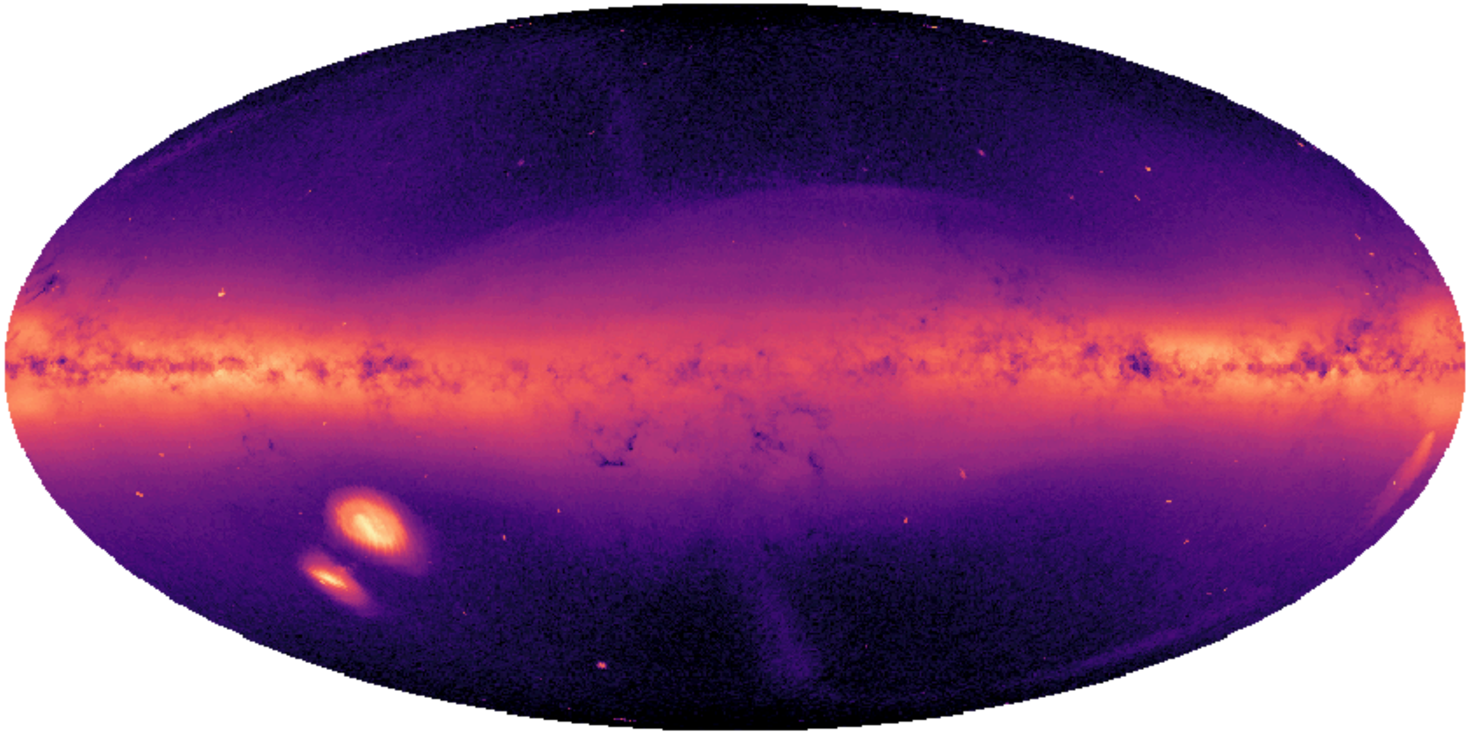
The Milky Way Assembly tale from its disc & substructures' properties



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UNIVERSITAT DE BARCELONA
EXCELENCIA MARÍA DE MAEZTU 2020-2023
European Research Council
Established by the European Commission

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João Amarante

Emily Bregou

Matthew Orkney

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Emily Bregou

Matthew Orkney

SDSS-V

NYX
>1000 cores
15GB RAM per core

MEAVE

& YOU?

VIA LACTEA Team

João Amarante

Talk

stellar halo structure & formation

Emily Bregou

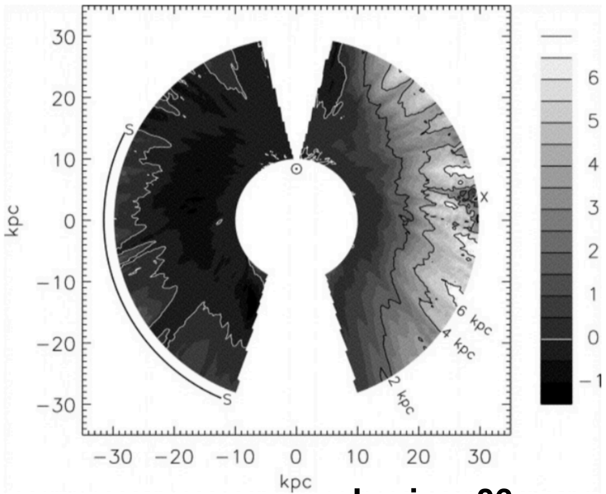
Matthew Orkney

Poster

GSE & metal poor stars in the Galaxy

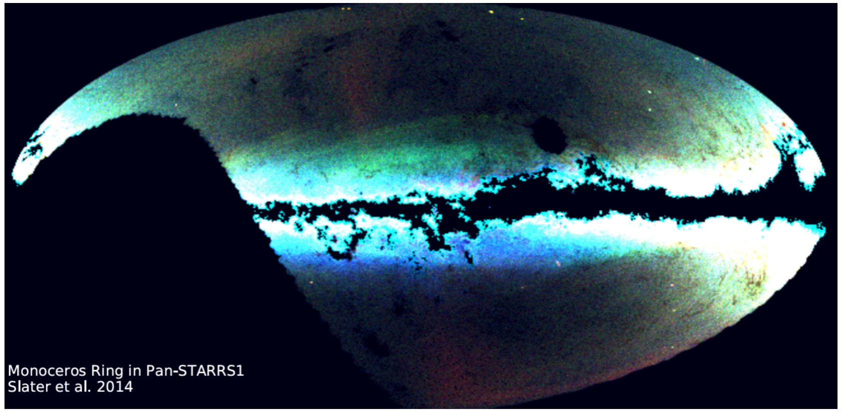
What can 99% of the baryons possibly tell us about the assembly history of the Milky Way?

Warp



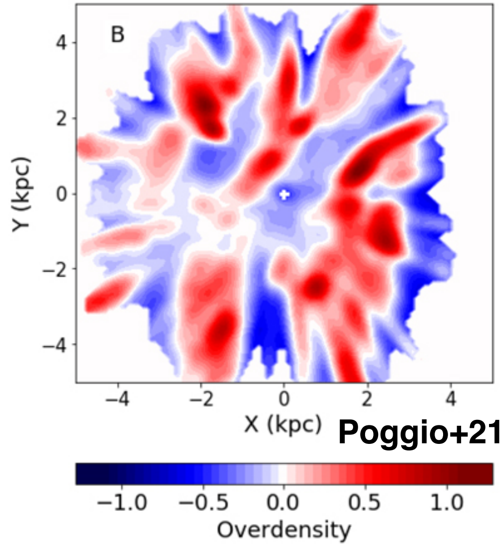
Levine+06

disc-halo interface
Low surface brightness structures



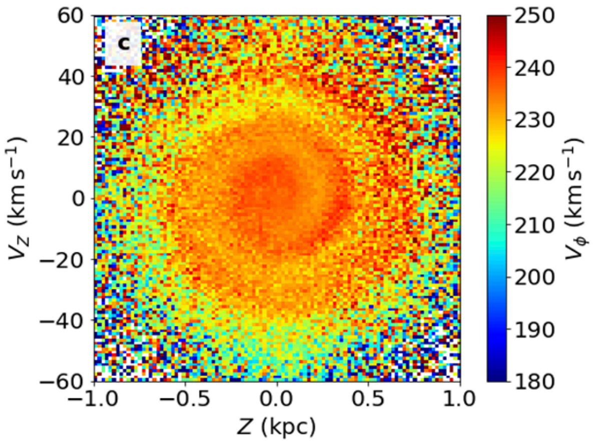
Slater+14

Spiral arms

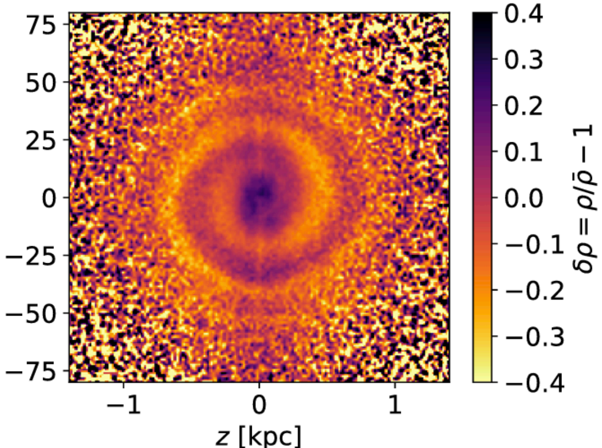


Poggio+21

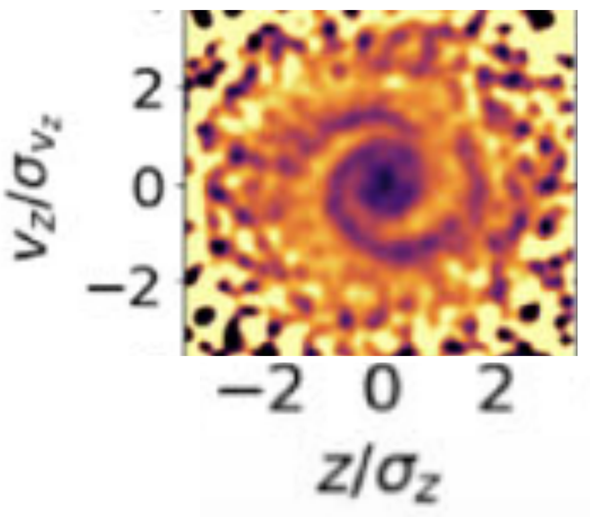
Phase-mixing across the disc



Antoja+18

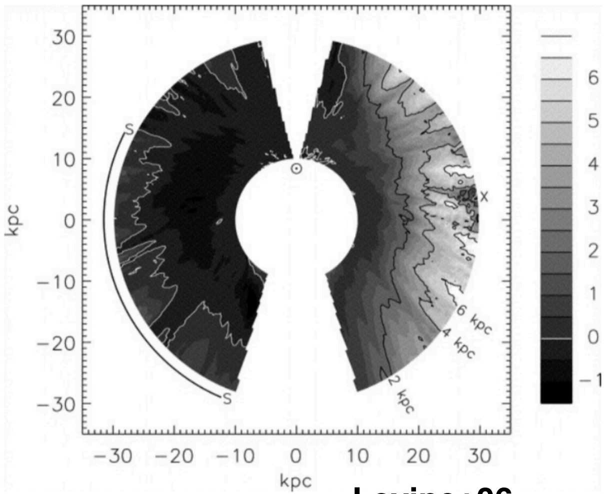


Laporte+19c



Hunt+22

Warp



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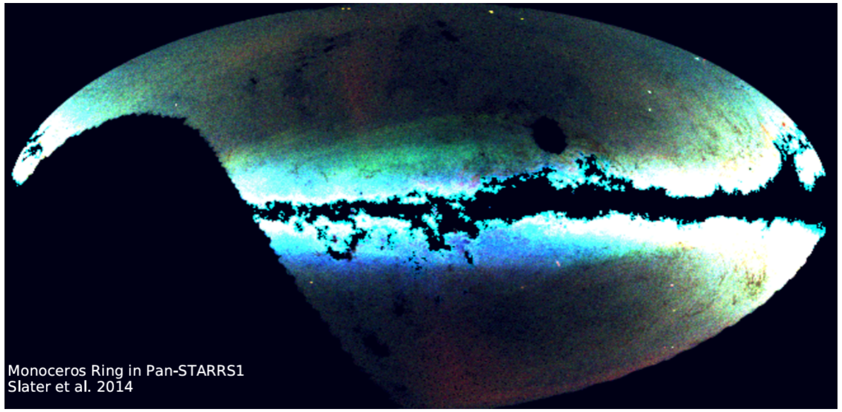
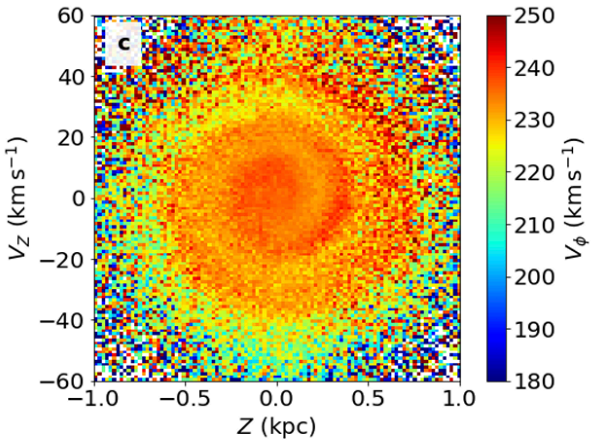


