

A Memória da Via Láctea

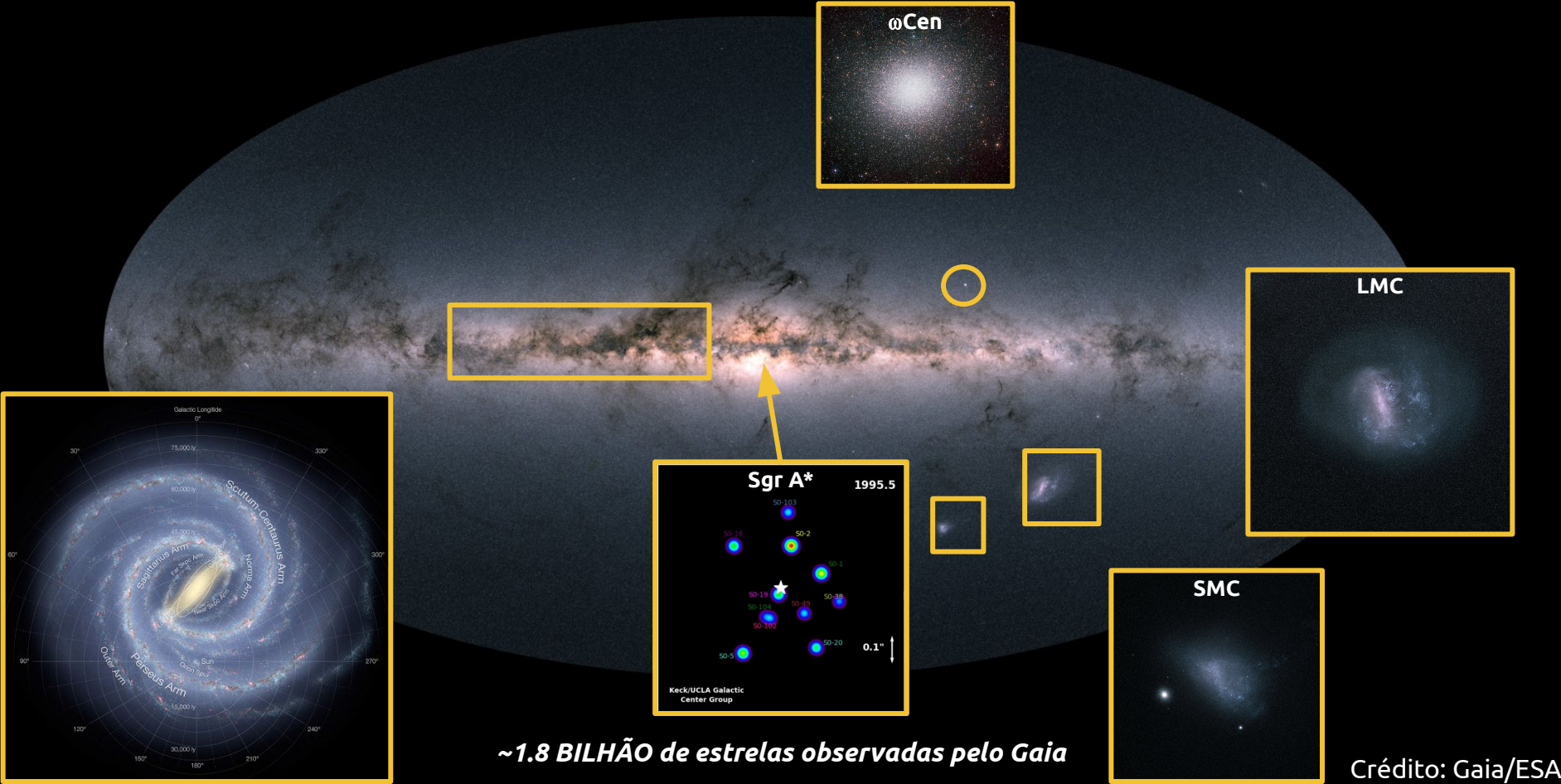
Escola de Inverno em Astrofísica 2025

Hélio Dotto Perottoni

Milky Way analog
(GSE + LMC)

Evans et al. (2020)

Milky Way



The Gaia Revolution

SKY-SCANNING COMPLETE FOR ESA'S MILKY WAY MAPPER GAIA

From 24 July 2014 to 15 January 2025, Gaia made more than three trillion observations of two billion stars and other objects, which revolutionised the view of our home galaxy and cosmic neighbourhood.



3 TRILLION
Observations

2 BILLION
Stars & other objects observed

938 MILLION
Camera pixels on board

15 300
Spacecraft 'pirouettes'

55 KG
Cold nitrogen gas consumed

580 MILLION
Accesses of Gaia catalogue so far

3827
Days in science operations

13 000
Refereed scientific publications so far

50 000 HOURS
Ground station time used

2.8 MILLION
Commands sent to spacecraft

142 TB
Downlinked data (compressed)

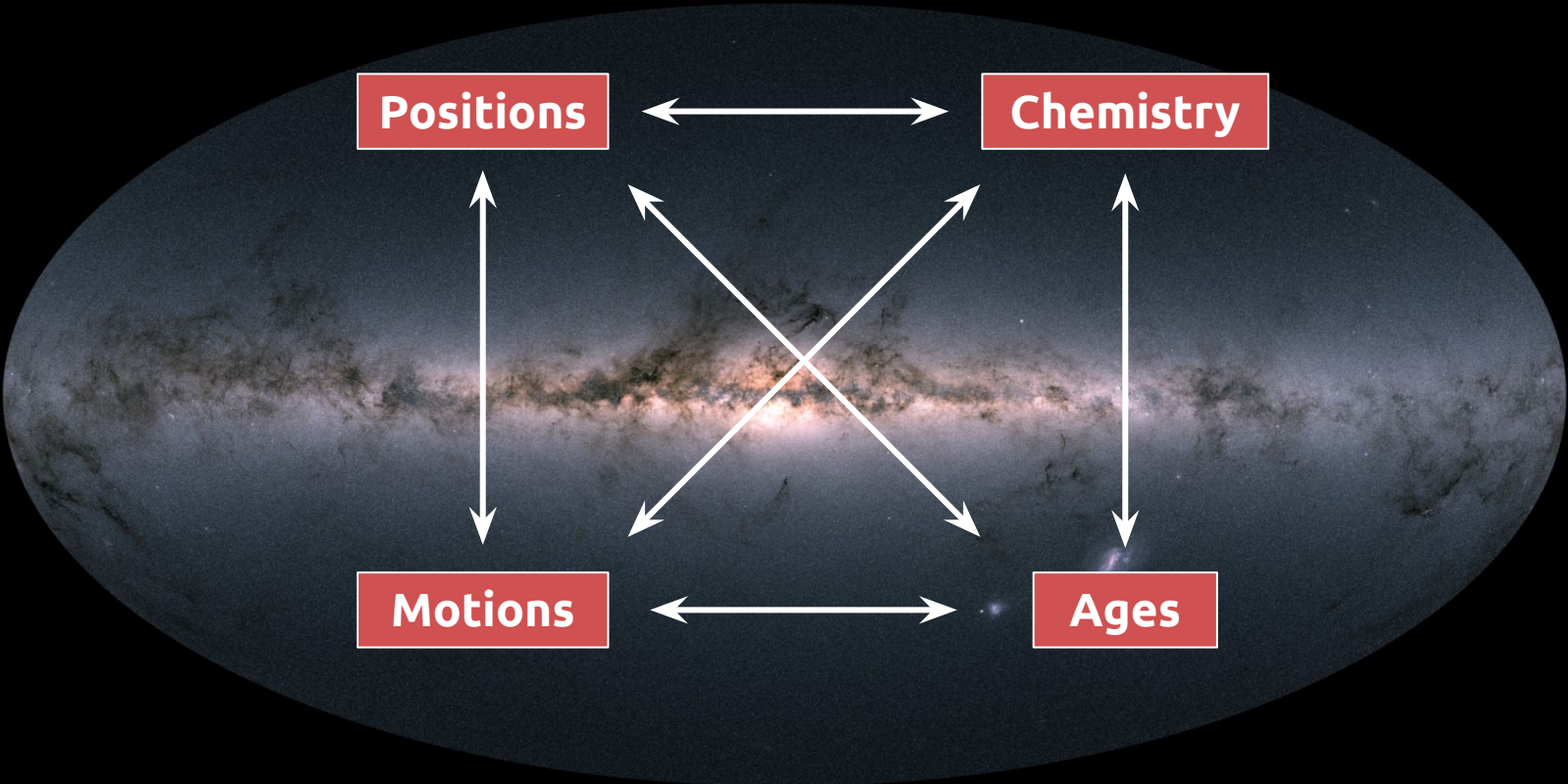
500 TB
Volume of data release 4
(5.5 years of observations)

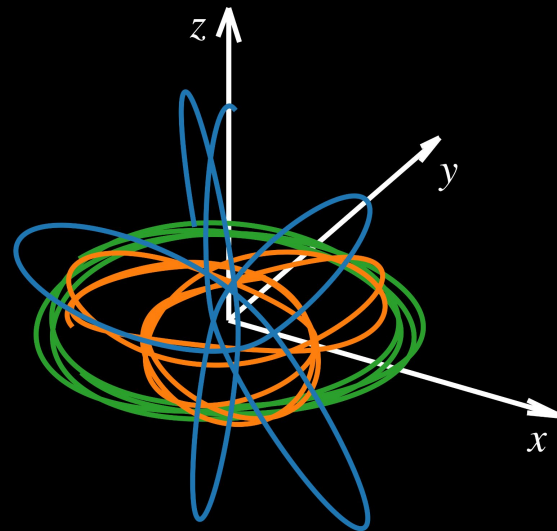
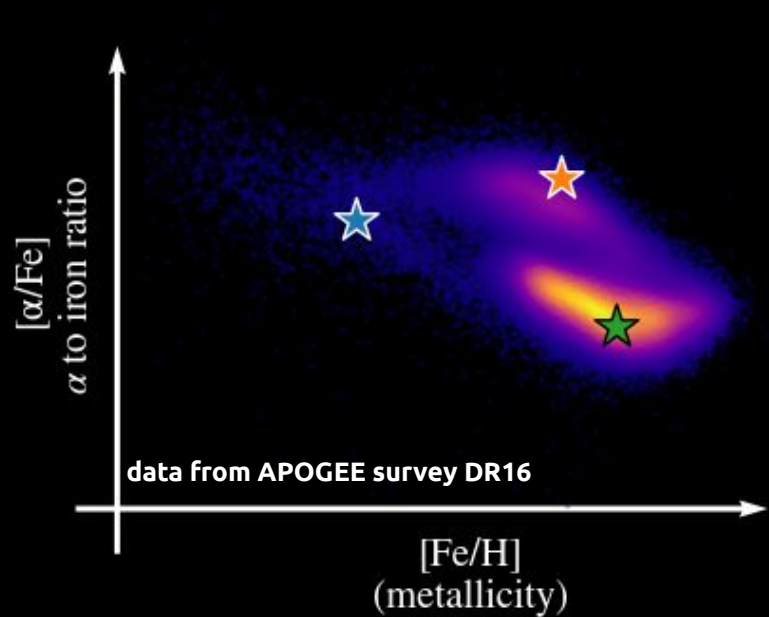


