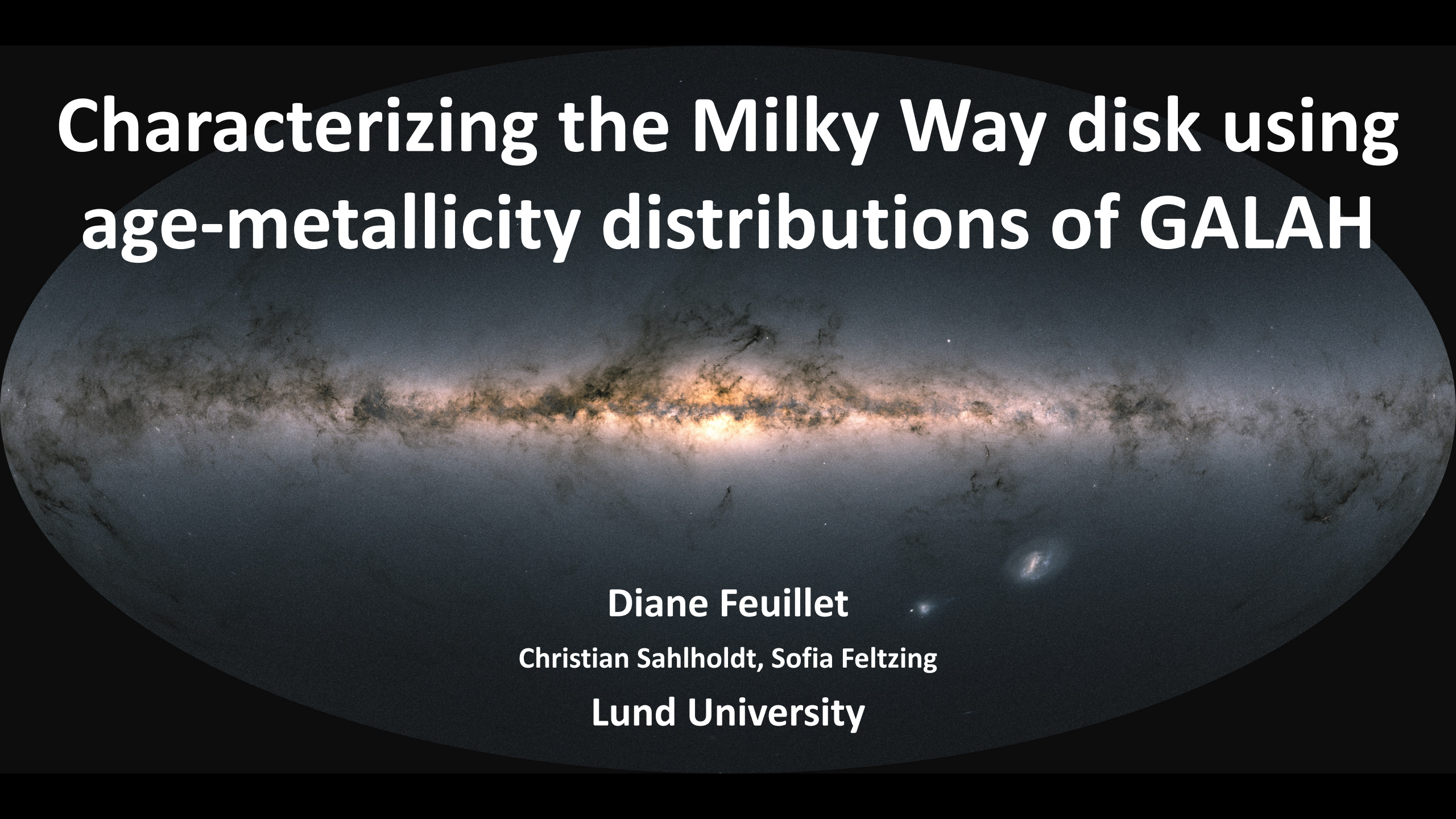
Characterizing the Milky Way disk using age-metallicity distributions of GALAH



Diane Feuillet

Christian Sahlholdt, Sofia Feltzing

Lund University

Why do we care?

Galaxy formation and evolution generally

~1 million stars with 6D motions/positions AND detailed elemental abundances

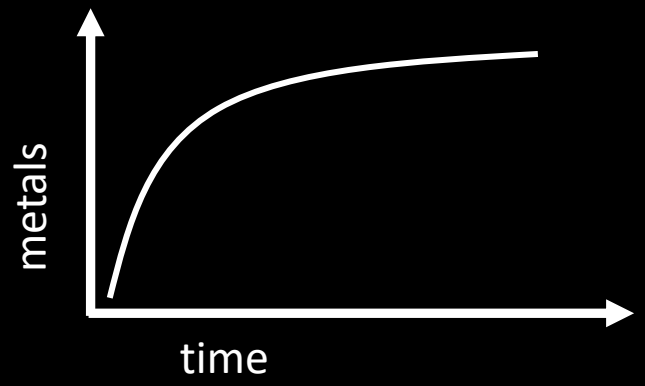
Characterizing the Milky Way disk using age-metallicity distributions of GALAH

Metallicity traces chemical enrichment/star formation

How does this map onto an absolute timescale across the Milky Way?

Spectroscopy for 180,000 turn-off & subgiant stars

Elemental Abundances



within a galaxy

H, He (Li)

