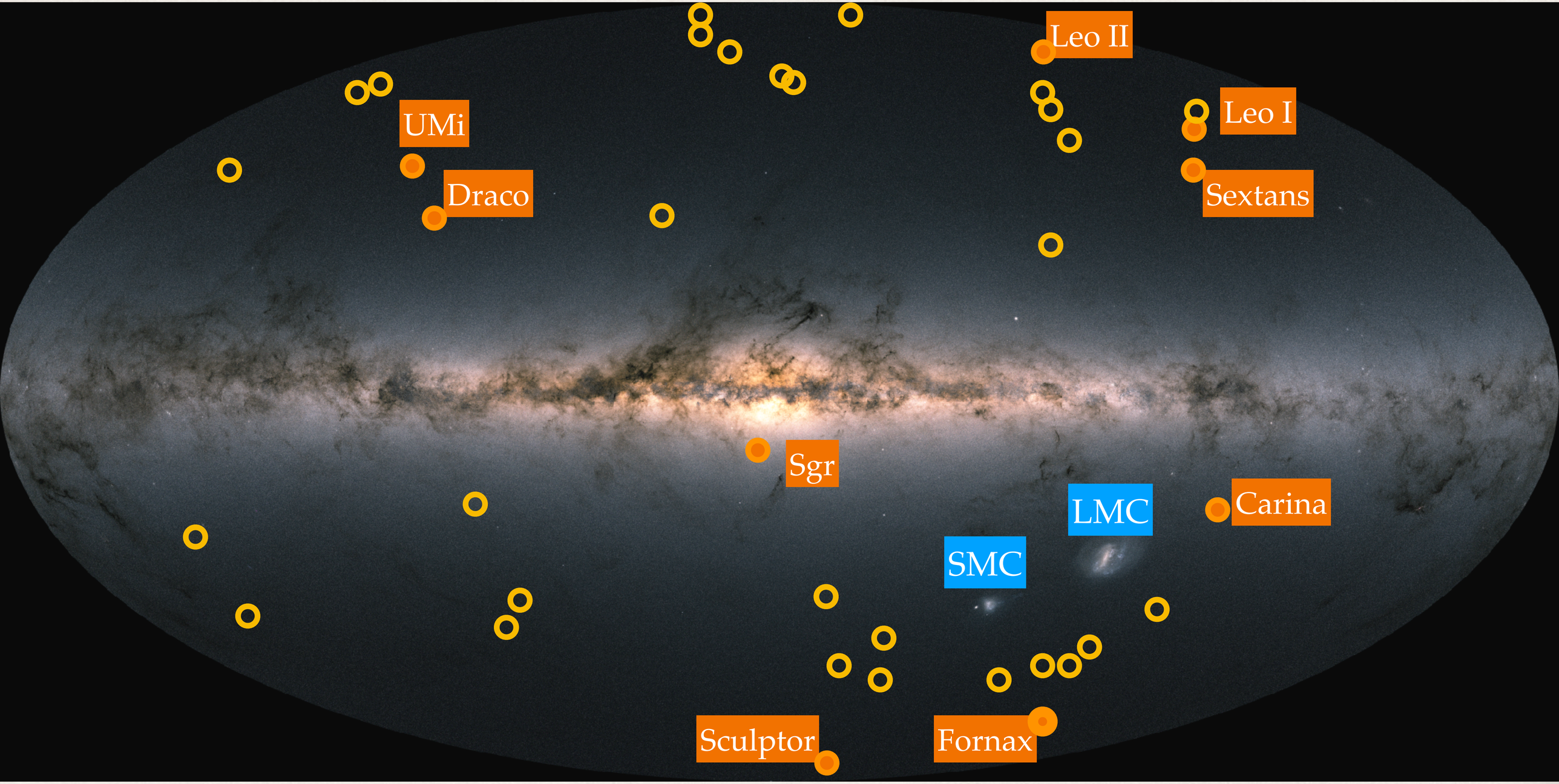
Gaia EDR3 proper motions, energies, angular momenta of Milky Way dwarfs:

a recent infall to the Milky Way halo

Presented by Yanbin Yang
(CNRS/Paris Observatory)

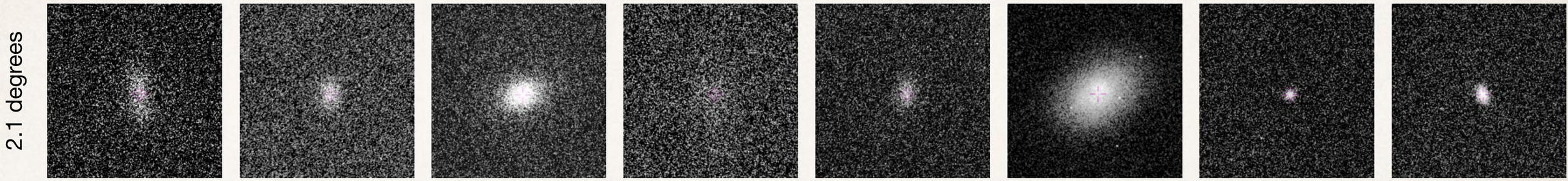
Collaborators:
Francois Hammer (Paris Observatory, France)
Jianling Wang(NAOC),
Marcel Pawlowski(AIP),
Piercarlo Bonifacio(ObsPM),
Hefan Li(UCAS),
Cuihua Du (UCAS),
Carine Babusiaux(CNRS, IPAG),
Yongjun Jiao (ObsPM)

MW dwarf galaxies



https://www.esa.int/ESA_Multimedia/Images/2021/11/Dwarf_galaxies_around_the_Milky_Way

	UMi	Draco	Sculptor	Sextans	Carina	Fornax	Leo II	Leo I
D_{mw}	78 kpc	79 kpc	85 kpc	89 kpc	141 kpc	149 kpc	227 kpc	273 kpc

