

# The accretion history of the Galaxy via field and globular cluster populations

Danny Horta



*Stellar populations in the Milky Way and beyond*  
*18/11/24*

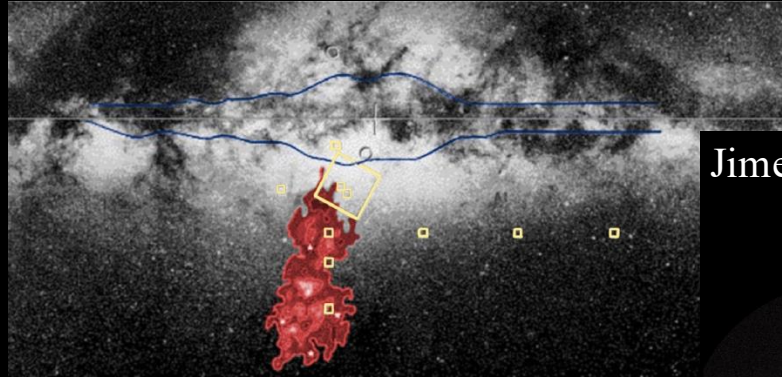
# The MW is flocked with debris

Gaia-Enceladus/Sausage



Helmi+18, Belokurov+18,  
Haywood+18, Mackereth+19

Sagittarius



Ibata+94

Helmi stream



Sestito+24

Helmi+99

Naidu+20



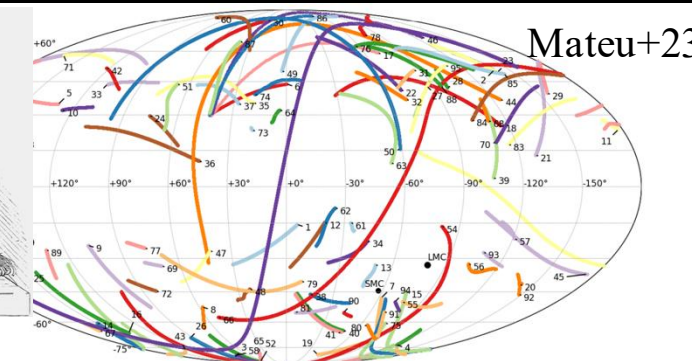
Arjuna I'toi Aleph

LMC/SMC

Jimenez-Arranz+22



Stellar streams



Mateu+23

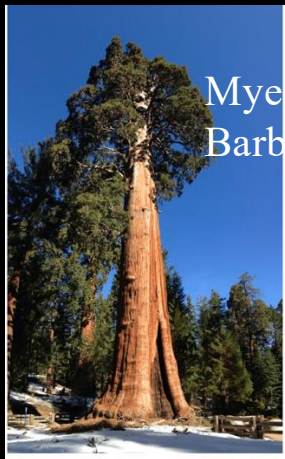
1=20.0-1	13=C-8	25=Gala-12	37=Hyllus	49=M5	61=NGC6362	73=Pal15	85=Slidr
2=3005	14=Cetus-New	26=Gala-2	38=Indus	50=M68-Fjorm	62=NGC6397	74=Pal5	86=Styx
3=AAU-ATLAS	15=Cetus-Palca	27=Gala-3	39=Jet	51=M92	63=OmegaCen-Fimbulthul	75=Palca	87=Styx
4=AAU-AliqaUma	16=Cetus	28=Gala-4	40=Jhelum-a	52=Molonglo	64=Ophiuchus	76=Parallel	88=Sylgr
5=ACS	17=Cocytos	29=Gala-5	41=Jhelum-b	53=Monoceros	65=Orinoco	77=Pegasus	89=Tri-Pis
6=Acheron	18=Corvus	30=Gala-6	42=Kshir	54=Murrumbidgee	66=Orphan-Chenab	78=Perpendicular	90=Tucanall
7=Alpheus	19=Elqui	31=Gala-7	43=Kwando	55=NGC1261	67=PS1-A	79=Phlegethon	91=Turbio
8=Aquarius	20=Eridanus	32=Gala-8	44=LMS-1	56=NGC1851	68=PS1-B	80=Phoenix	92=Turanburra
9=C-19	21=GD-1	33=Gala-9	45=Leiptr	57=NGC2298	69=PS1-C	81=Ravi	93=Wambelong
10=C-4	22=Gala-1	34=Gunnthra	46=Lethe	58=NGC2388	70=PS1-D	82=Sagittarius	94=Wilka_Yaku
11=C-5	23=Gala-10	35=Hermus	47=M2	59=NGC3201-Gjoll	71=PS1-E	83=Sangarius	95=Ylgr
12=C-7	24=Gala-11	36=Hrid	48=M30	60=NGC5466	72=Pal13	84=Scamander	

Heracles



Horta+21

Sequoia (GCs)