Galactic Archaeology

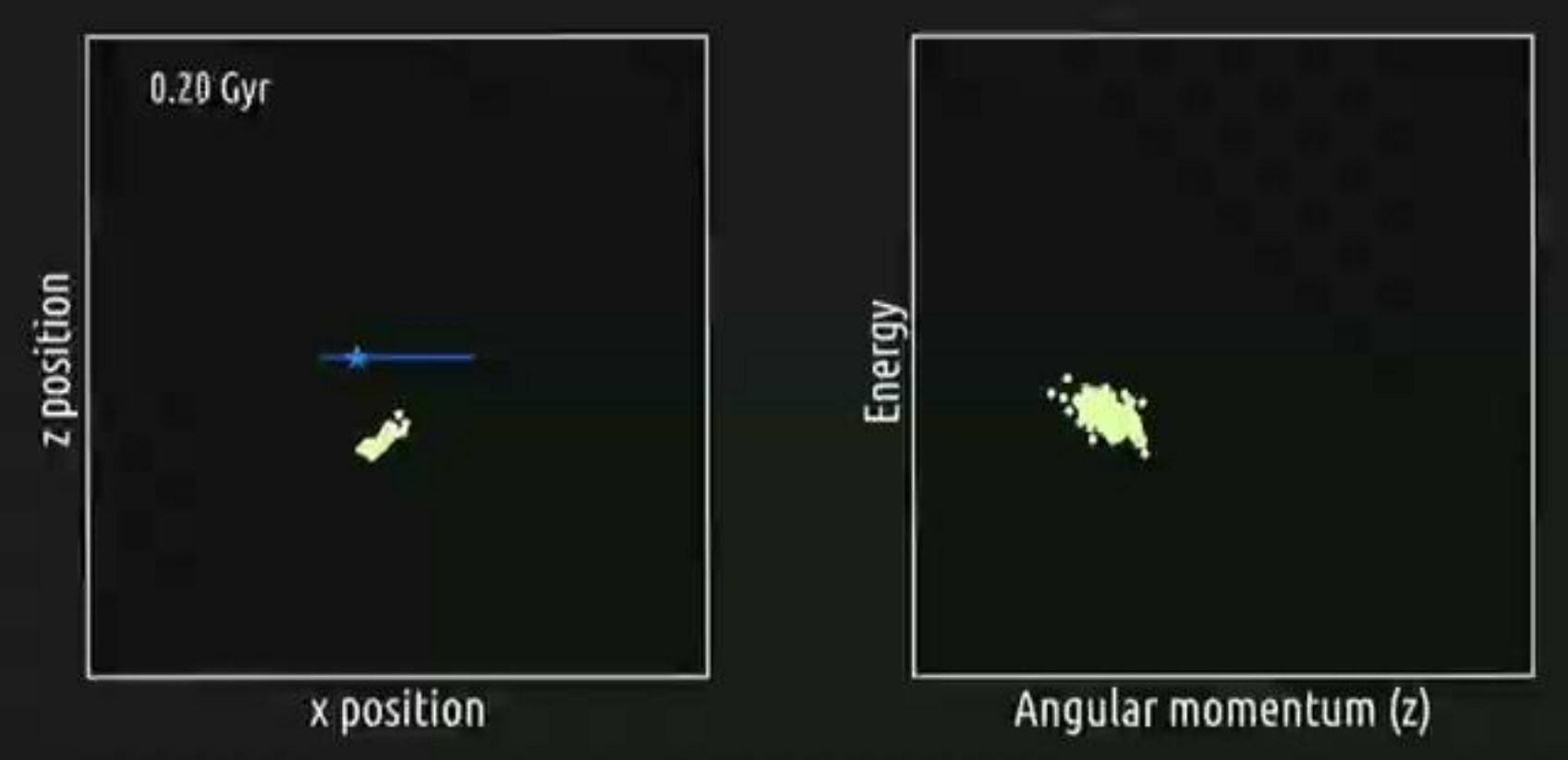
**The stars carry a long-term
memory of their origin in their
chemical compositions and
(sometimes) in their dynamics.**

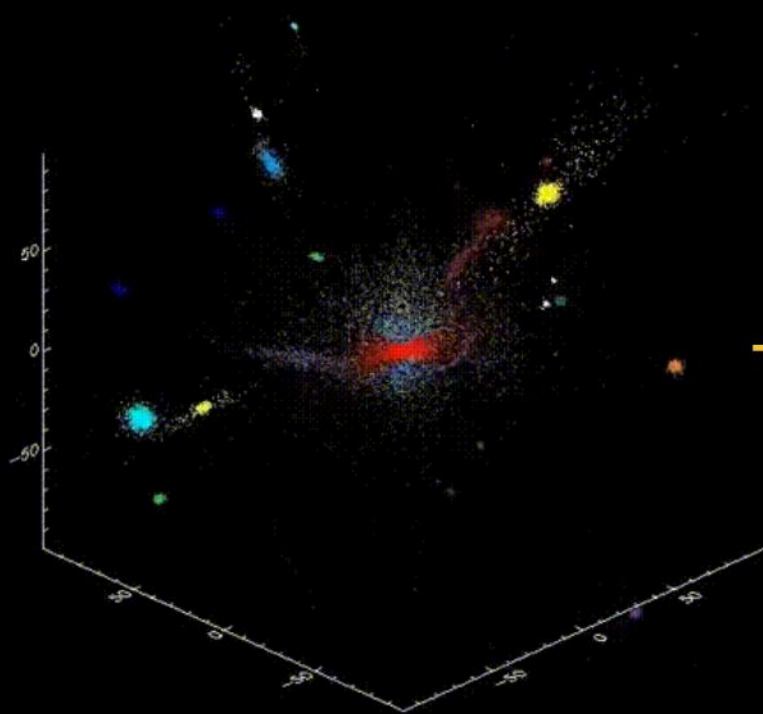
Stellar Populations





Orbital Parameters

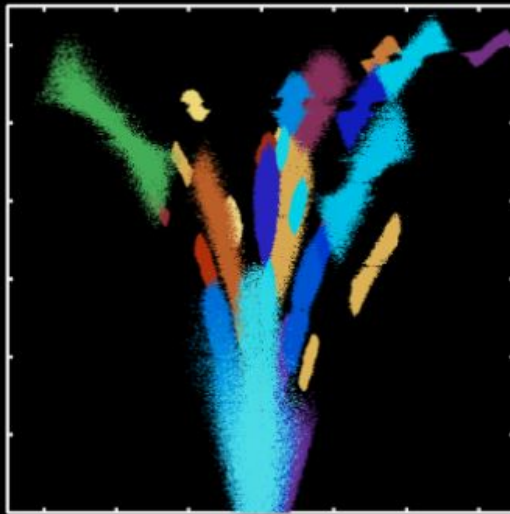




Bullock & Johnston (2005)



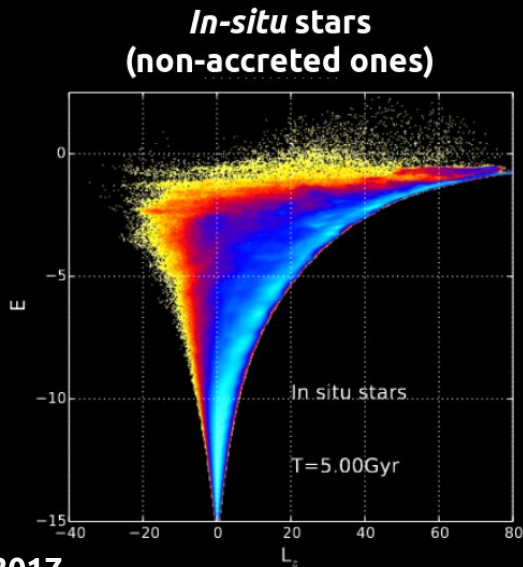
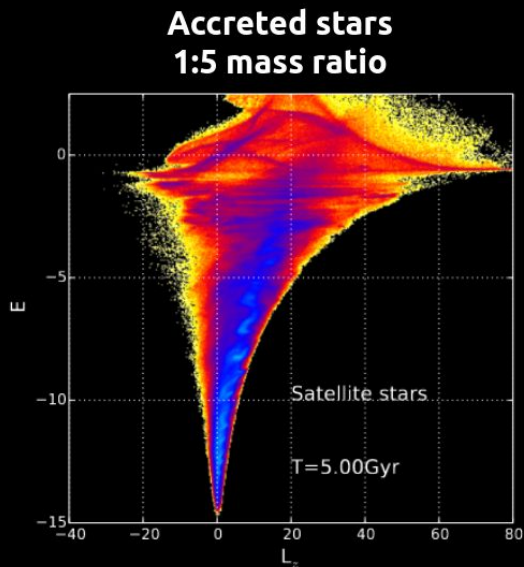
Orbital energy



Angular momentum

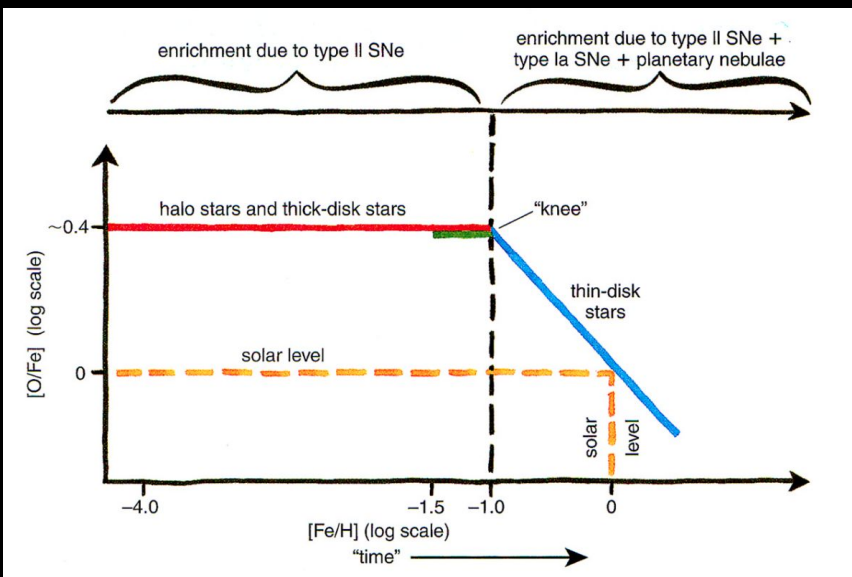
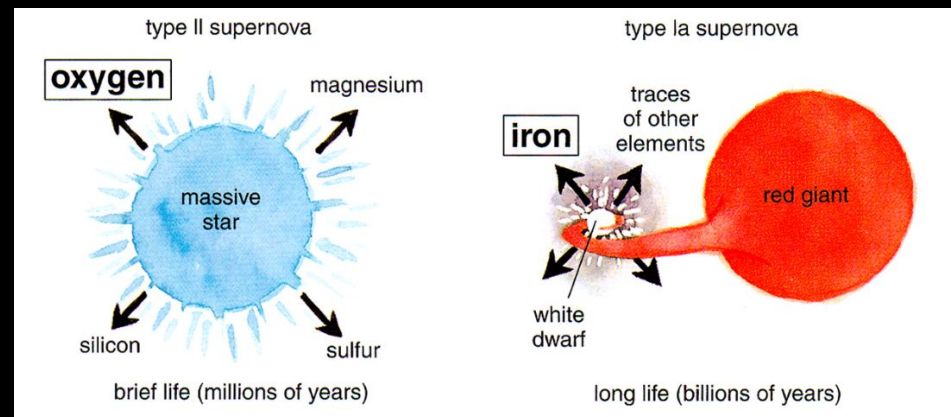
Gómez+2010

A single merger



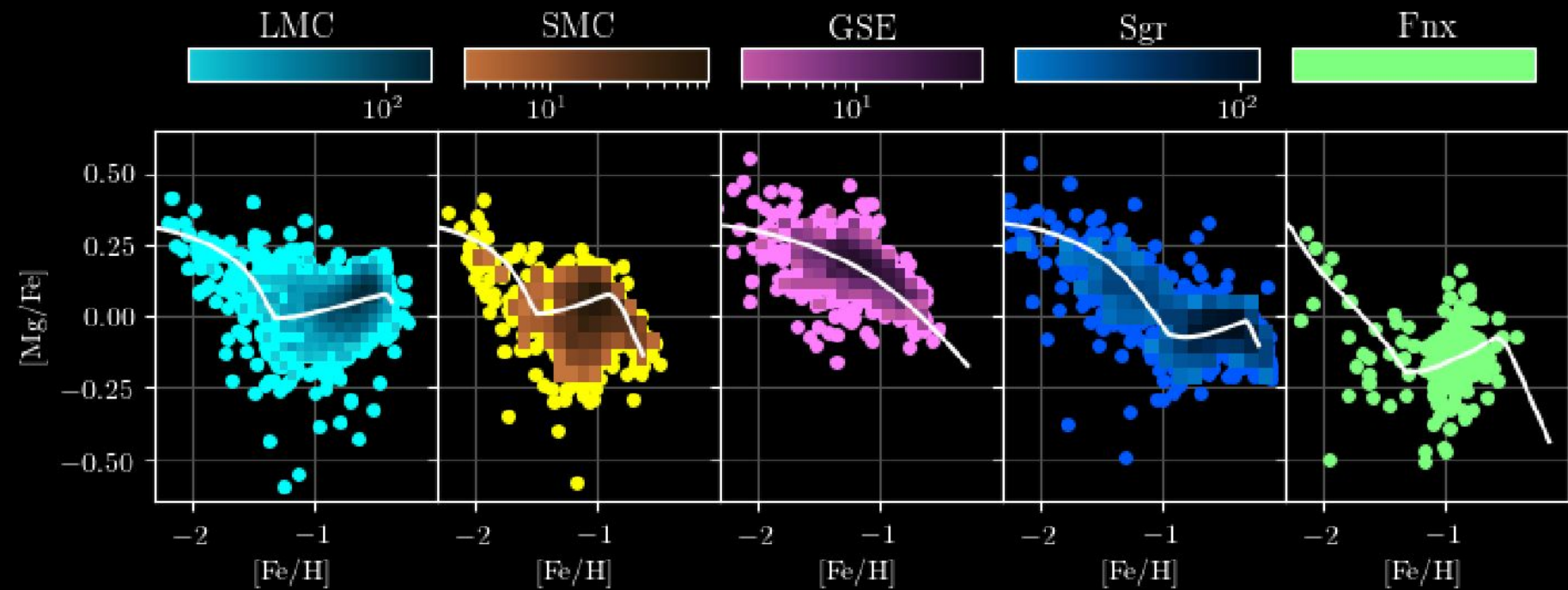
Jean-Baptiste+2017

Chemical Abundances



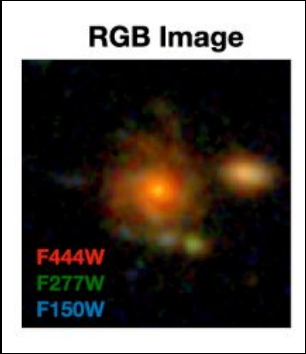
The Formation and Evolution of the Milky Way - Chiappini

