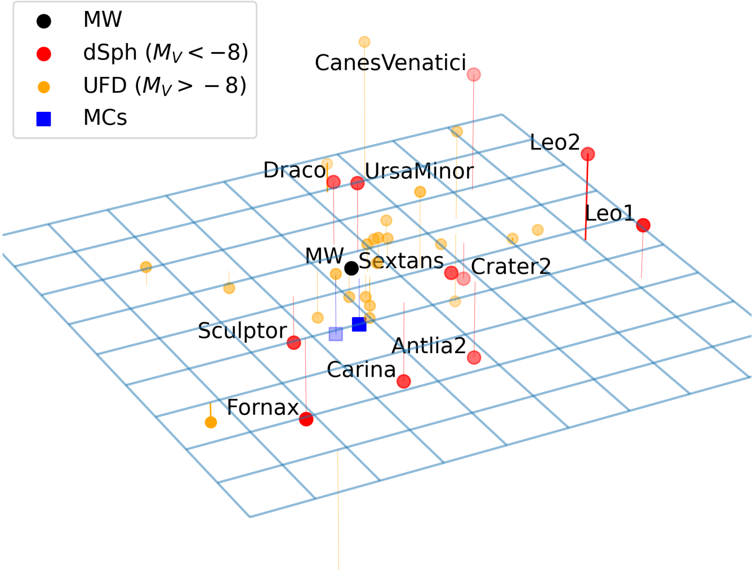
Leibniz-Institut für
Astrophysik Potsdam

A portrait of the Vast Polar Structure as a young phenomenon

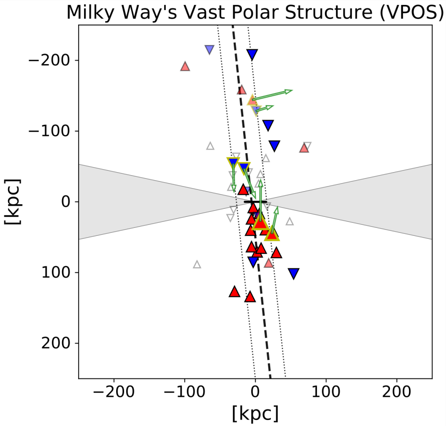
Salvatore Taibi
in collaboration with: M. S. Pawlowski, S. Khoperskov, M. Steinmetz, N. I. Libeskind (AIP)

The MW assembly tale, Bologna, May 28, 2024

The Milky Way system of satellites



The plane of satellites of the Milky Way

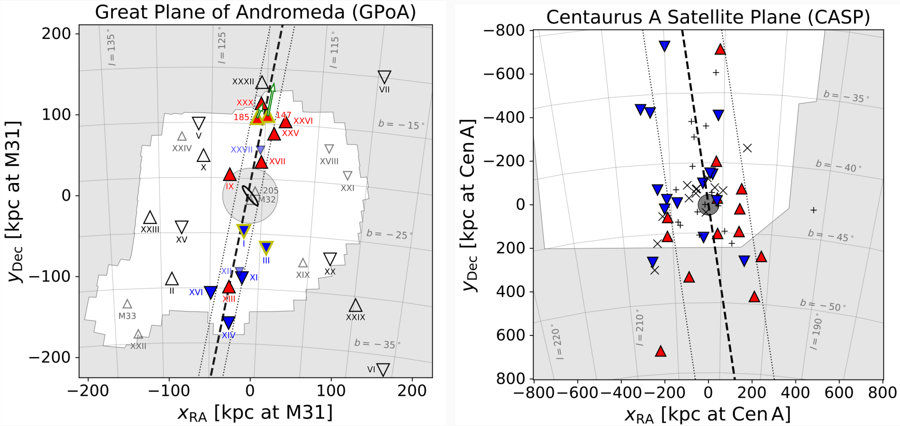


(Pawlowski 2021)