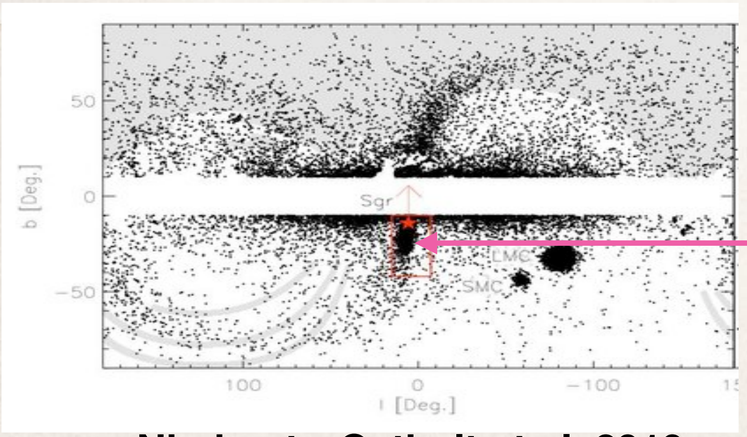


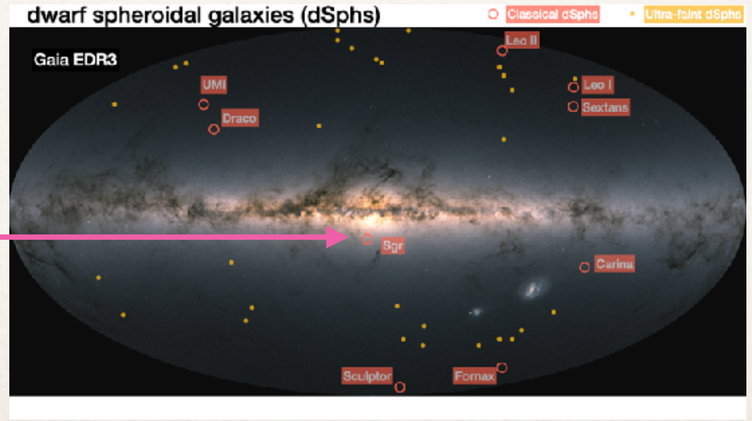
Long-lived satellites in the MW halo

mystery : no clear evidences for tidal tails except Sgr and Tuc III

Sagittarius / Sgr

D_{mw} 18 kpc



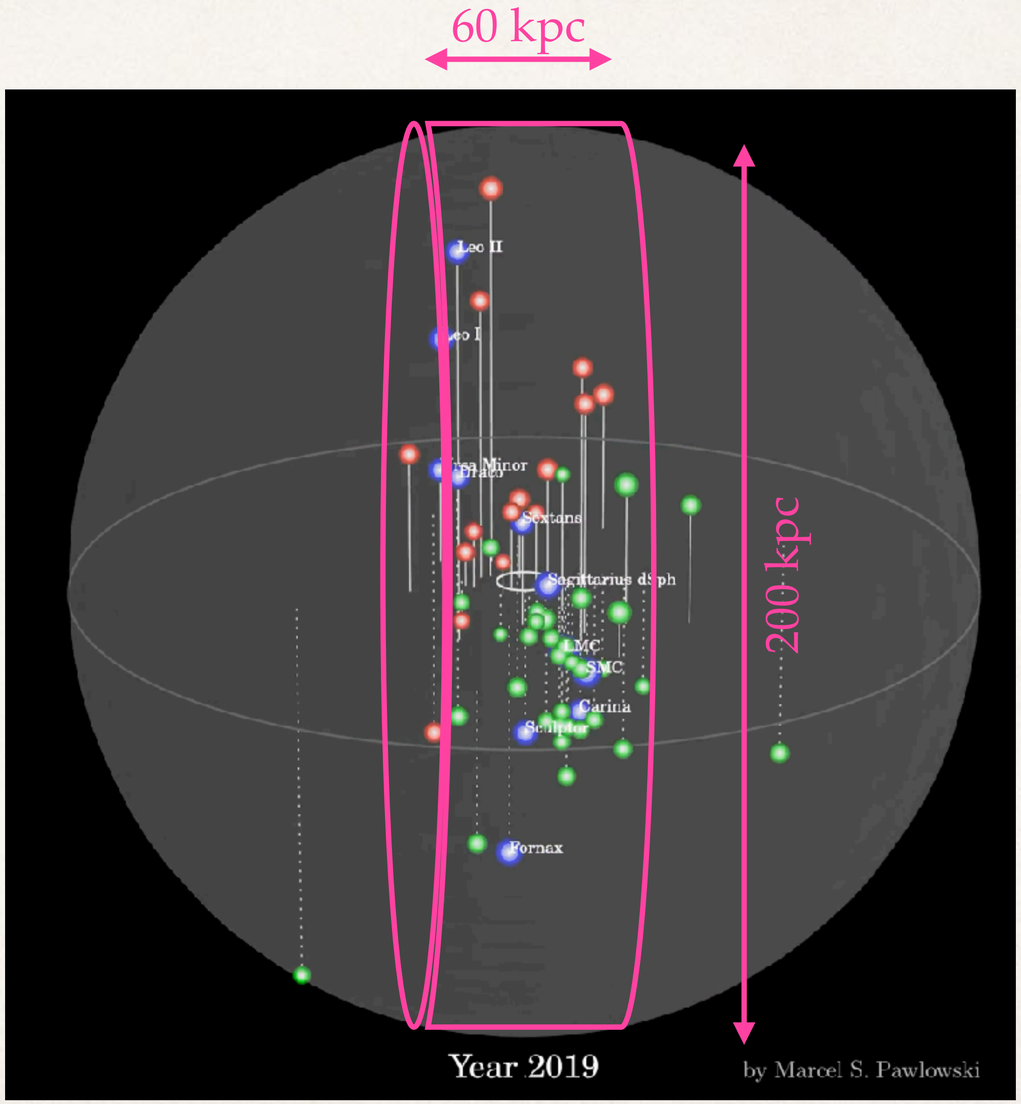


Niederste-Ostholt et al. 2010

The Vast POlar Structure (VPOS)

Many Milky Way dwarfs lie and coherent motions in the Vast Polar Structure (200x60 kpc^2), still not consistent with LCDM halo/ subhalos(Pawlowski et al. 2014-2021).

Comparison with simulated subhaloes:
$P < 0.005$ (Pawlowski 2018, and others)



http://marcelpawlowski.com/research/movies-astronomy/

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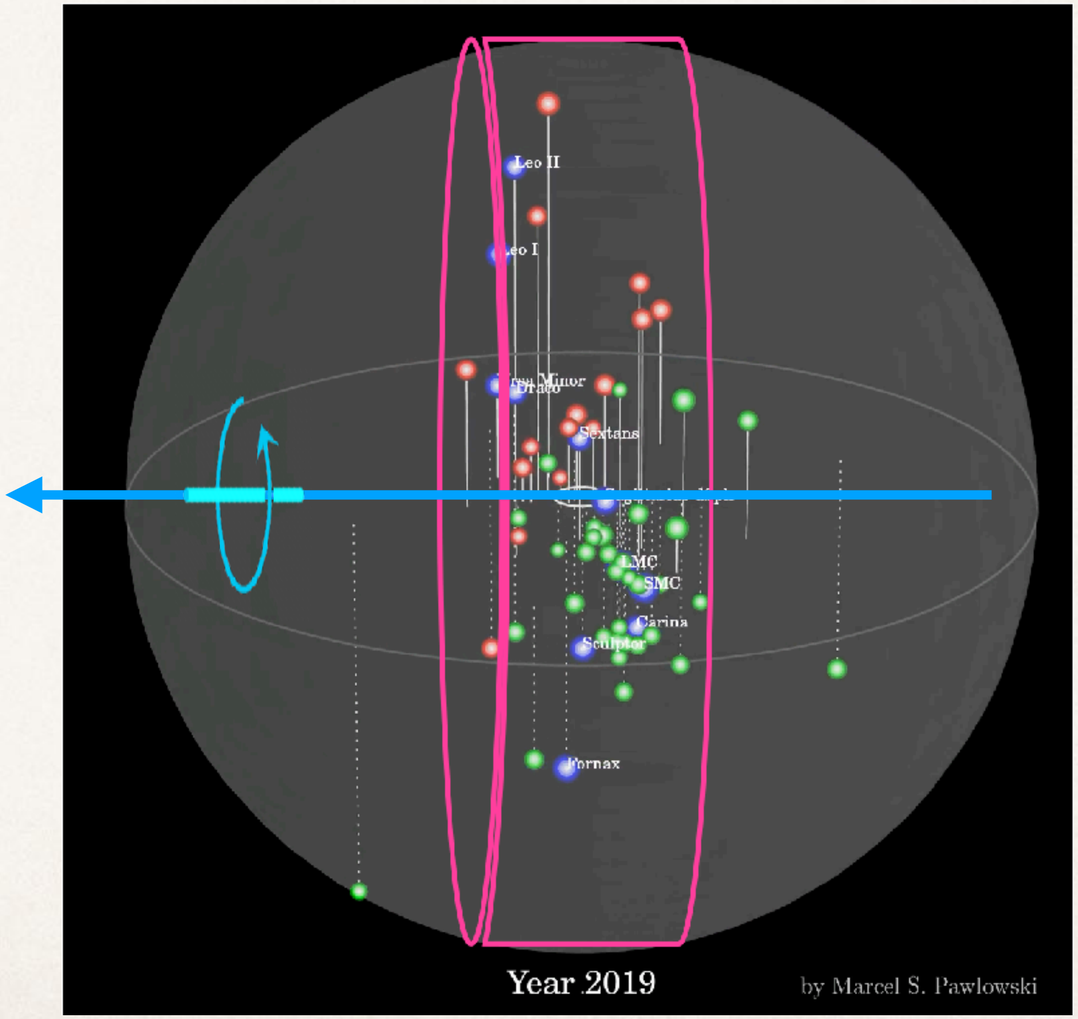

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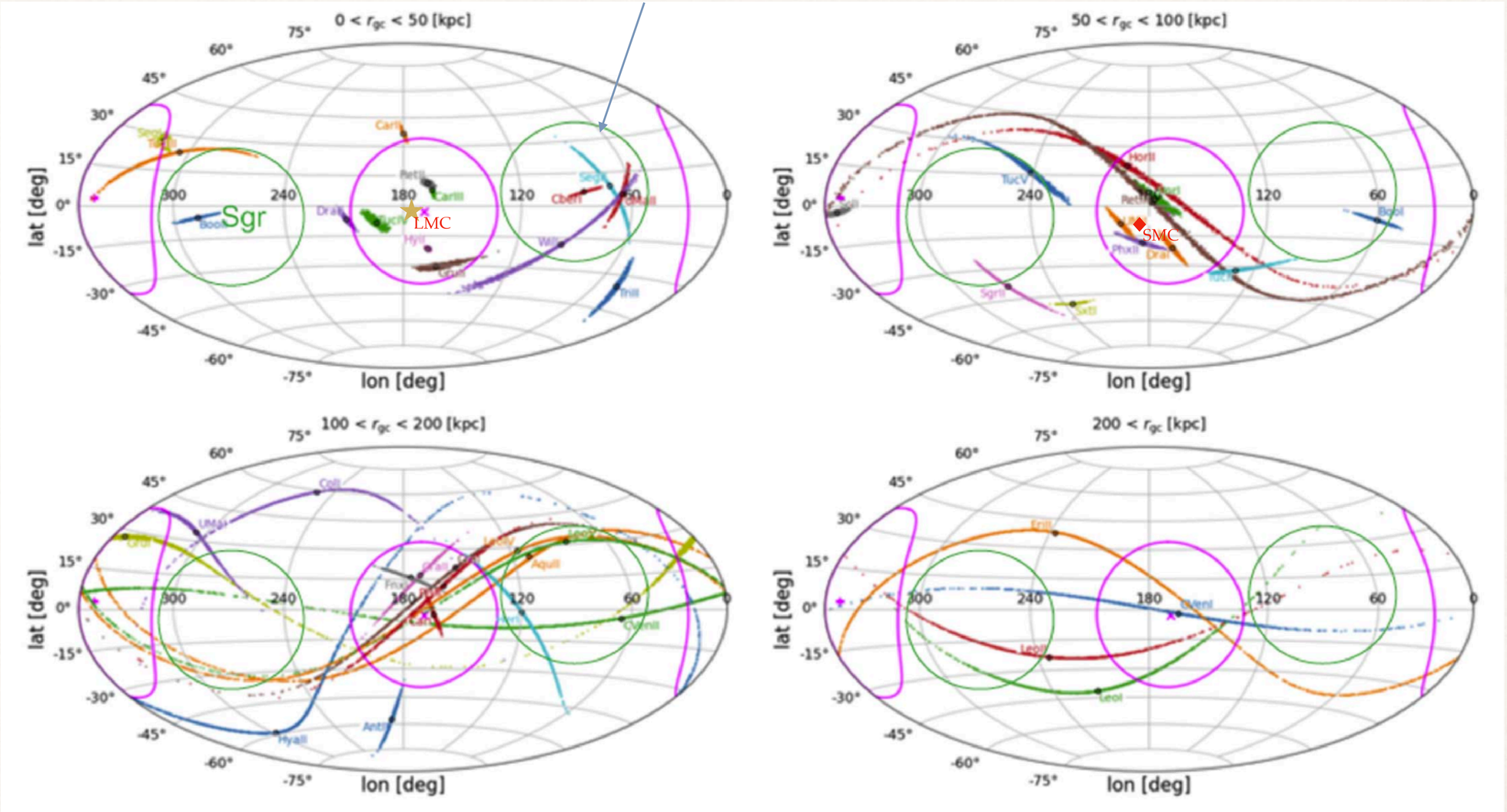
The VPOS