Slater+14

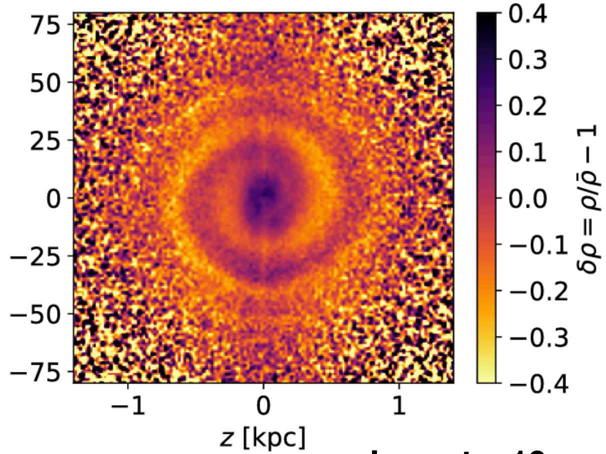
~~Spiral arms~~

Talk to Aneesh, Zoe, Keith…

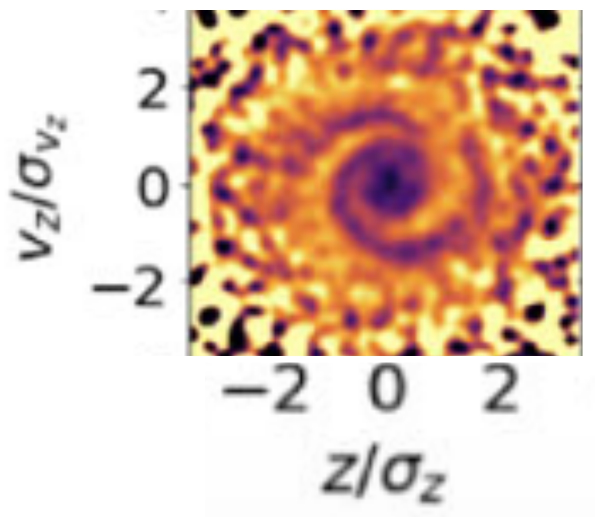
Phase-mixing across the disc



Antoja+18



Laporte+19c



Hunt+22

Accretion history of the Milky Way

- Magellanic Clouds: 2 Gyrs ago, LMC~2.5e11Msun (Penarrubia+16)

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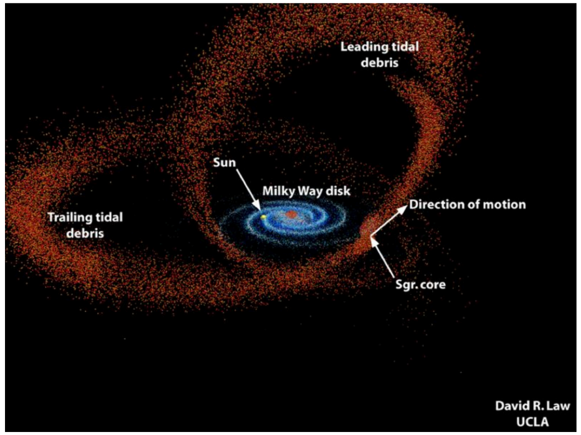
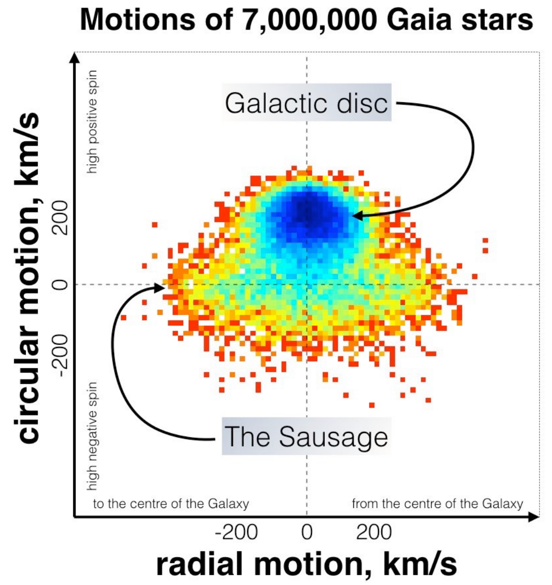


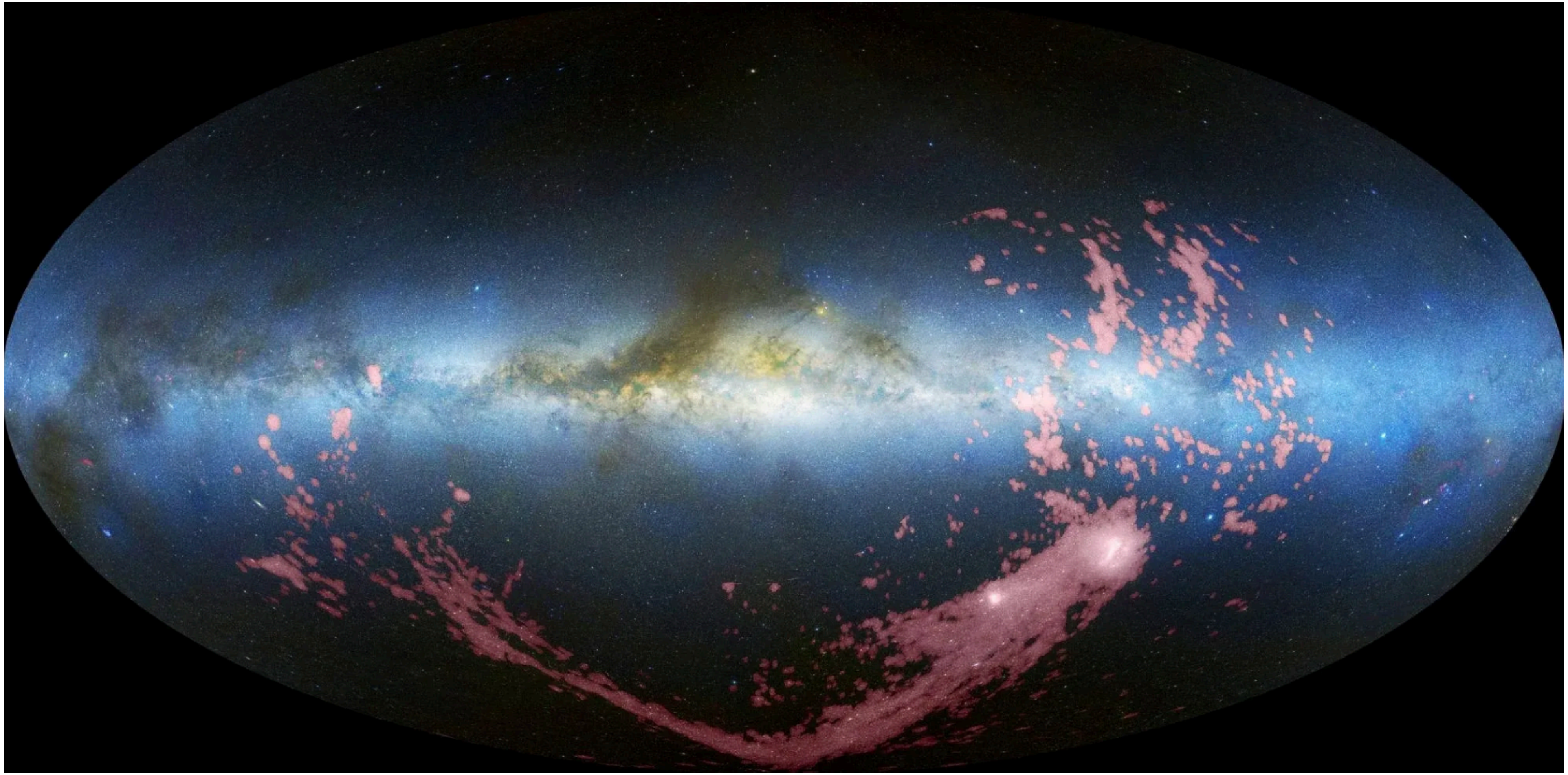
Accretion history of the Milky Way

- Magellanic Clouds: 2 Gyrs ago, LMC~2.5e11Msun (Penarrubia+16)
- Sagittarius: 6-8 Gyr ago, progenitor mass >6e10Msun (Gibbons+17, Laporte+18b), remnant mass 5e8Msun (Vasiliev+20).
- Gaia-Sausage-Enceladus - ~10 Gyrs ago, LMC-mass (Belokurov+18, Helmi+18).