Most MW satellites distribute along the Vast Polar Structure

A polar extended structure of ∼20 kpc height showing mostly a coherent motion

Plane of satellites: M31 and Cen A

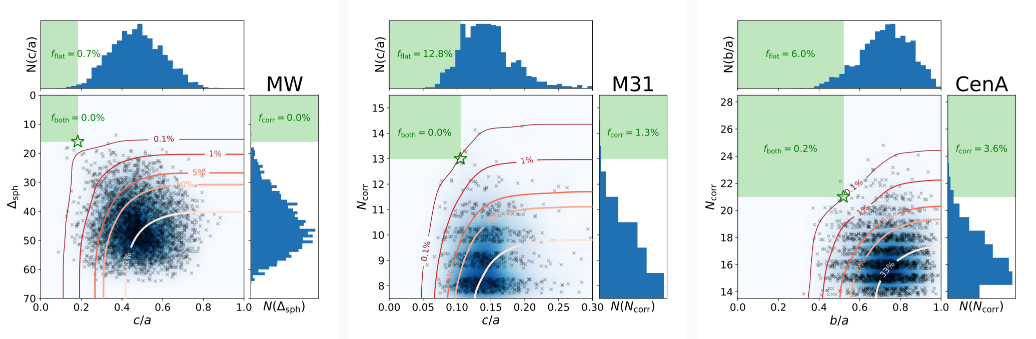


(Pawlowski 2021)

Evidences of planes with coherent kinematics around M31 and Cen A

Flattened distributions also observed around M 81, M 101, NGC 4490

Plane of satellites: at odds with Λ-CDM

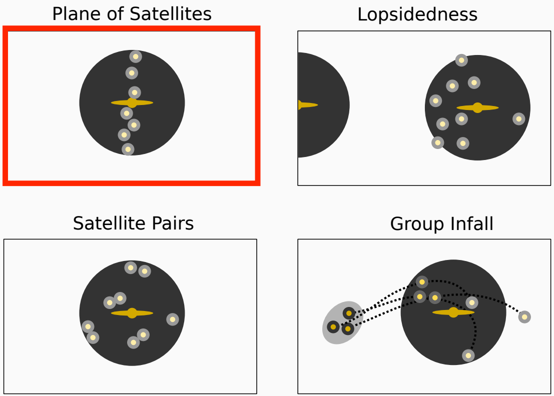


(Pawlowski 2021)

Simulations struggle to reproduce observed phase-space correlations

$<1\%$ of halos in both dark-matter only and hydro-dynamical simulations

Phase-space correlation in systems of satellite galaxies

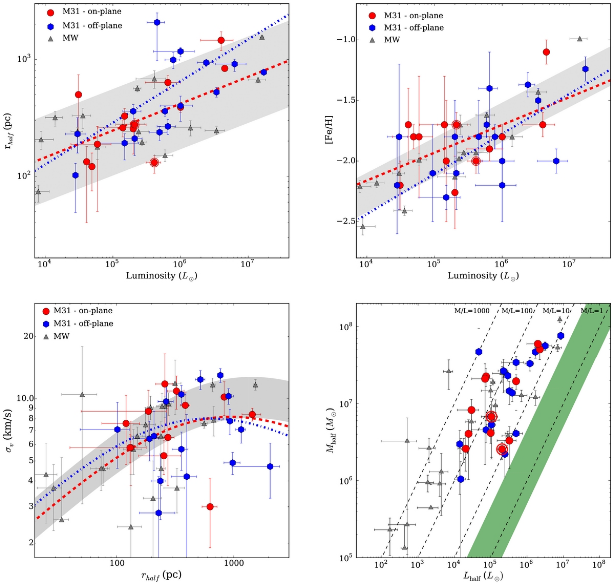


(Pawlowski 2021)