Myeong+19  
Barbá+19

Thamnos



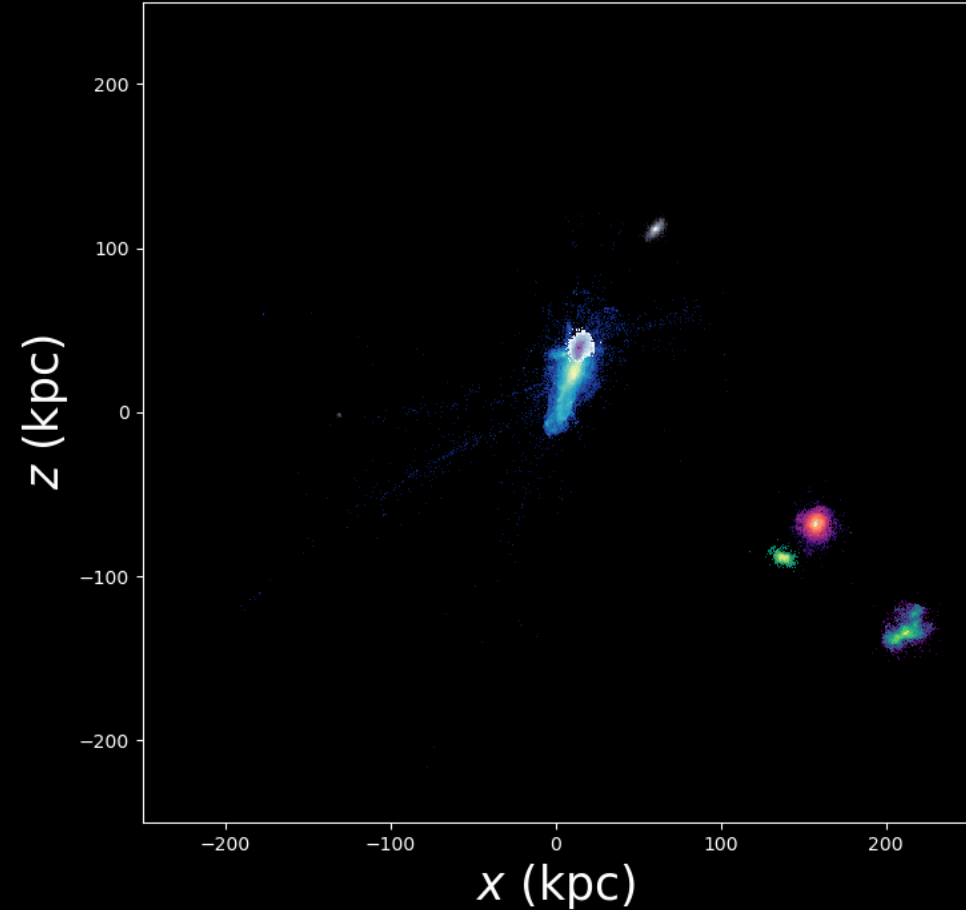
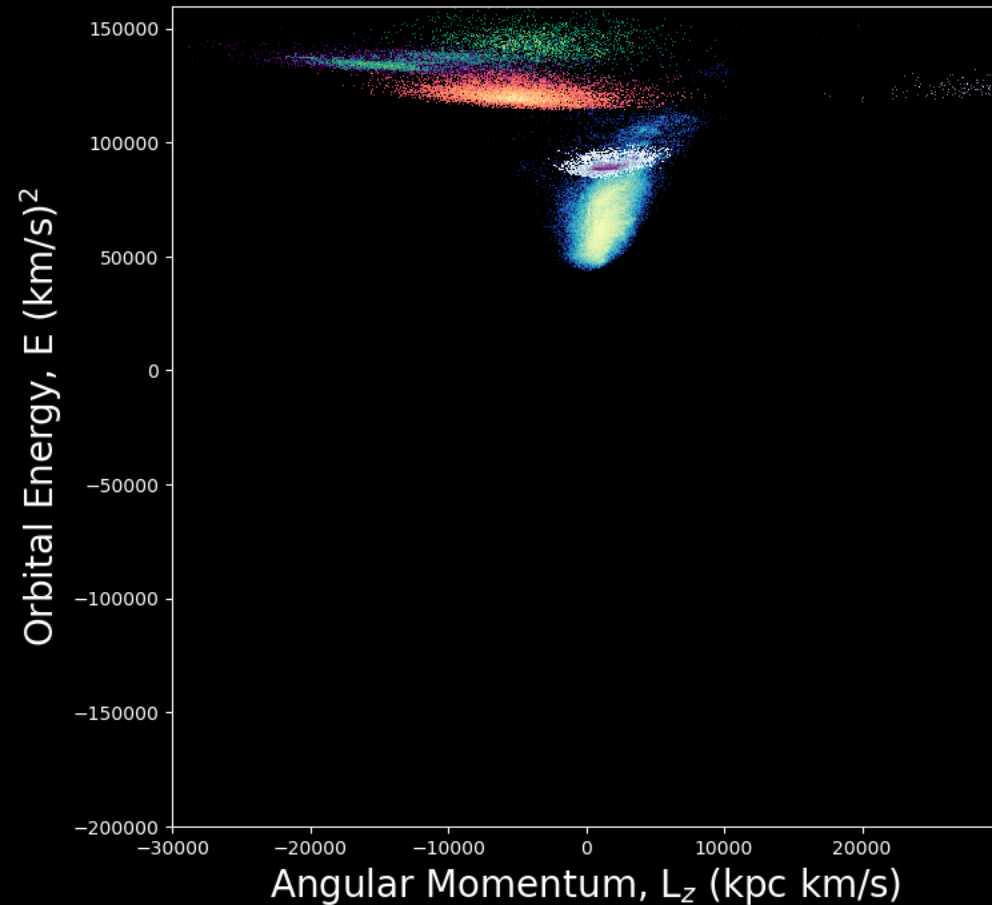
Koppelman+20

Many smaller stellar streams:  
Cetus, LMS-1, GD-1, Pal5, OCS, ATLAS, AliqaUma, Indus, Jhelum, Phoenix, ED-1

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# Finding structures in kinematic/dynamic samples

- Accreted samples can overlap with *in situ* and other accreted populations
- Single debris can leave multiple clumps



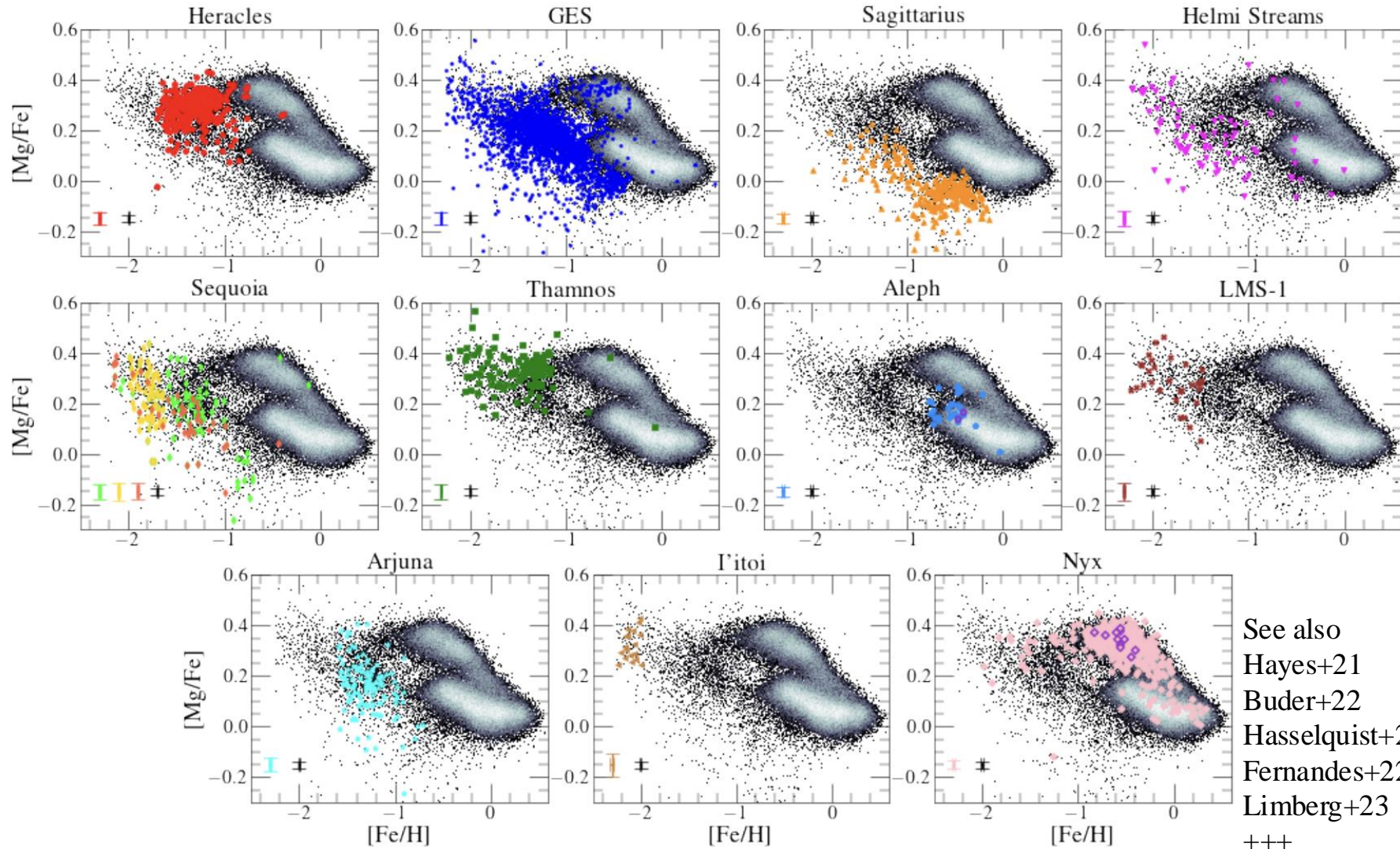
# Spectral line information enables chemical tagging