Orbital pole distributions

a possible Sgr-polar-structure



Li H. et al. 2021

Hammer et al. 2021

Gaia EDR3 revolution :

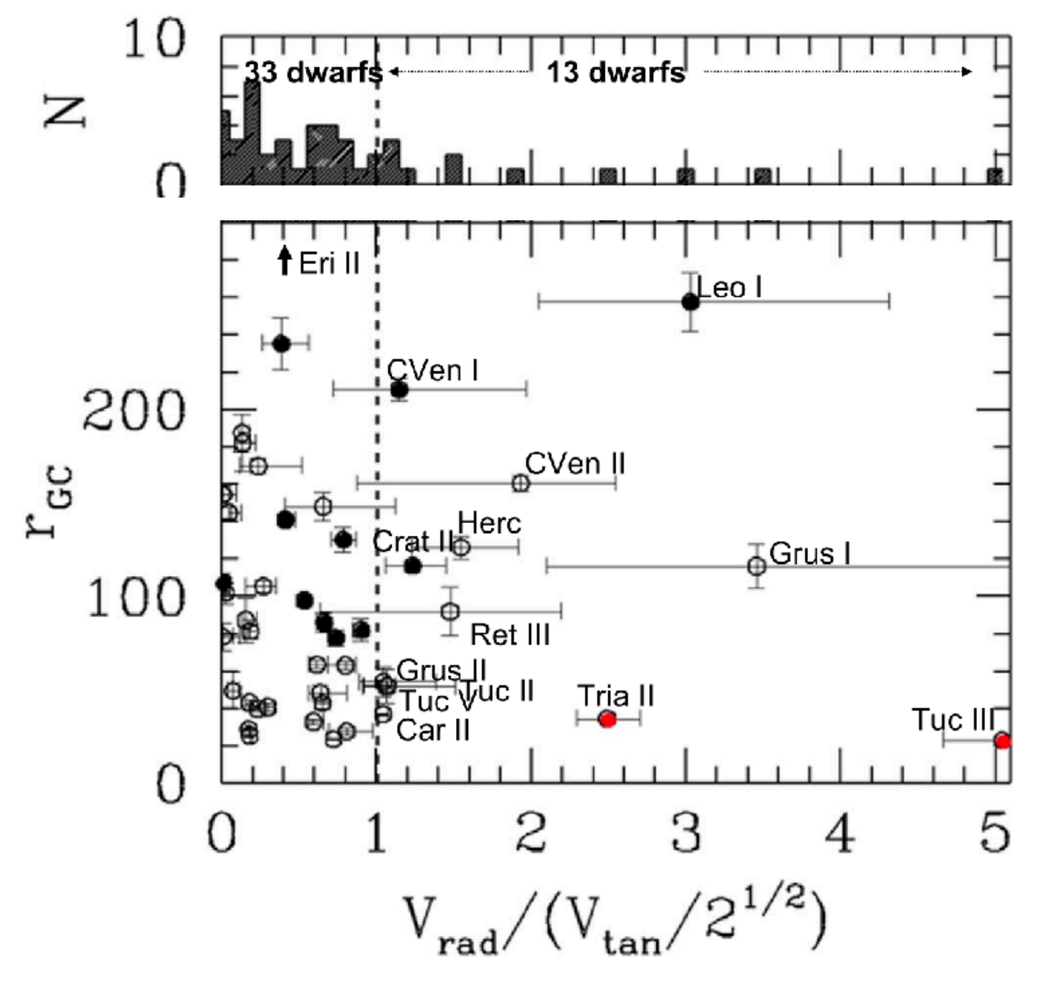
accurate orbits of the Milky Way dwarf galaxies

- Error on proper motions (PM) is reduced by a factor ~2.5
- robust determination of 3D velocities for 33 of 46 Milky Way dwarfs

Li H. et al. 2021

(see also Battaglia et al. 2021, McConnachie & Venn 2020 for PM)

The Excess of Tangential Velocities

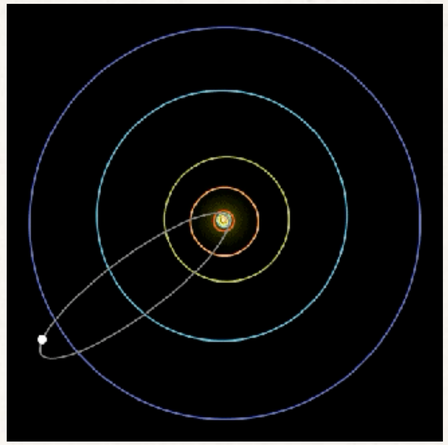


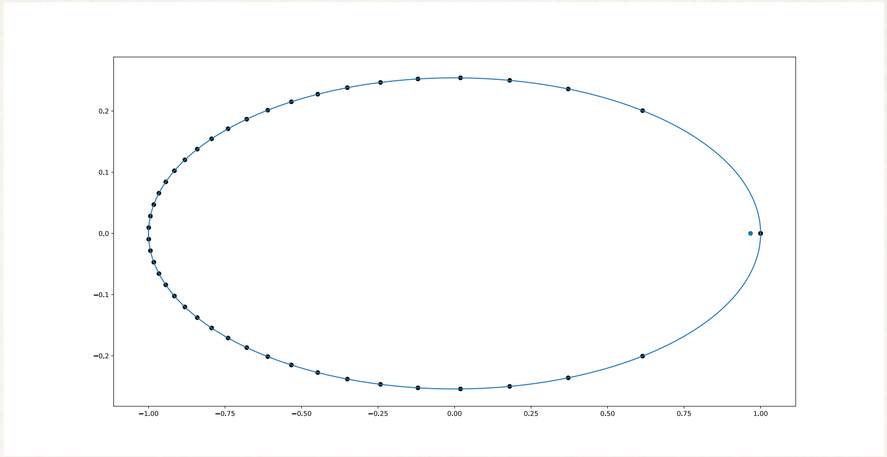
Hammer et al. 2021 (with Gaia EDR3)

- Cautun & Frenk (2017)
- Riley et al. (2019) (Gaia-DR2)

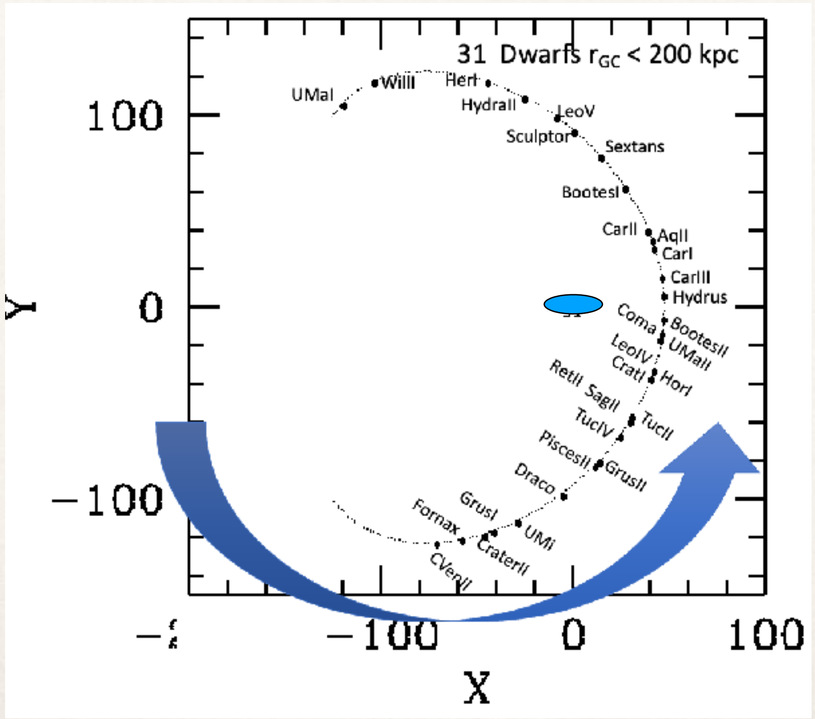
MW dwarf galaxies show a tendency of being close to their pericenters.