Numerous different types of phase-space correlations have been investigated

The most popular is the Plane of Satellites issue which challenges Λ-CDM

M31 case: no differences between on- and off-plane systems

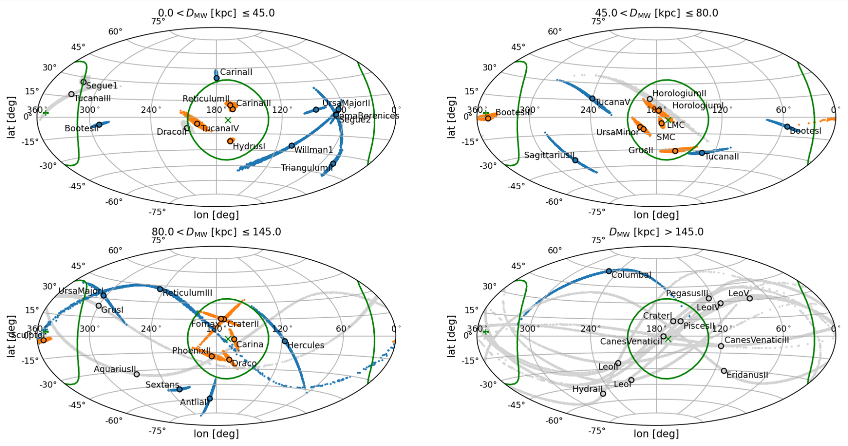


Collins et al. (2015)

- No significant differences recovered between the on- and off-plane systems
- Ruled out scenarios in which on-plane systems have a different formation

The VPOS case

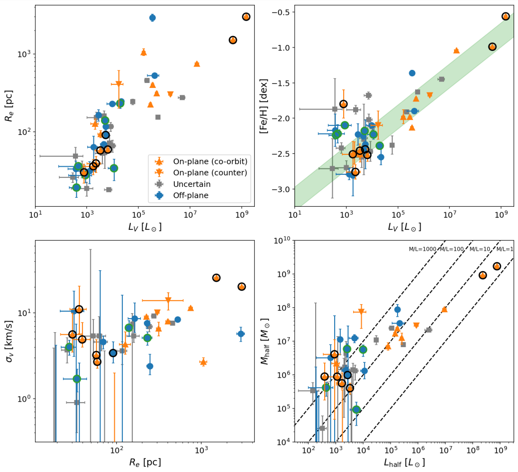
VPOS: Taibi et al. (2024, A&A, 681, A73)

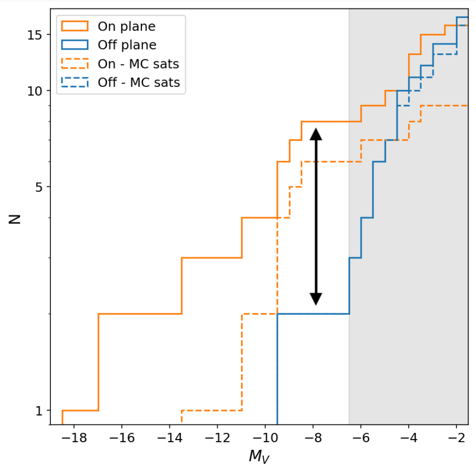


Are there any differences between on- and off-plane MW satellites?

Orbital poles for 50 systems using Gaia-eDR3 data from Battaglia et al. (2022)

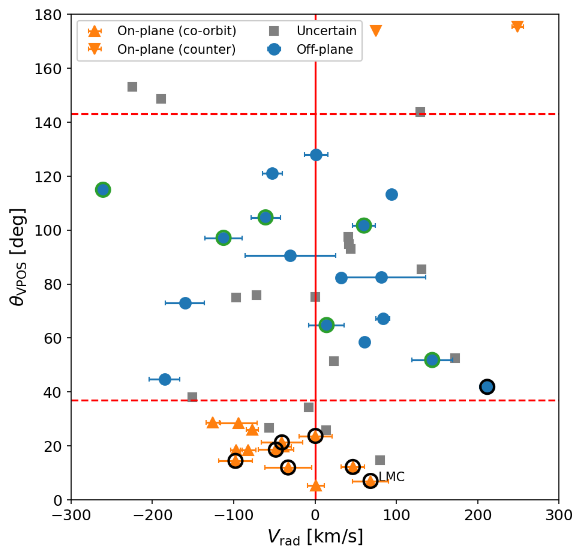
Comparison of physical properties





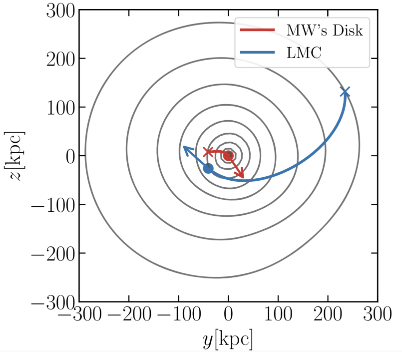
Differences on scaling relations driven by the bright on-plane systems