*“With sufficiently detailed **spectral line information**, it is feasible that the ‘chemical tagging’ will allow temporal sequencing of a large fraction of stars in a manner analogous to building a family tree through **DNA sequencing**.”*

*- Ken Freeman & Joss Bland-Hawthorn*

# Chemical abundances help reveal nature of halo substructures

$\alpha$ -to-iron



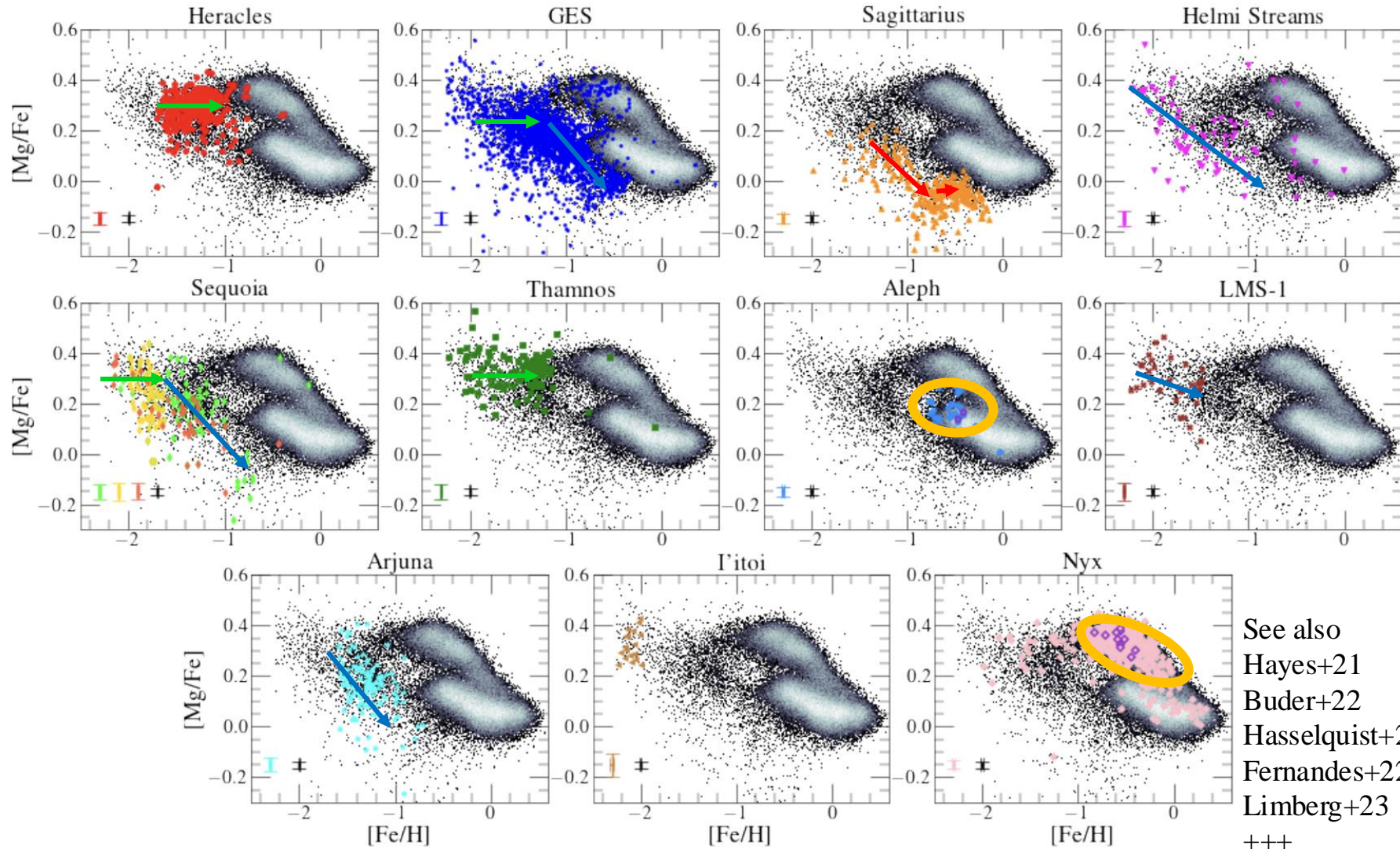
Horta+23

See also  
Hayes+21  
Buder+22  
Hasselquist+22  
Fernandes+22  
Limberg+23  
+++

Iron-to-hydrogen

# Chemical abundances help reveal nature of halo substructures

$\alpha$ -to-iron



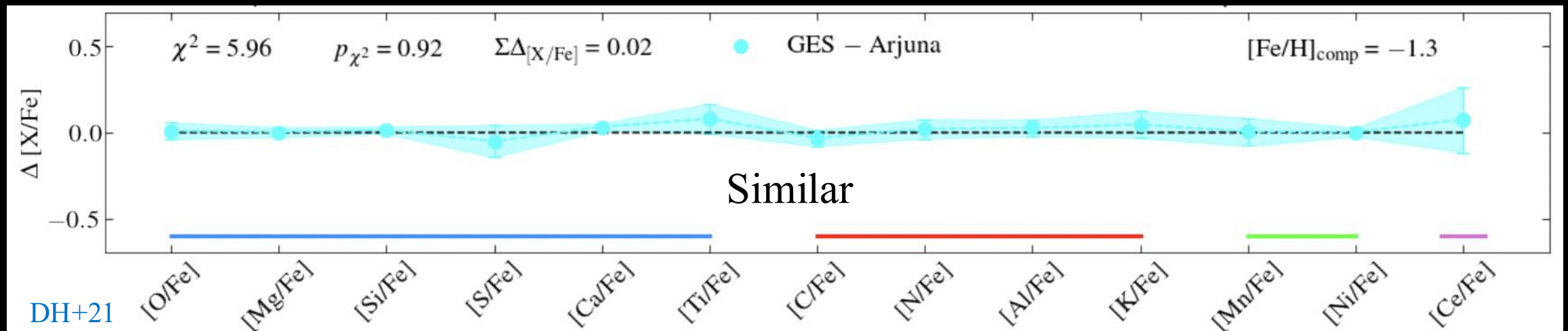
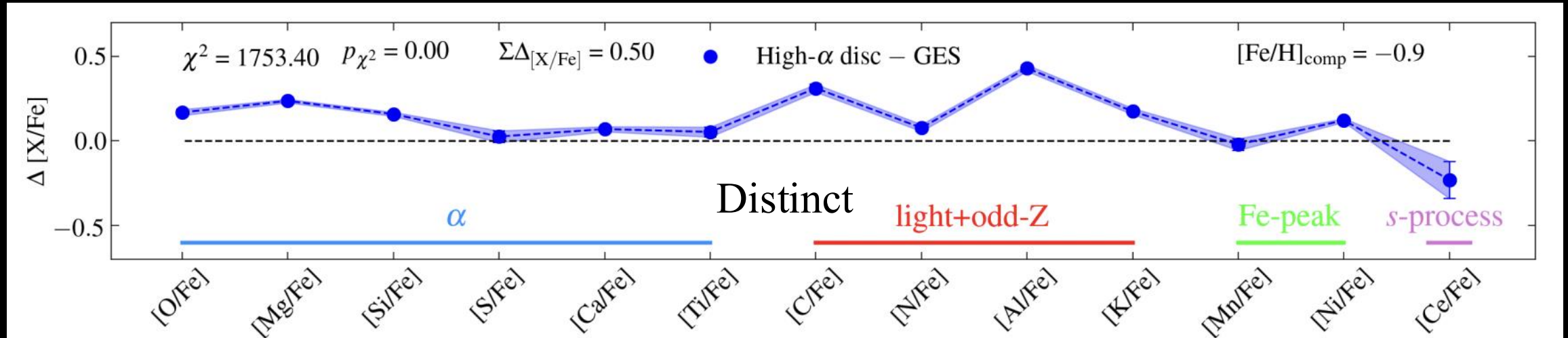
Horta+23