Chemical Abundances



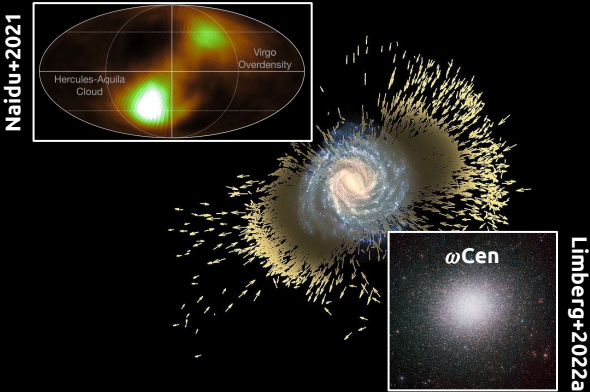
History of Milky Way

Xiao+2025



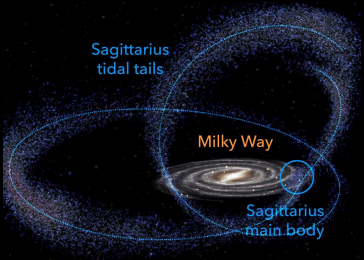
Disk Formation
Proto MW + Spin Up
> 11 Gyr

Helmi+2018



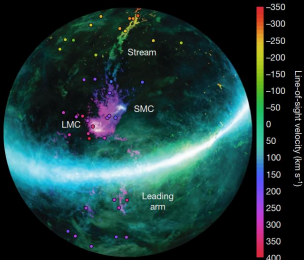
Gaia Sausage Enceladus
Heated Disk/Splash + Starburst + Inner Halo + Warp (?)
~11 - 9 Gyr

Ruiz-Lara+2020



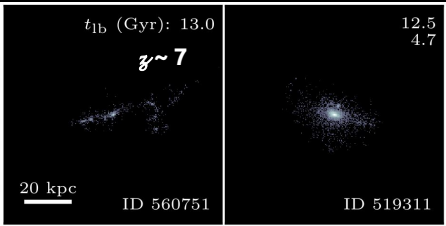
Sagittarius dSph
Disk Stellar Overdensities+SFR Increase
~ 5 Gyr

Lucchini+2020

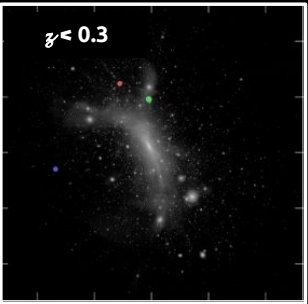
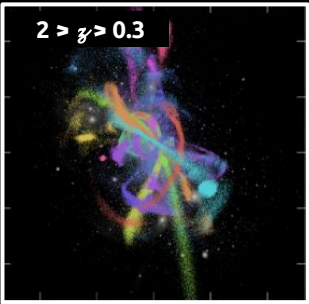
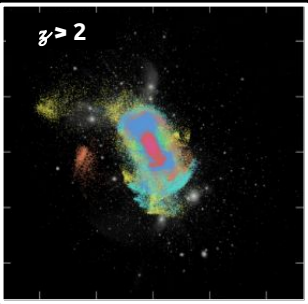


Magellanic clouds
Halo Awake
first infall
> ~3.5Gyr

Semenov+2024



Morinaga et al. (2019)

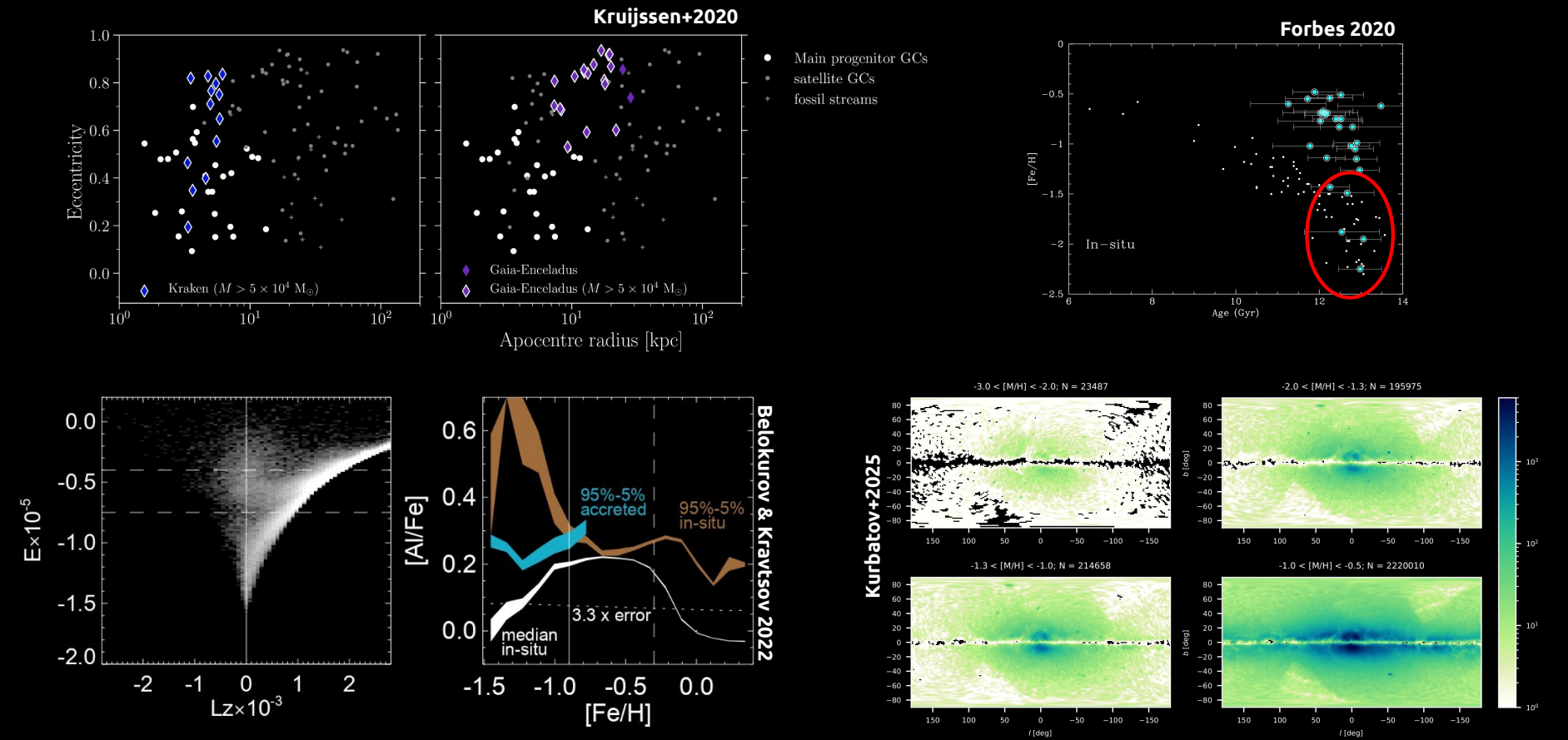


Proto Milky Way

dubbed Kraken, Koala, Heracles, Aurora, Poor Old Heart, Pangu

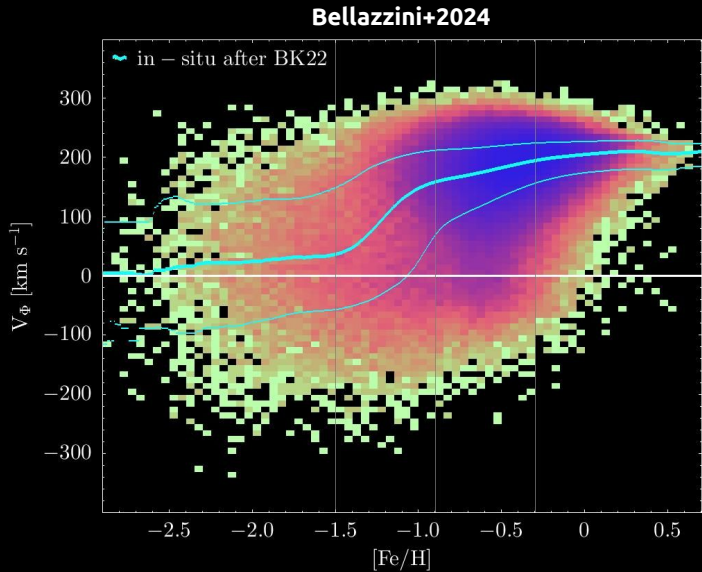
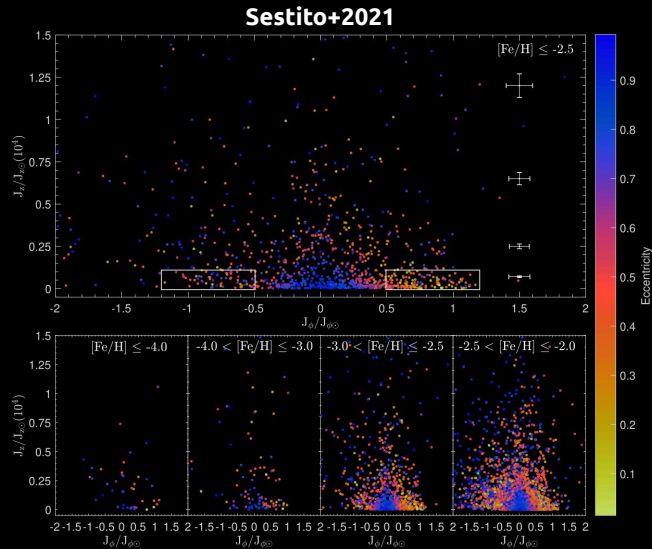
Kruijssen+2019/2020, Forbes2020, Horta+2021, Rix+2022, Belokurov & Kravtsov 2022, Xiang+2025