a long time ago

Metals

C

N

Mg

O

Ca

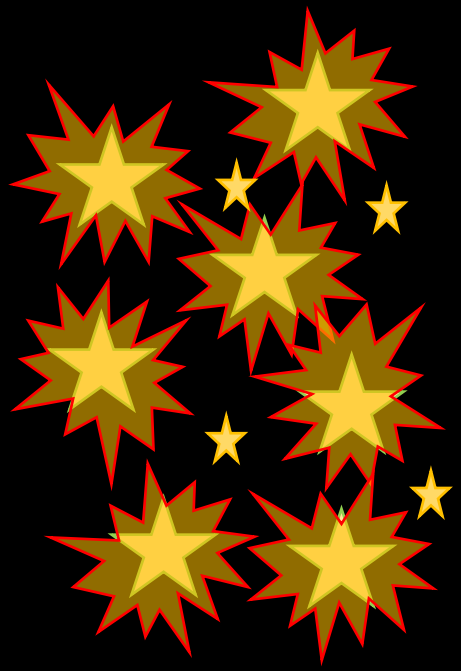
Si

Fe

first stars form

H, He, Li, C, N, O, Mg, Ca, Si … Fe

now gas has more elements



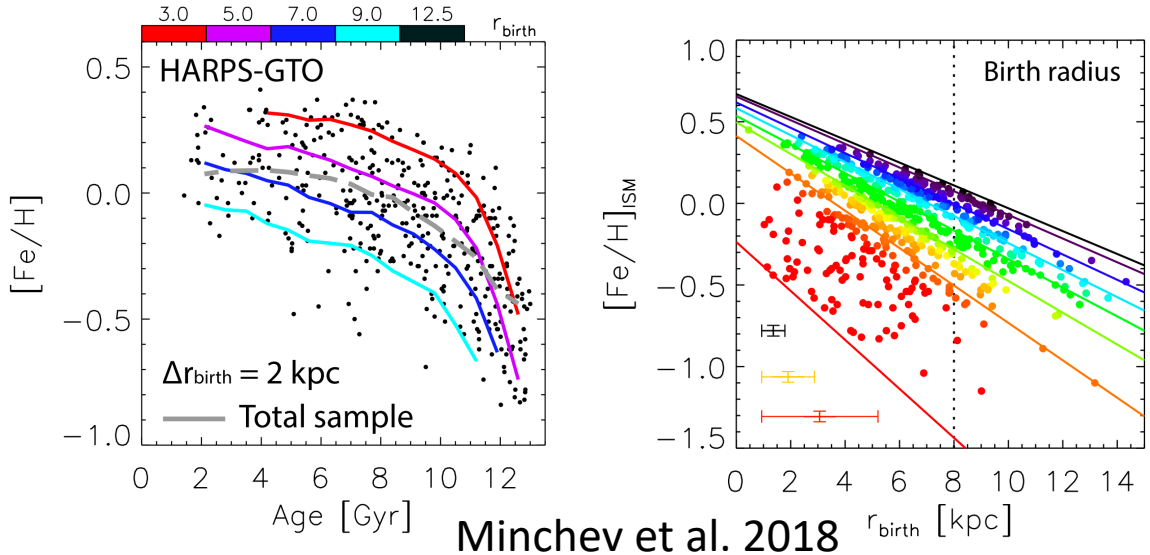
next generation of stars

H, He, Li, C+, N+, O+, Mg+, Ca+, Si+ … Fe+

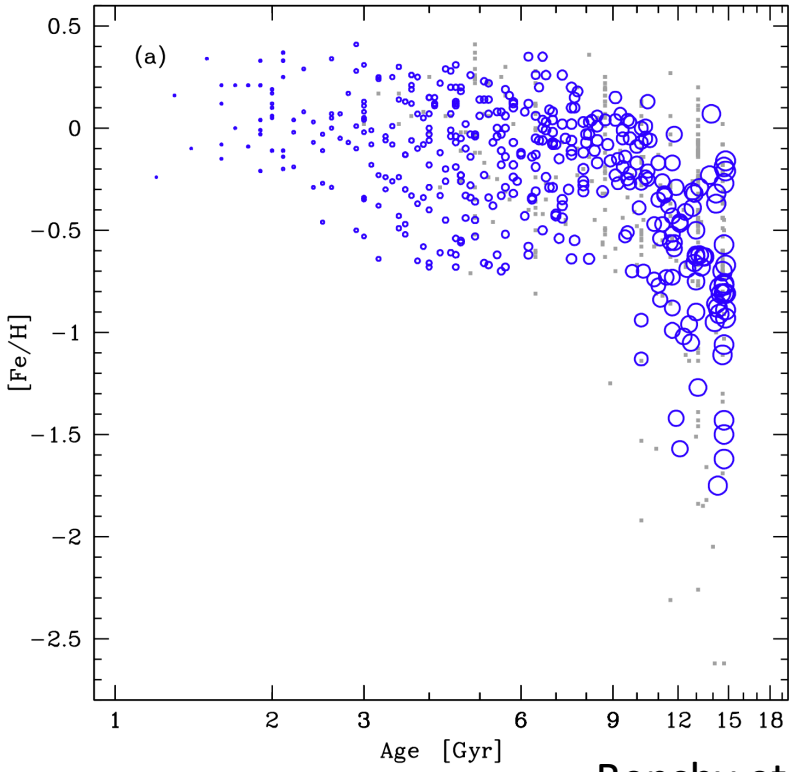
even more elements

Milky Way Age-Metallicity Relation

- Nearly flat with a large scatter in metallicity at all ages
  Edvardsson et al. 1993, Feltzing et al. 2001, Casagrande et al. 2011, Bensby et al. 2014, Bergemann et al. 2014 …
- Galaxy evolution theory predicts narrow tracks in age-metallicity space
- Evidence of radial migration



Minchev et al. 2018



Bensby et al. 2014

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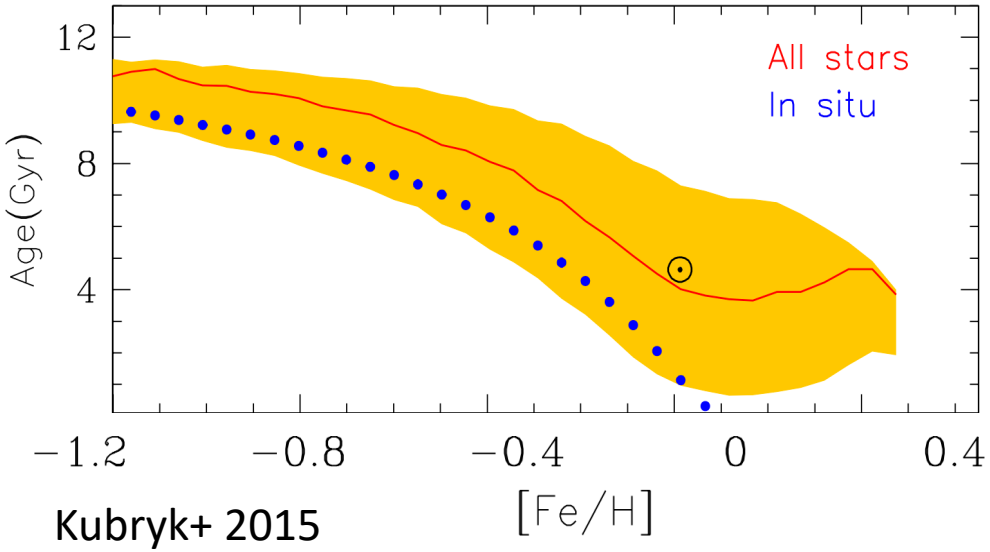
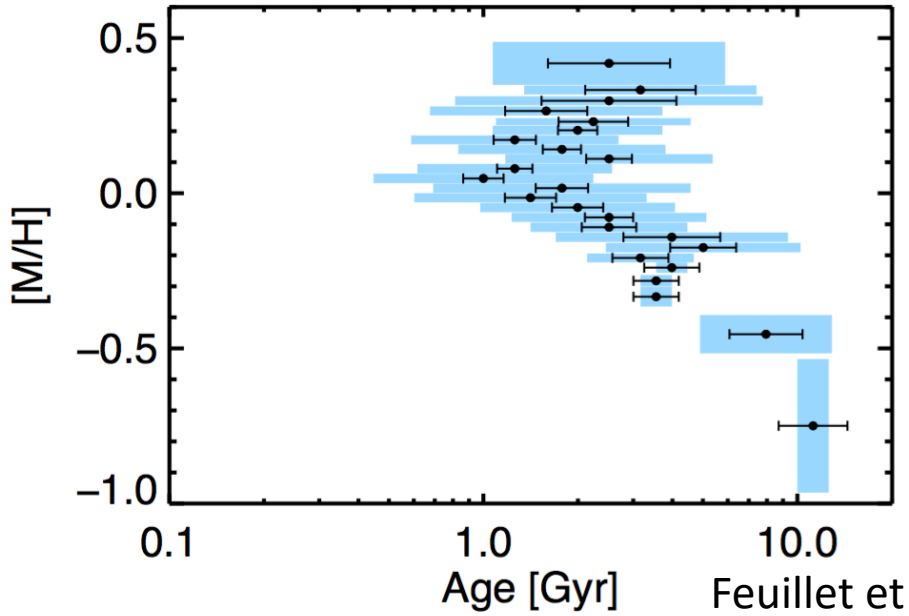


Kubryk+ 2015



Feuillet et al. 2018

Milky Way Age-Metallicity Relation

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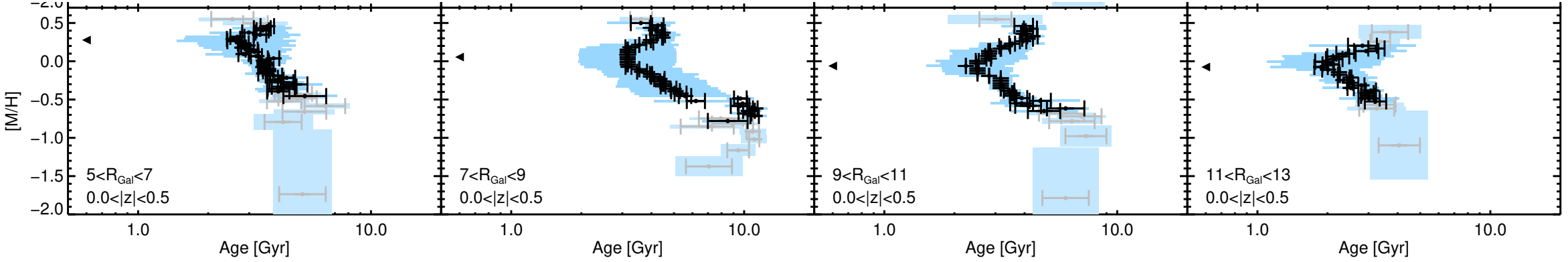
- Evidence of radial migration
- AMR changes across the disk