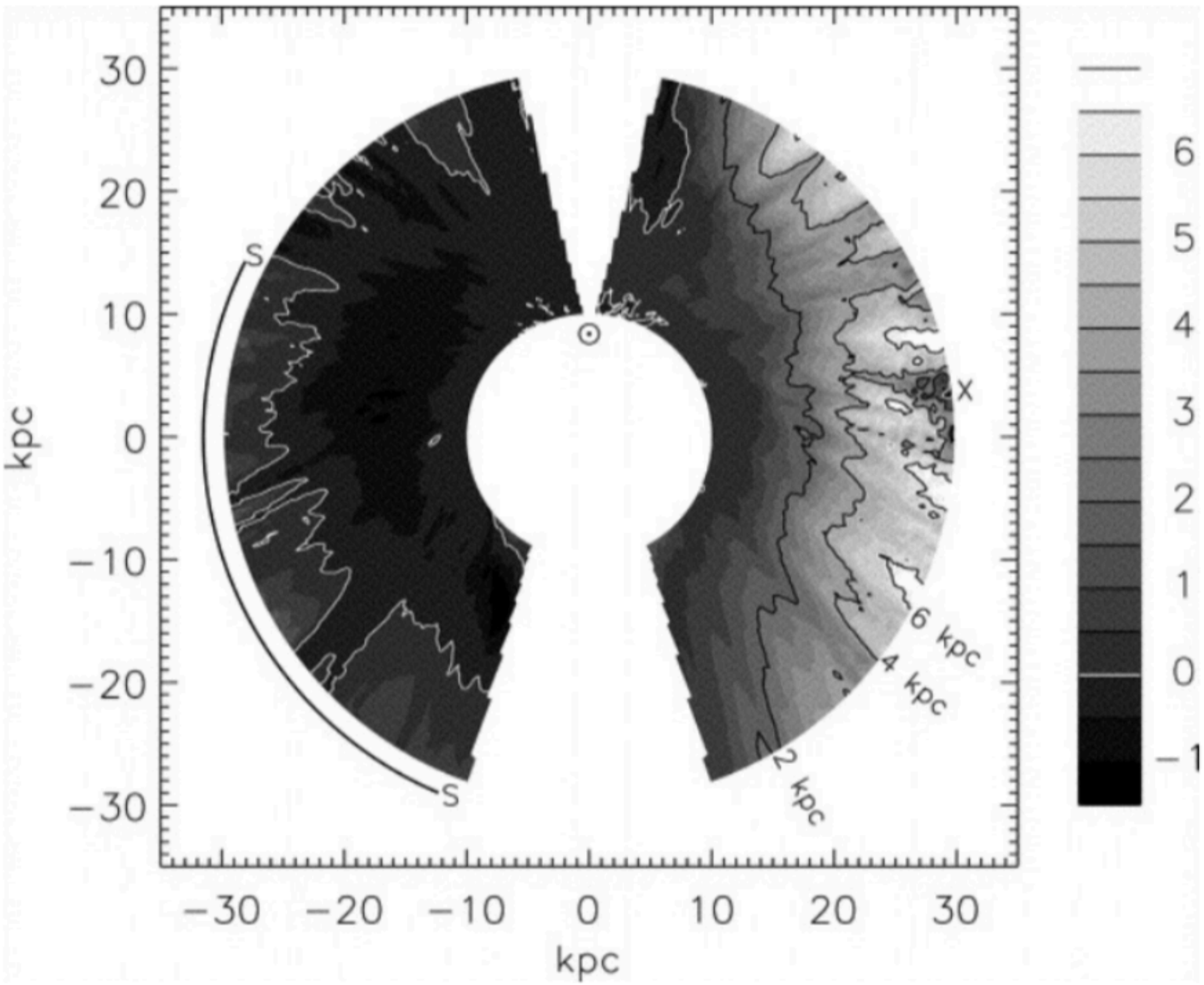


see also Chiba & Beers 2000, Brook+03, Meza+05 for earlier signs…

The LMC



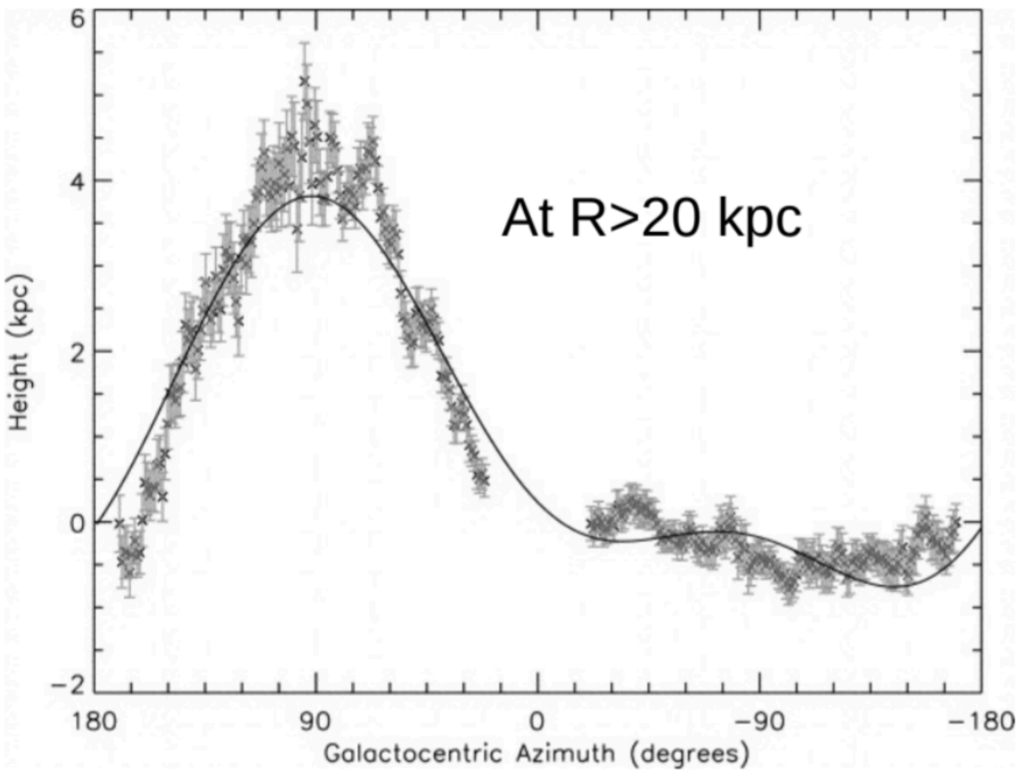
HI vertical Structure



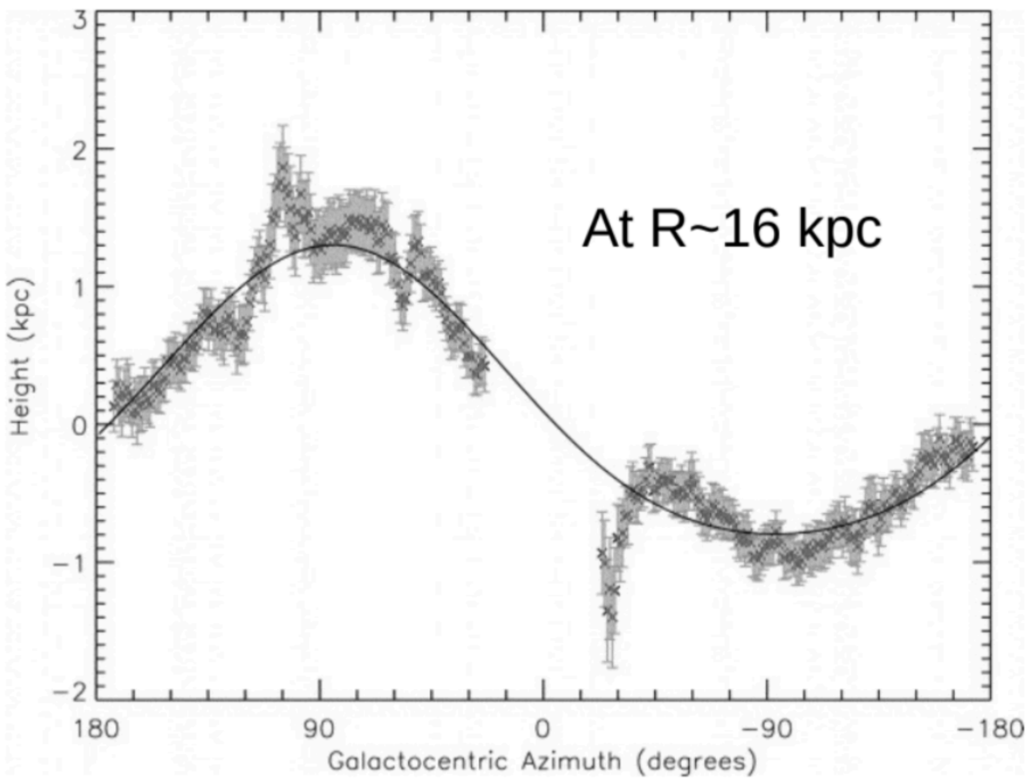
Levine et al. (2006)