Comparison of kinematic properties



Co-orbiting on-plane systems mostly approaching the MW

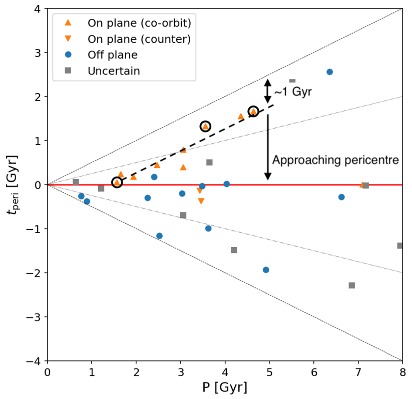
Minor changes due to LMC's caused reflex motion

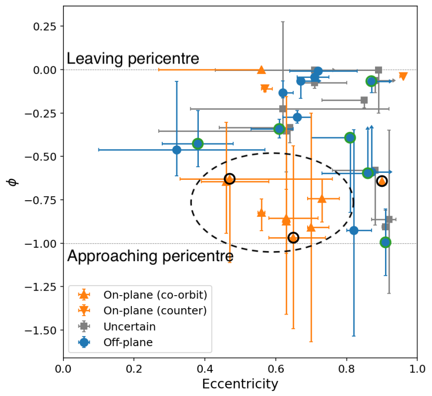


(Garavito-Camargo et al. 2021)

Comparison of orbital properties

Low-mass potential ($M_{\mathrm{vir}} = 8.8 \times 10^{11} M_\odot$; adapted from Vasiliev et al. 2021)



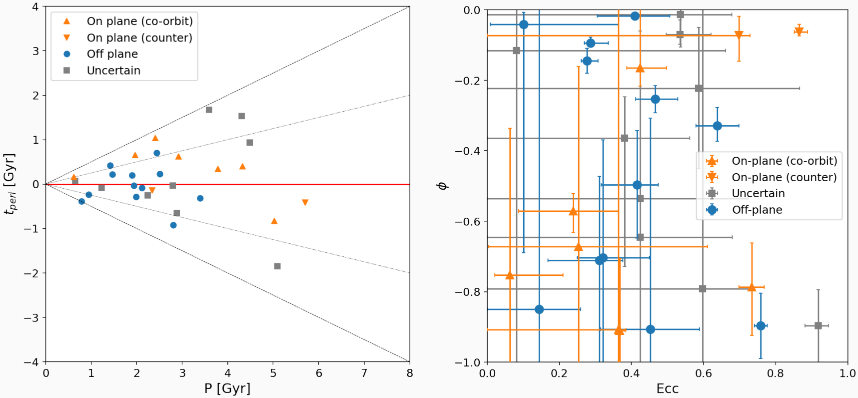


On-plane co-orbiting systems coordinately approaching pericentre

Valid also for high-mass MW potential ($1.6 \times 10^{12} M_\odot$)

The role of the LMC

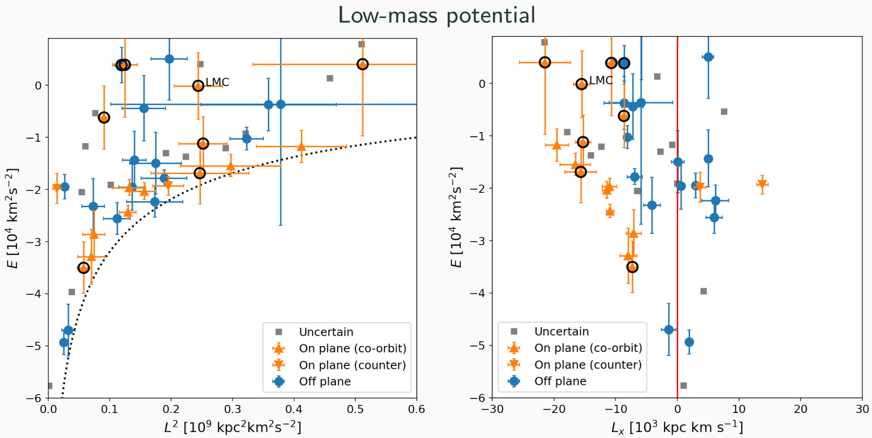
Low-mass potential perturbed by a massive LMC ($M_{\rm vir} = 1.5 \times 10^{11} M_\odot$; Vasiliev+21)