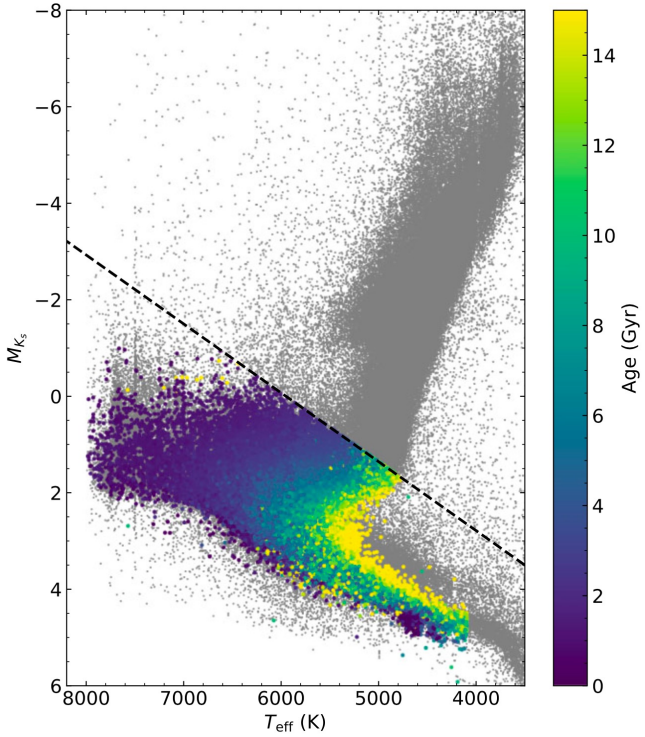


Feuillet et al. 2019

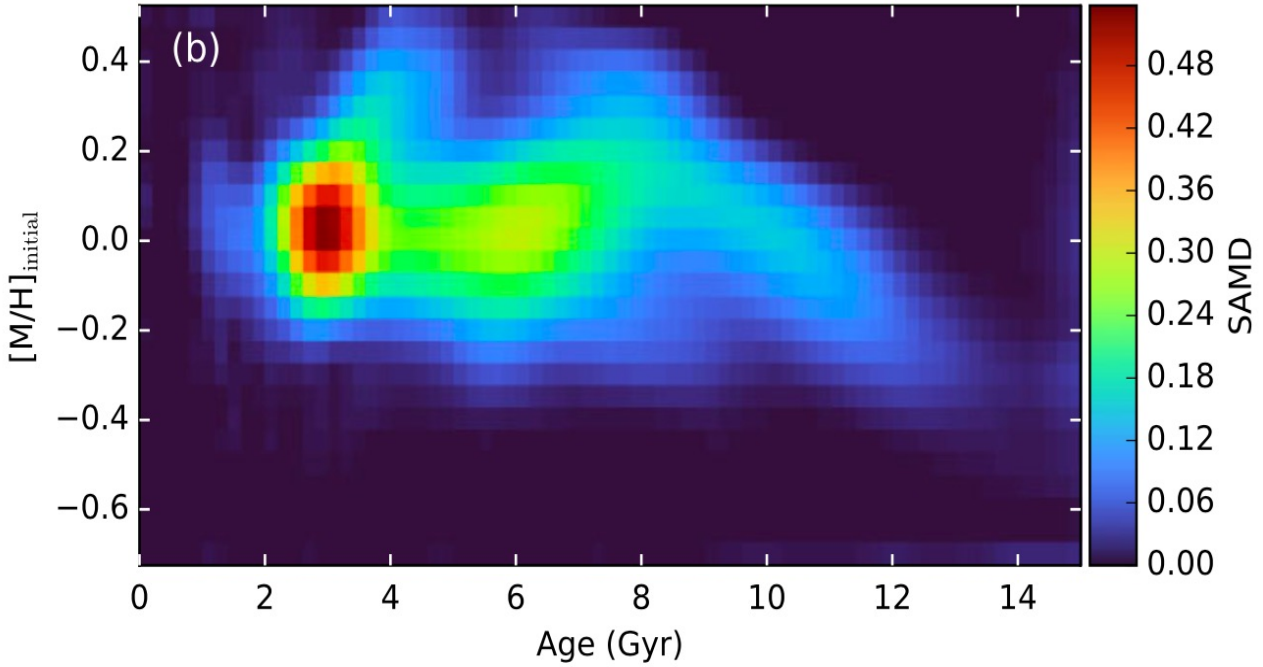
Milky Way Disk

- GALAH DR3 + Gaia EDR3
- Subgiant & dwarf stars
- Stellar model fitting
  Teff, [M/H], m_{Ks}, $\bar{\omega}$

~1 kpc sample



Sahlholdt, Feltzing & Feuillet 2022

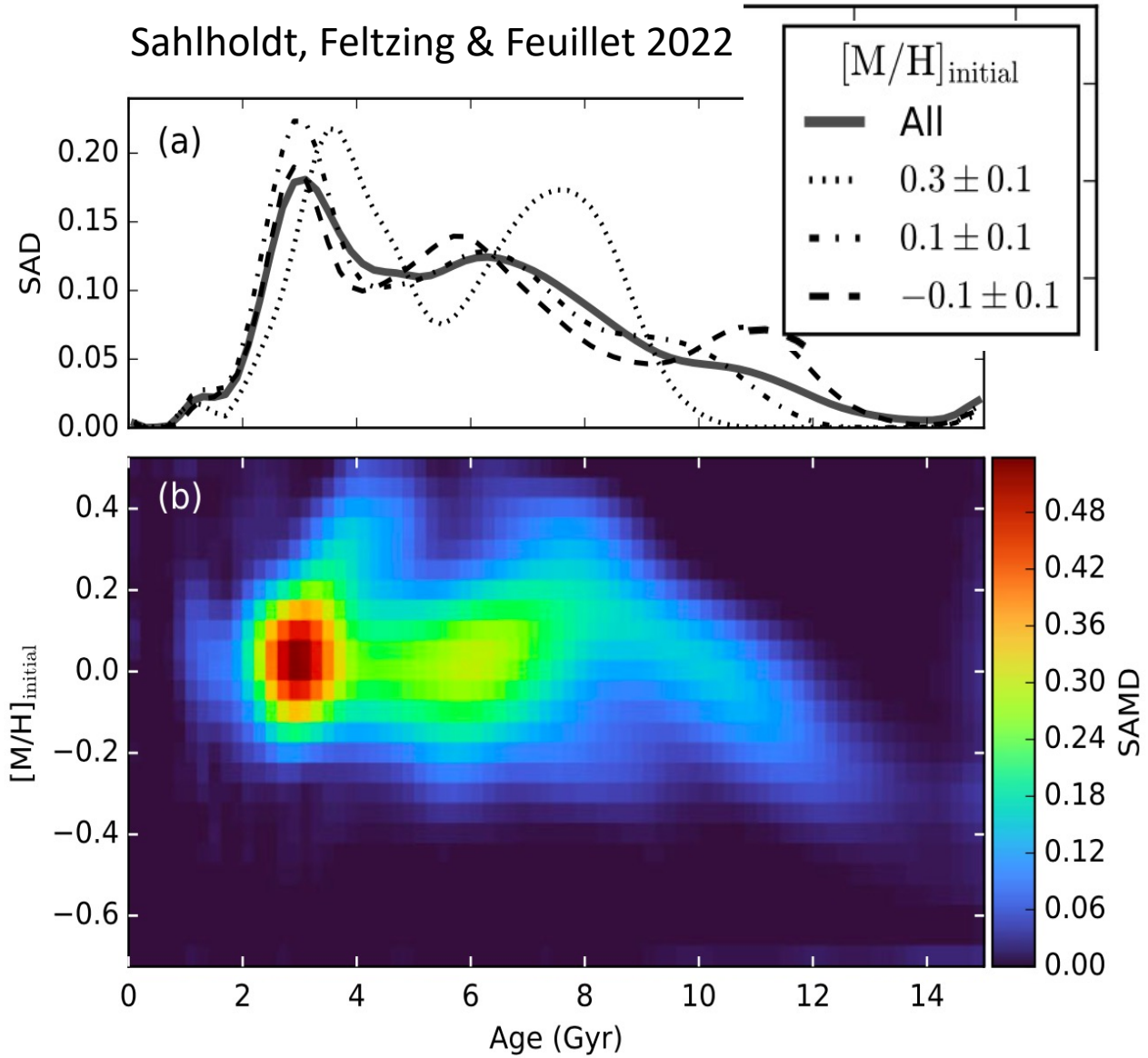


Sample Age-Metallicity Distribution (SAMD)