Proto Milky Way

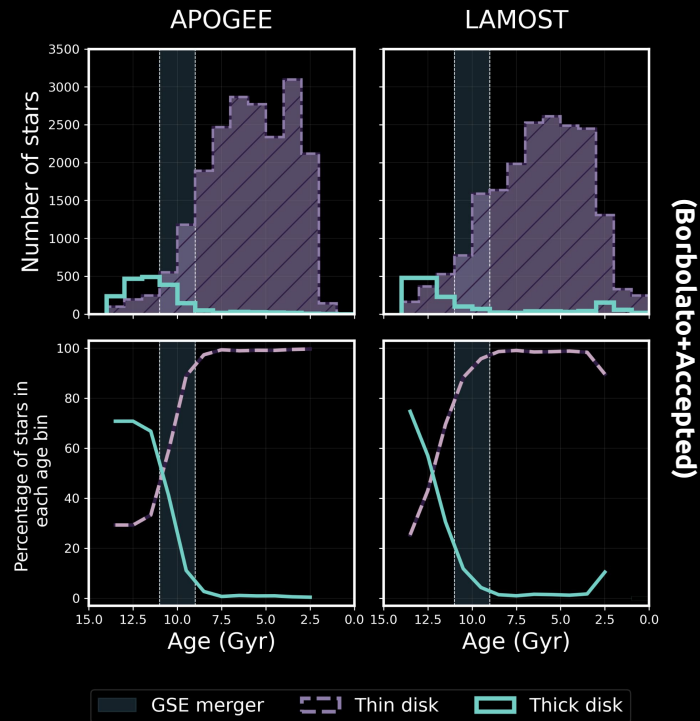
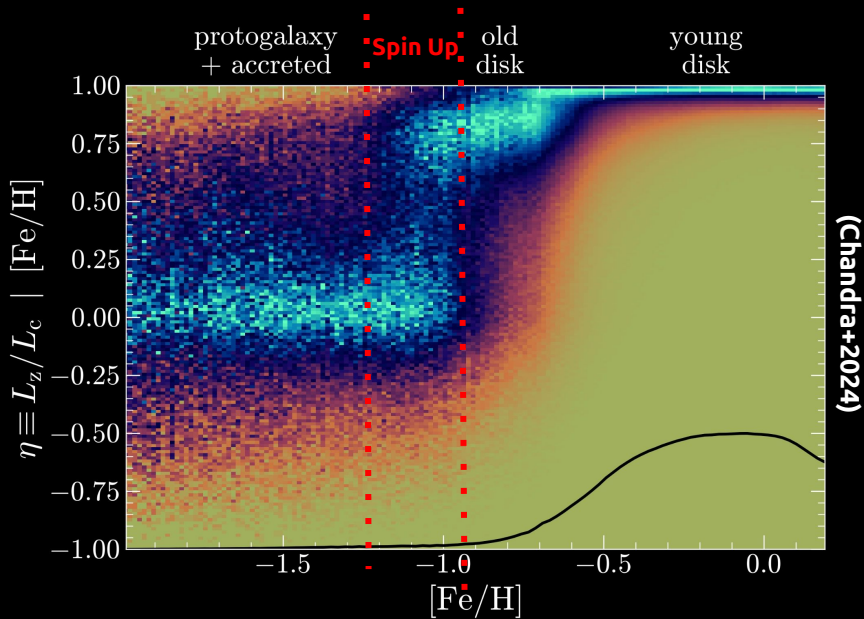


see Rix+2022

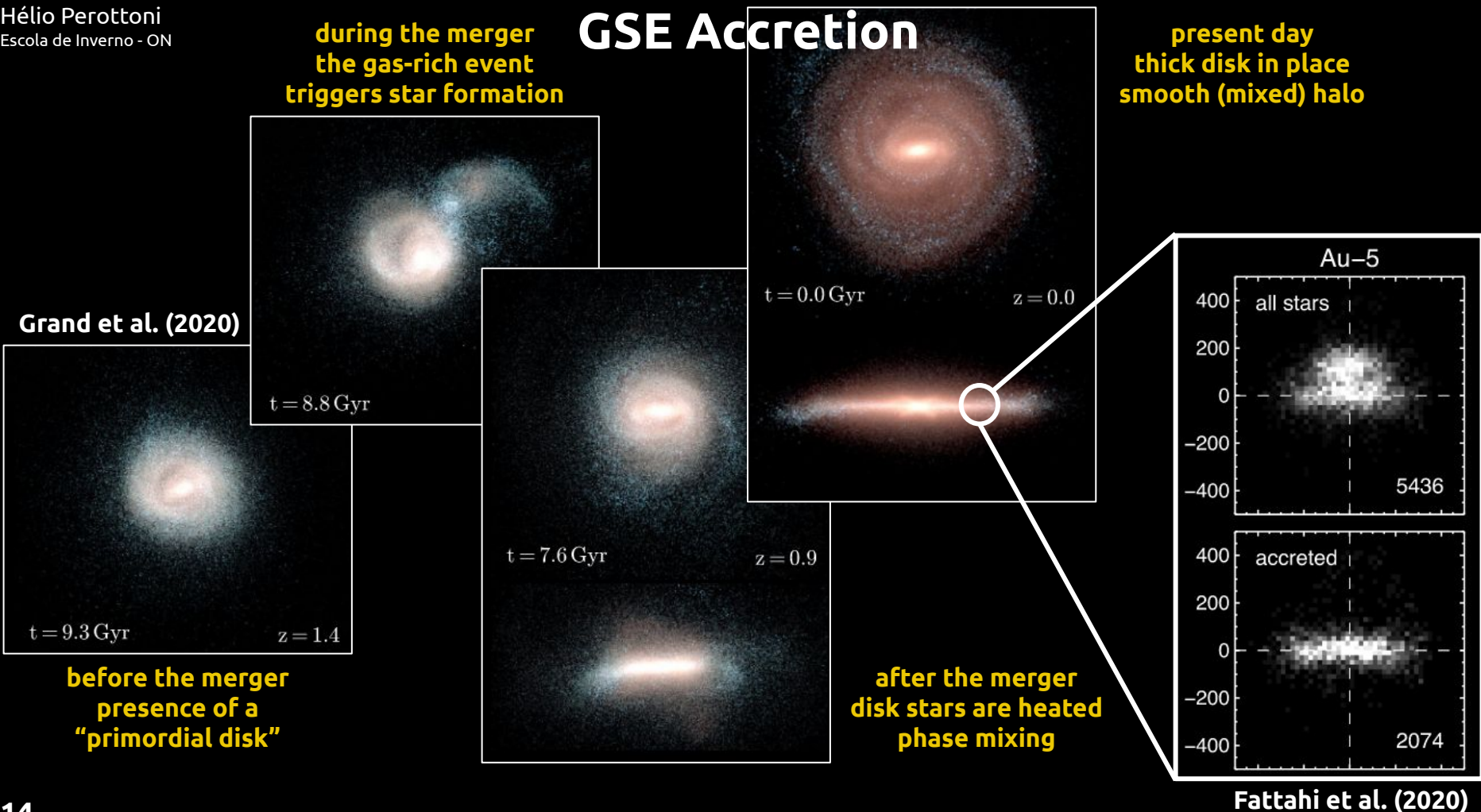
Primordial Disk (?)



Formation of Galactic Disk - Spin Up



No need for a gas-rich merger to mediate the transition from thick to thin disk in the Milky Way



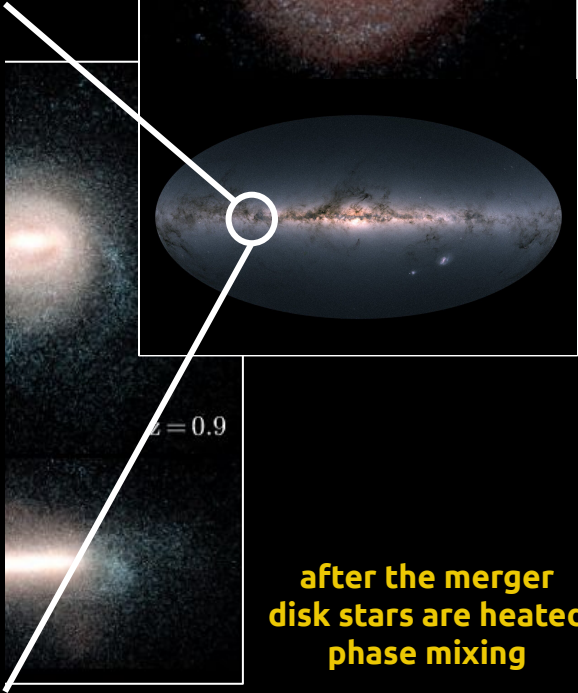
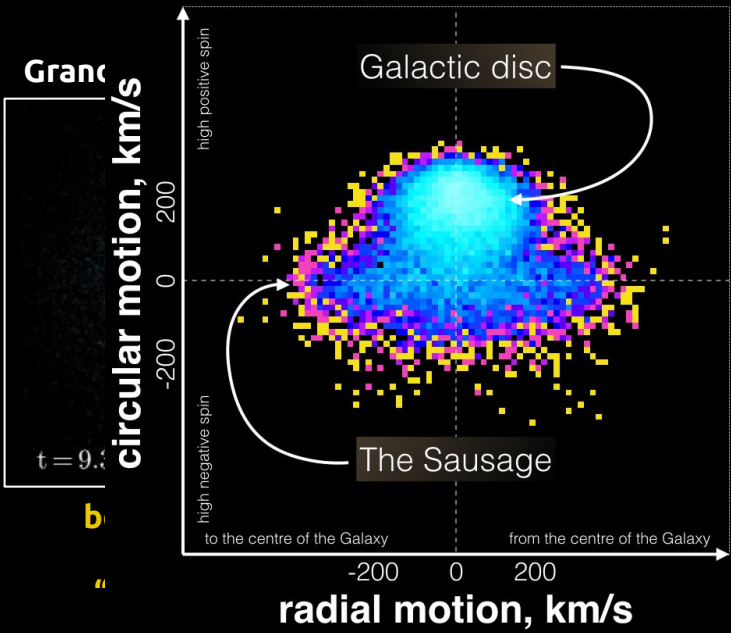
during the merger
the gas-rich event
triggers star formation



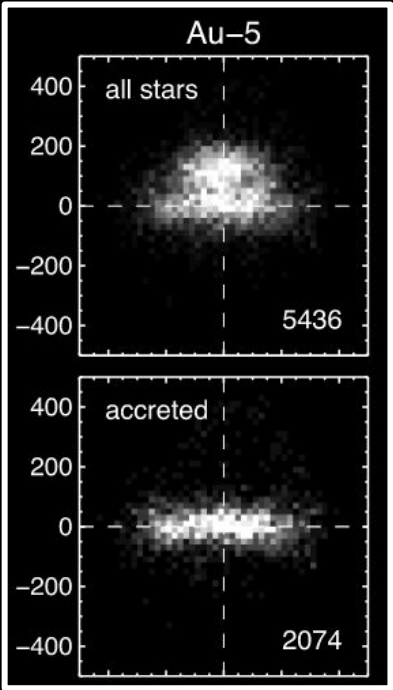
GSE Accretion

present day
thick disk in place
smooth (mixed) halo

Motions of 7,000,000 Gaia stars



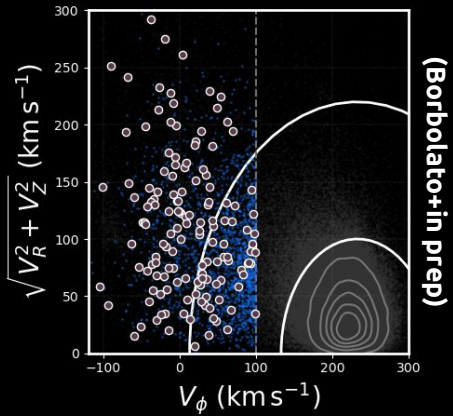
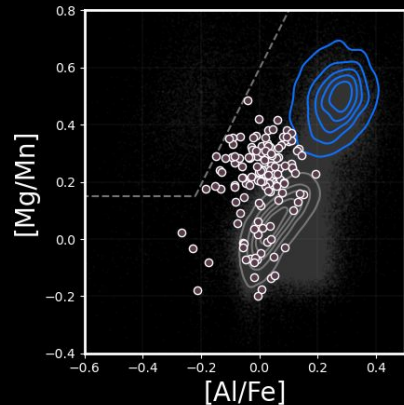
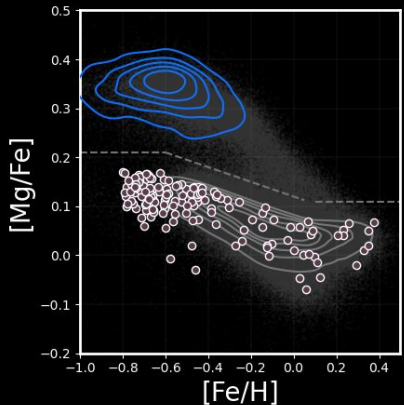
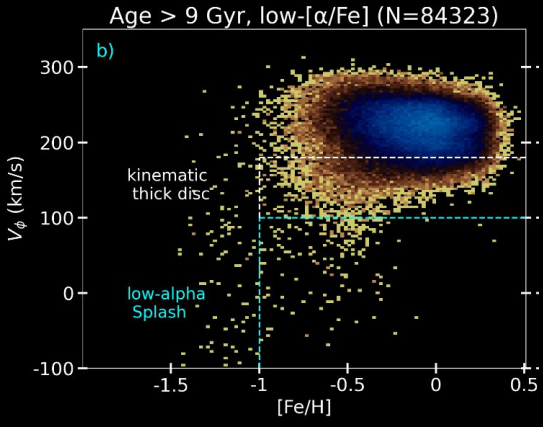
after the merger
disk stars are heated
phase mixing



Fattahi et al. (2020)