See also  
Hayes+21  
Buder+22  
Hasselquist+22  
Fernandes+22  
Limberg+23  
+++

Iron-to-hydrogen

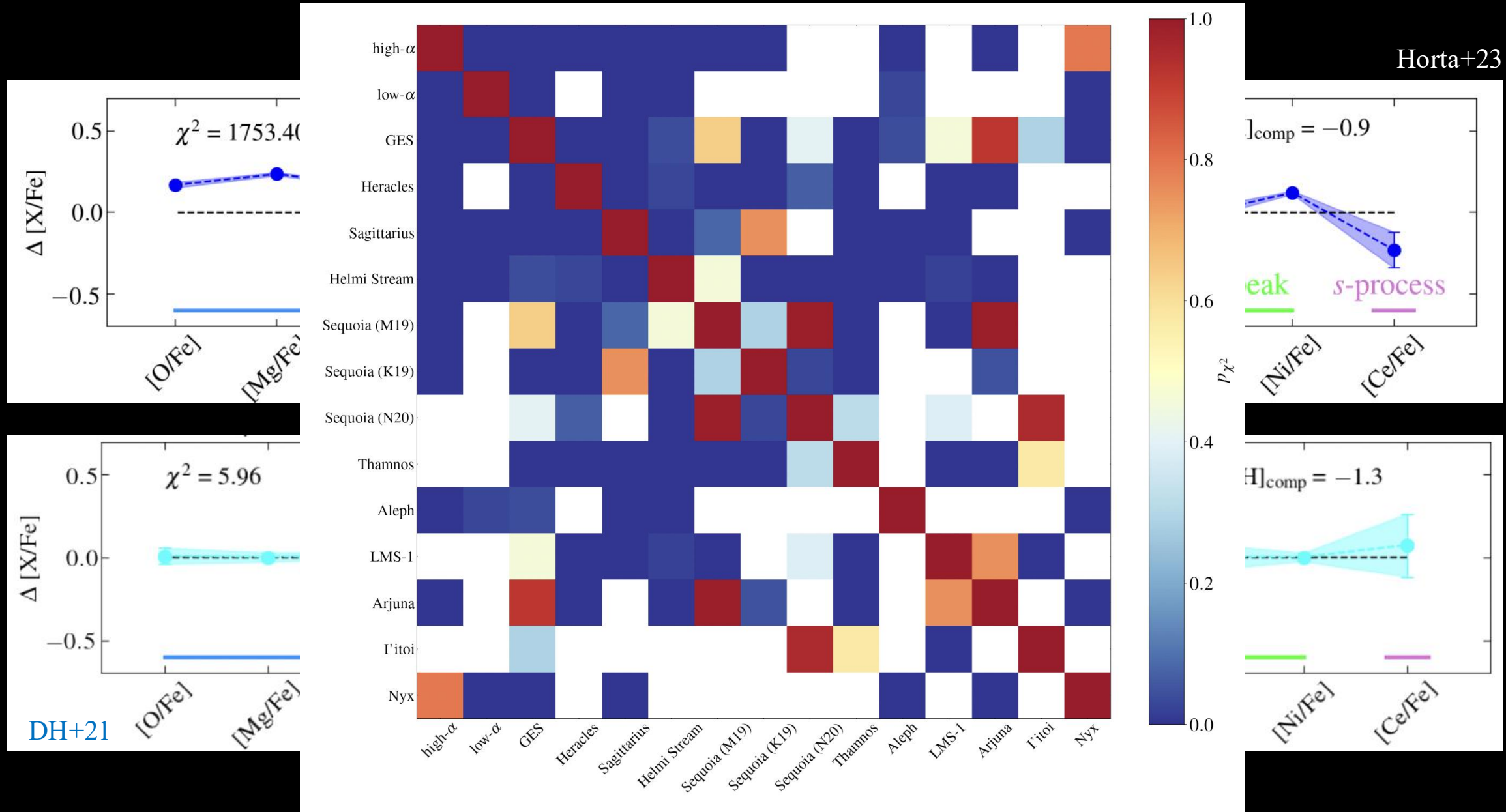
# Chemical abundances can help distinguish substructures

Horta+23



DH+21

# Chemical abundances can help distinguish substructures





# The earliest stages of assembly of the MW

*Evidence of the remnant of a major building block*

- likely major building block of MW
- qualitative agreement with simulations (i.e. El Badry+18, Fragkoudi+19, Orkney+23, Horta+23)
- only  $\sim 5\%$  of the mass within 4-5 kpc