Warp asymmetry

Asymmetric

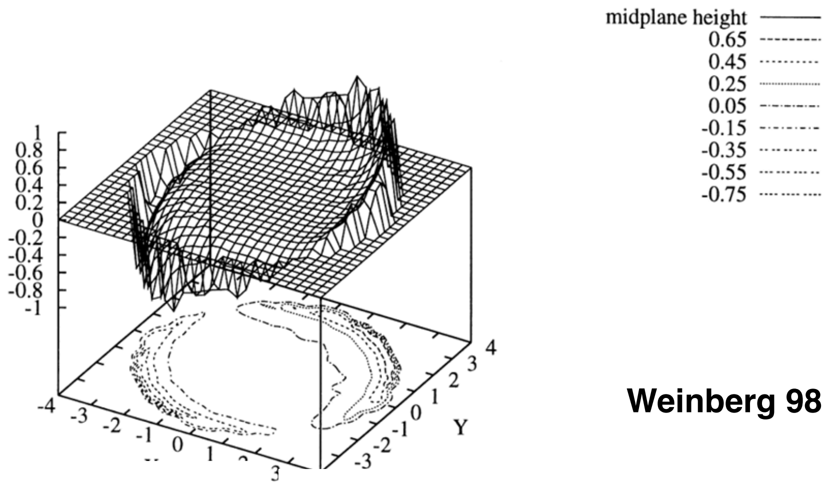


Symmetric

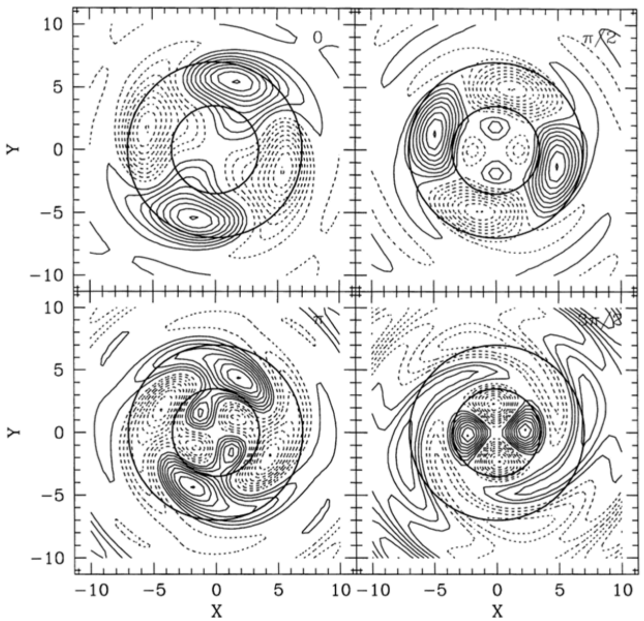


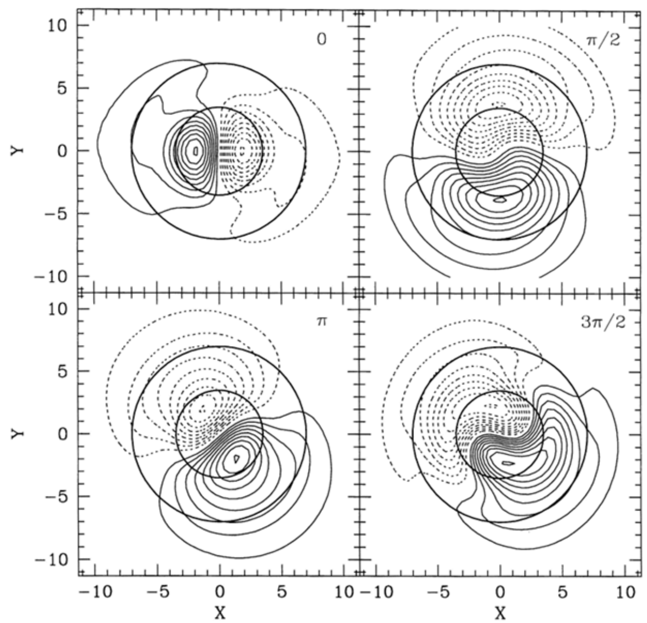
LMC-induced disequilibrium

Dark matter halo wakes and warps



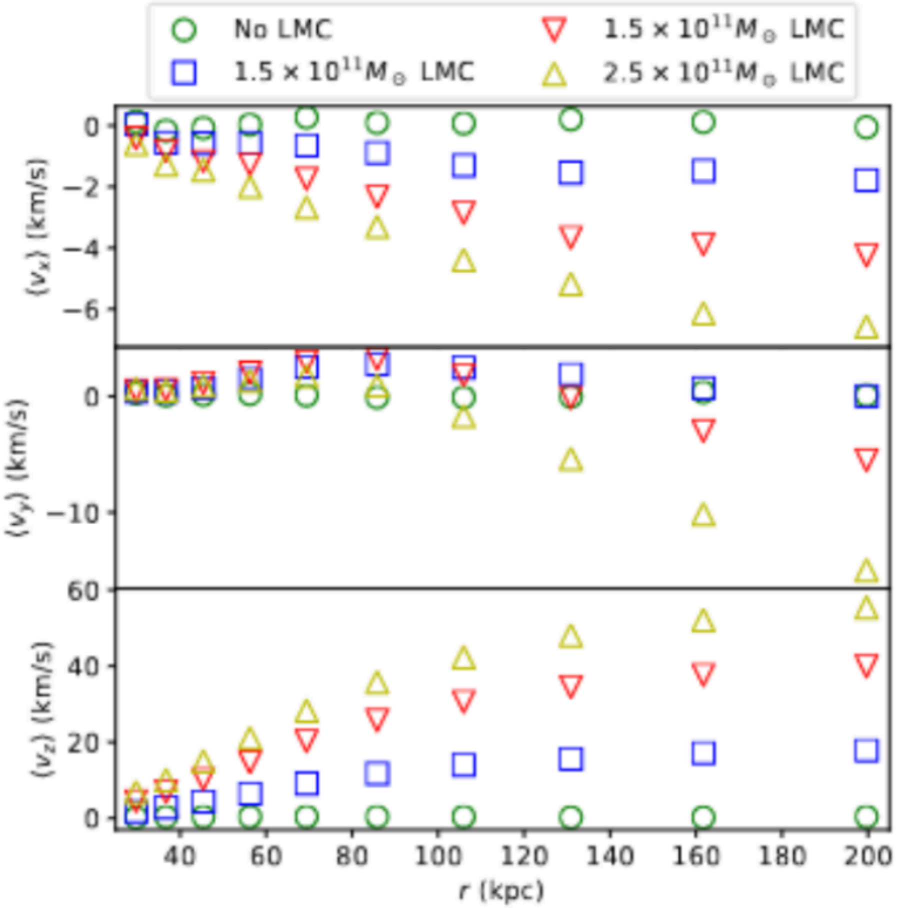
Weinberg 98



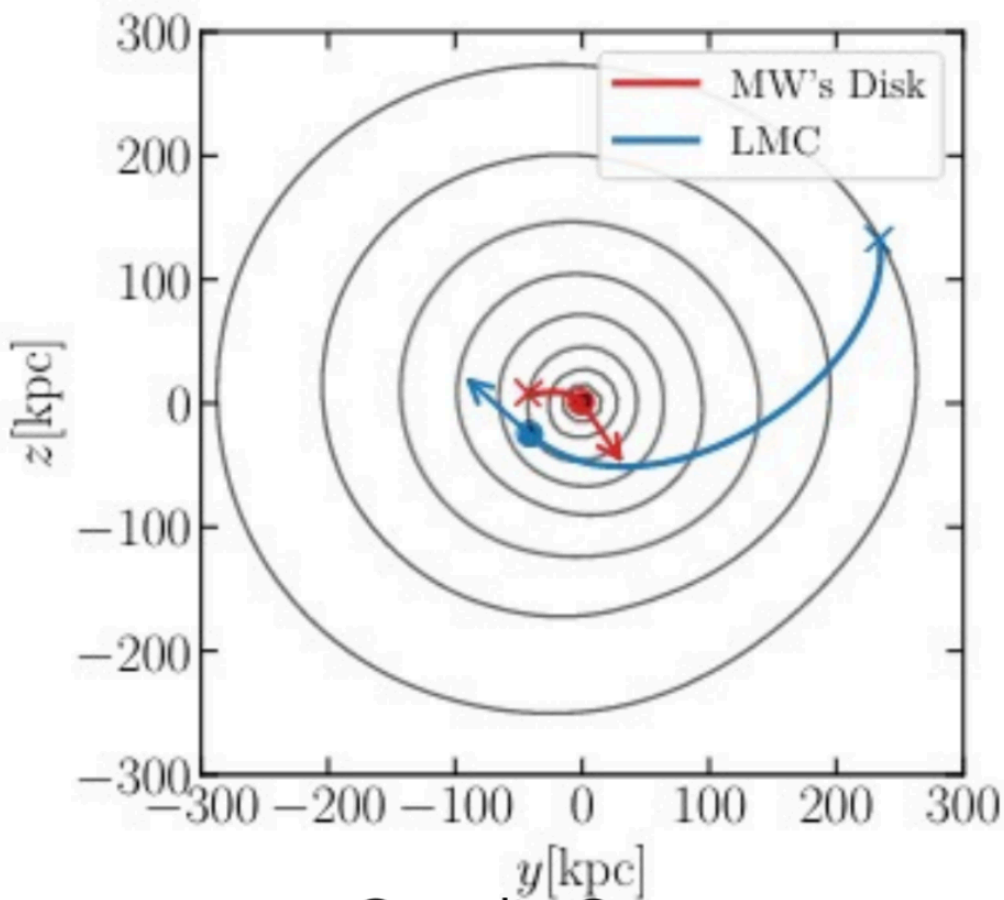


See also Gomez+16, Laporte+18a, Garavito-Camargo+19, Vasiliev+23

The LMC pulls the MW down

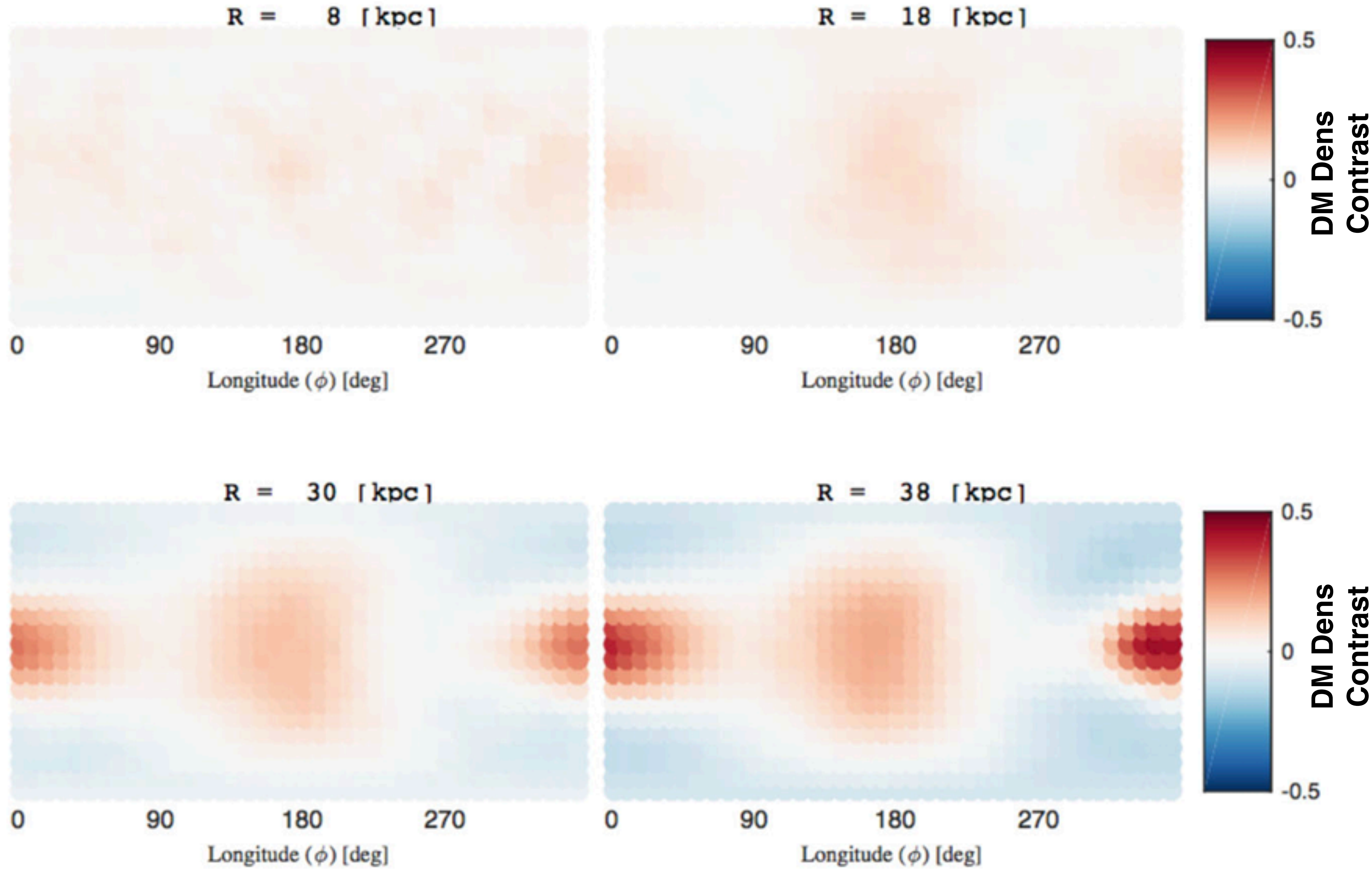


Erkal et al. (2020)



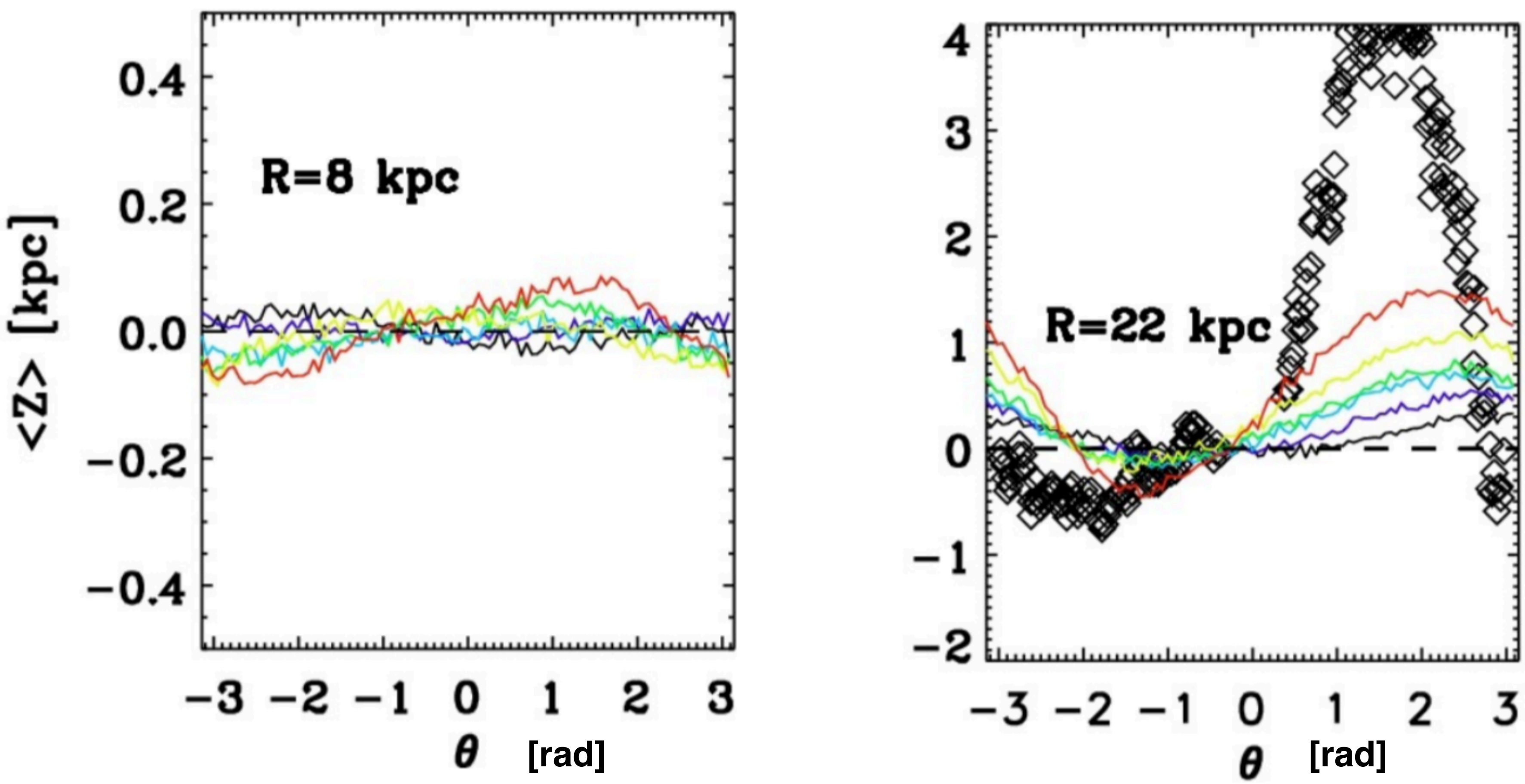
Garavito-Camargo et al (2022)

MW DM halo LMC-induced density dipole



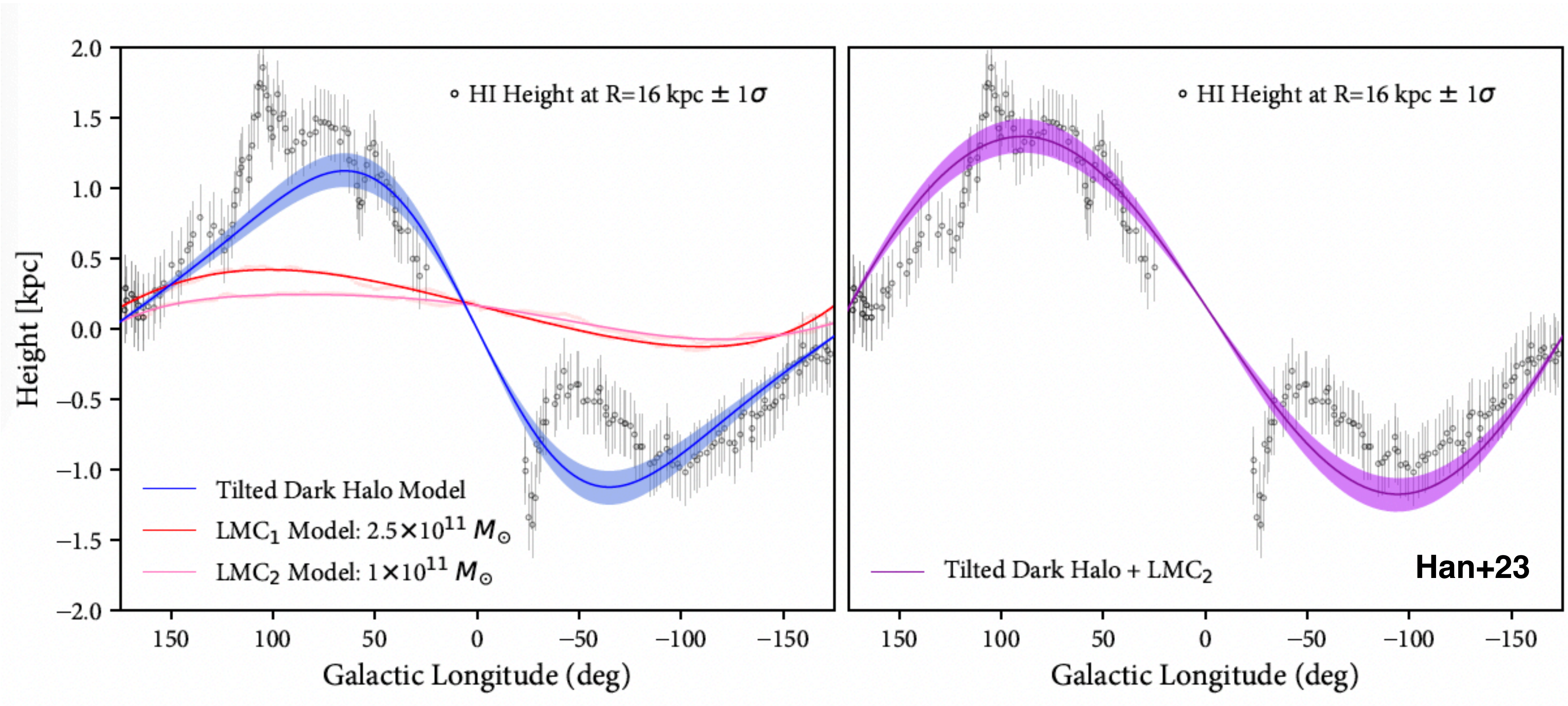
Laporte+18a

live N-body simulations of LMC on first infall orbit



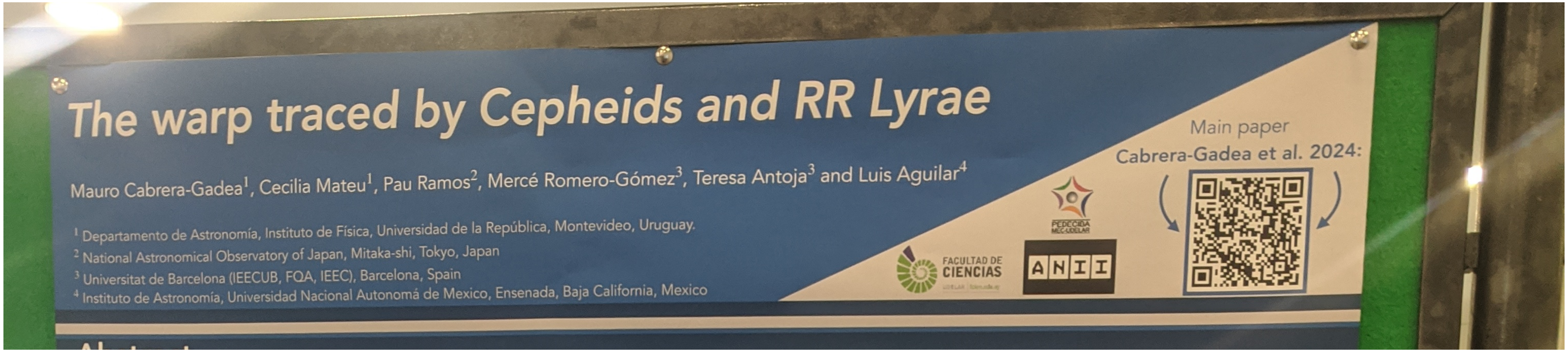
*See Han+23 for interpretation of flare/warp at radii =<16kpc

Warp at 16kpc (symmetric), evidence for a tilted DM halo?