On-plane systems are still approaching pericentre

Evidence of a recent group accretion event?

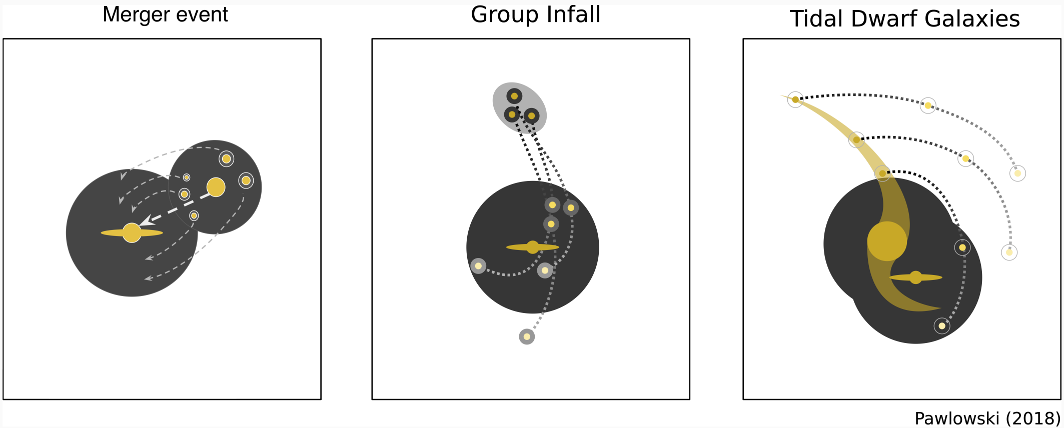
Inspecting $E - L$



A part for the LMC-system, on-plane systems have lowest E for given L

What are the implications for the VPOS longevity?