26,000 light-years



Heracles

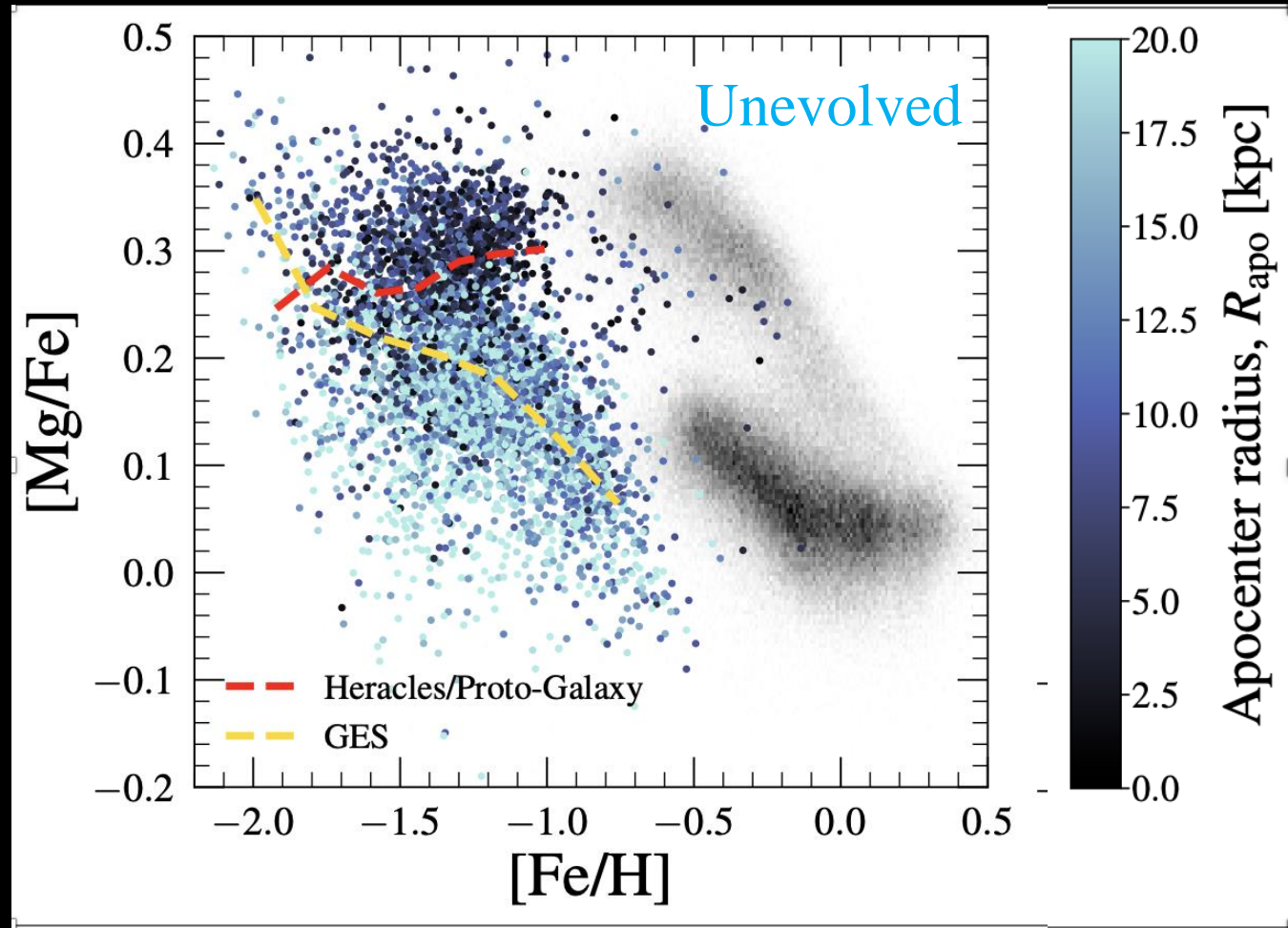
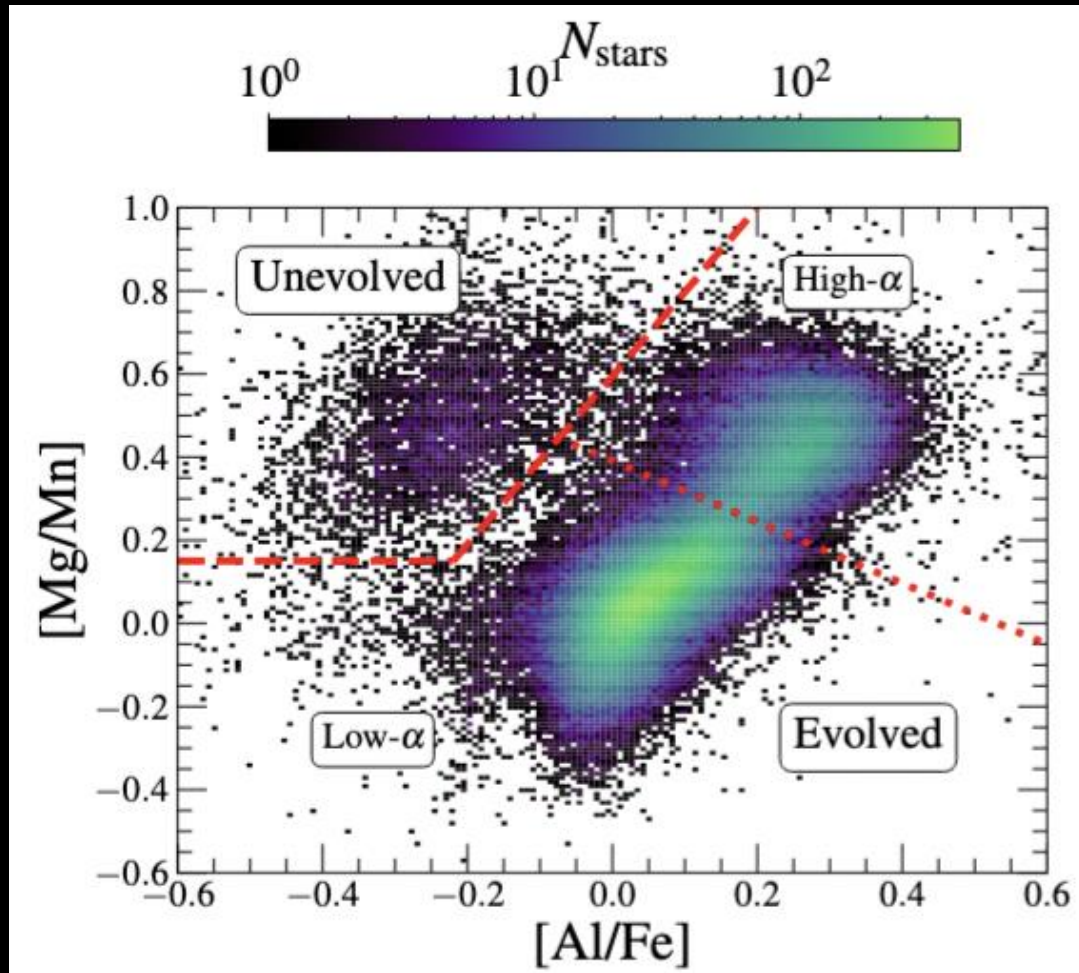
Sun