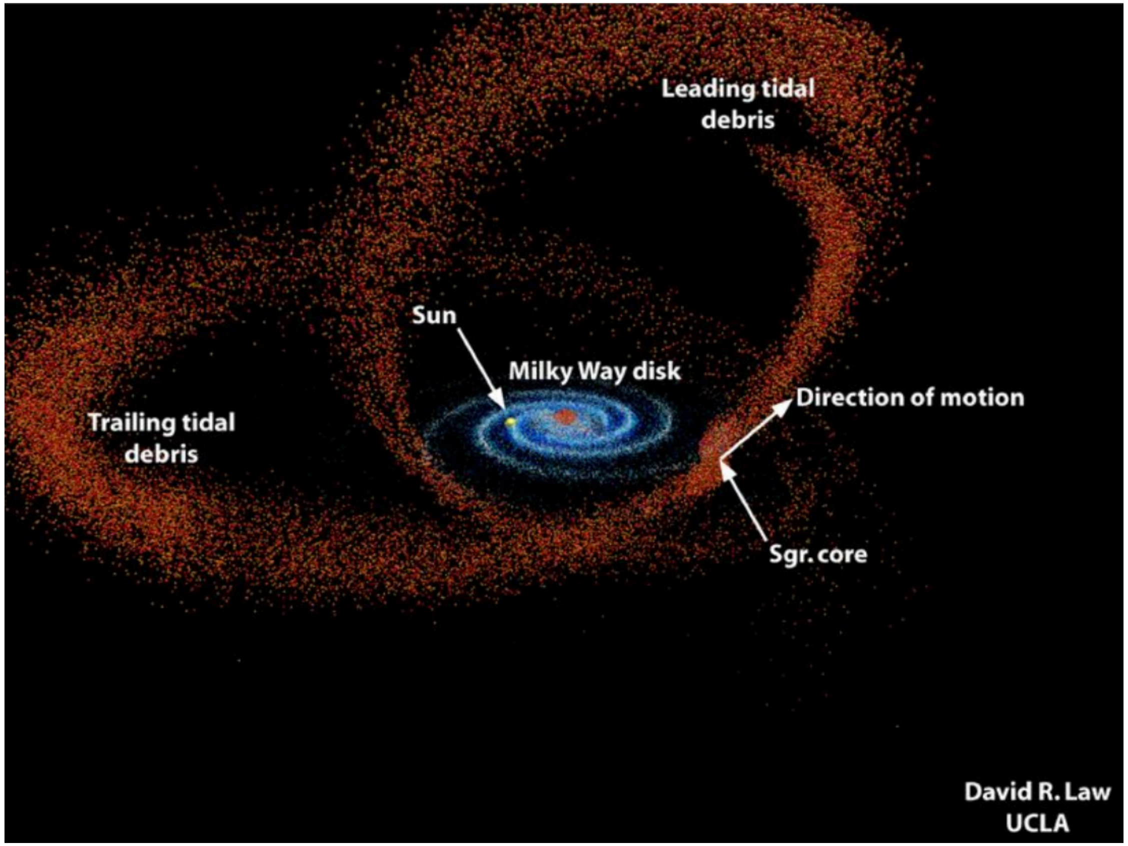
Or unreliable kinematically inferred distances (Reid et al. 2016)? Or something else

More on warps

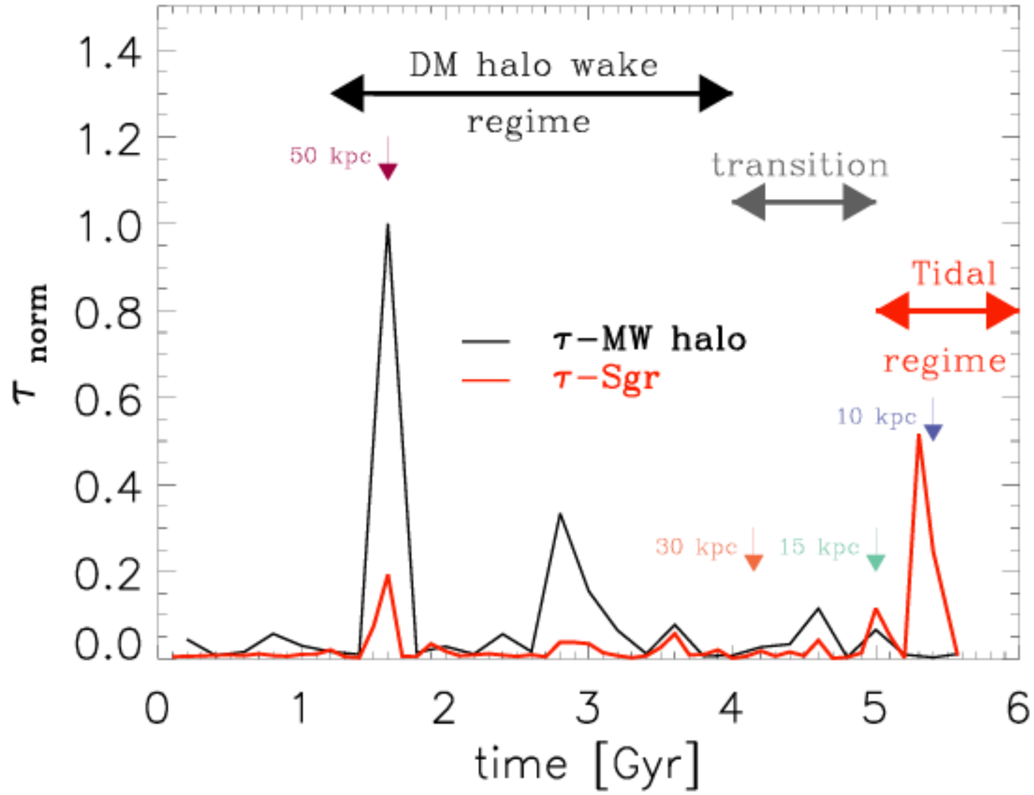


Talk to Mauro, Cecilia, Teresa

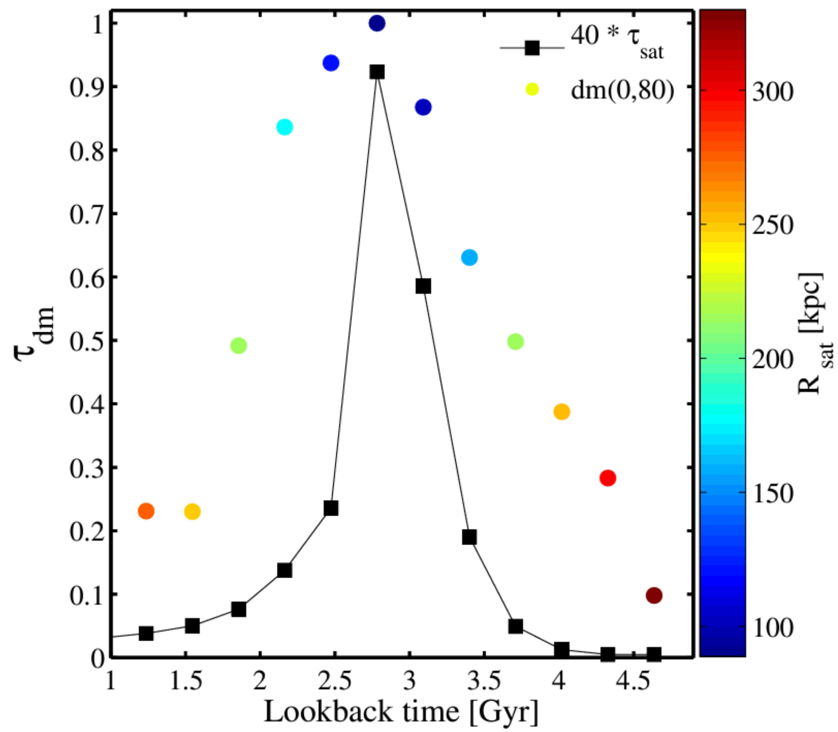
Dynamics of a Sgr-like galaxy and its impact on disc evolution



Torques from DM halo deformation & main body (optional*)