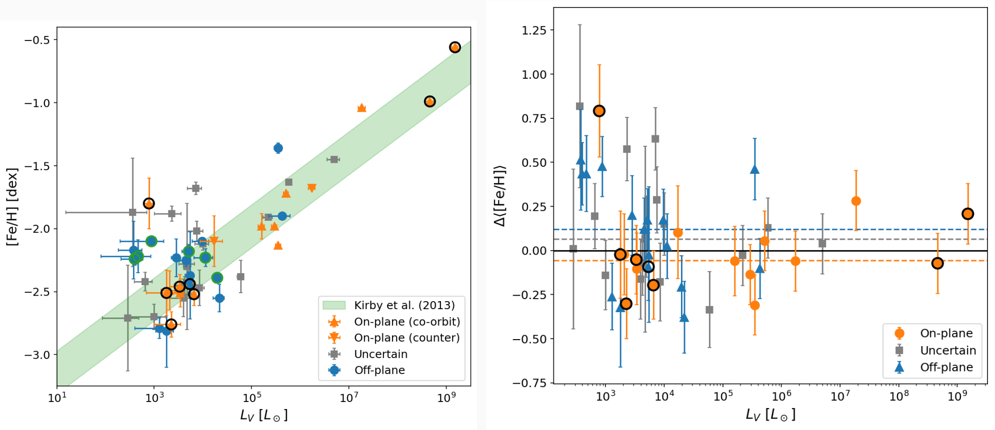
VPOS: possible formation mechanisms



Several scenarios related to the late accretion of satellite systems

$\rightarrow$ the VPOS as a young structure

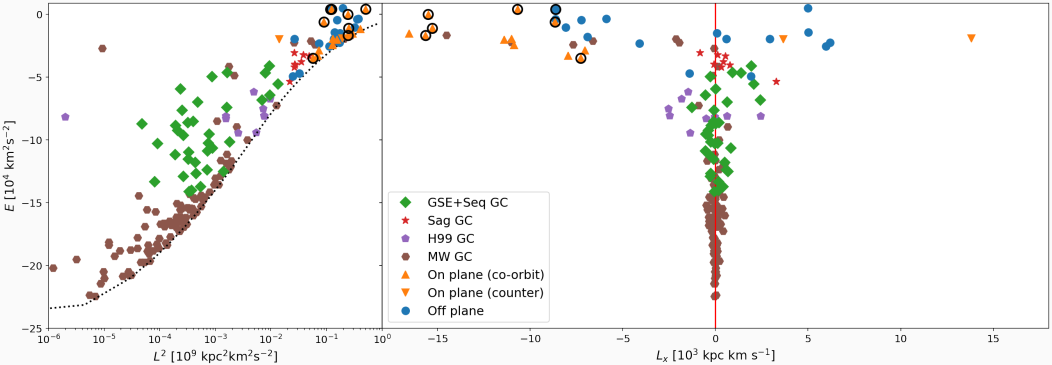
Do on-plane systems have a tidal origin?



If TDGs ⇒ on-plane systems should have higher [Fe/H] (Recchi et al. 2015)

Recovered differences are not significant **but** LMC-satellites show a −0.1 dex offset

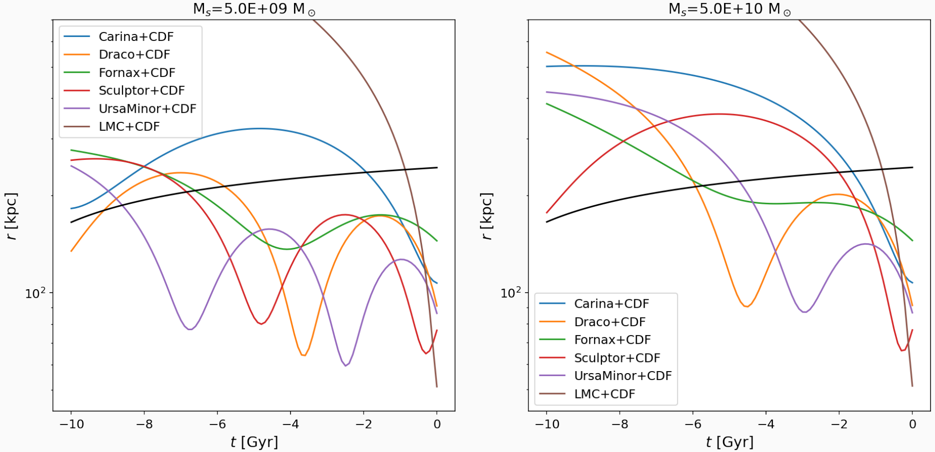
A link between the VPOS and the MW's merger history?



The GSE progenitor could have bring its own population of satellites

We do not recover a dynamical connection with accreted GCs

Are the on-plane systems part of a group infall?



Indirect approach based on a toy-model maximising dynamical friction

Too high individual masses for a single pericentric passage, but not as a group

Conclusions

From the comparison of the observed properties between on and off-plane systems:

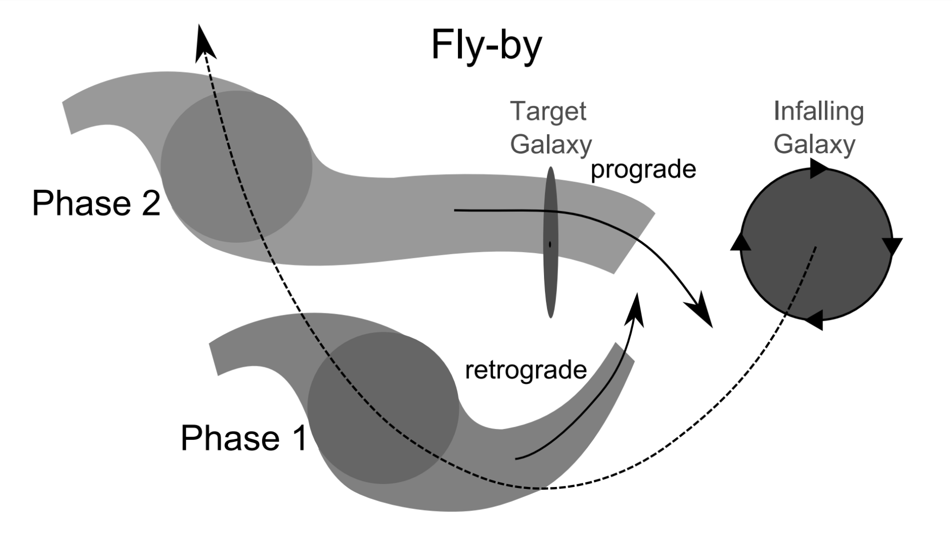
- the large majority of bright MW satellites are on the VPOS
- co-(counter-)orbiting on-plane systems approaching (leaving) the MW, possibly close to pericentre
- Excluding the LMC-system, the on-plane satellites have minimum E-L

Implication for the VPOS as a young structure:

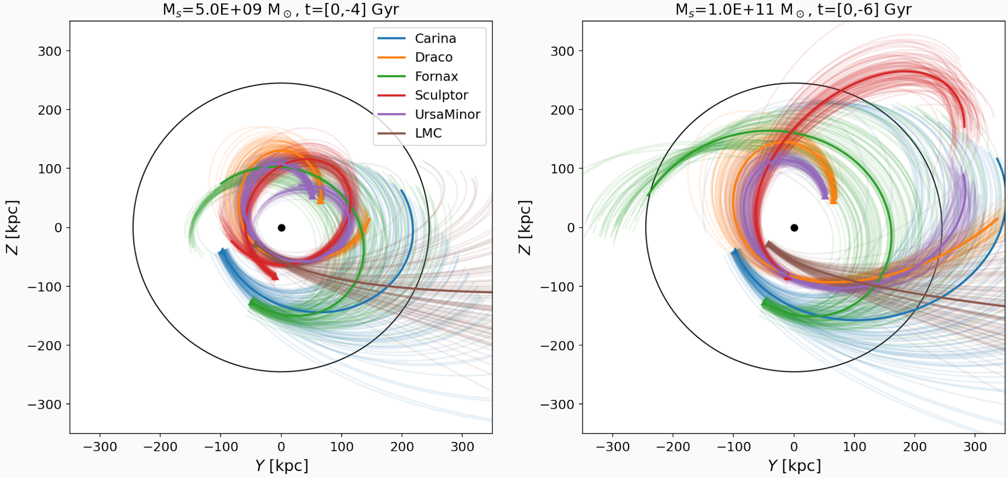
- TDG origin seems unlikely
- An association with the progenitor of GSE remains unclear
- Group infall scenario reminiscent of Greater Magellanic Galaxy suggestion (Lynden-Bell 1976)? $\rightarrow$ See also E. Vasiliev and M. Pawlowski talks!

Backup

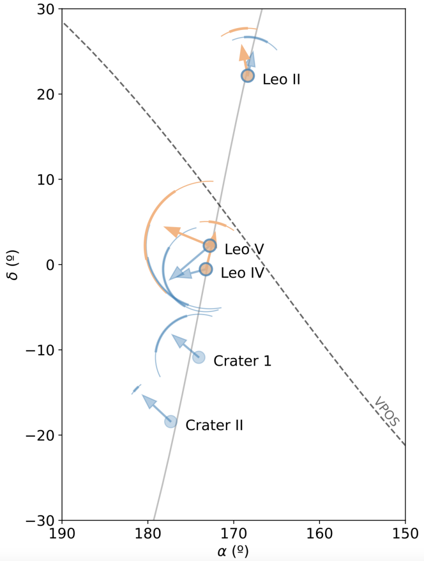
Group infall: Pawlowski et al. (2011) mechanism