Horta+21

# Chemically selecting Milky Way populations

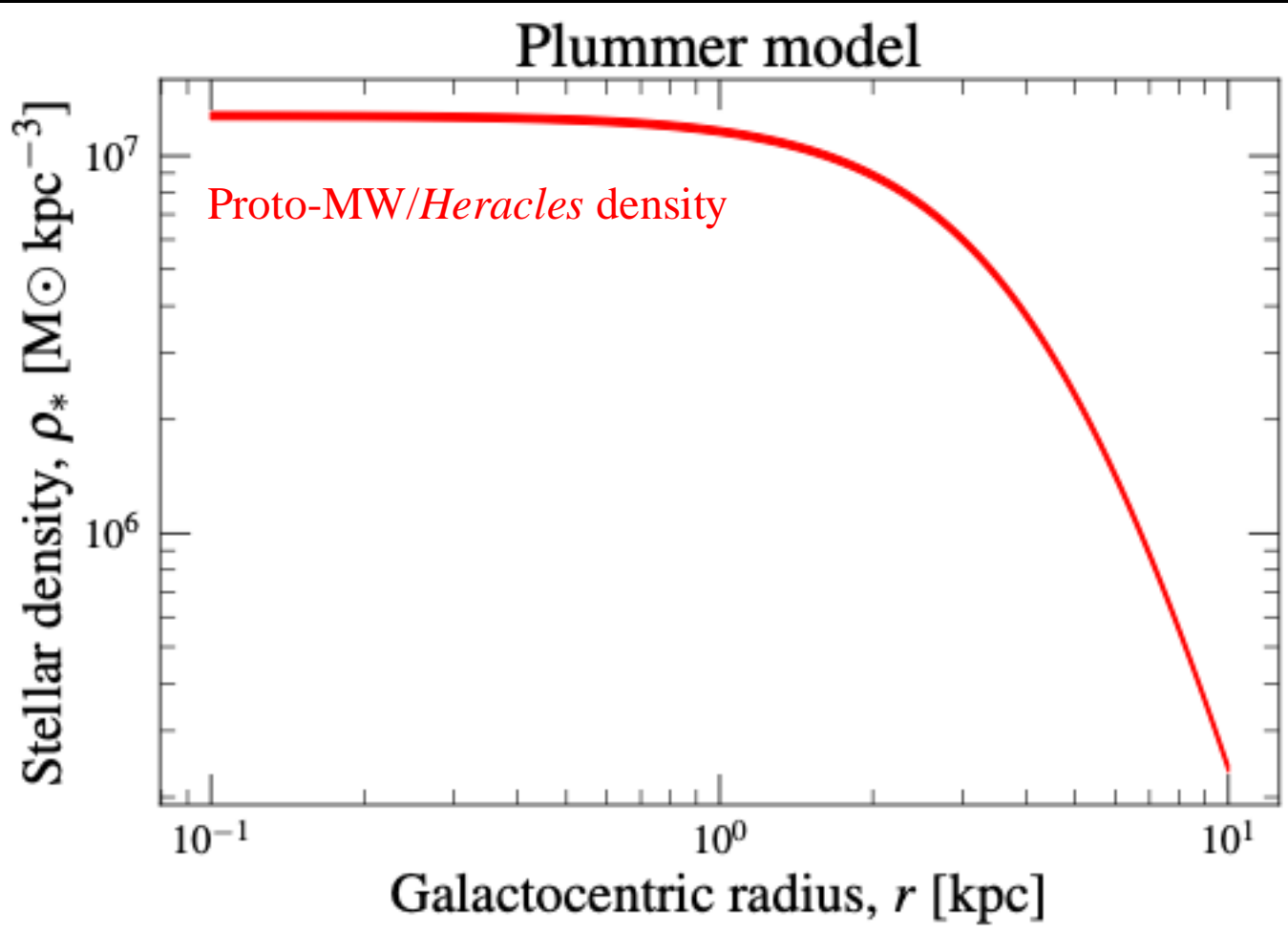
Horta & Schiavon, submitted



See also Hawkins +15, Das+20  
Fernandes+23

# Proto-MW/*Heracles* is tightly packed

Horta & Schiavon, submitted



Proto-MW/*Heracles* well described  
by **oblate Plummer model**

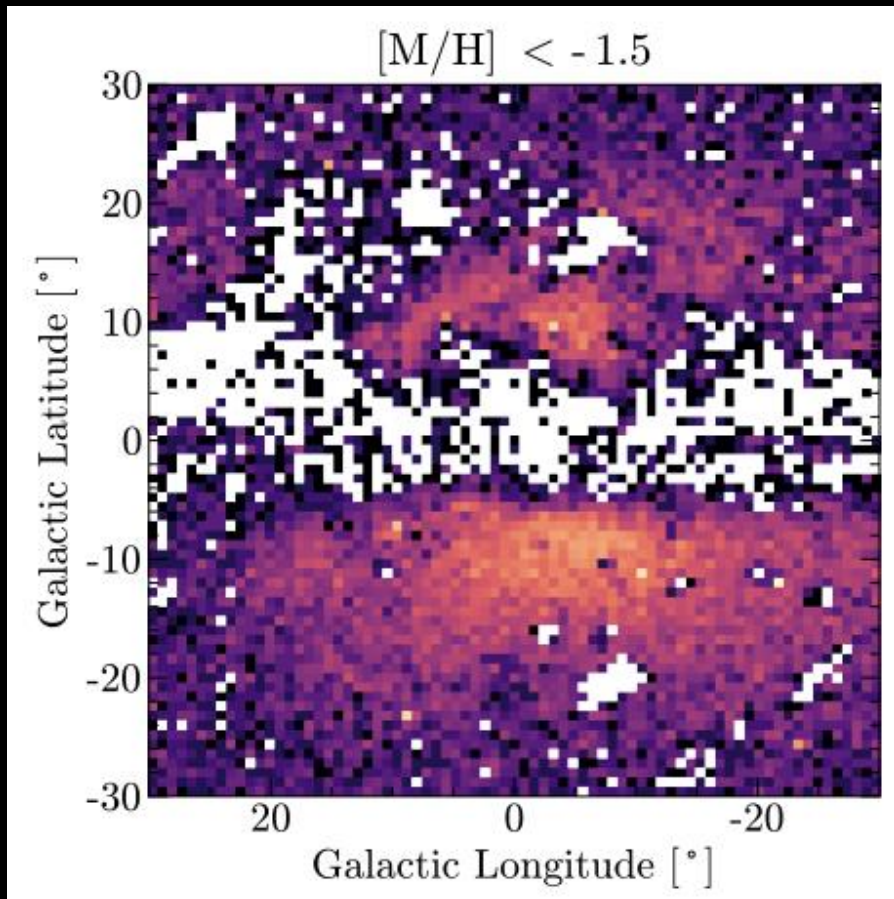
Proto-MW amounts to a **mass of**  
 **$\sim 10^9 M_\odot$**  within  $r < 10$  kpc, and  
*Heracles* accounts for  **$\sim 7 \times 10^8 M_\odot$**