Splash Thin Disk

Nepal+2024

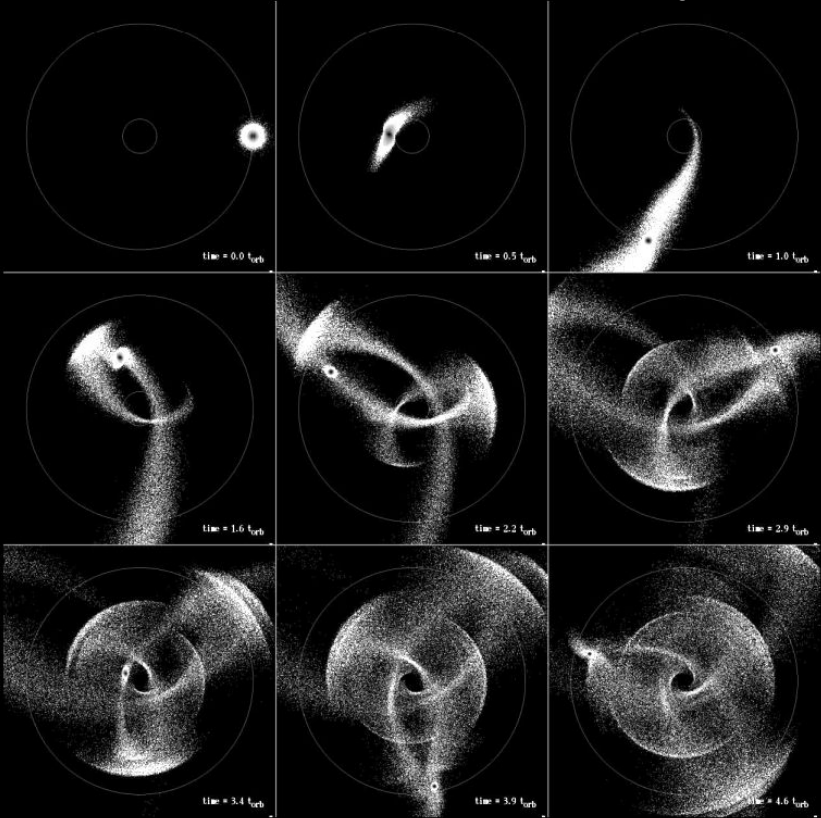


— Canonical thin disk ♦ High- α splash ○ Low- α splash

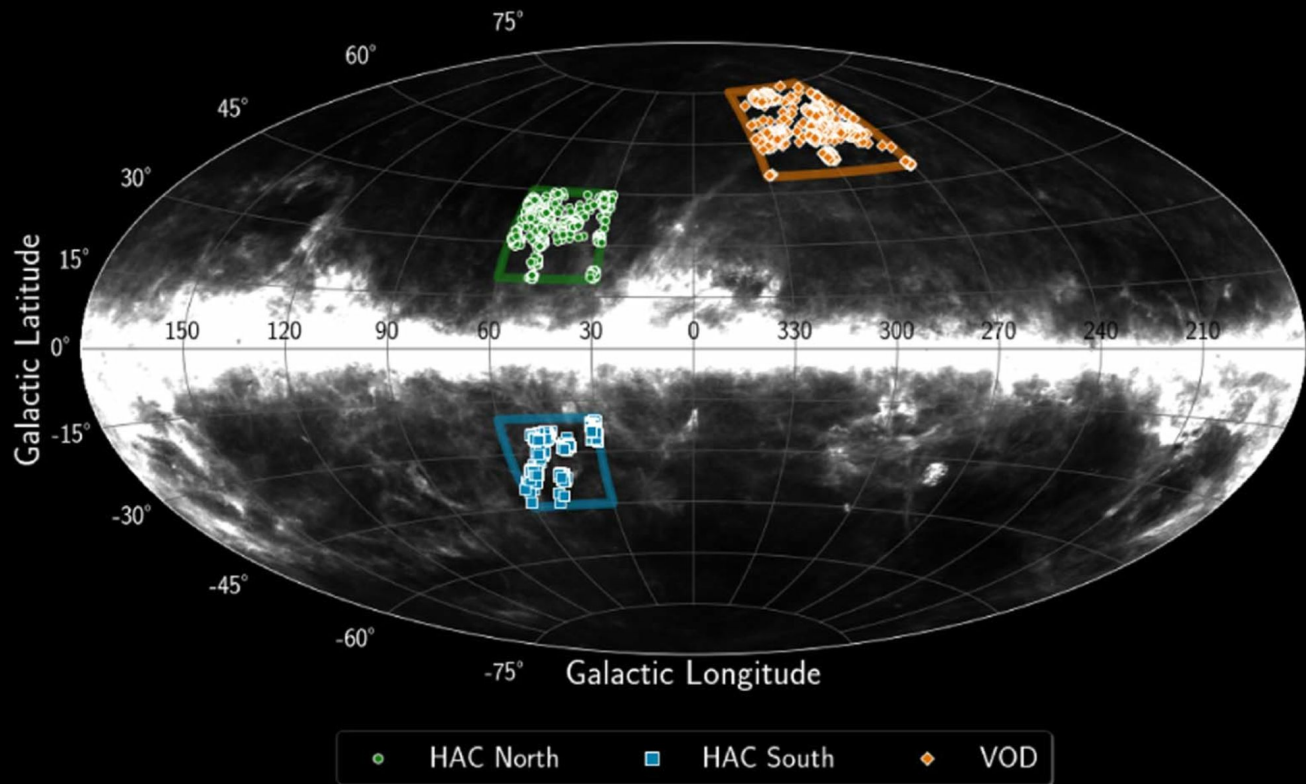
*Gaia Sausage-Enceladus is not essential
for thin disk formation*

Inner Halo Stellar Overdensities

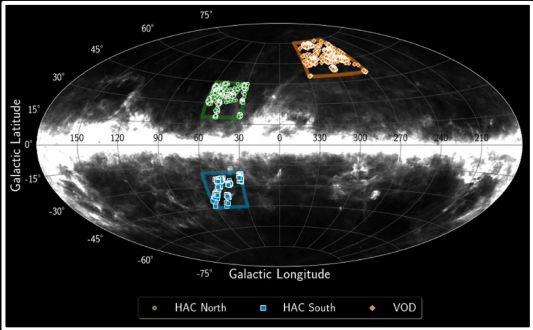
Hayashi+2003



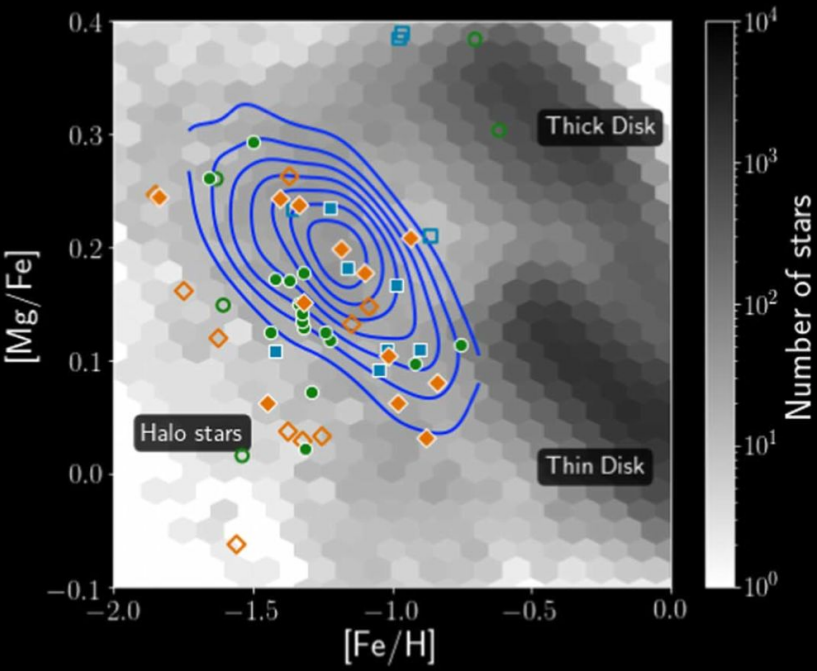
Inner Halo Stellar Overdensities



Inner Halo Stellar Overdensities

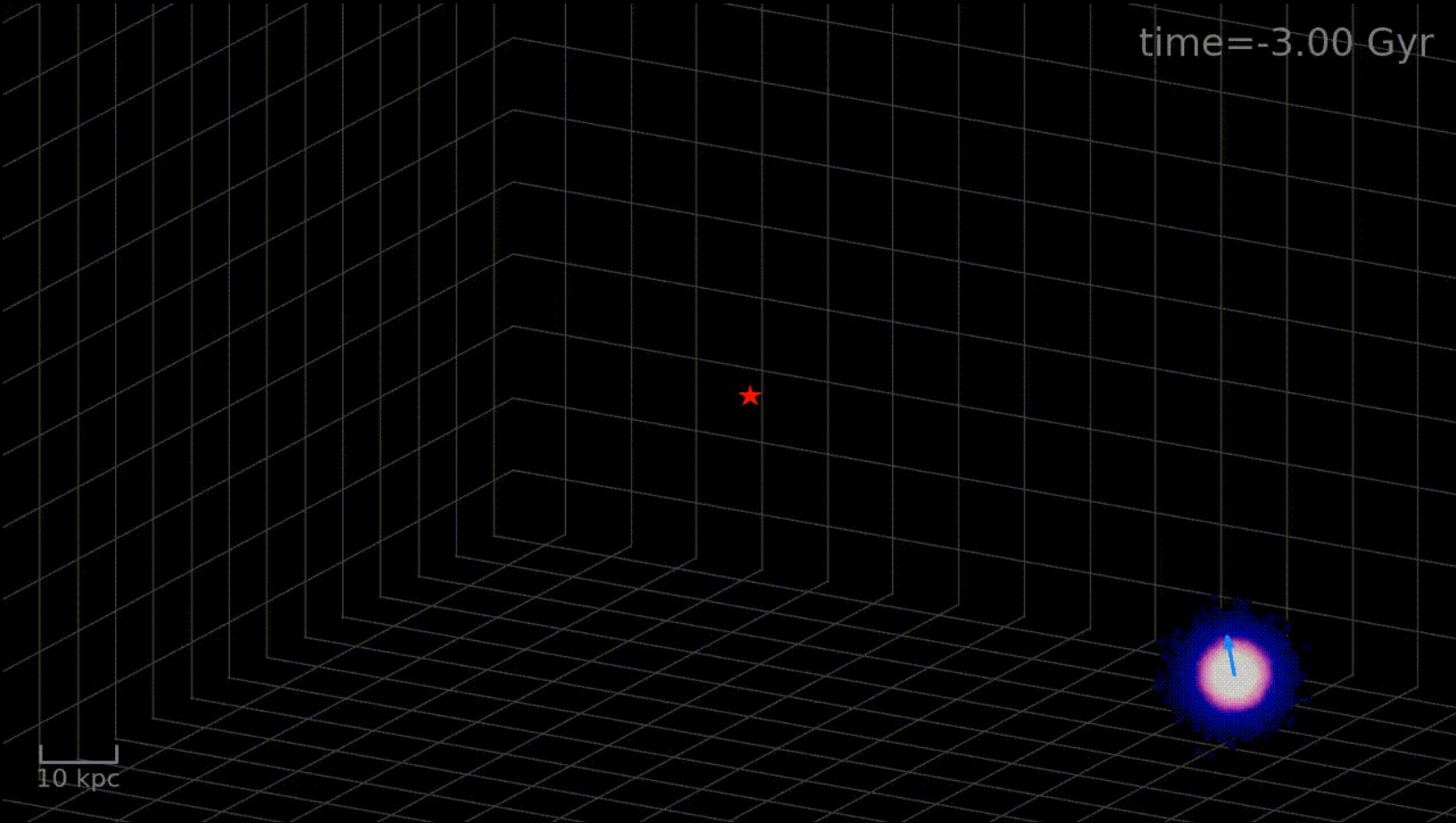


The Inner Halo Stellar Overdensities are Indistinguishable from GSE population.