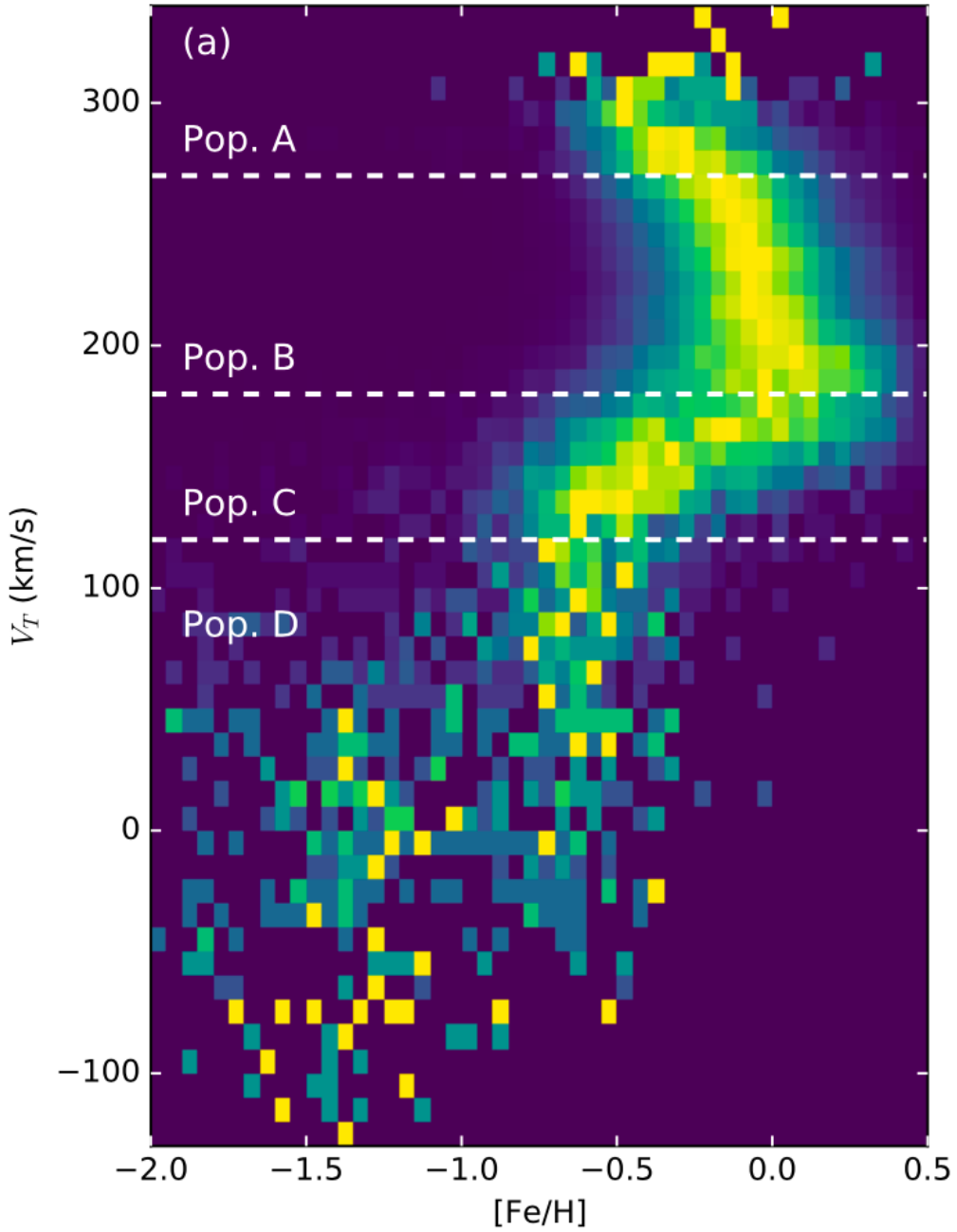
developed in Sahlholdt & Lindegren 2021

Milky Way Disk SAMD

Interesting features



- 2-4 Gyr peak enhanced by selection effects
- Also observed in studies using other tracers
  Mor et al. (2019), Isern (2019)
- Local minima ~5 Gyr, ~10 Gyr
- Other features caused by specific populations