- Plummer radius  $\sim 3.5$  kpc, and  
flattening of  $q \sim 0.6$

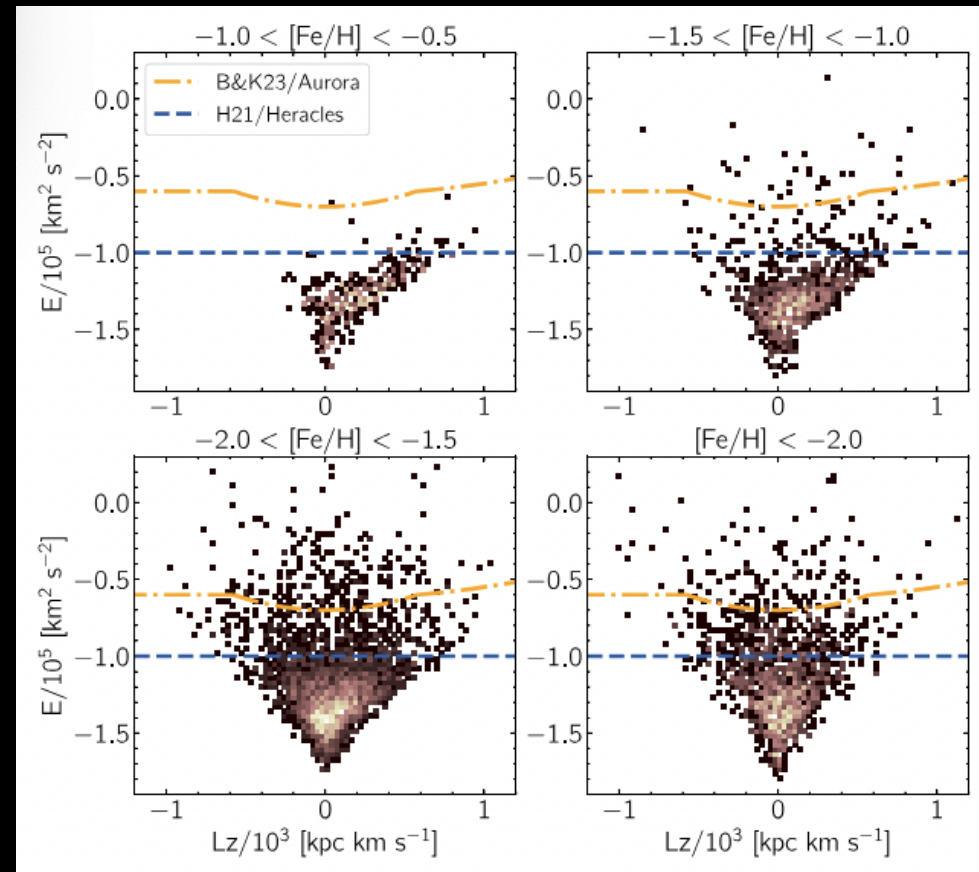
See also Belokurov & Kratsov 22

# The very metal-poor stars

Rix+22

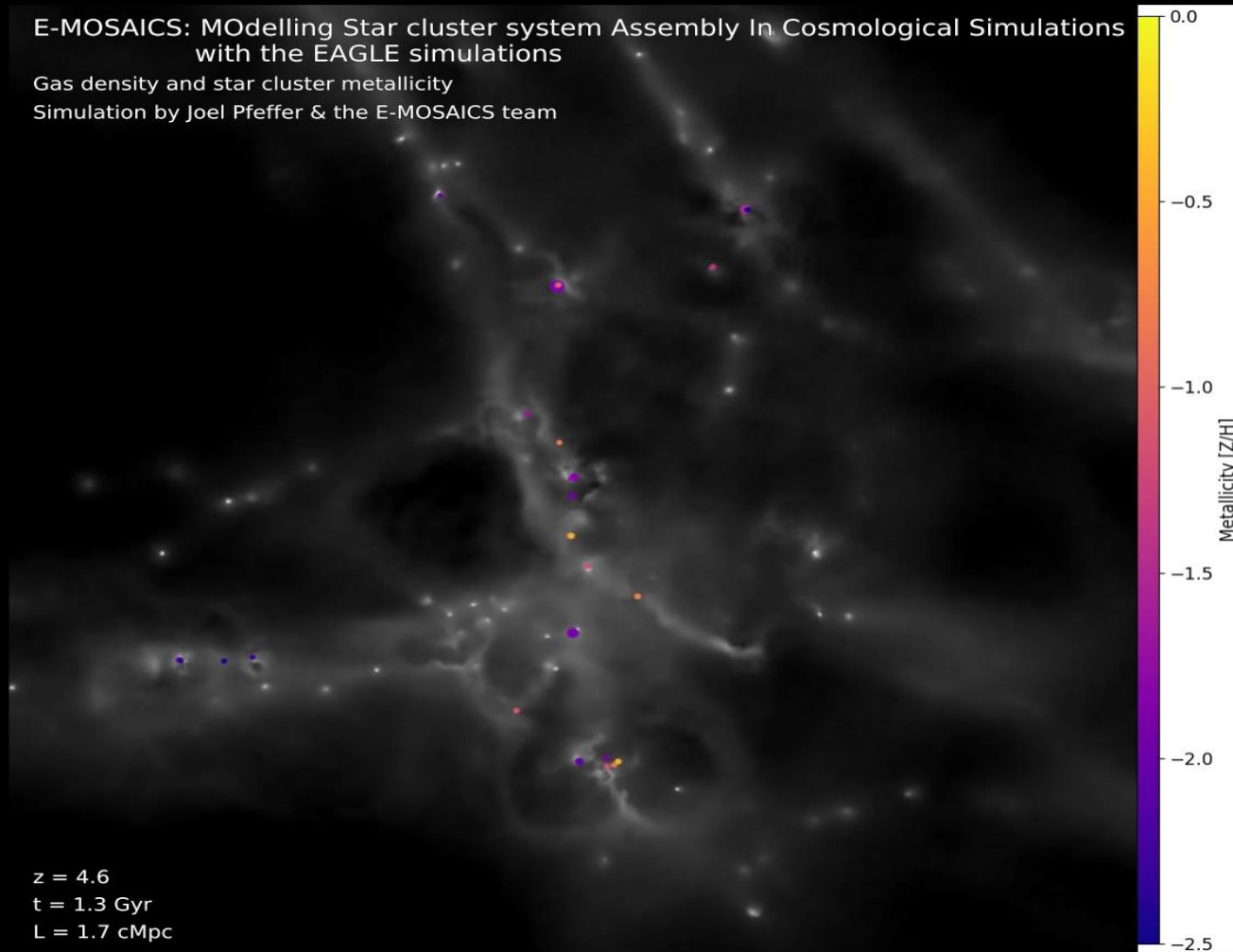


Ardern-Arentsen+24



See Anke's and Else's talk!