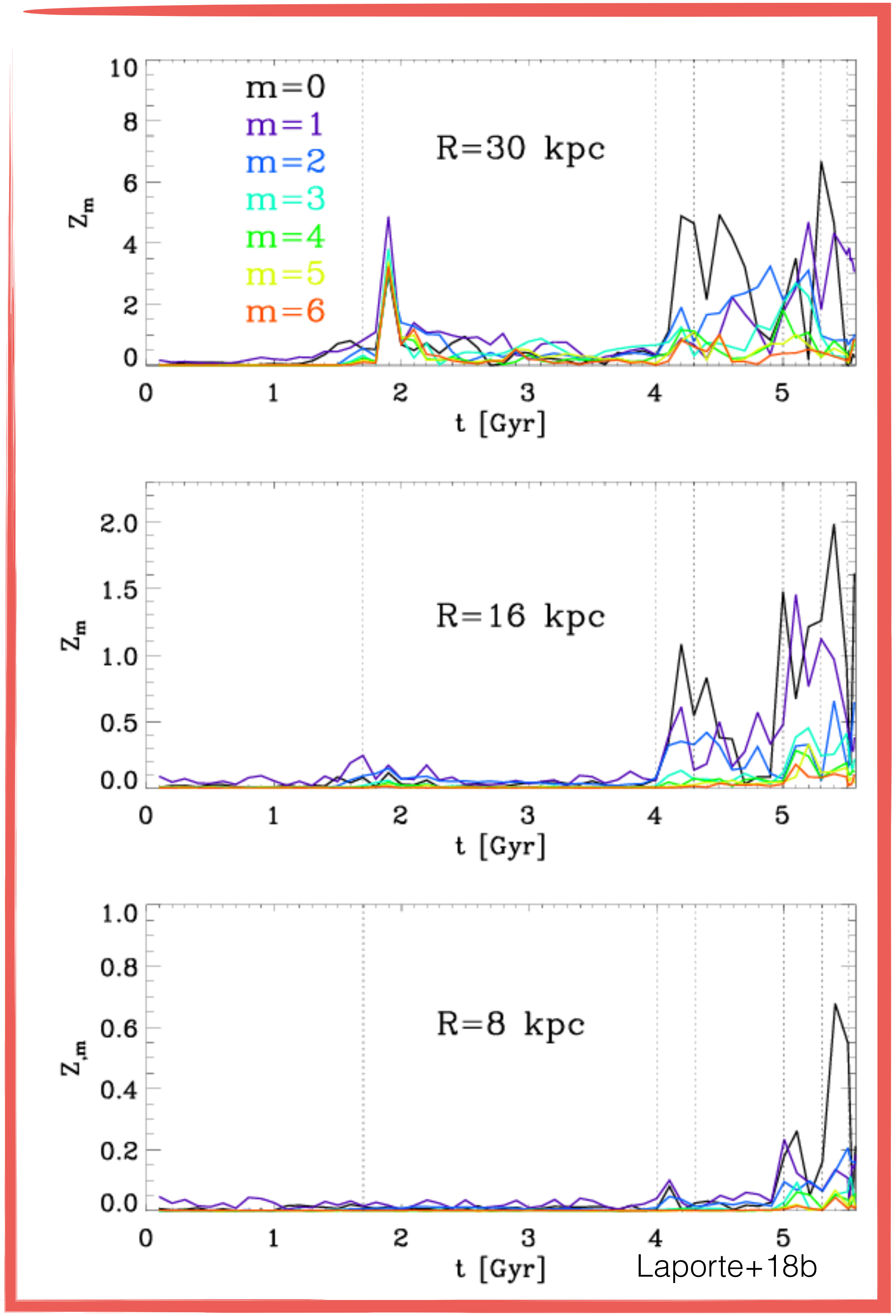
Laporte+18b

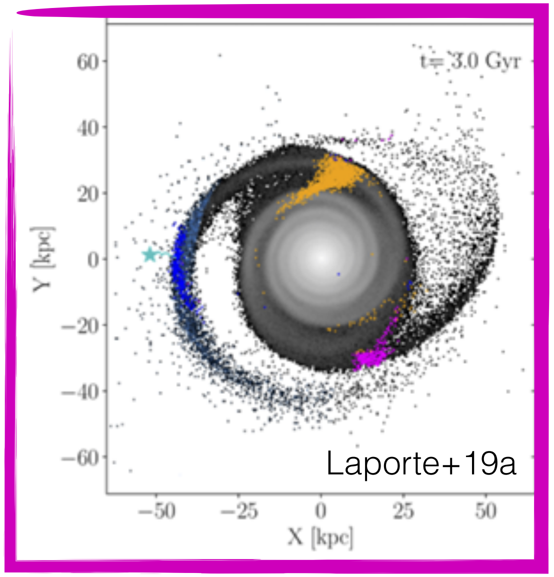


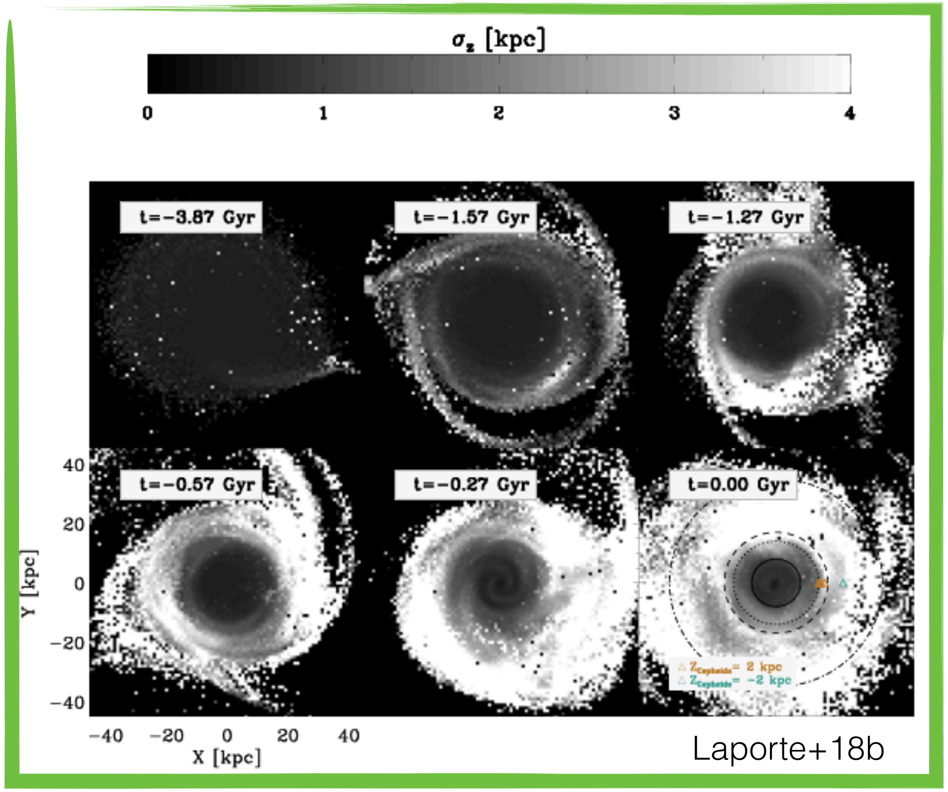
Gomez+16

See also Grand+23

Sgr induces: bending, ripping, flaring, breathing in the disc







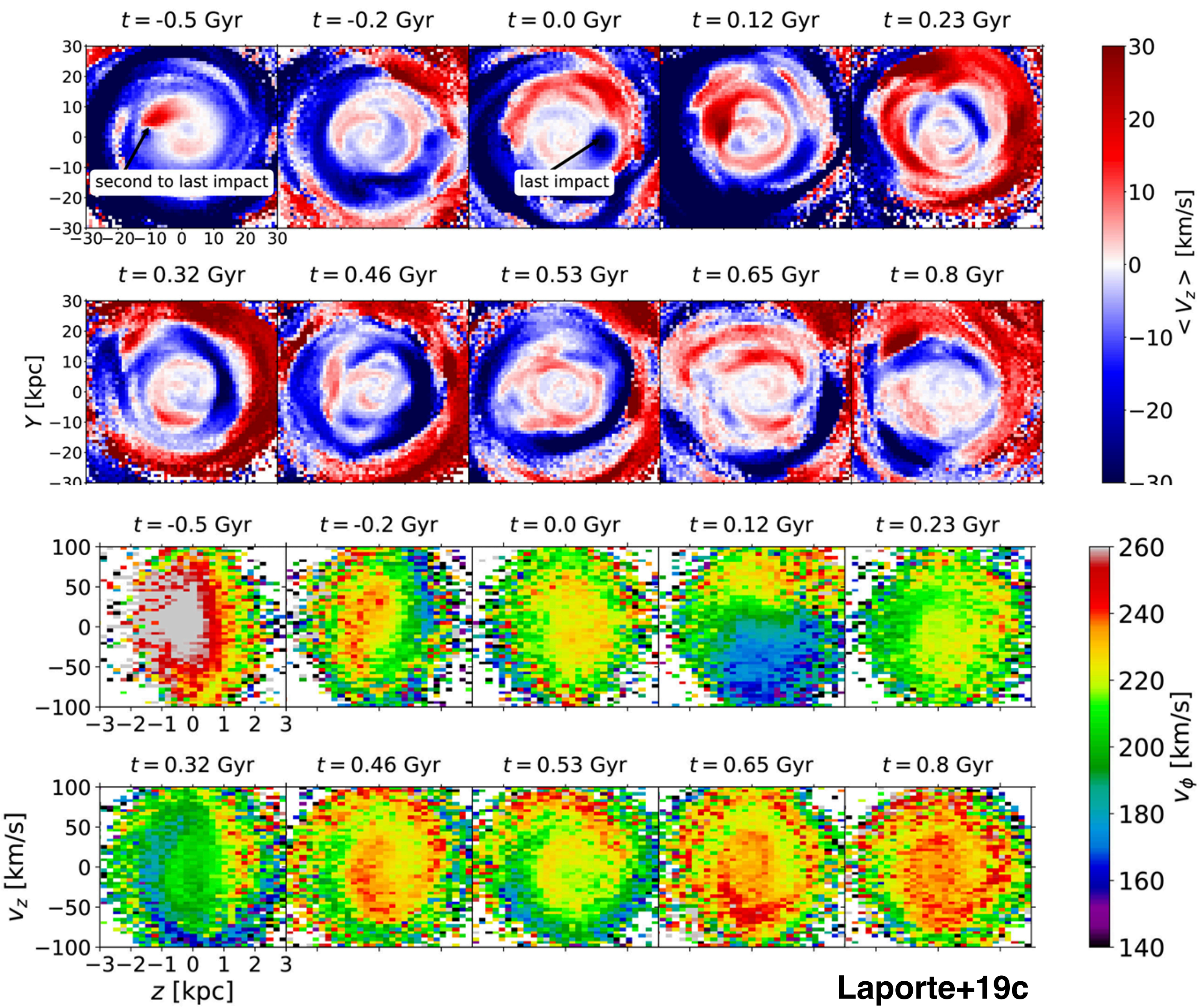
Sgr can seed phase-space spirals through **wake** or **direct hit**

last pericentric passage of Sgr in its last phase of disruption. In Fig. 8, we show a time series of the mean vertical velocity of the disc. We note that as Sgr hits the disc, it excites vertical density waves throughout the whole disc, which are maintained on Gyr time-scales. One can discern by eye the local impacts of Sgr during each pericentric passages that give local velocity kicks of a few 10s of $\mathrm{km\,s^{-1}}$ but also set new generations of bending waves for which the disc is *globally* perturbed as seen in the snapshot ~100 Myr after the last pericentric passage. The latter phenomenon is unique to self-gravitating discs and missed in toy models of phase-mixing (Minchev et al. 2009; Antoja et al. 2018; Binney & Schönrich 2018). Moreover, throughout its interaction Sgr sets off previous generations of bending waves that also gave rise to phase-space spirals.

Laporte+19c

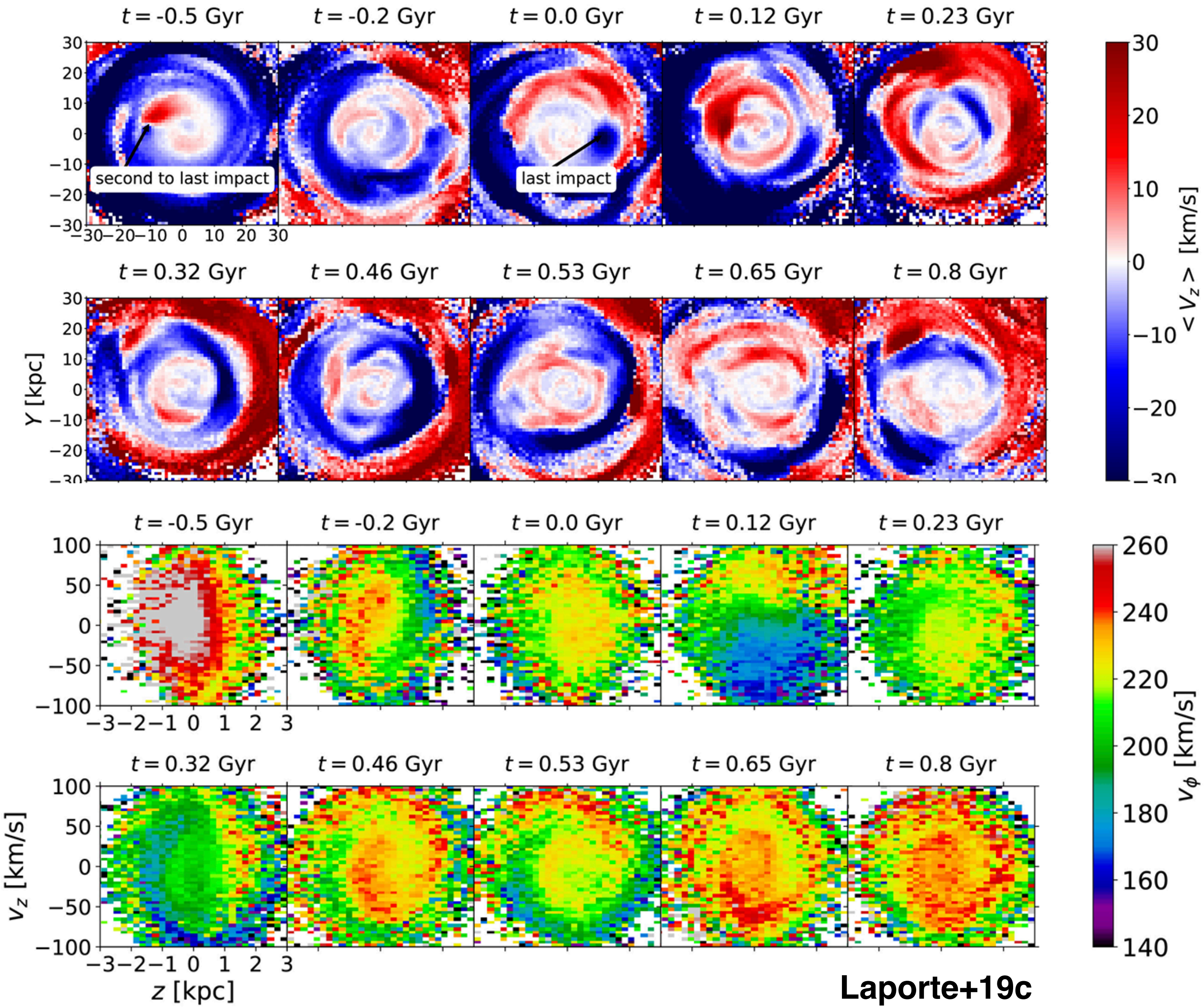
See Rob Grand's talk on Friday

Sgr can seed phase-space spirals through wake or direct hit



And can be sustained long after

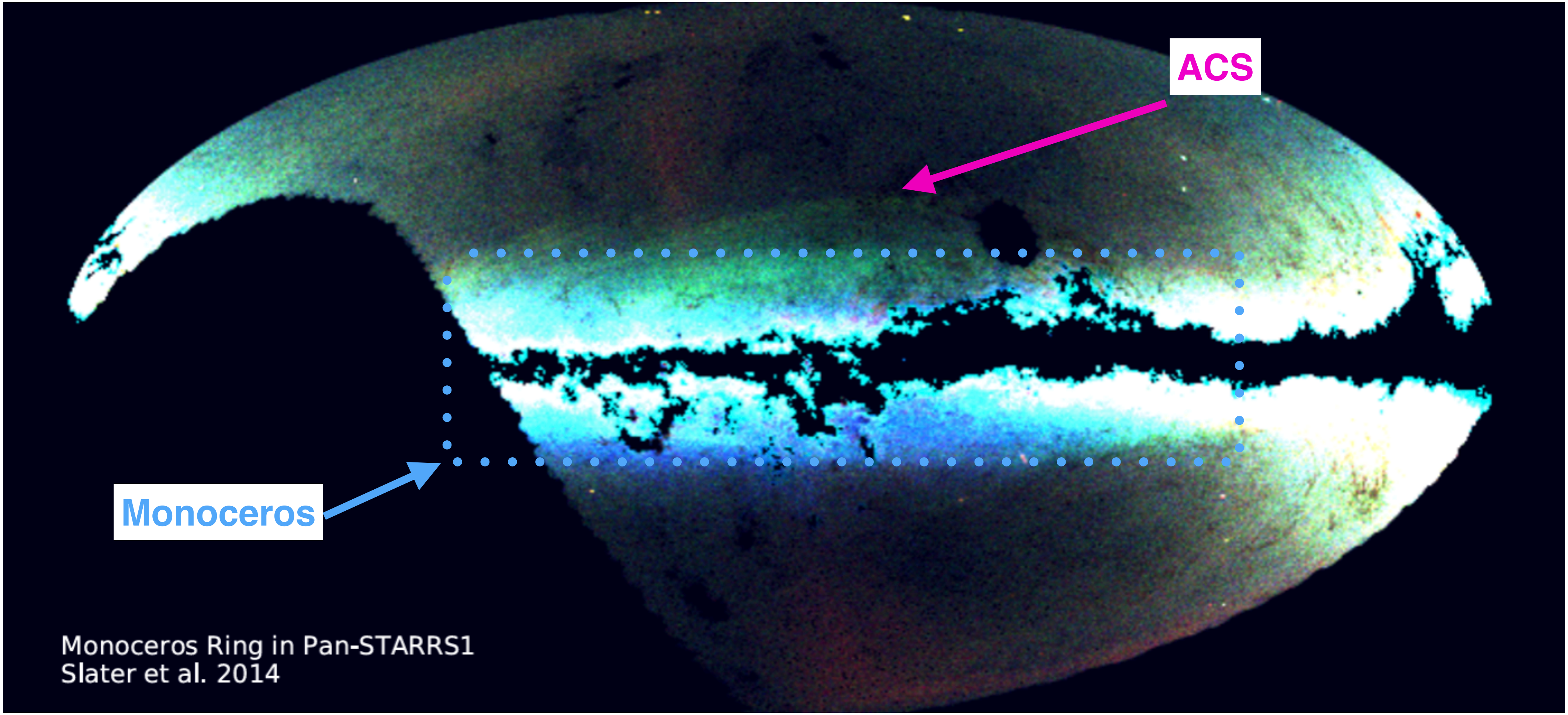
Sgr can seed phase-space spirals through wake or direct hit