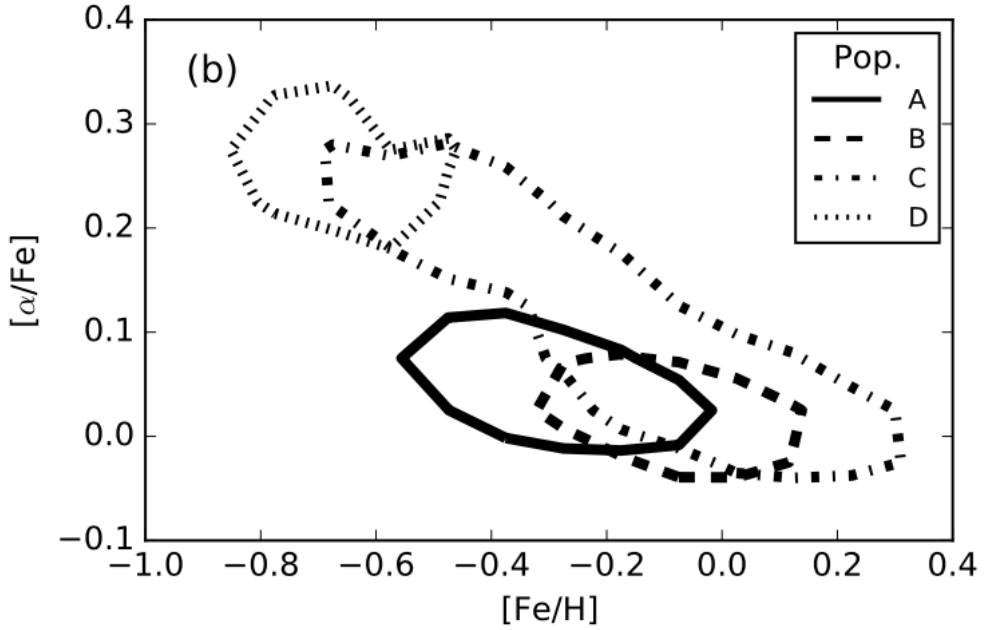
Row-normalized

“thin” disk

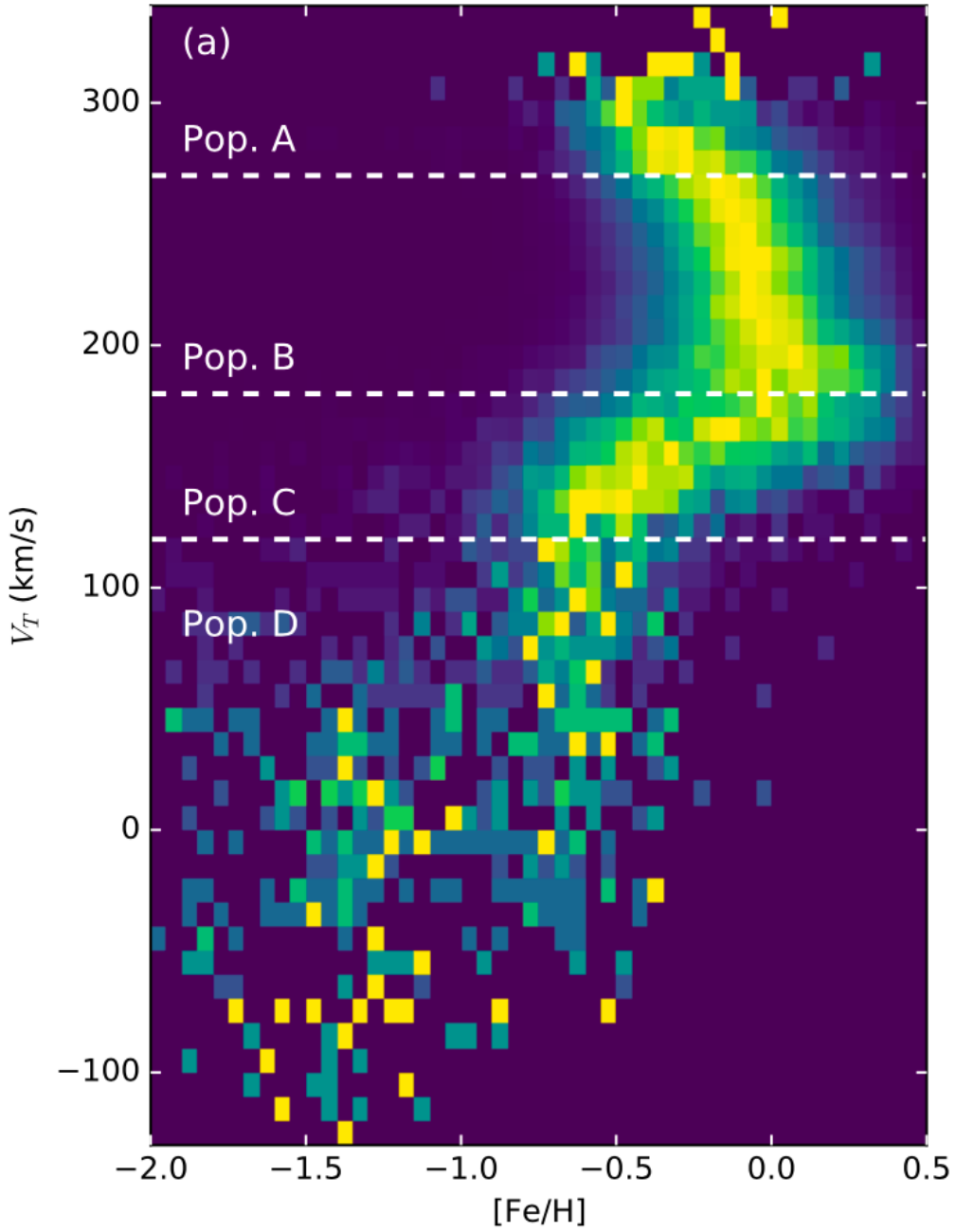
“thick” disk

halo

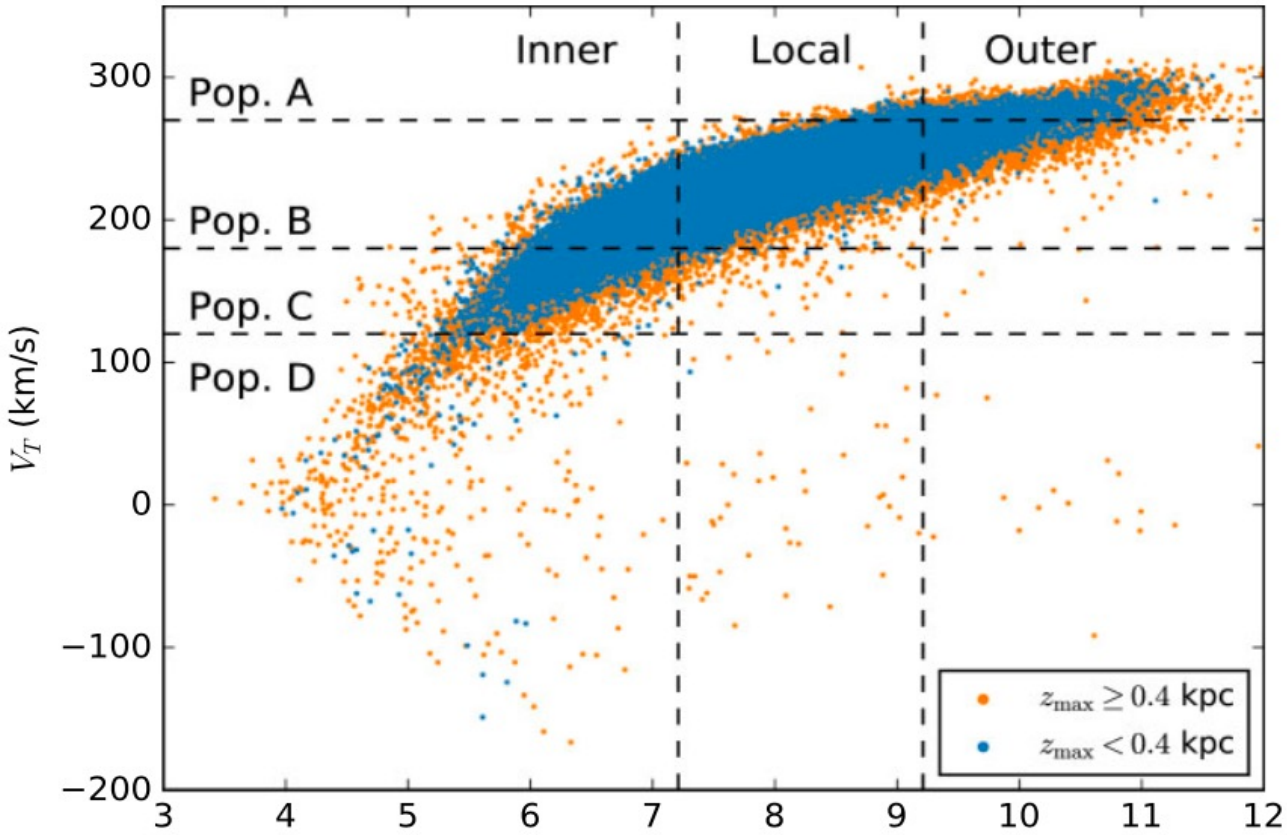
azimuthal component of galactocentric velocity in cylindrical coordinates