Stellar Streams

Disruption of Sagittarius

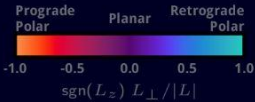


Stream Atlas

THE MILKY WAY STREAM ATLAS

May 2024

Legend



Streams

Total number: 87

Typical mass: $9 \times 10^3 M_{\odot}$

Longest stream:
Orphan-Chenab [210 deg]

Narrowest stream:
C-20 [0.072 deg]

Most member stars:
Fimbulthul [3724]

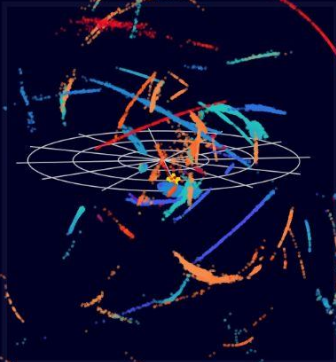
Largest Galactocentric distance:
Kwando [53 kpc]

Closest to the Earth:
New-3 [1.0 kpc]

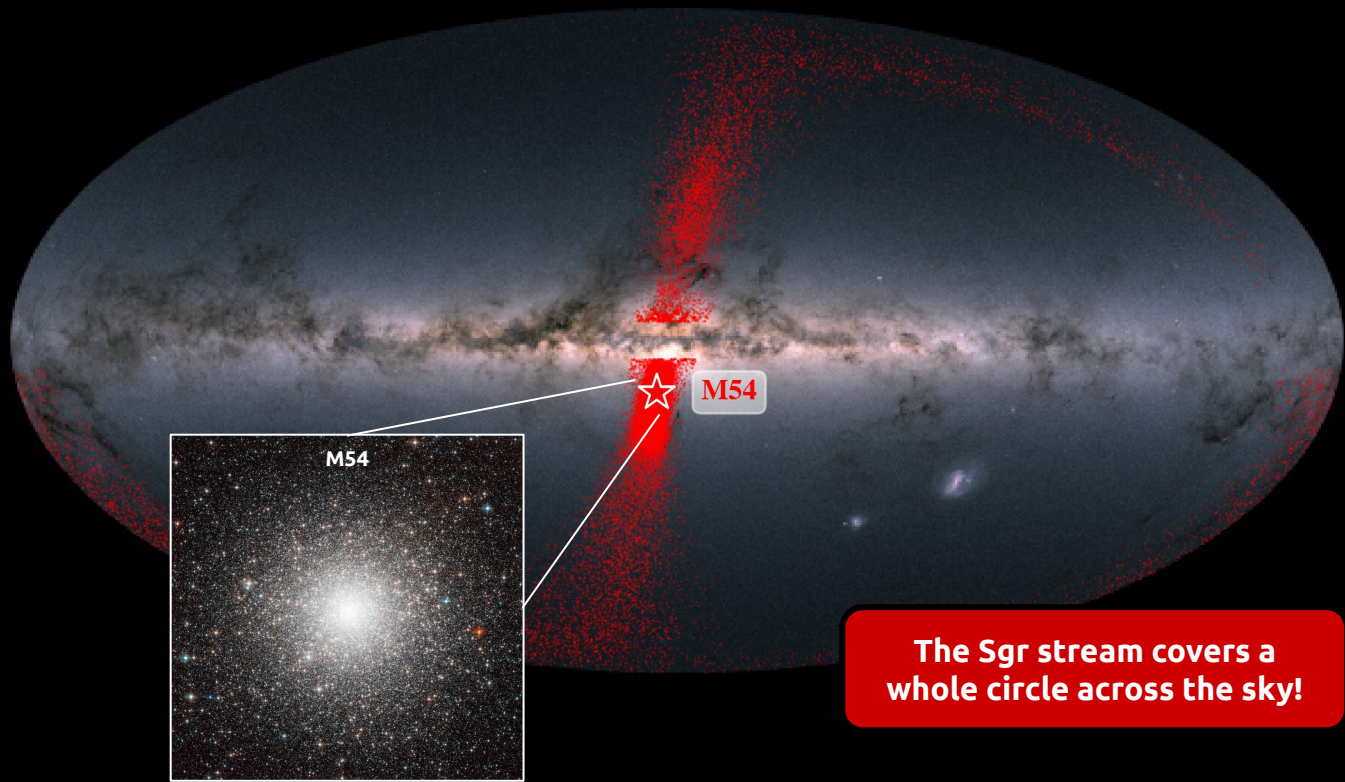
Credit

Ana Bonaca & Adrian Price-Whelan

Data: Ibata et al., arXiv:2311.17202

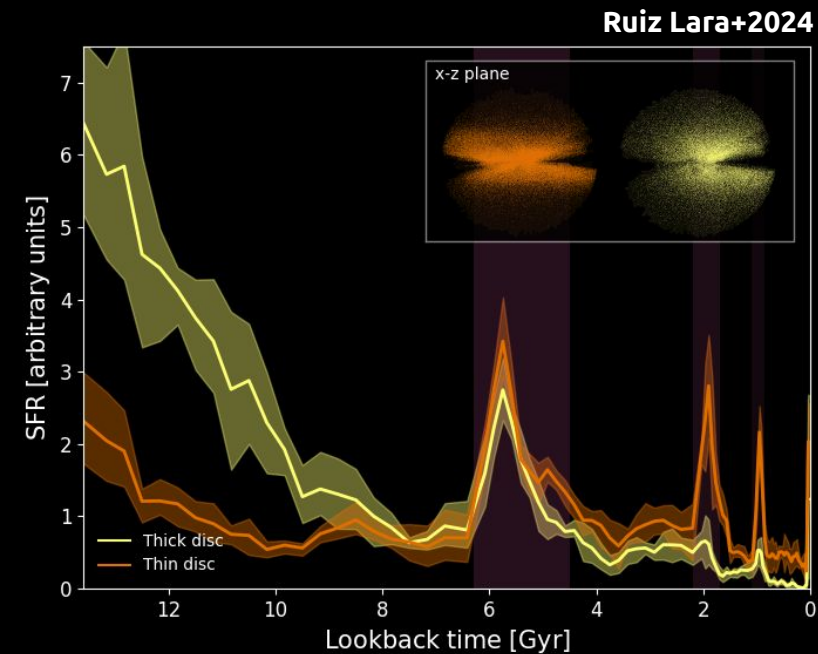
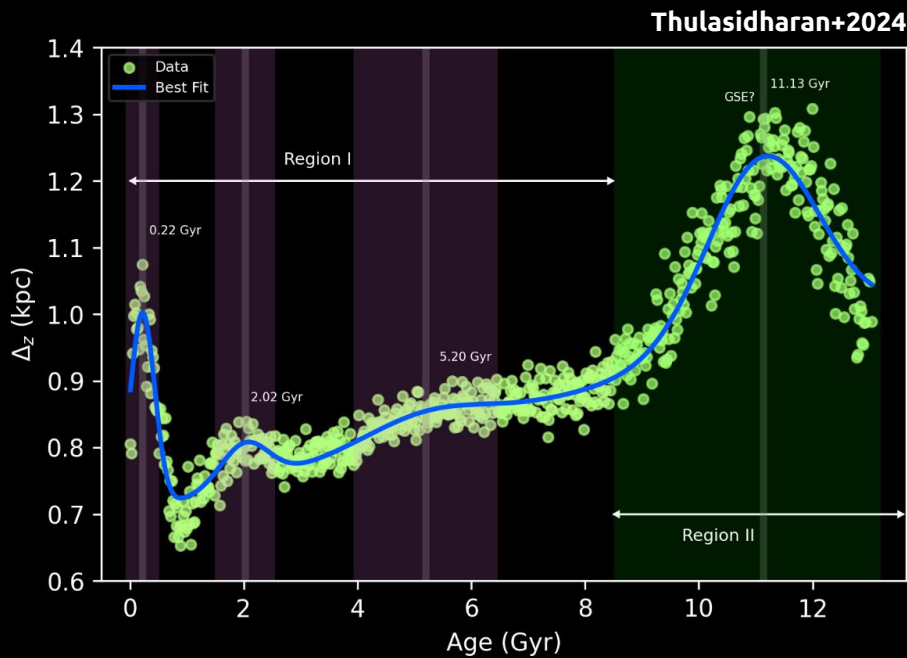


Sagittarius dSph



The Sgr stream covers a whole circle across the sky!

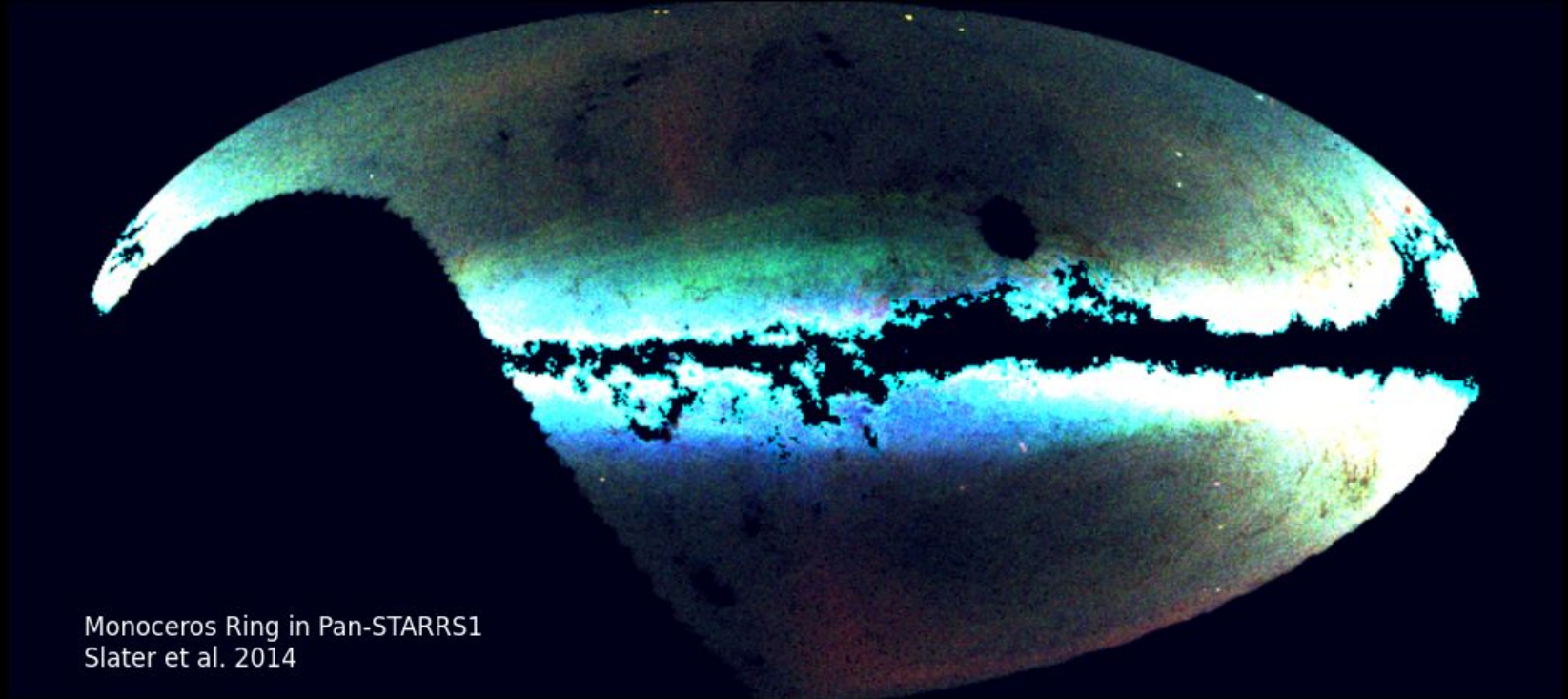
Sagittarius dSph



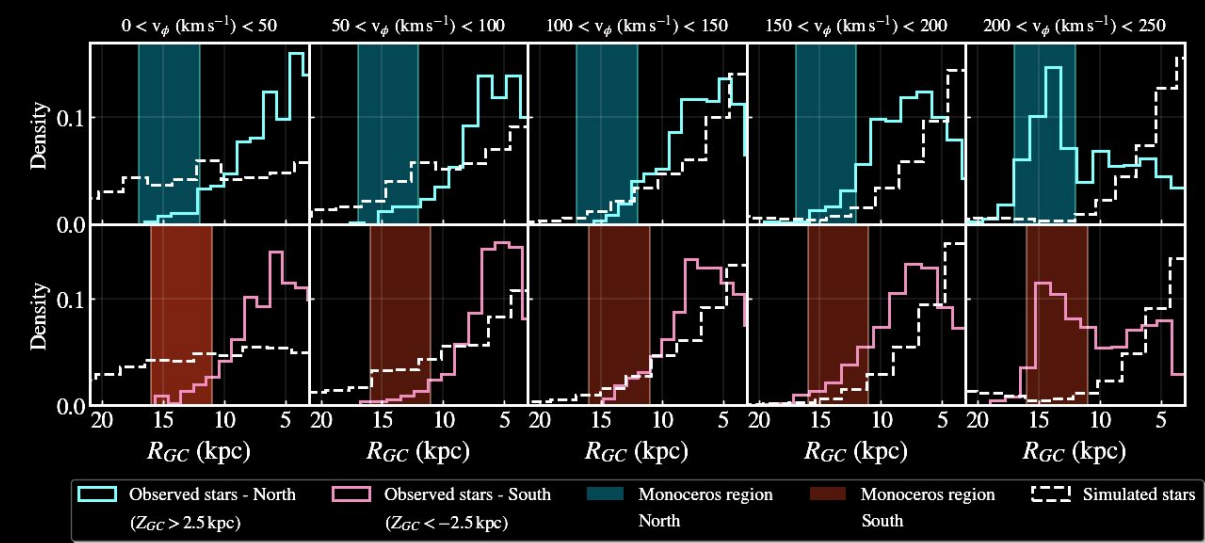
**Ages and dispersion reveal
when Sagittarius started
interacting with the Milky Way.**