Laporte+19c

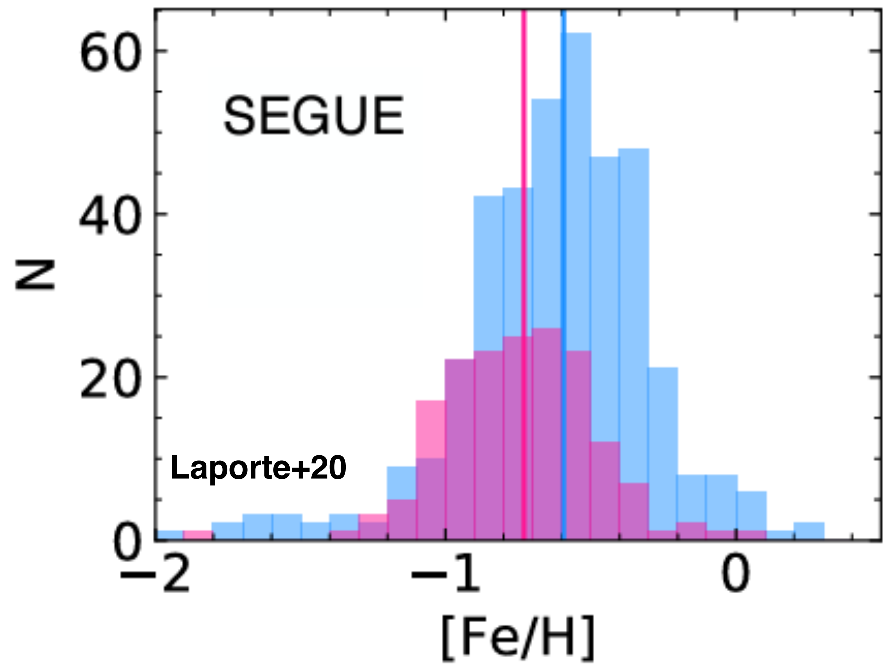
See also Bland-Hawthorn+21, Hunt+21, Hunt+22, Grand+23

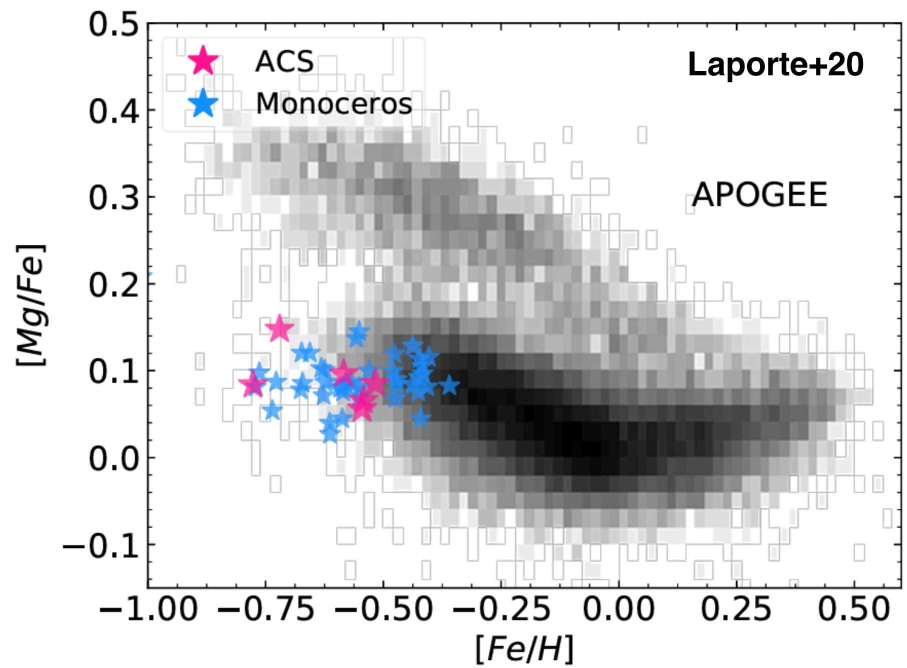
The Galactic outer disc



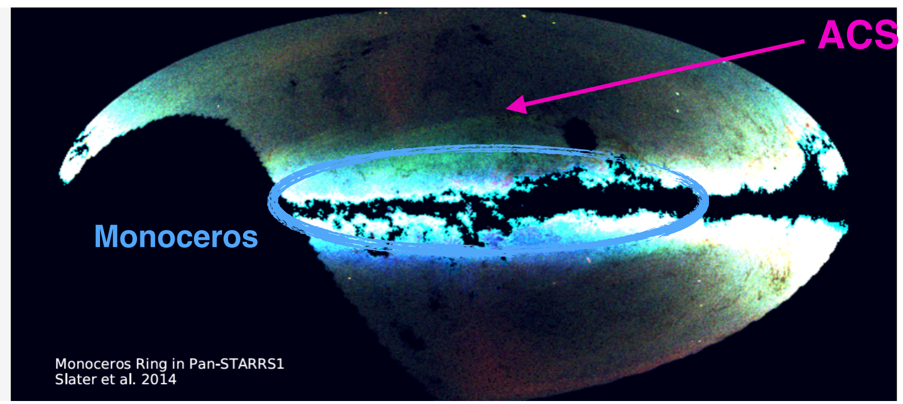
Confirming the disc origin of these stars in kinematics & chemistry

[Fe/H]~-0.7, -0.6

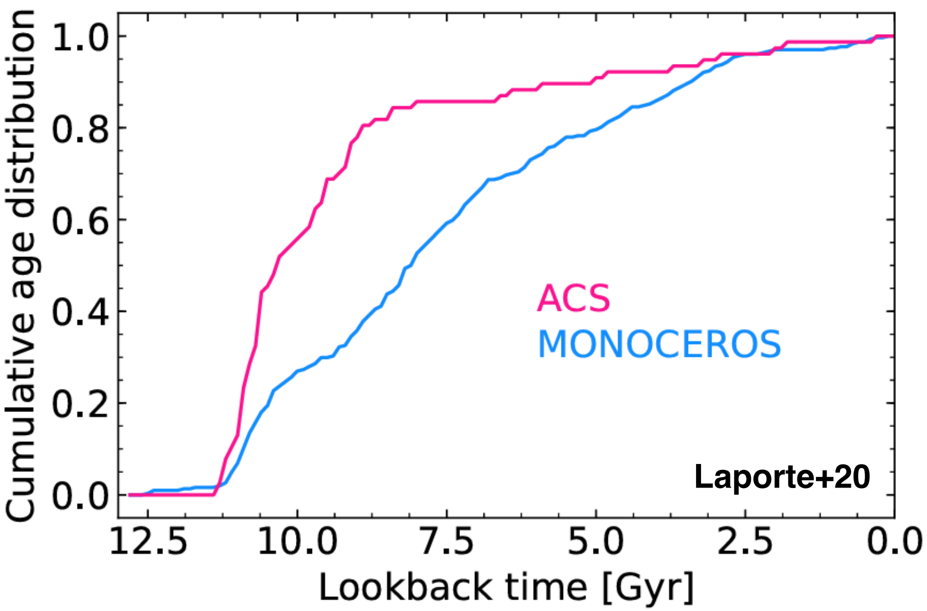




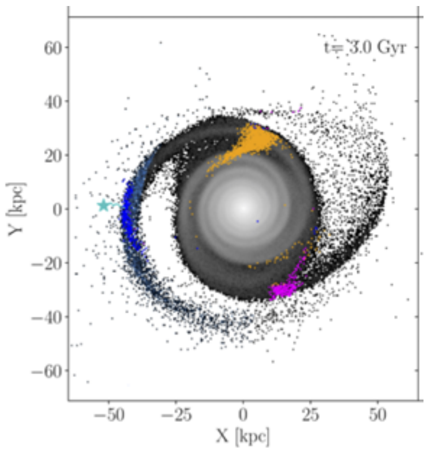
If Monoceros & ACS were dwarf debris
They'd blow up the stellar halo by a factor 6



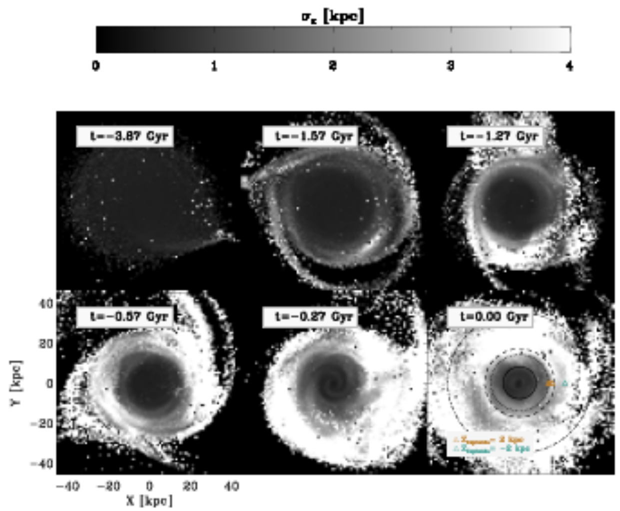
Formation histories of ACS & Monoceros



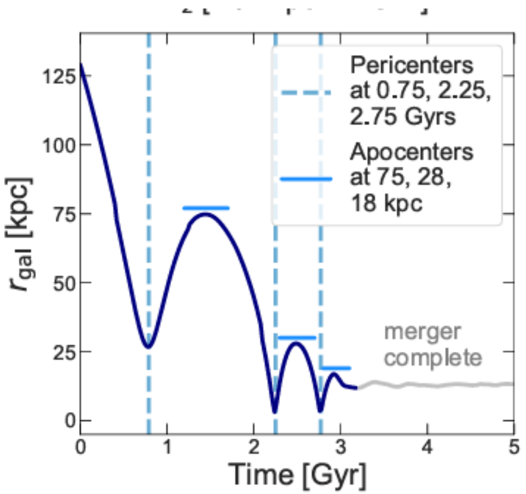
Fly-by excited
Instantaneous

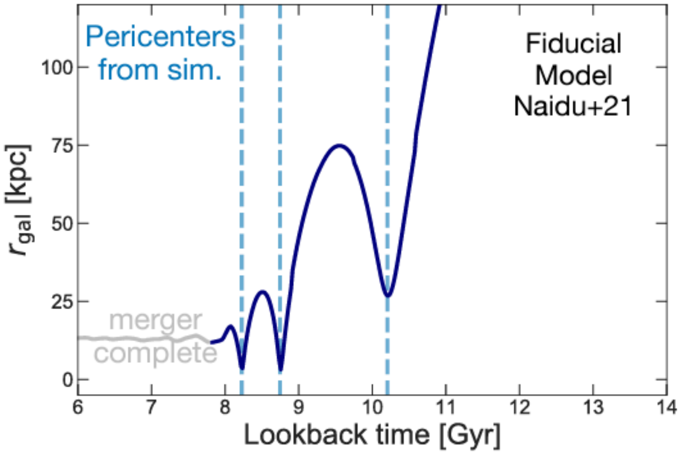


Heating/flaring
Extended



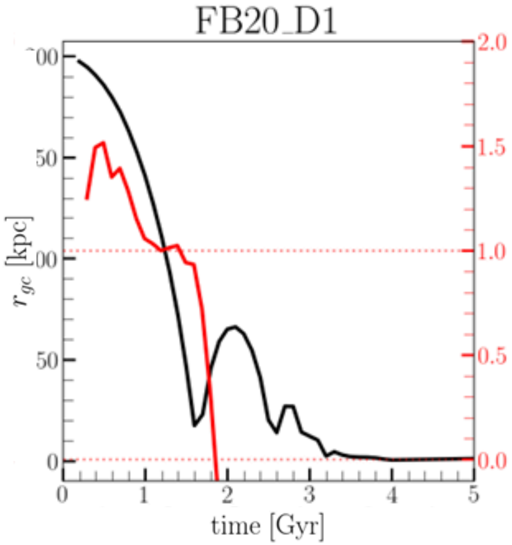
When did the GSE merge?