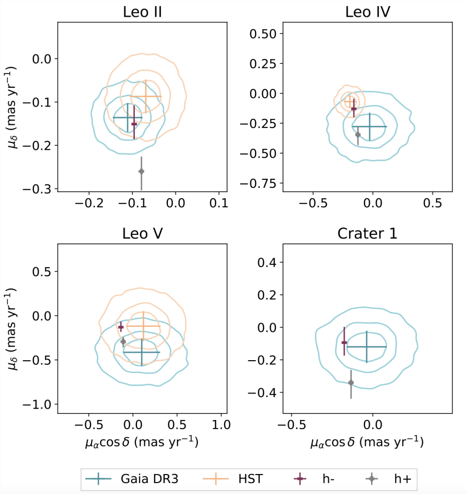


Group infall: effects of dynamical friction



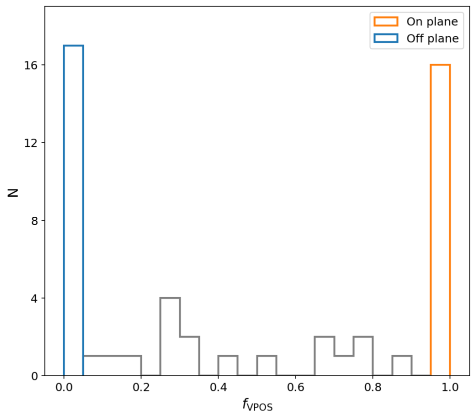
Group infall: the Crater-Leo case (Julio et al. 2024)

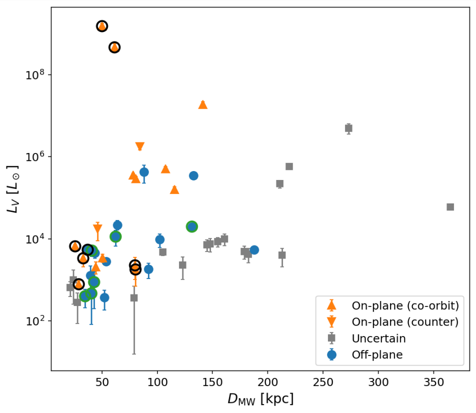




Observed PM in agreement with prediction

Milky Way satellites: sample selection





16 systems classified on-plane, 17 resulted off-plane

Uncertain systems have large PM errors due to low-luminosity and/or large distance

Results: correlation matrixes

	L_V	R_h	⟨[Fe/H]⟩	σ_v	Pericenter	Apocenter	Eccentricity	t-last-peri
L_V	1.0	0.9	0.8	0.6	0.4	0.6	-0.4	-0.3
R_h	0.8	1.0	0.7	0.5	0.2	0.7	0.1	-0.3
⟨[Fe/H]⟩	0.1	0.2	1.0	0.7	0.3	0.7	-0.2	0.1
σ_v	0.4	0.4	0.2	1.0	0.4	0.6	-0.3	0.0
Pericenter	0.7	0.6	-0.1	0.2	1.0	0.5	-0.8	-0.3
Apocenter	0.3	0.2	-0.1	0.3	0.3	1.0	-0.2	0.1
Eccentricity	-0.3	-0.3	-0.3	-0.3	-0.3	0.8	1.0	0.3
t-last-peri	0.1	0.3	-0.4	0.1	0.3	-0.2	-0.4	1.0

	L_V	R_h	⟨[Fe/H]⟩	σ_v	Pericenter	Apocenter	Eccentricity	t-last-peri
L_V	1.0	0.9	0.8	0.6	0.2	0.2	-0.2	-0.2
R_h	0.8	1.0	0.7	0.5	0.0	0.1	0.1	-0.1
⟨[Fe/H]⟩	0.1	0.2	1.0	0.7	0.3	0.4	0.0	0.2
σ_v	0.4	0.4	0.2	1.0	0.4	0.4	0.0	0.0
Pericenter	0.6	0.5	-0.1	0.2	1.0	0.5	-0.5	-0.5
Apocenter	0.4	0.3	-0.3	0.3	0.5	1.0	0.4	-0.5
Eccentricity	-0.3	-0.3	-0.3	-0.1	-0.4	0.5	1.0	0.0
t-last-peri	0.1	0.1	-0.1	-0.4	0.0	-0.2	-0.3	1.0