Stellar Overdensities near the Galactic Plane

Monoceros Overdensity



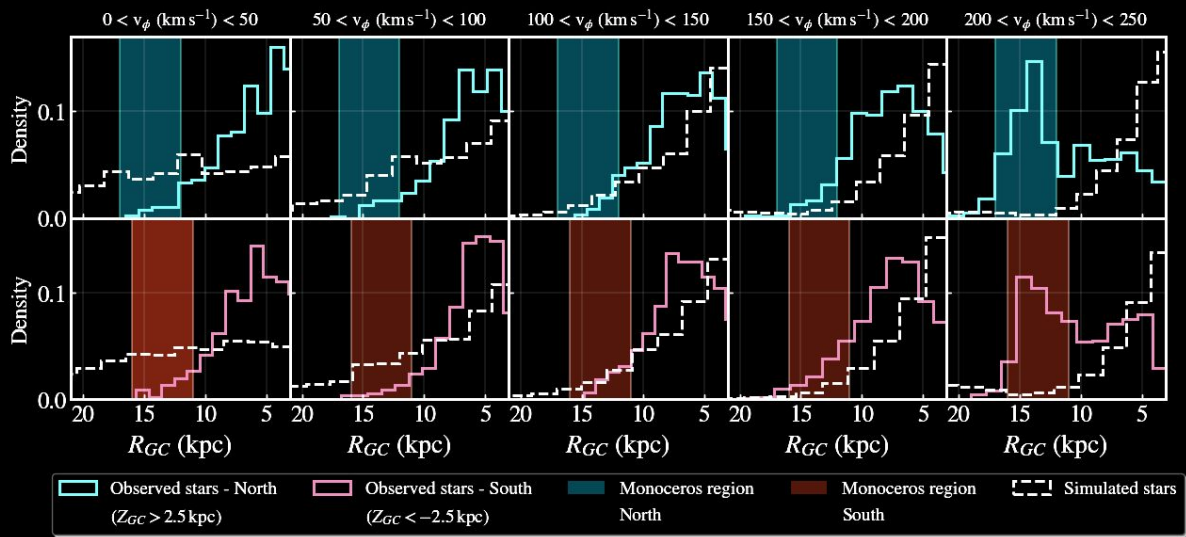
Monoceros Overdensity



M Giants (2MASS+AllWise)
StarHorse distances
Orbital Parameters (Agama)
Galaxia Model

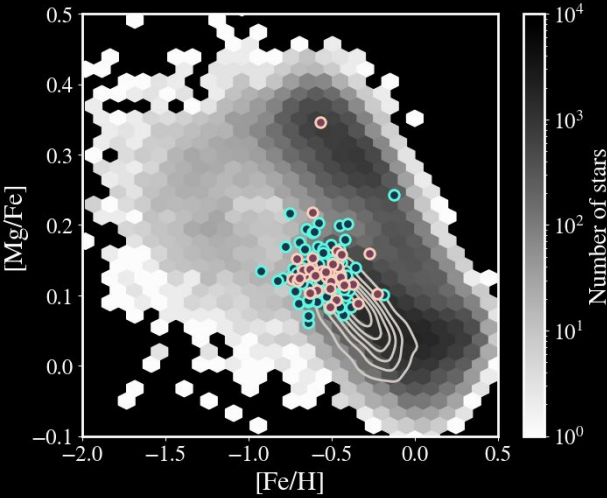
Borbolato, [Perotoni+2024](#)

Monoceros Overdensity



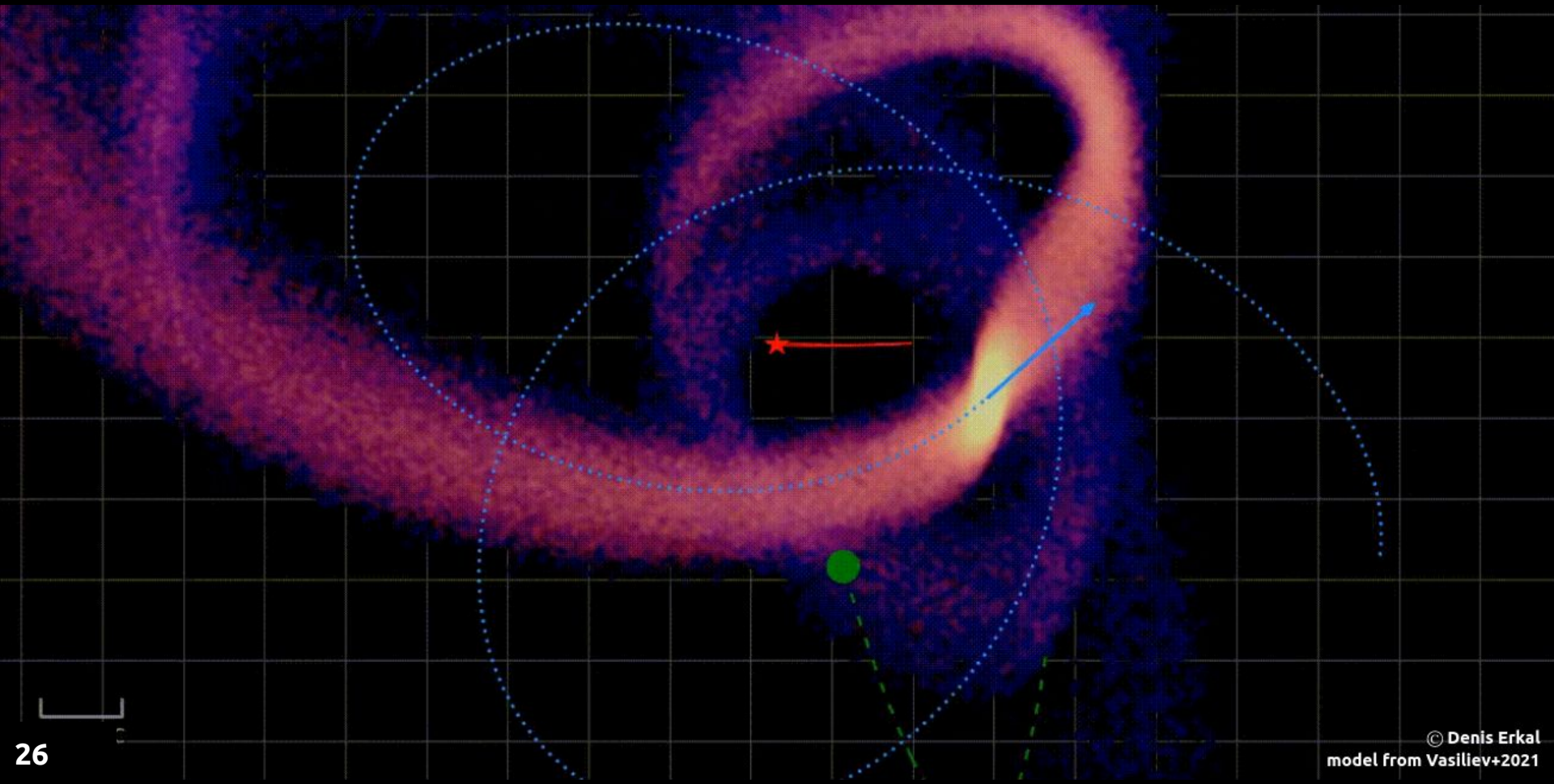
Borbolato, [Perottoni+2024](#)

M Giants (2MASS+AllWise)
StarHorse distances
Orbital Parameters (Agama)
Galaxia Model

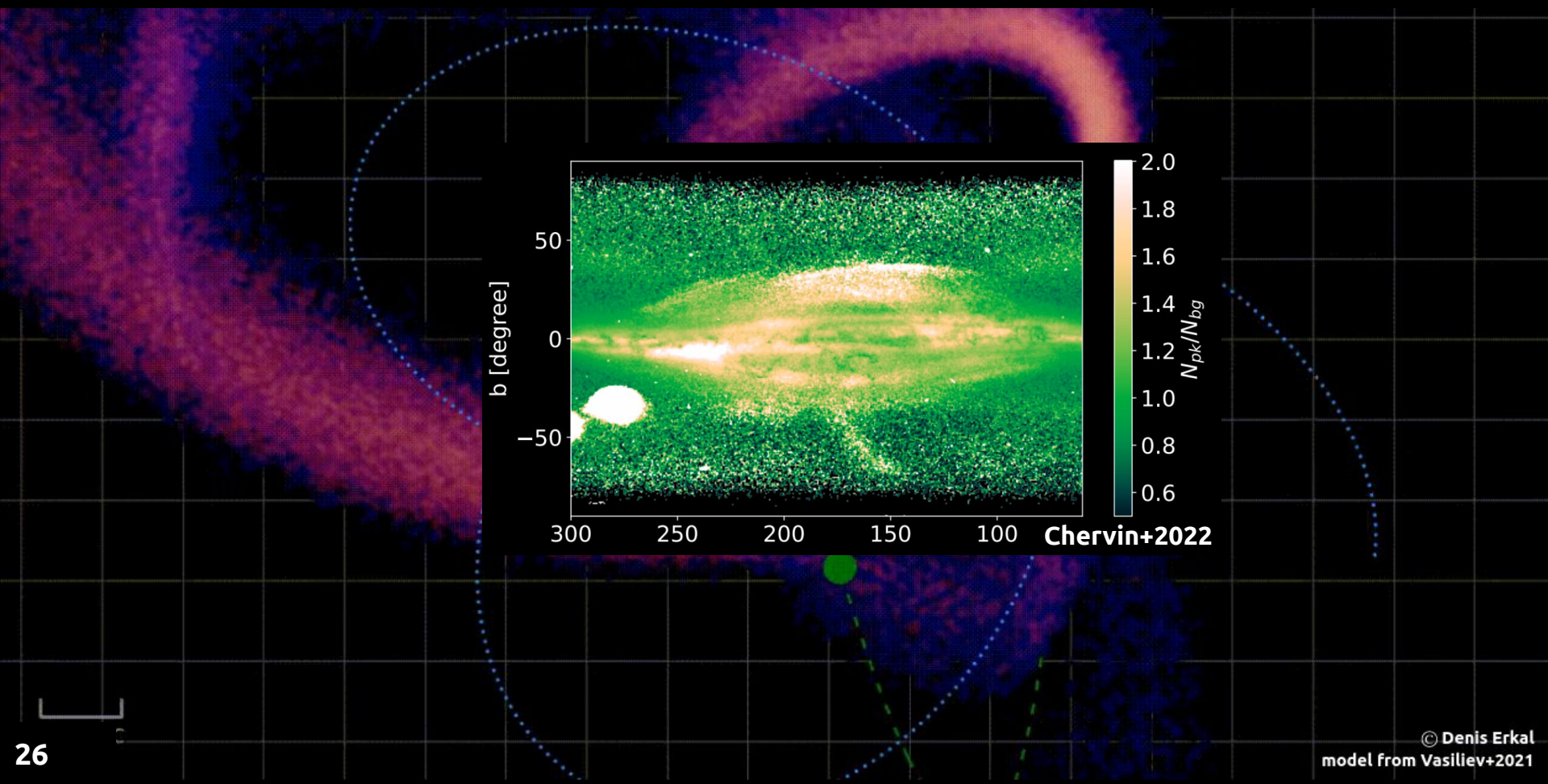


APOGEE
(Distance+Velocity)