# The role of globular clusters

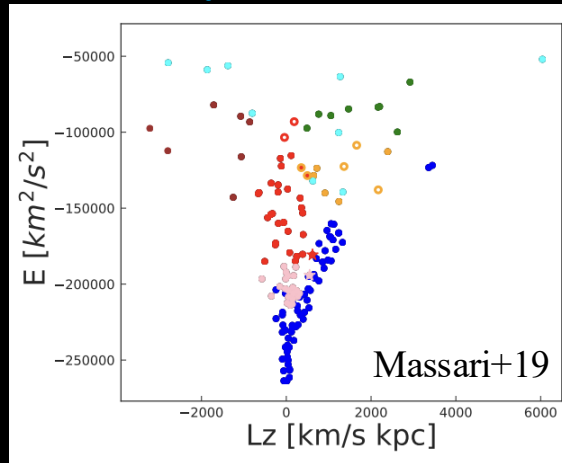


See also:  
Forbes+18  
Li & Gnedin 18  
Choksi & Gnedin 19  
+++

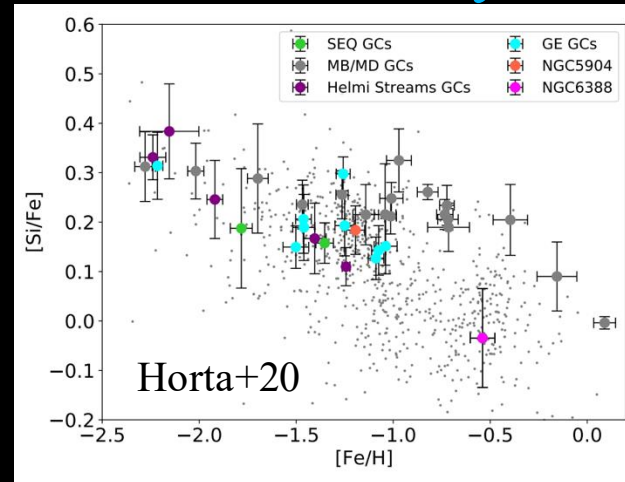
Video credit: Joel Pfeffer

# Globular clusters as tools for unravelling accretion histories

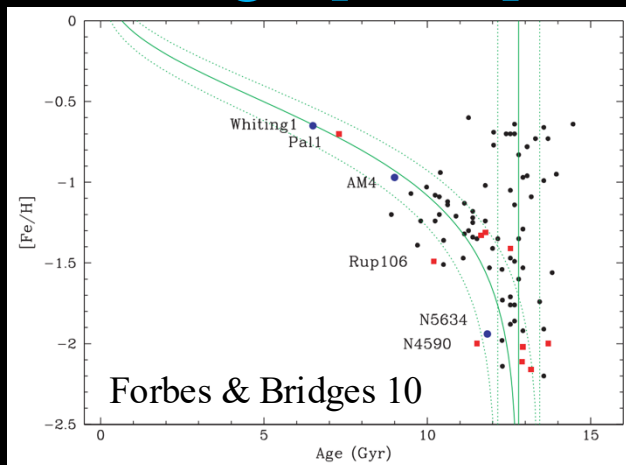
Dynamics



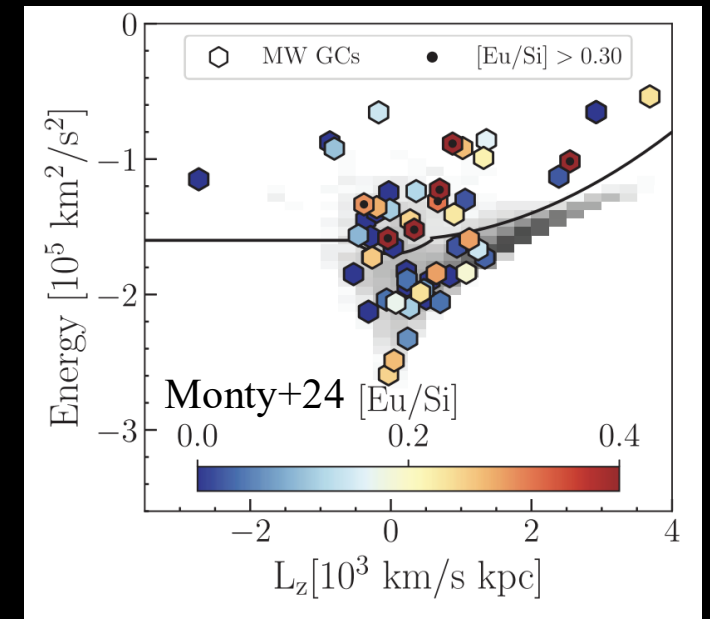
Chemistry



Age-[Fe/H]



Chemistry  
+  
Dynamics



See also  
Vasiliev+22,  
Baumgardt+22,  
Callingham+22

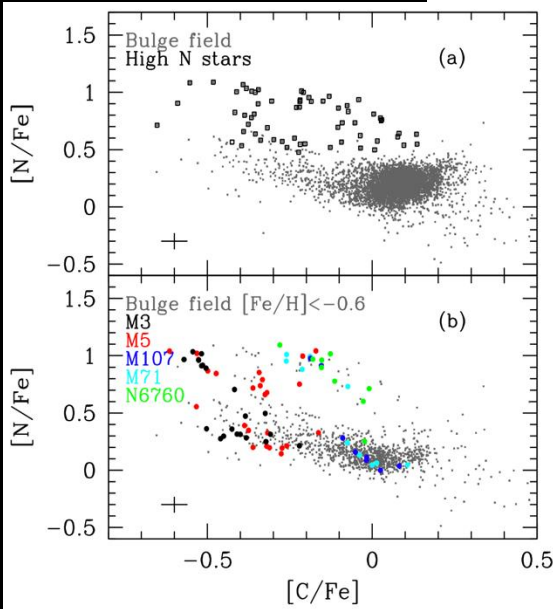
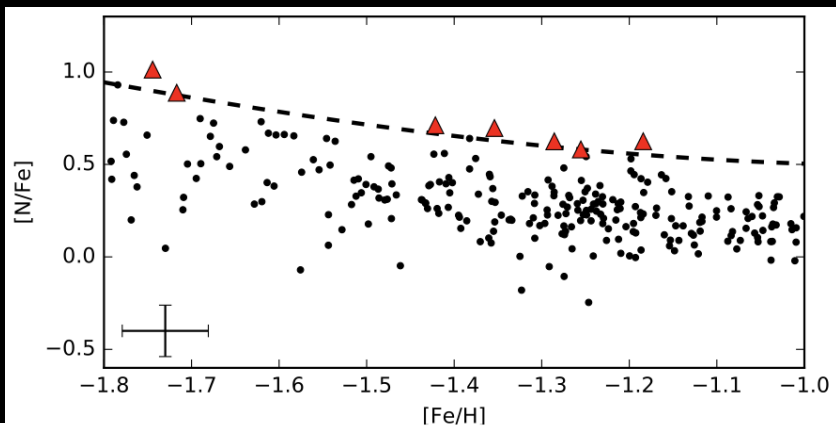
See Davide's talk!

# Globular clusters: mass contribution to stellar halo

Chemically finding globular cluster escapees

Martell+16

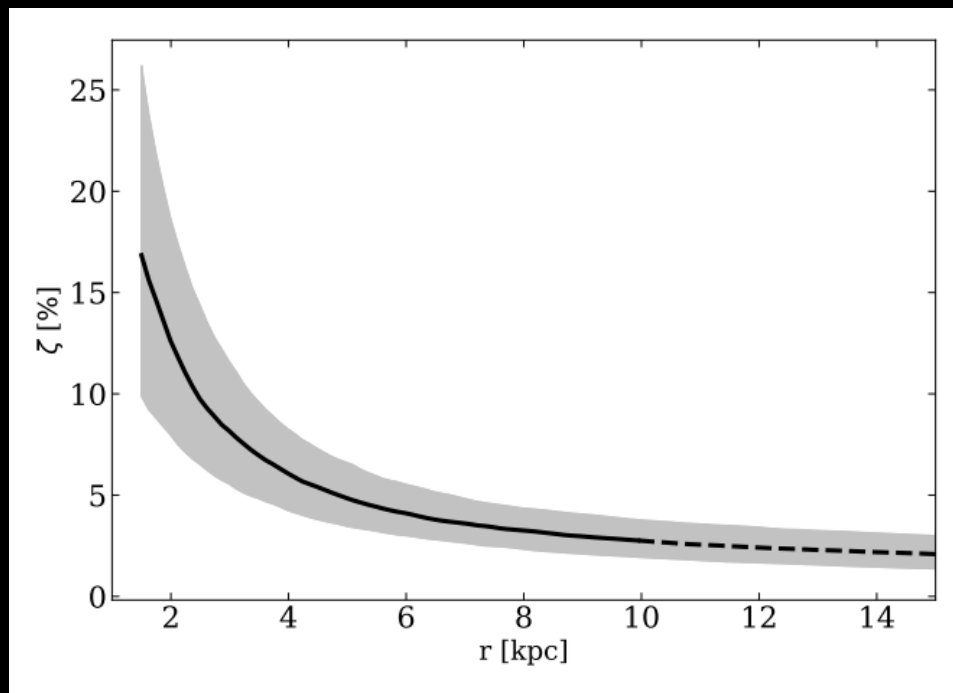
See Ricardo's and Carmela's talk!



See also:  
 Martell&Grebel+10  
 FernandezTrincado+19  
 Lee+19  
 Hanke+20  
 Belokurov+23  
 more...

Schiavon+17

Mass fraction of globular cluster escapees



Fraction of globular  
 cluster escapees

Horta+21

# Summary and outlook:

- Many discoveries have led to a detailed picture of the intermediate ( $5 < r < 30$ ) stellar halo; chemistry has helped elucidate the nature of these populations.
- We still don't have a good understanding of the innermost ( $r < 6$  kpc) and outermost ( $r > 30$  kpc). Upcoming surveys will help tackle that.
- Globular clusters are a useful tool, and play a key role in the build up of stellar halos.