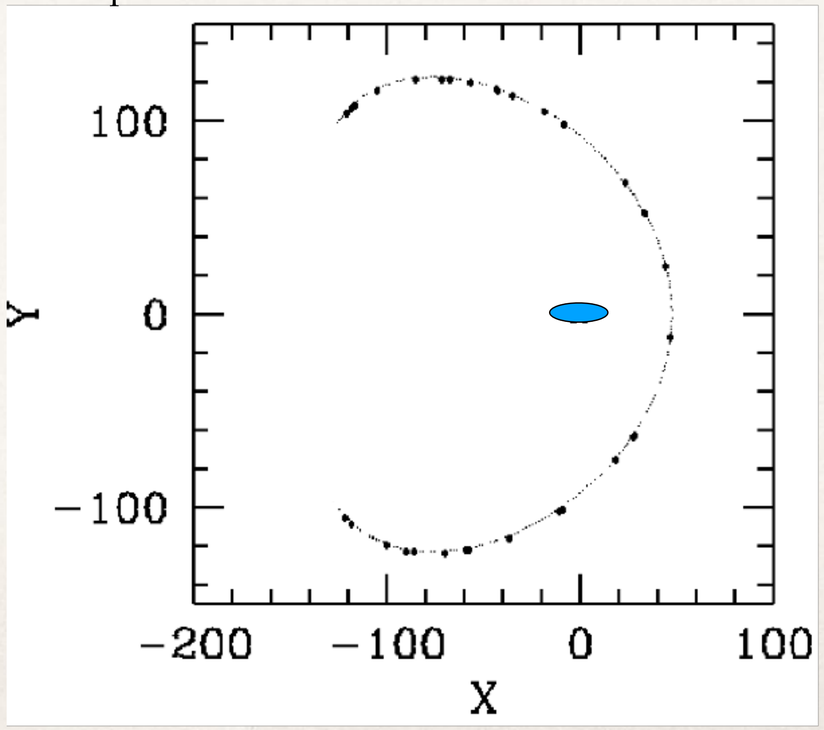
the orbit of Hale comet





expectation from a random distribution of orbit



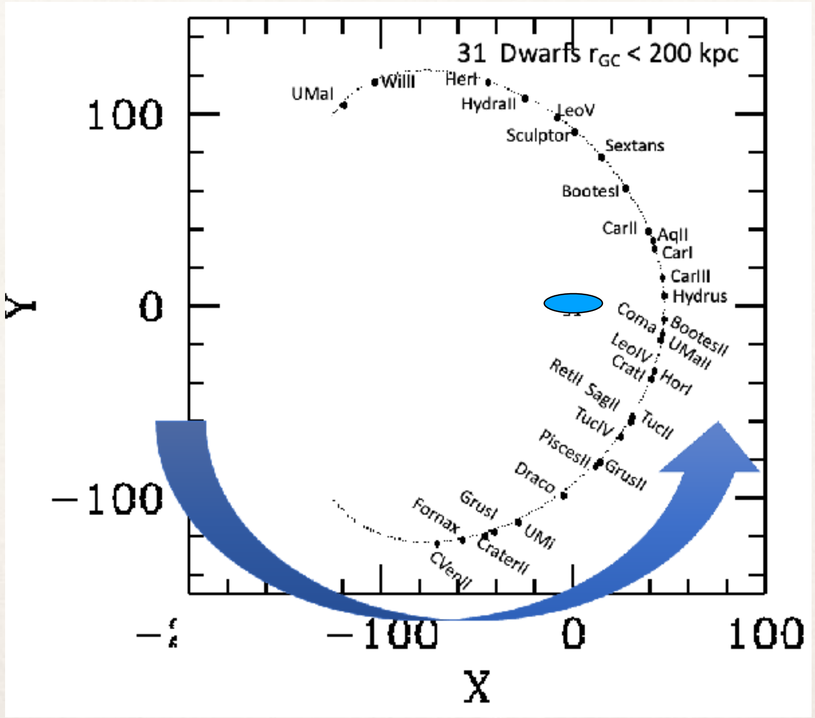


Li H. et al. 2021

MW dwarf galaxies show a tendency of being close to their pericenters.

- Coordination in time!

- The result is independent from MW mass (ref. Poster by Yongjun Jiao/ Jiao et al. 2021 A&A)



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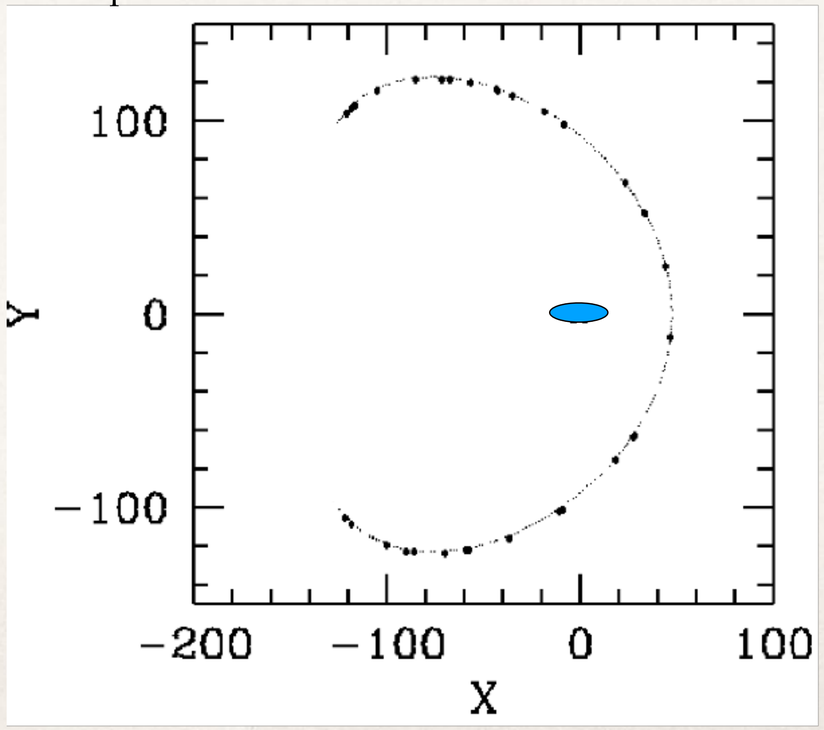
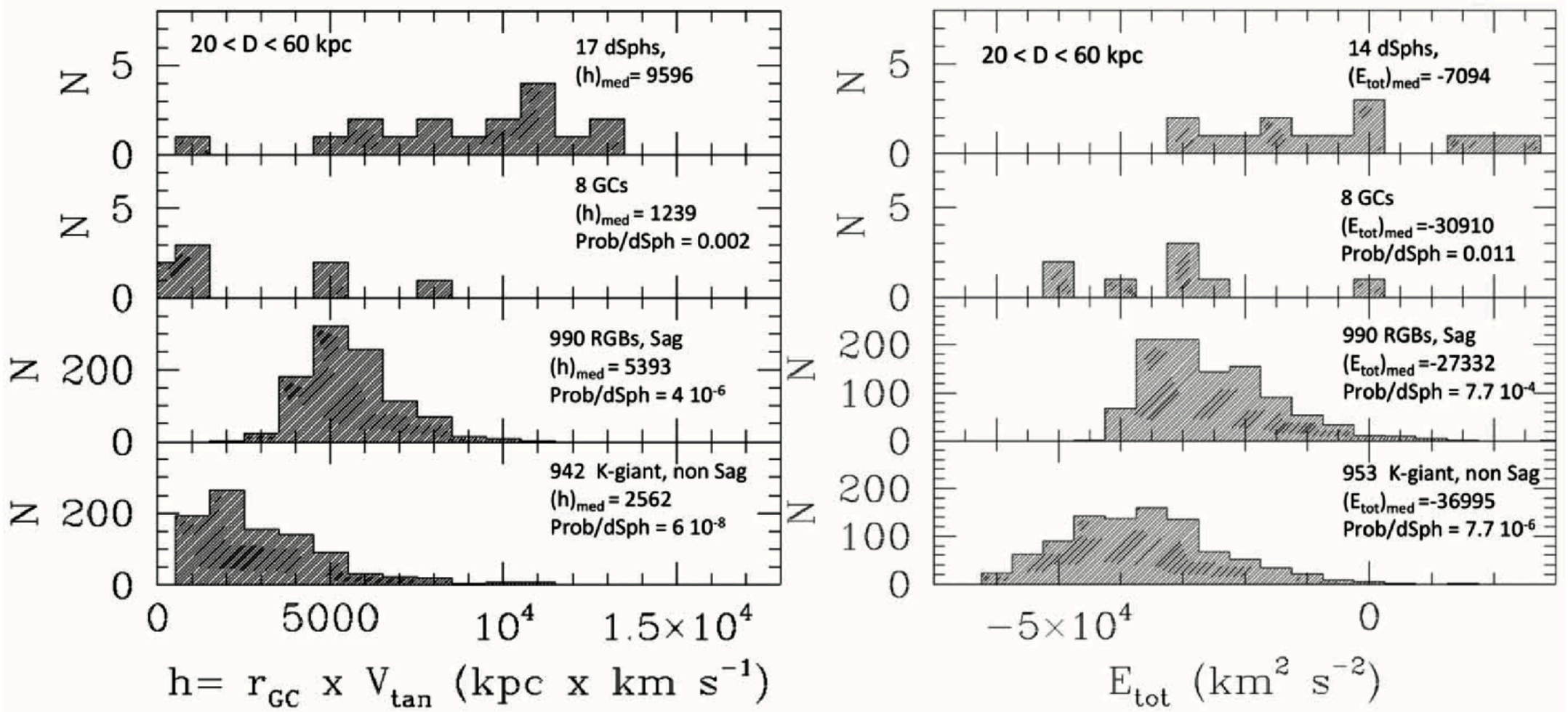