Sahlholdt, Feltzing & Feuillet 2022

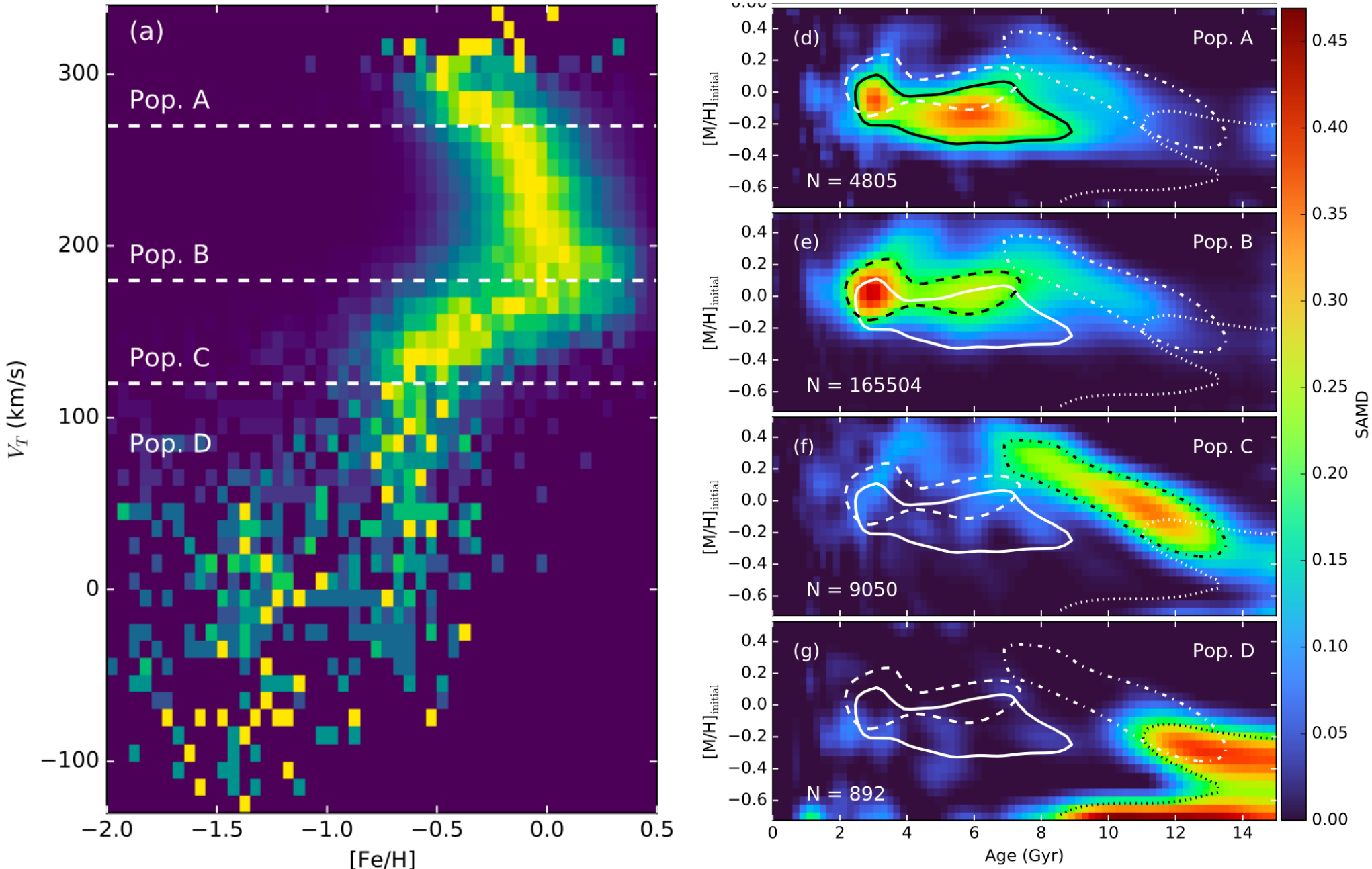


Sample is currently
within ~1 kpc



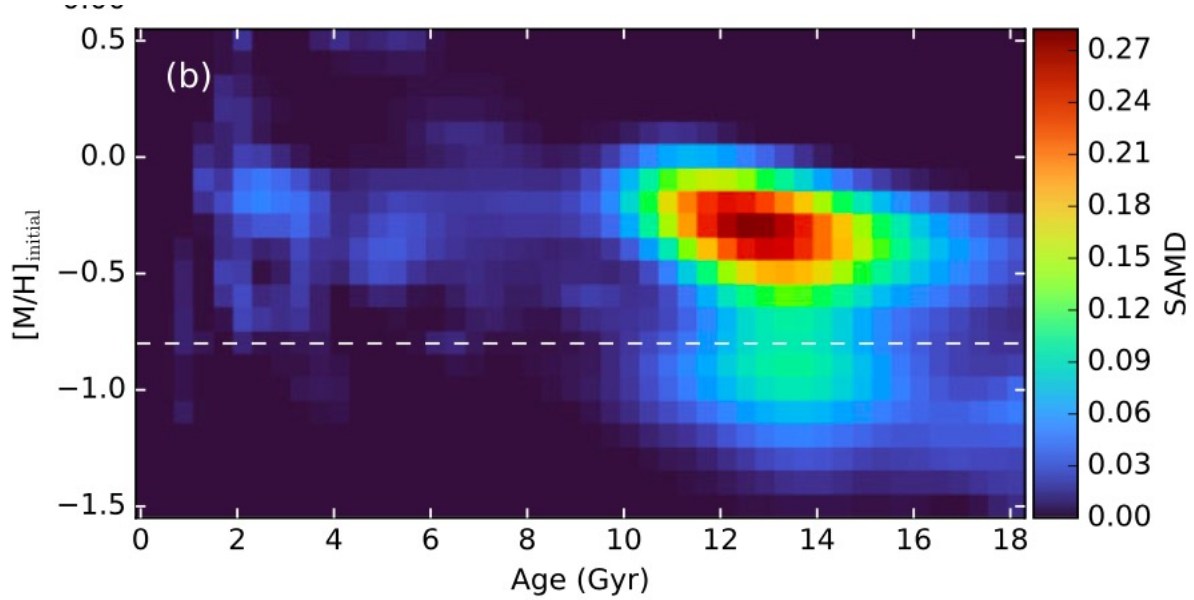
R mean (kpc)