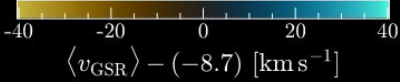
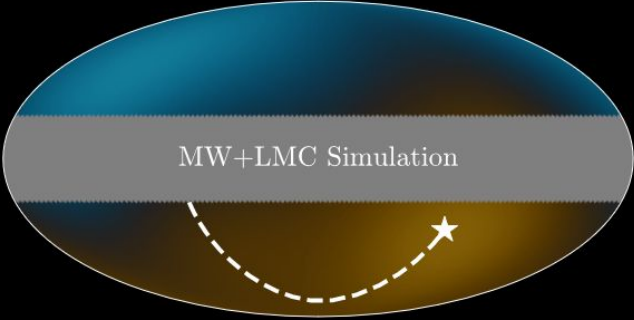
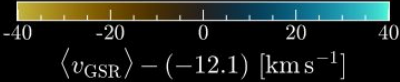
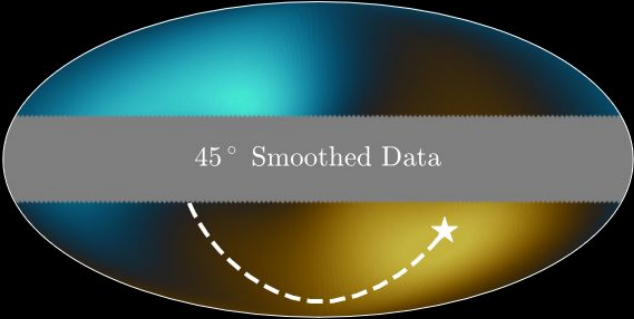
Disruption of Sagittarius



Formation of Stellar Overdensities



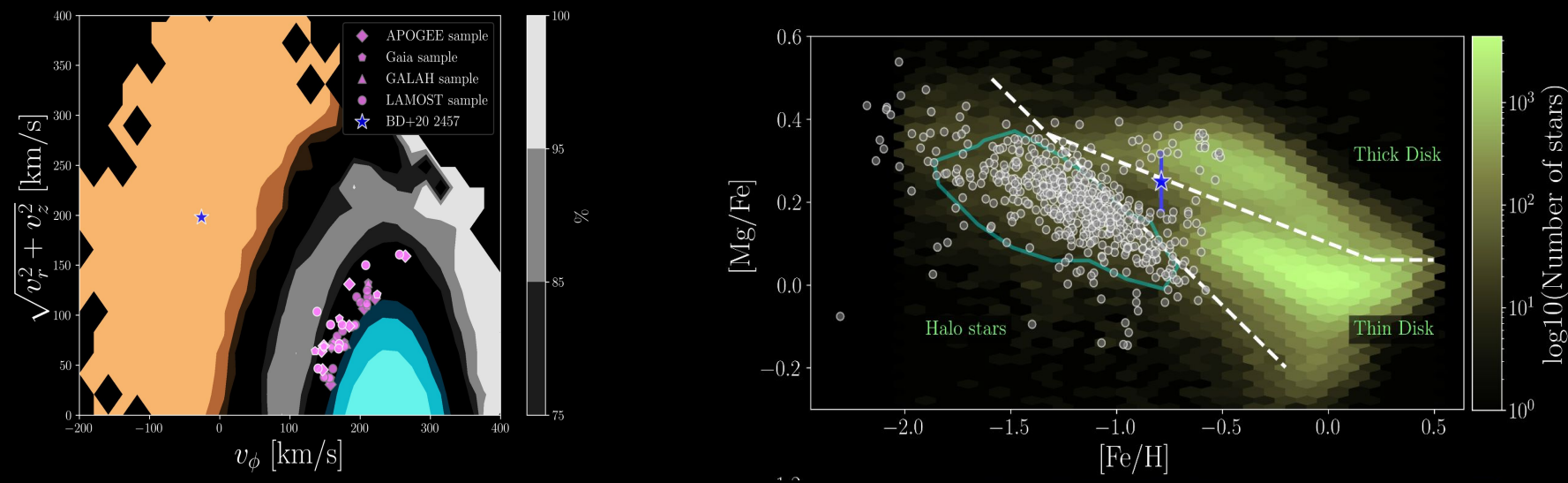
The LMC+SMC are



Xandra+2025

Planet populations in the galactic context

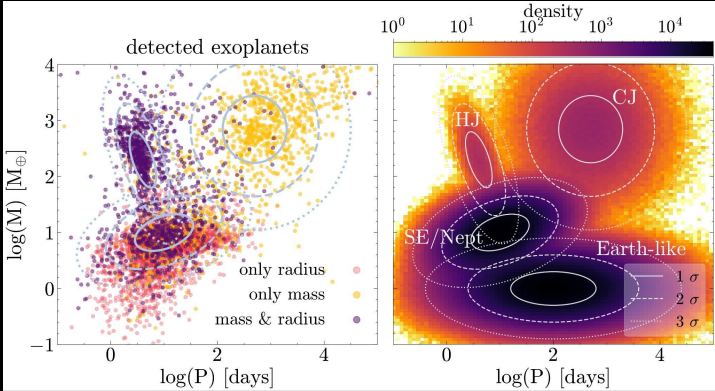
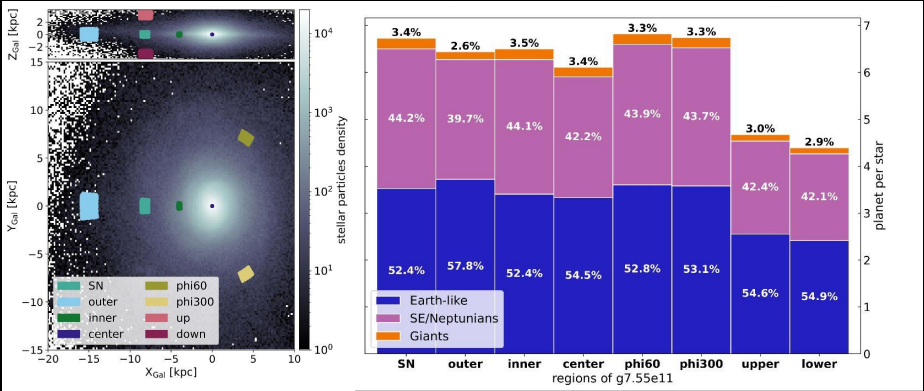
BD+20 2457: Extragalactic Exoplanet



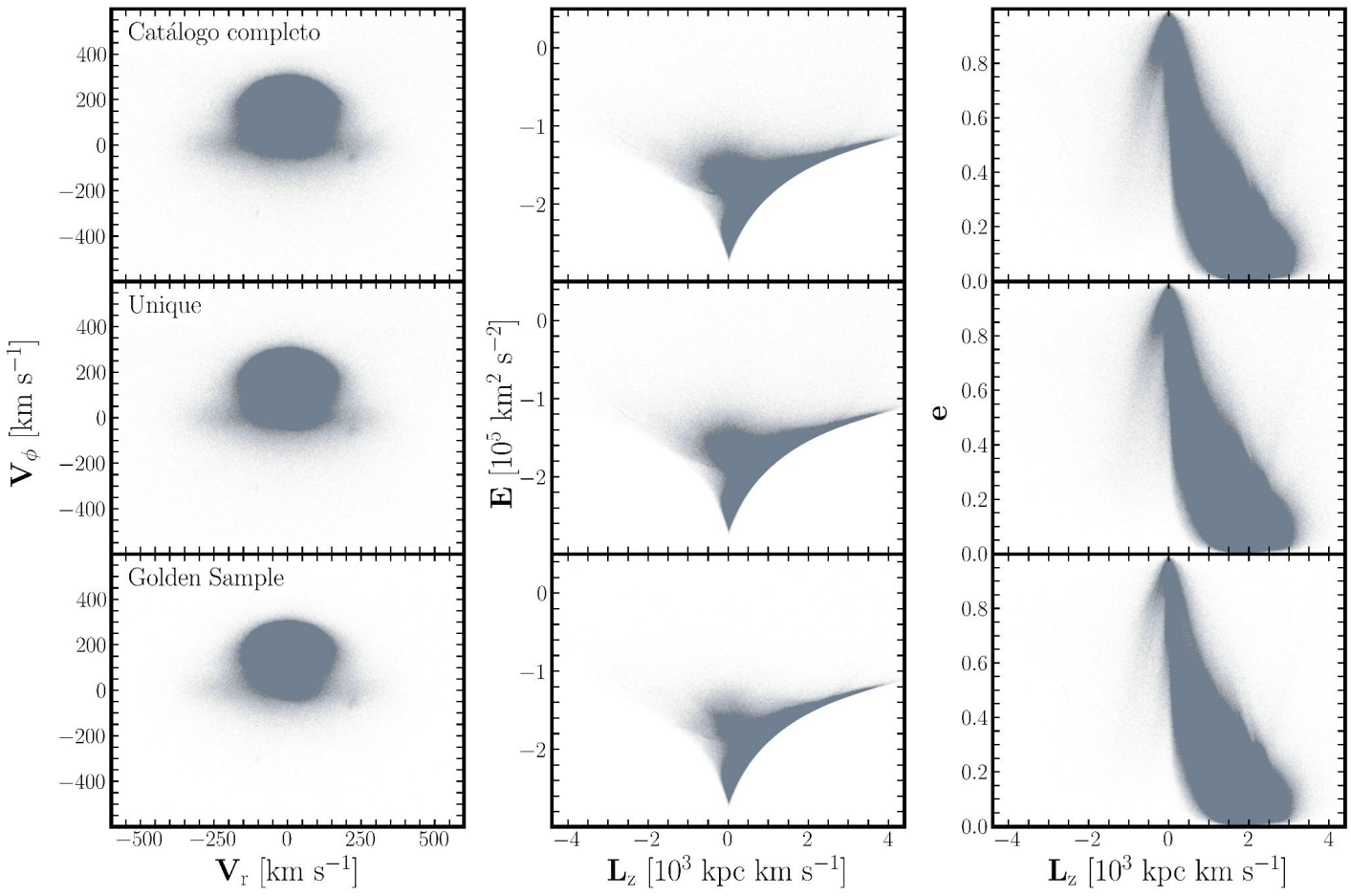
We show for the first time how to find extragalactic exoplanets inhabiting the Galactic stellar halo.

Modelling the Milky Way's exoplanet population

Padois+submitted



Homogeneous Orbital Parameters for 47M Stars

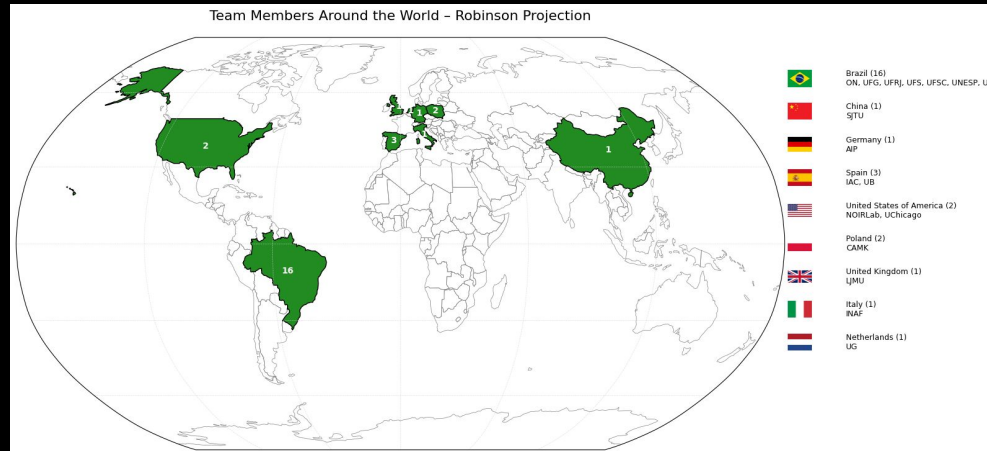


Feliciano Souza+in prep

Milky Way Brazilian Group

Milky Way Brazilian Group

- ✳ **Início 2020** (Hélio Perottoni, João Amarante e Guilherme Limberg)
- ✳ **Grupo Interinstitucional de Brasileiros (Estrutura/Formação/Evolução MW)**
 - Países: 7 - **Instituições: 12** - Doutorandos: 6 - Pós Docs: 4 - Prof.: 5 - **Membros: 25**
- ✳ **Journal Club Semanal** (Lais - laisborbolato@usp.br)
- ✳ **Estrutura de Grandes Colaborações – Grupos Independentes;**
- ✳ **Especialistas de Diferentes Áreas;**
- ✳ **Seminário Mensal, Semestral Apresentações;**



Milky Way Brazilian Group

- ✳ **Astronomia galáctica é claramente a área mais legal que existe!**
- ✳ **É uma das áreas mais ativas e em transformação da astrofísica, impulsionada por missões como Gaia e grandes surveys espectroscópicos.**
- ✳ **A missão Gaia revolucionou o que sabemos da Via Láctea.**
- ✳ **Arqueologia galáctica: reconstruir a história da Galáxia analisando a química, dinâmica, idade e posição das estrelas.**
- ✳ **A Via Láctea se formou por meio de fusões sucessivas.**
- ✳ **Ainda estamos escrevendo a história da Via Láctea, e os próximos anos prometem ainda mais descobertas.**
- ✳ **Tem um grupo muito legal aprontando todas na Galáxia.**