Li H. et al. 2021

Comparing angular momenta, total energy …

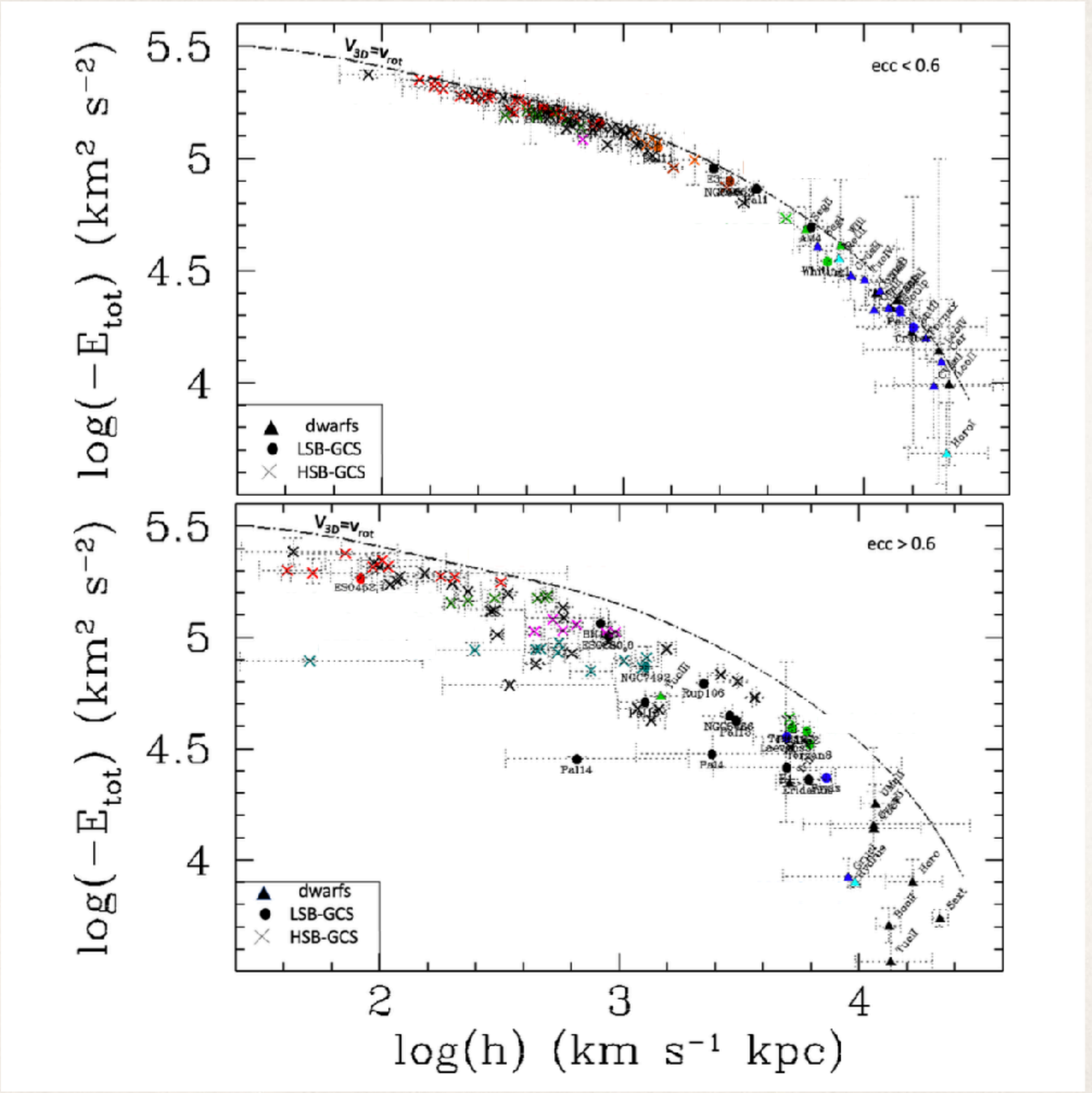


Hammer et al. 2021

HSB-GCS : high-surface brightness globular clusters

LSB-GCS : low-surface brightness globular clusters

156 GCs from Baumgardt (2017); Baumgardt & Hilker (2018); Baumgardt et al. (2020); Baumgardt & Vasiliev (2021); Sollima & Baumgardt (2017), Vasiliev & Baumgardt (2021)



Hammer et al. 2023

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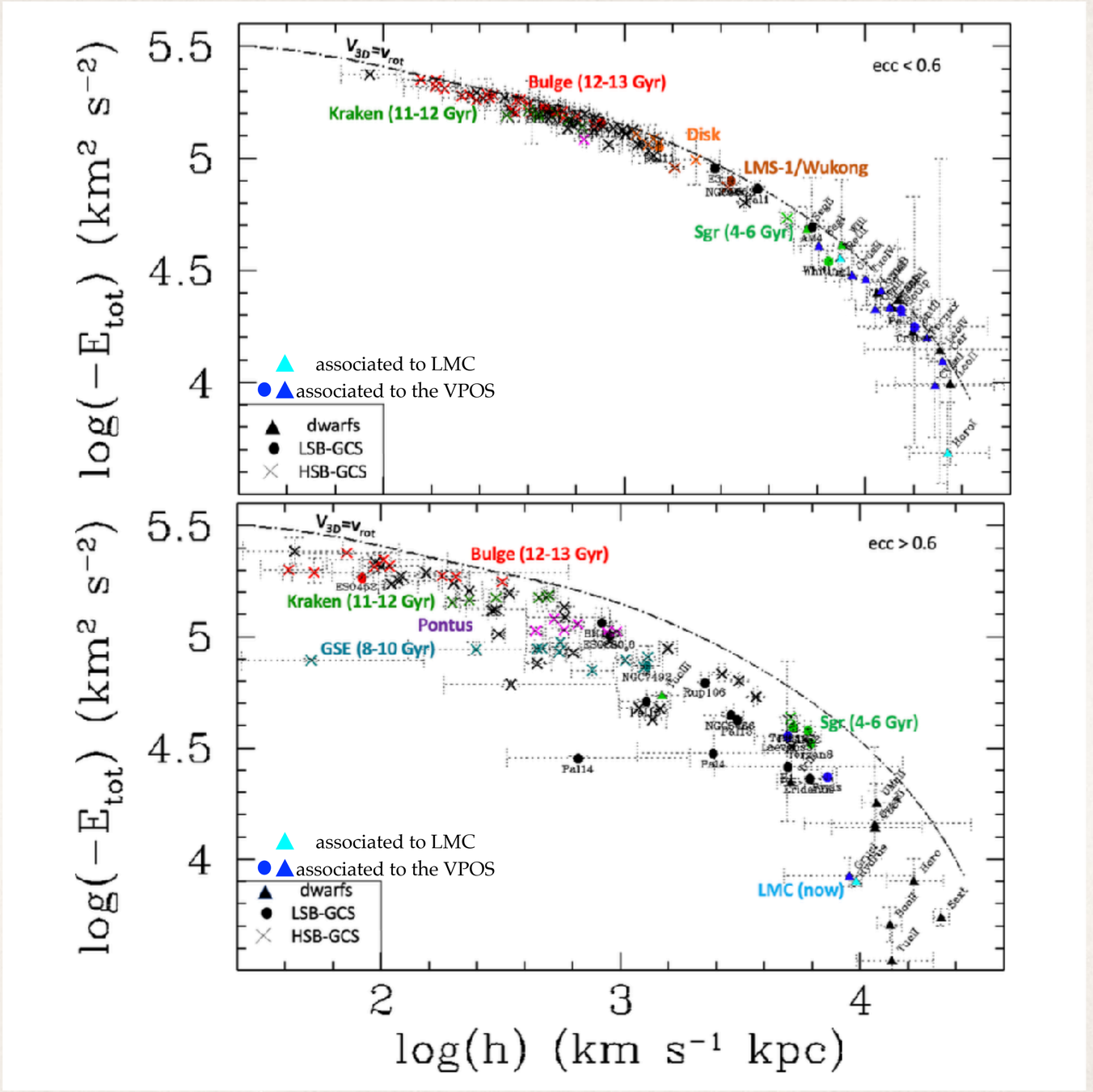