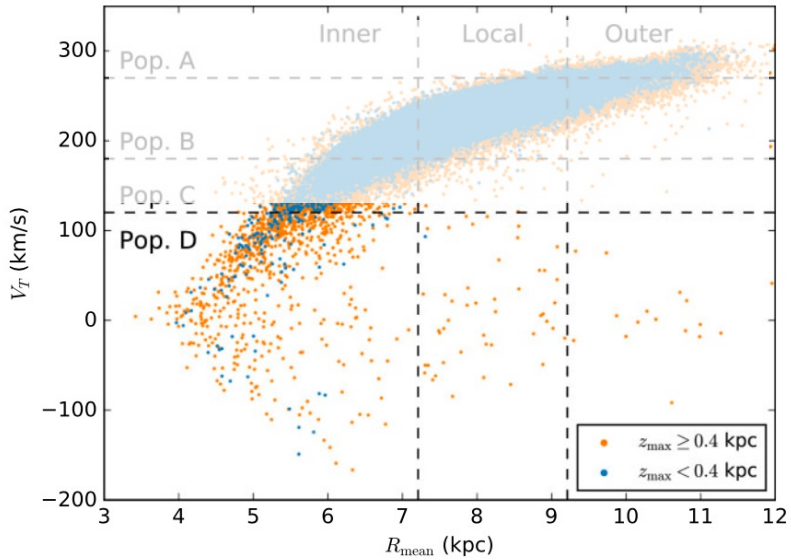
Sahlholdt, Feltzing & Feuillet 2022

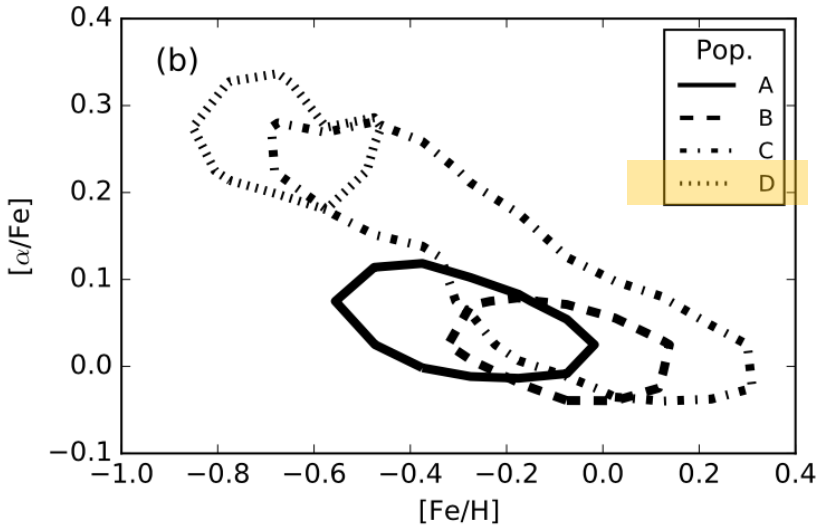


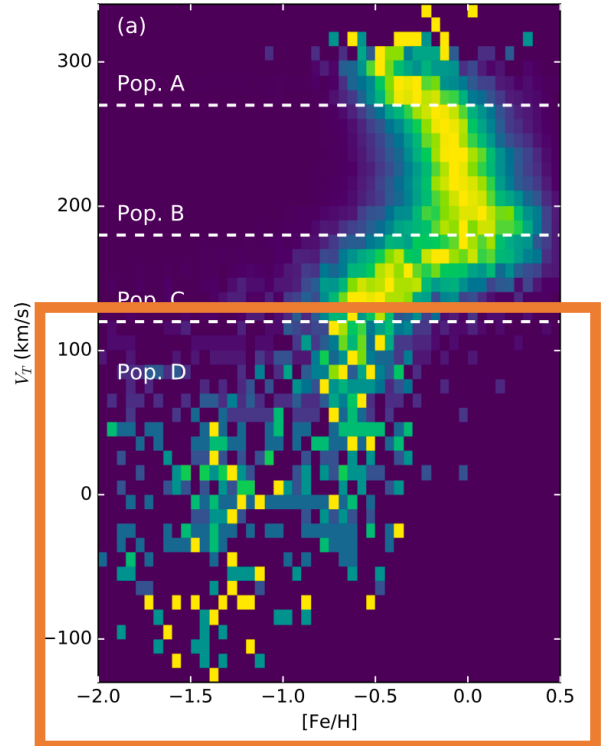
Sahlholdt, Feltzing & Feuillet 2022

Pop D









Sahlholdt, Feltzing & Feuillet 2022

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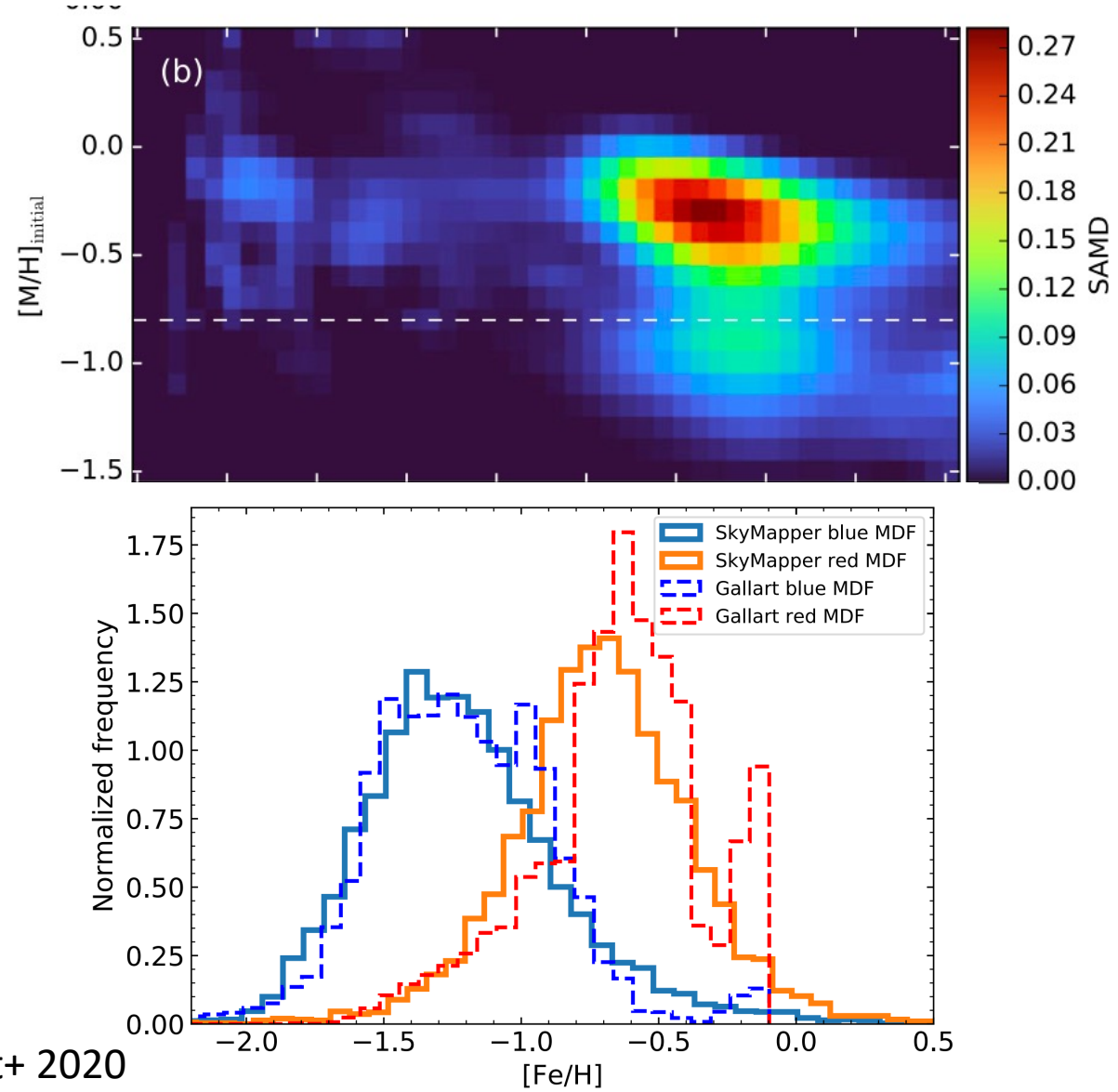
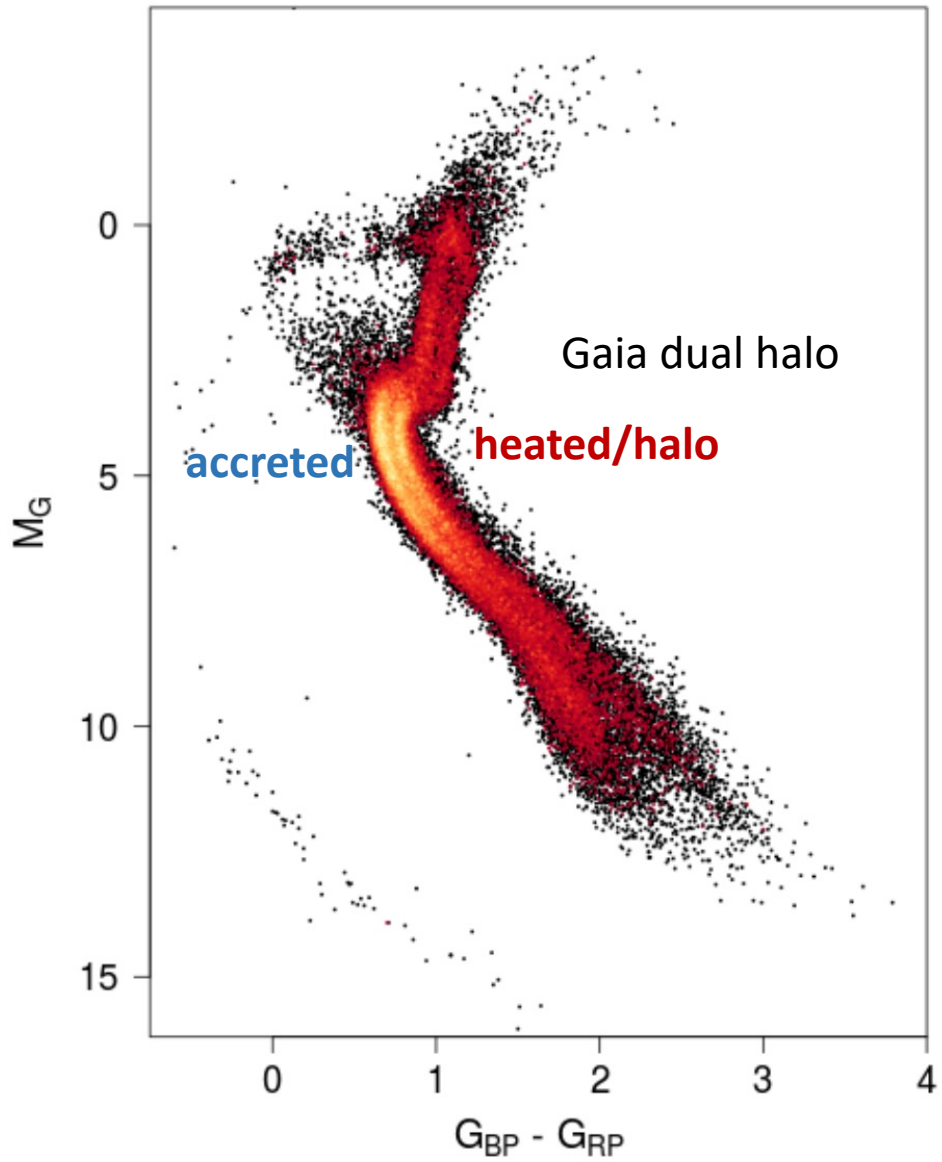
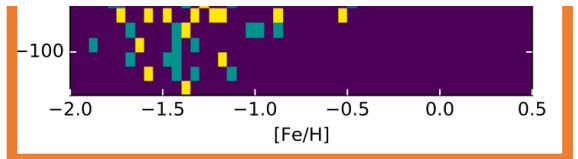