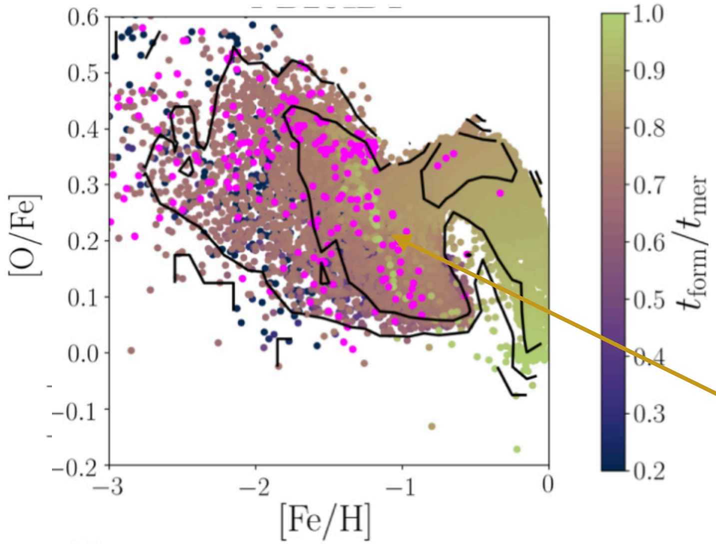




N-body only

Naidu+20





Amarante+(CFPL)+22

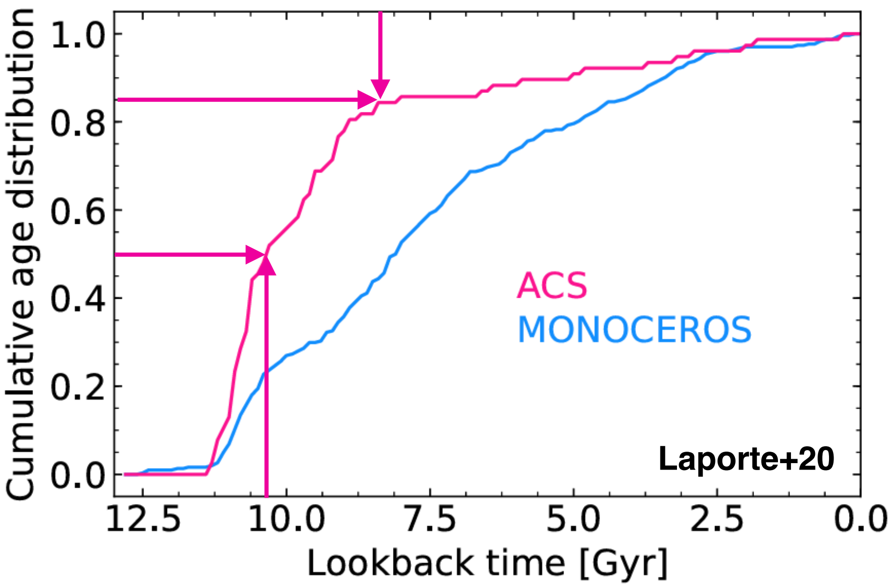
Hydrodynamical simulation

newer stars formed during peri centric passage

predicted SF in GSE host at ~ 8-9Gyr look back time associated

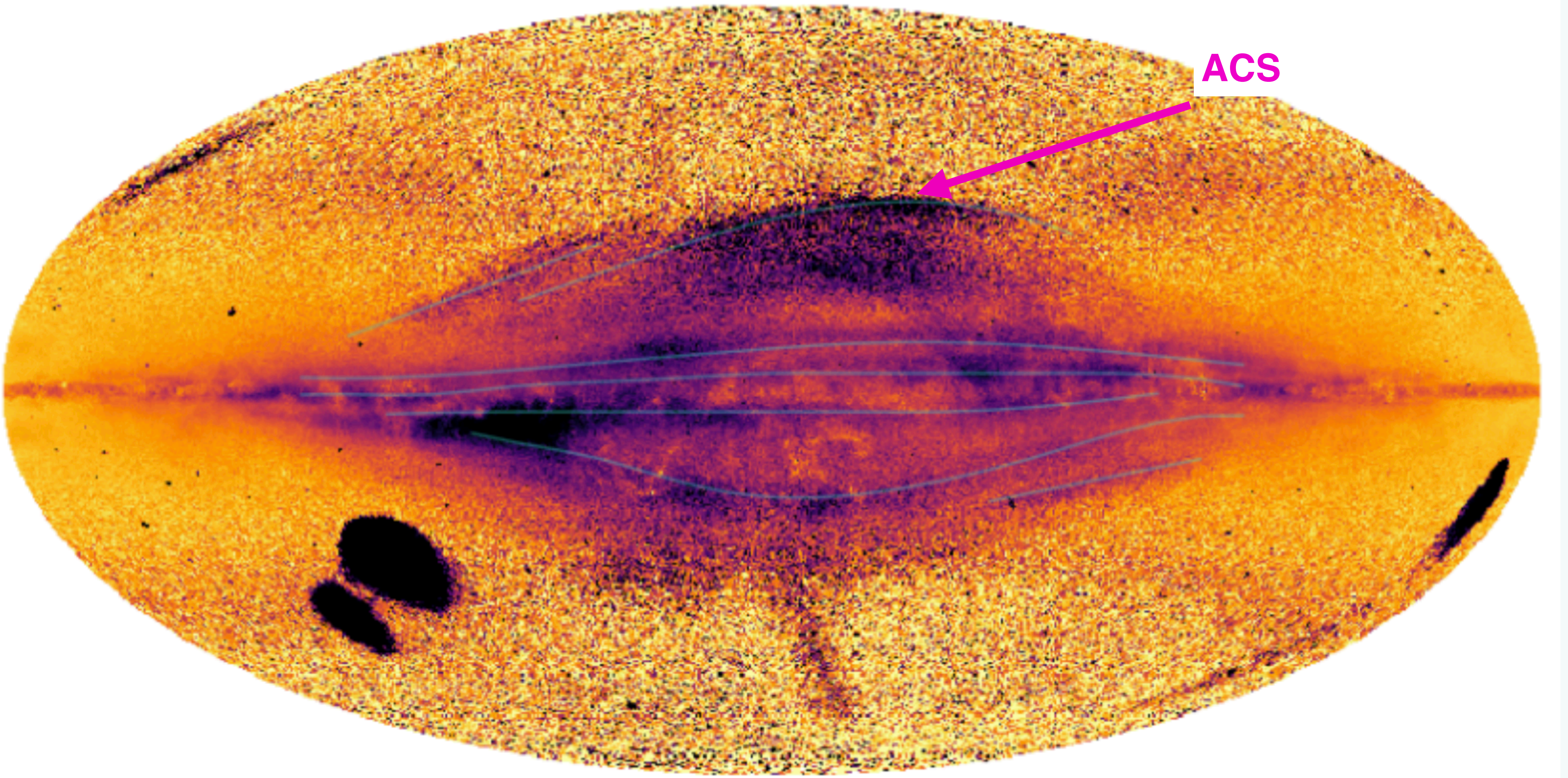
Possibly found by Horta+24?

At face value low-alpha disc was already forming at z~2

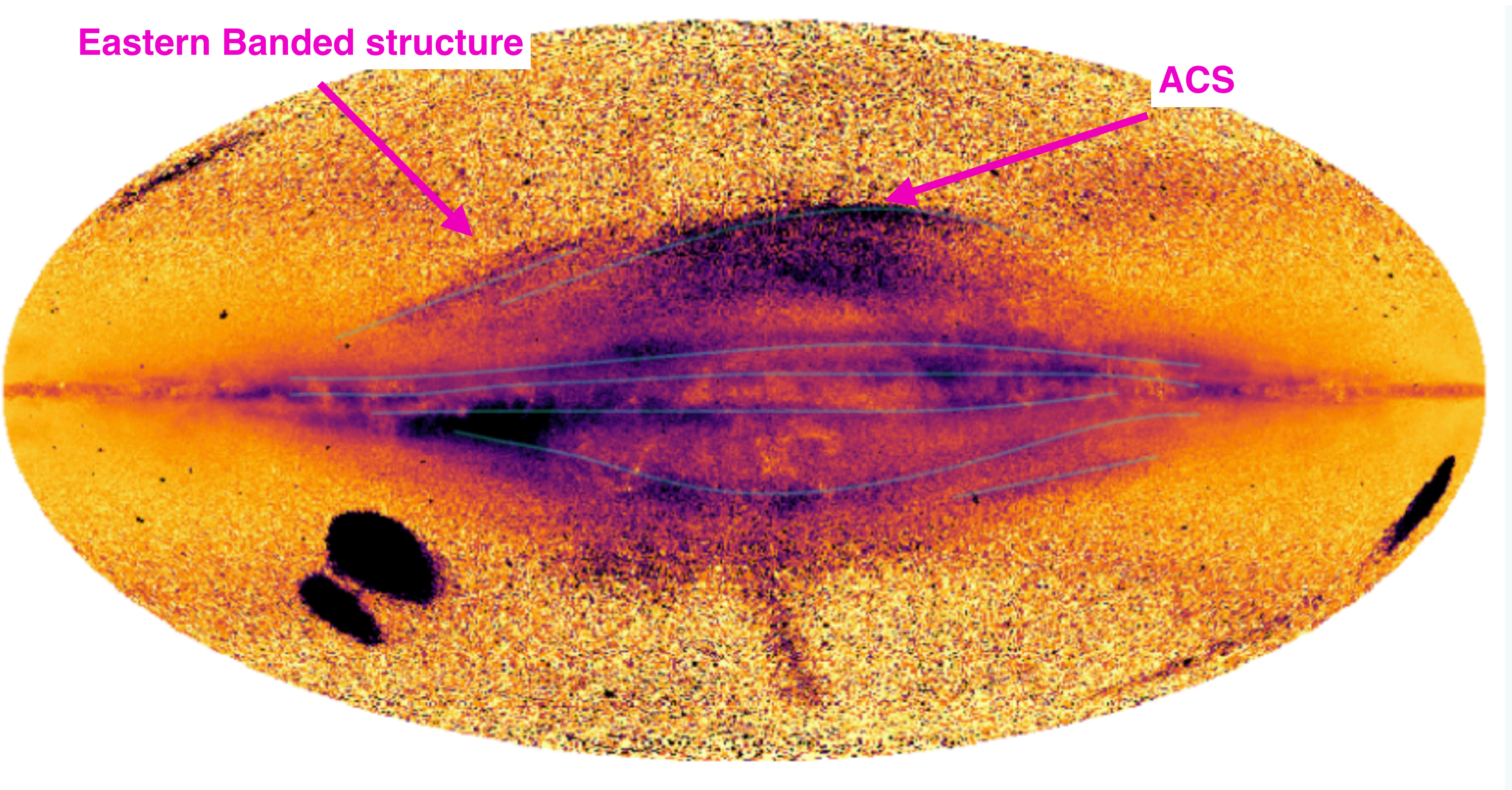


At face value low-alpha disc was already forming at z~2

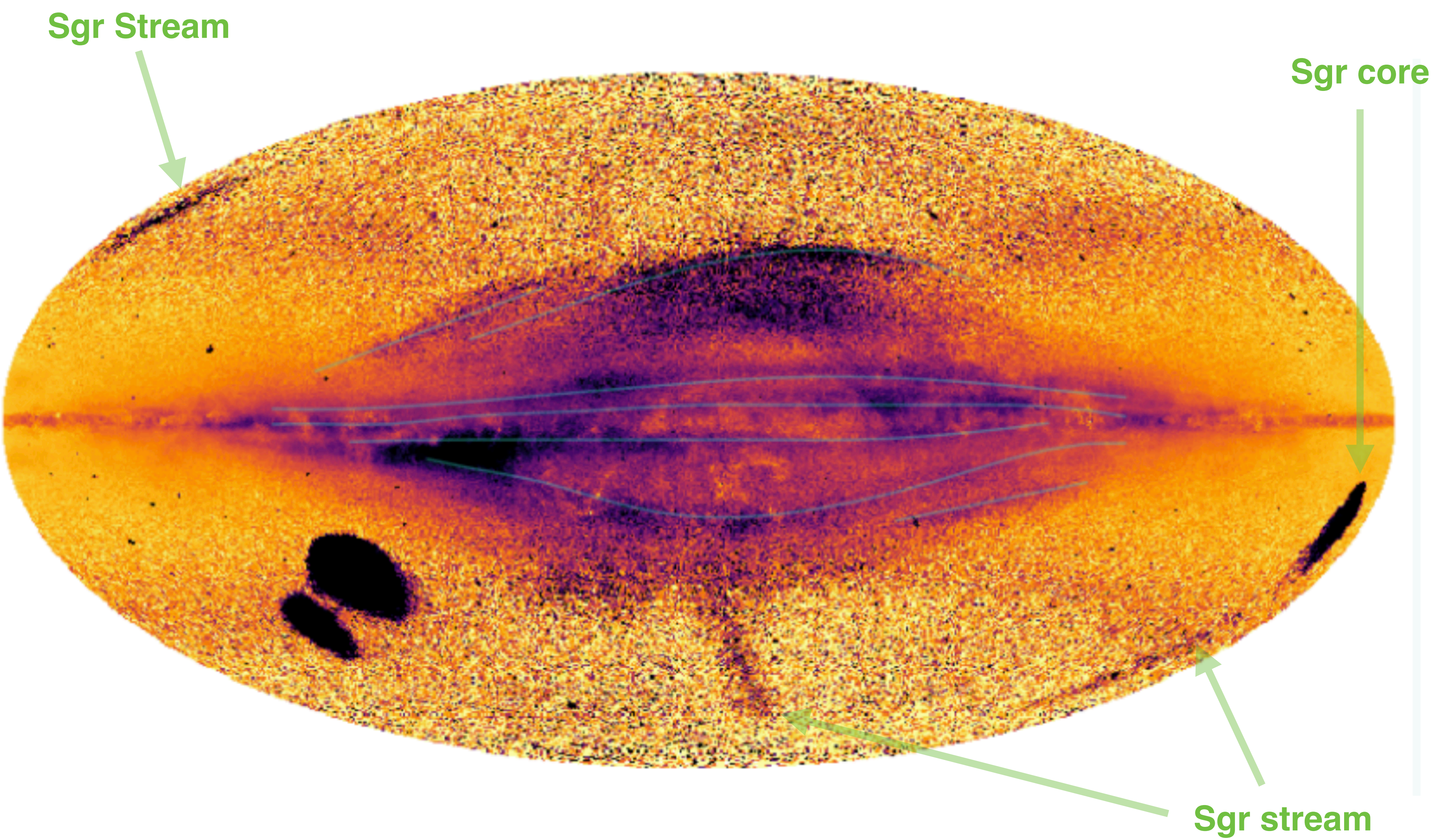
Unveiling the Milky Way's mid-plane structure



Unveiling the Milky Way's mid-plane structure



Unveiling the Milky Way's mid-plane structure



Conclusions and some open issues

- LMC affects the halo and the disc: the ***antisymmetric*** shape/structure of the HI warp at R>20kpc is a manifestation of the LMC pulling the MW disc down (Laporte+18a).

- A Sgr-like dwarf galaxy **seed a diverse number of large/small scale perturbations *across the entire disc*** through the action of the DM halo response, main body which can be sustained by disc's self-gravity long after the perturbation (Laporte+18b, Laporte+19c, Hunt+22).

- Despite a similar metallicity distribution as Monoceros, ACS has a very different cumulative age distributions, gives glimpse into early phases of low-alpha disc formation (Laporte+20) but also clues the dynamical mechanism(s) at play in its formation process.

- At face value, suggests that low-alpha disc was already forming at z~2, suggesting that GSE possibly played no role in the formation of the low-alpha sequence (see also Beraldo e Silva+21, Gent+24).

- However, if ages were uncertain by 20%, this could all be reconciled with Sgr induced excitation, but this should affect both high/low-alpha stars alike and does not get rid of the existence of co-eval low-alpha stars with ages consistent with tform z~2.

What can 99% of the star in the Milky Way tell us about its assembly tale?

That what makes up the remaining 1% may be more important than you initially thought.