Malhan et al. 2022
Kruijssen et al. 2020

Hammer et al. 2023

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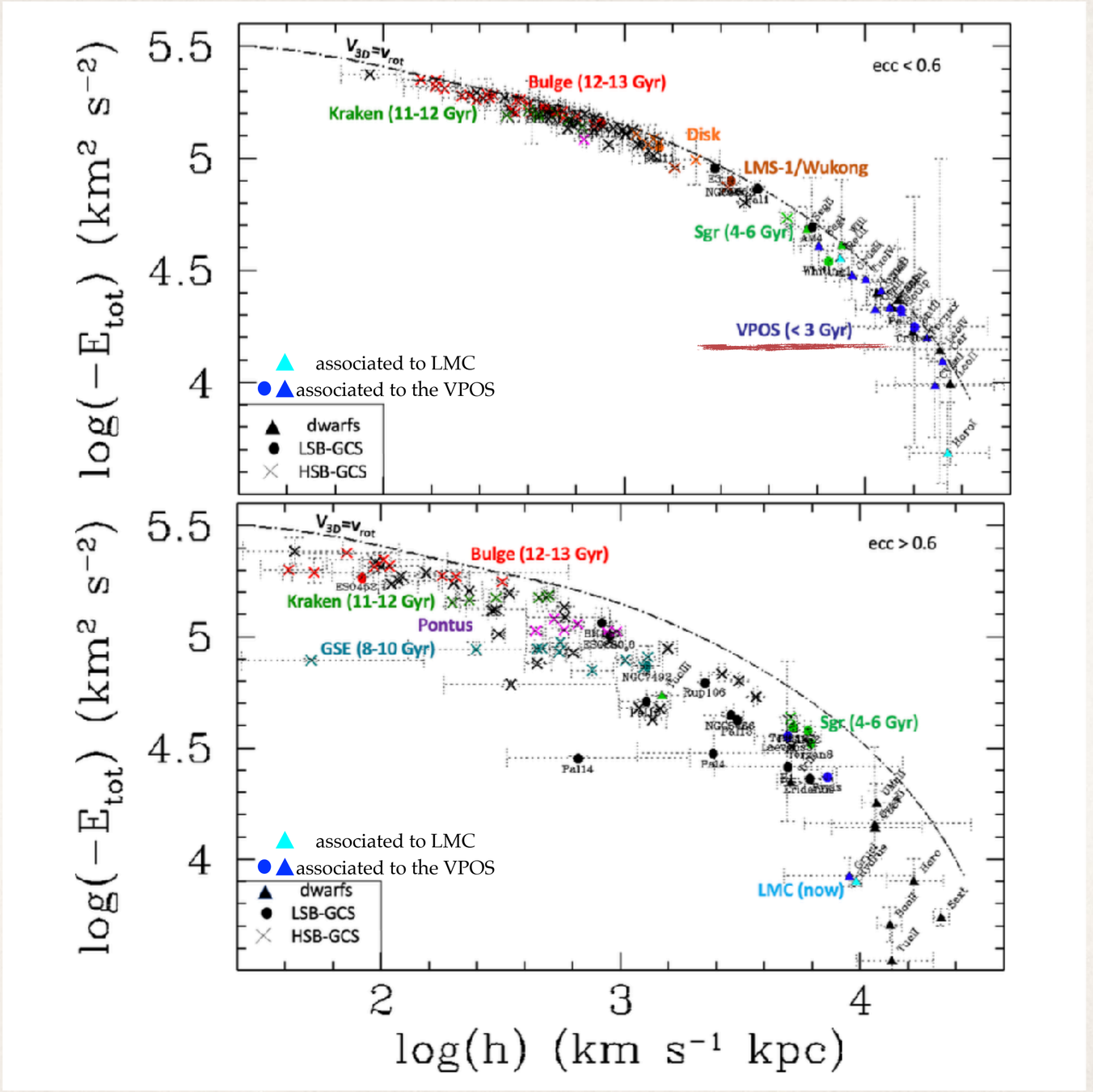
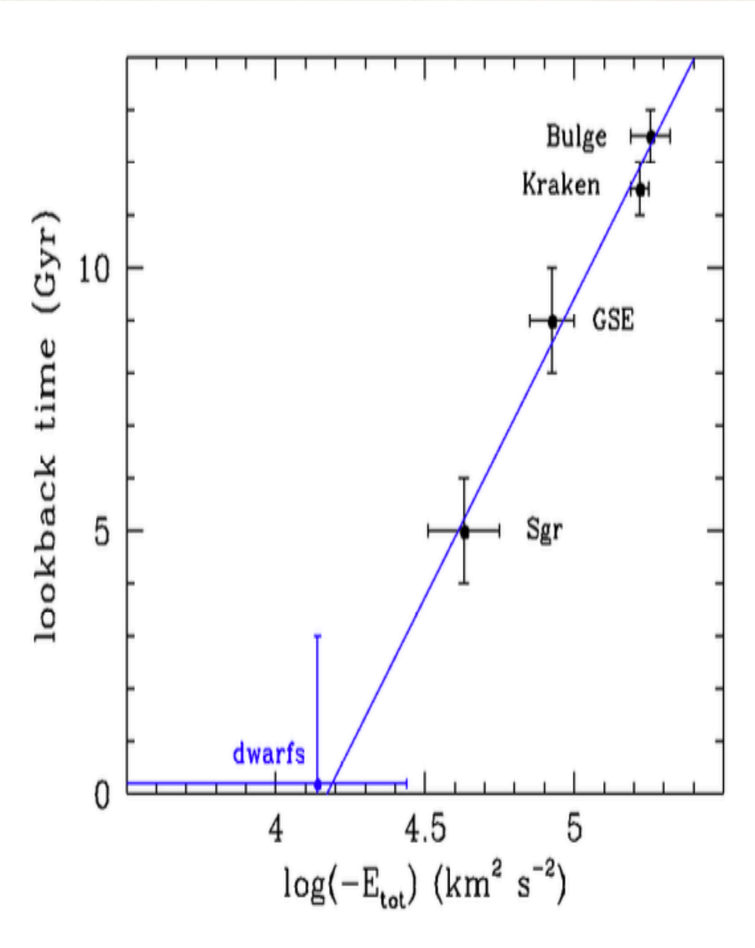
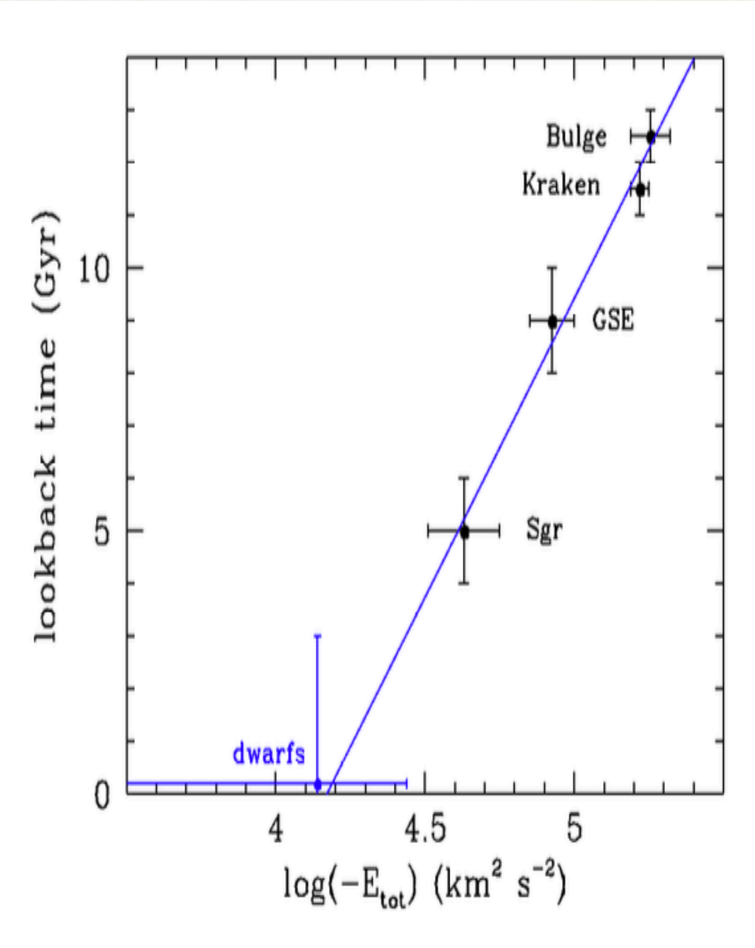


Malhan et al. 2022
Kruijssen et al. 2020

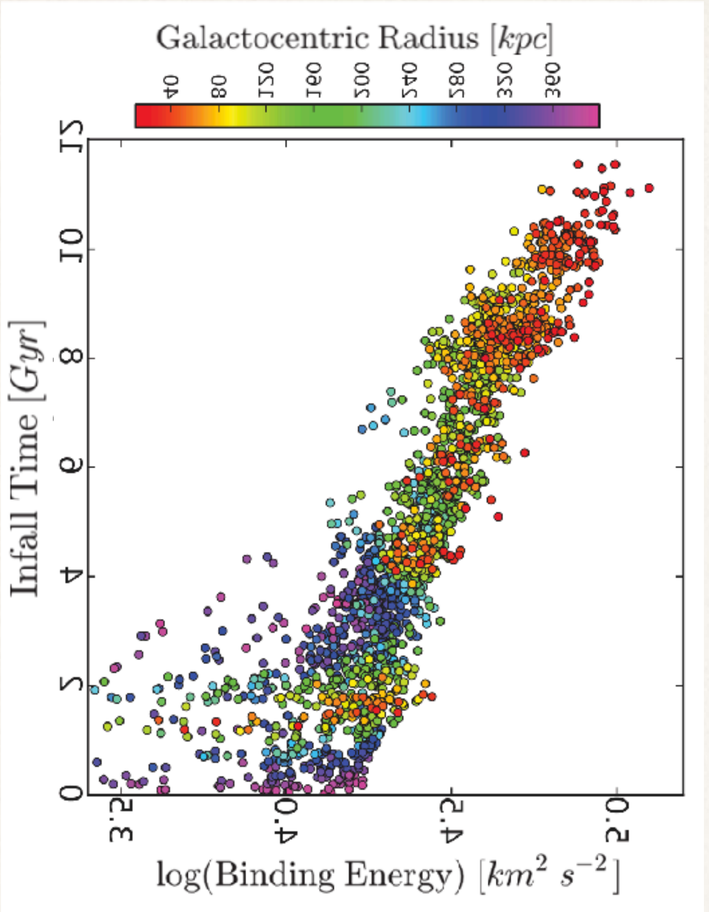
Hammer et al. 2023



Hammer et al. 2023

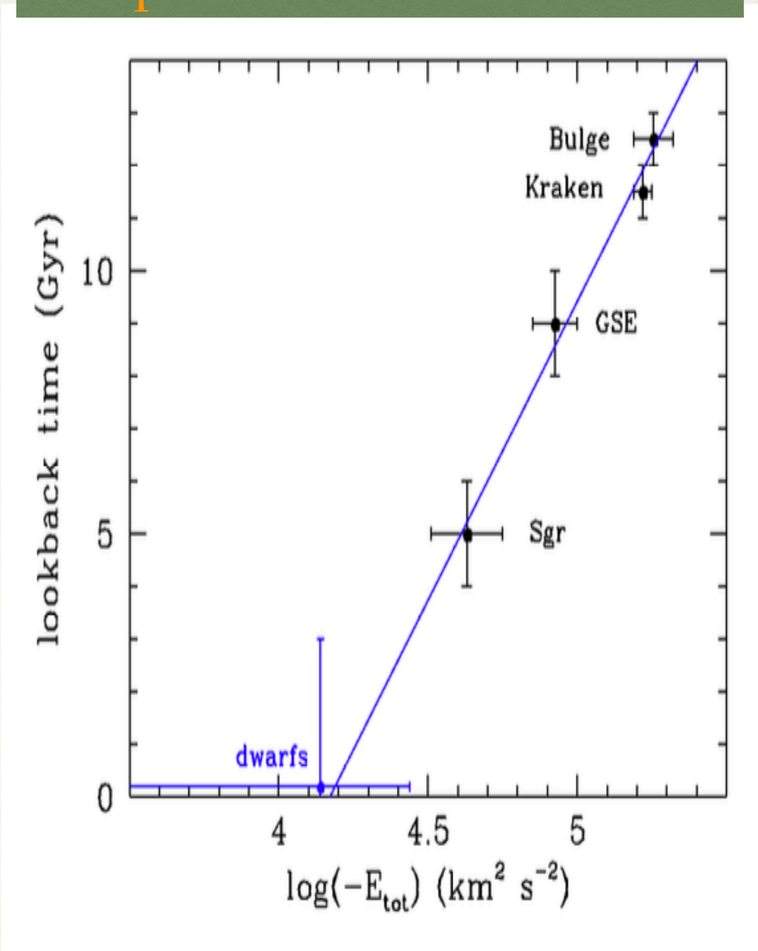


Hammer et al. 2023

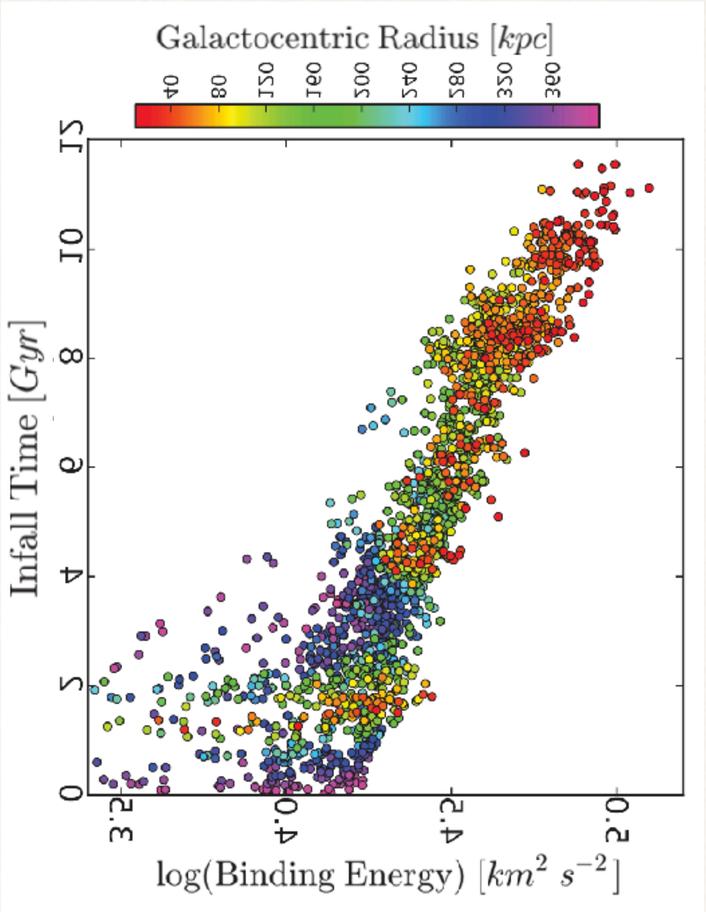


Rocha et al. 2012 **(cosmological simulation)**
see also Boylan-Kolchin et al. 2013

independent from MW mass



Hammer et al. 2023

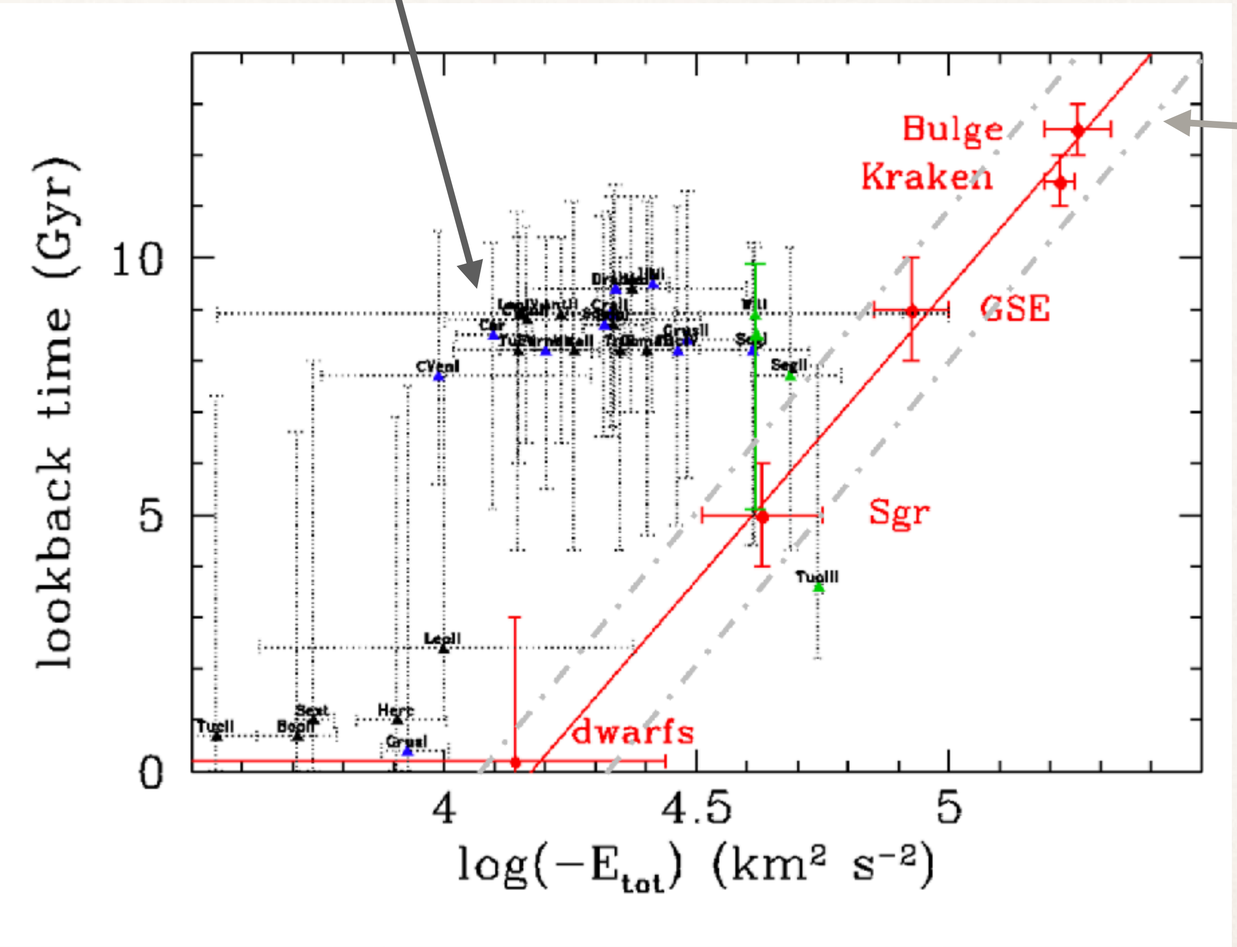


Rocha et al. 2012 (Via Lactea II (VL2) cosmological simulation)

see also Boylan-Kolchin et al. 2013

Barmentloo & Cautun(2023)

(EAGLE cosmological simulation & Machine Learning)



rescaled Rocha et al. 2012

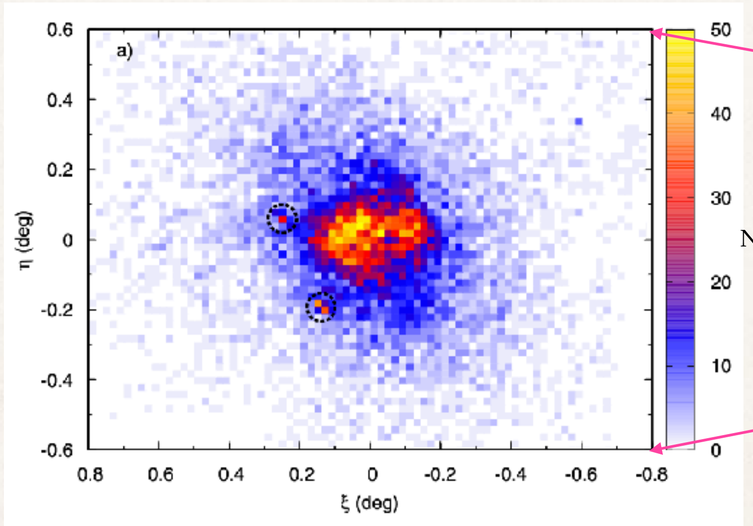
Possible consequences of the recent infall of MW dwarf galaxies

- Another mechanism may affect the dwarf galaxies: **ram pressure** (ref. …).

Possible consequences of the recent infall of MW dwarf galaxies

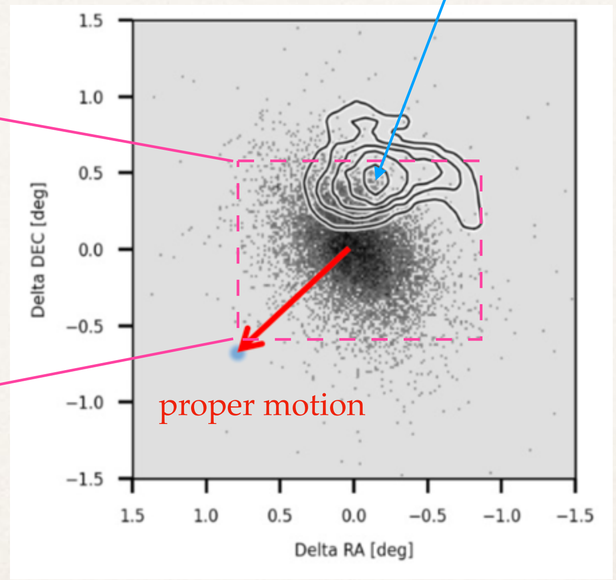
- Another mechanism may affect the dwarf galaxies: **ram pressure**.
- Star formation history & Chemical evolution

Fornax : Extended Star formation till recent 150 Myr



de Boer et al. 2012, 2013

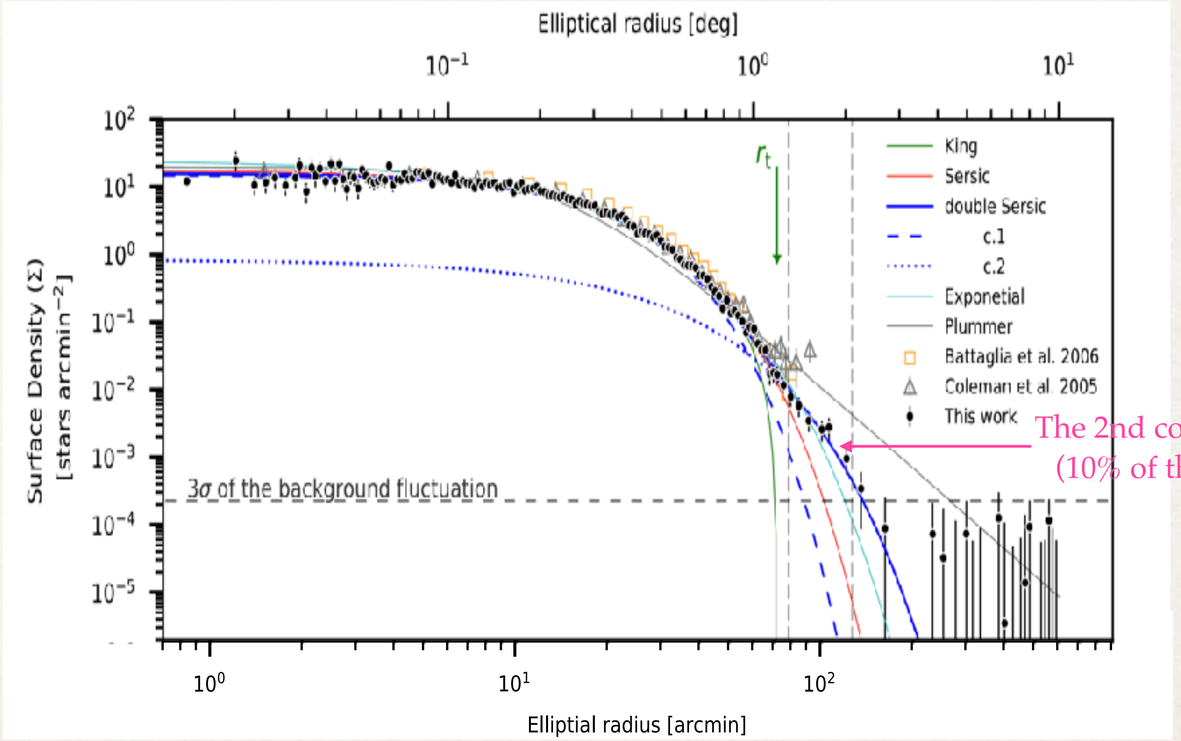
HI cloud (Bouchard et al. 2006)



Yang, Y.-B. et al. 2022
(based on Gaia EDR3)

Possible consequences of the recent infall of MW dwarf galaxies

- Another mechanism may affect the dwarf galaxies: **ram pressure**.
- Star formation history & Chemical evolution
- Morphology & kinematics(3d) & masses
  - 7 (out of 9) **classical dSphs have extended stellar halo** (i.e., the 'break' in density profiles)
    Sculptor (Westfall et al. 2006, Coleman et al. 2005), Carina (Kuhn, Smith & Hawley 1996; Majewski et al. 2000, 2005; Munoz et al. 2006), Leo I (Sohn et al. 2007), Draco (Wilkinson et al. 2004), Sextans (Gould et al. 1992), UMi (Kocevski & Kuhn 2000; Martinez-Delgado et al. 2001; Palma et al. 2003; Munoz et al. 2005) , Fornax (Yang Y.-B et al. 2022)
  - increasing number of UFDs are being detected to have very extended stellar halos : Ursa Minor (Sestito et al. 2023), Ursa Major I, Coma Berenices, Bootes I (Waller et al. 2023), and Tucana II (Chiti et al. 2023), Grus I (Cantu et al. 2021)



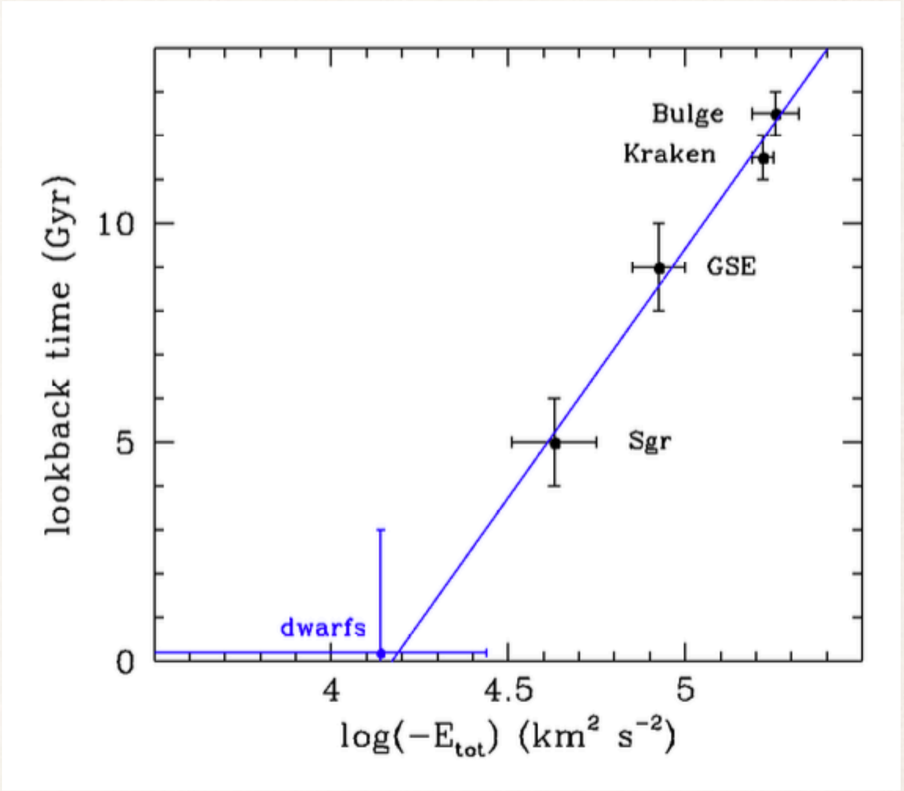
Yang, Y.-B. et al. 2022
(based on Gaia EDR3)

Conclusion

Thanks to Gaia EDR3 proper motions, we are able to make a full analysis of the orbital properties of MW dwarf galaxies, and we find that

MW dwarf galaxies are in-falling recently, ~3 Gyr.

- Together with other peculiarities of MW dwarfs, this may help us to understand better about their :
  - SFH & Chemical evolution
  - Morphology & Kinematics
  - their masses & origins



Hammer et al. 2023