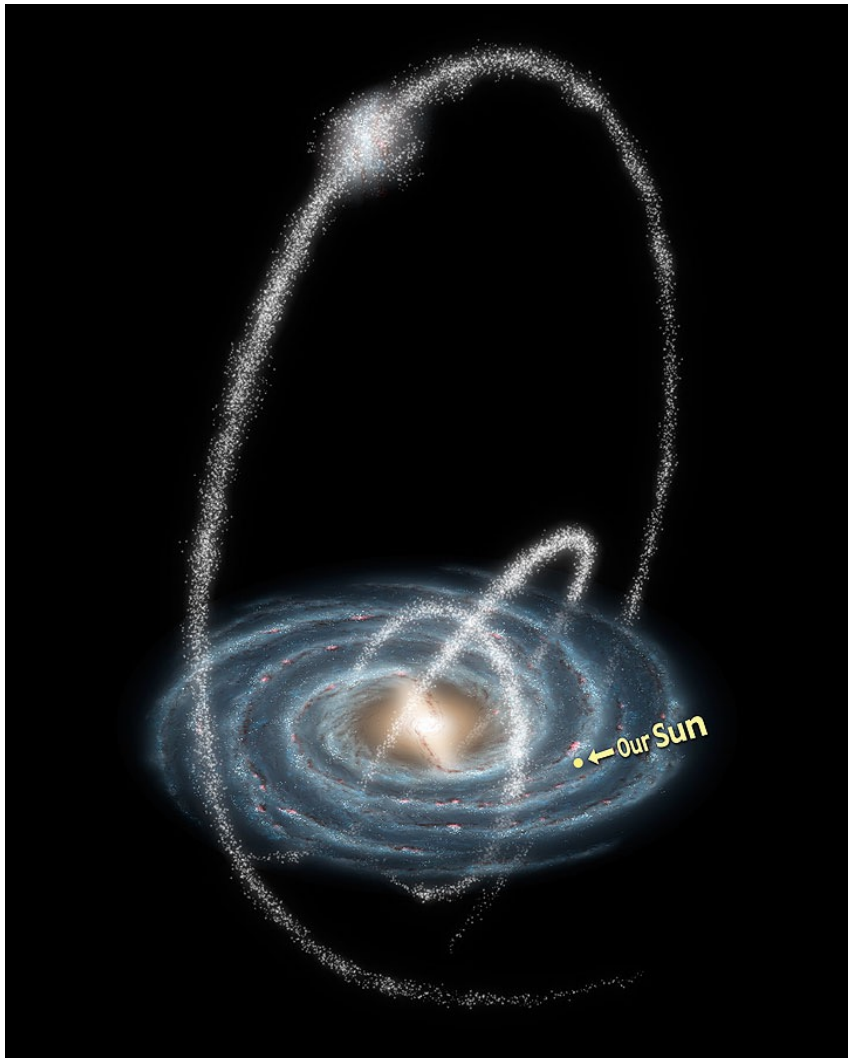
Sahlholdt+ 2020

Gaia, Babusiaux, + 2018





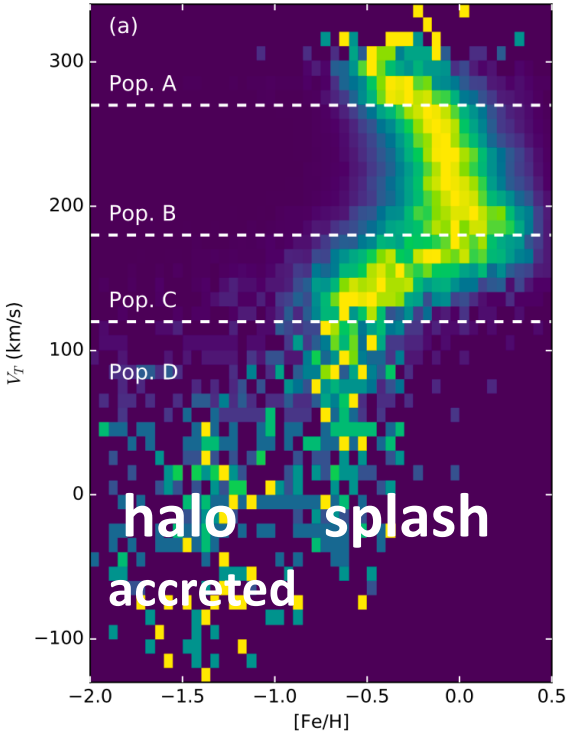
Pop D

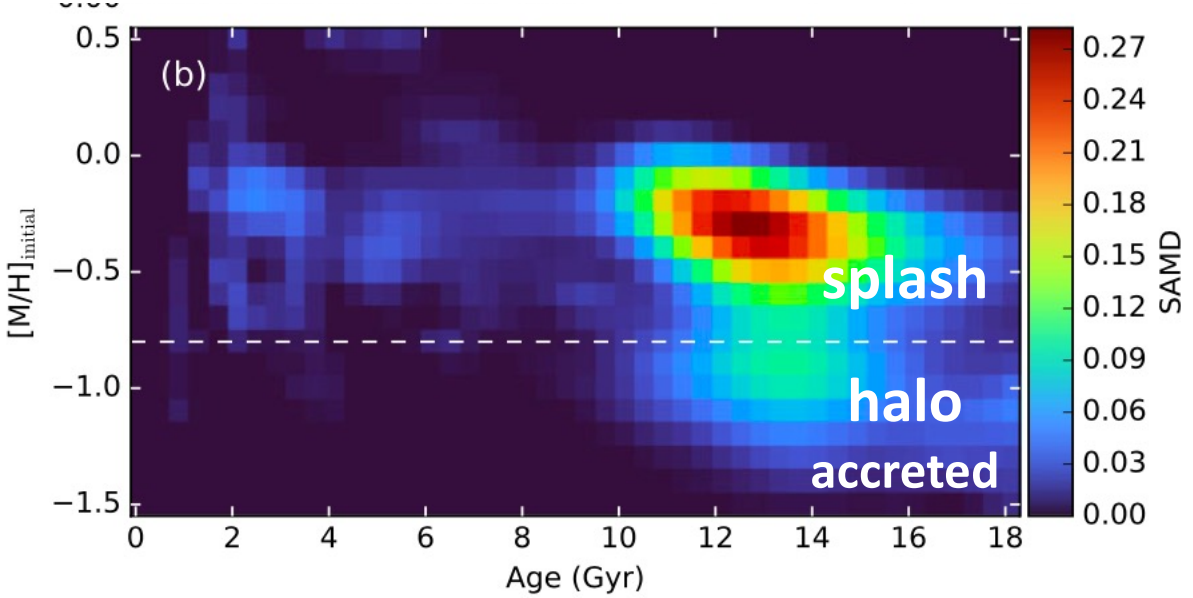


Artist's impression of the accretion of Sagittarius
NASA/JPL-Caltech/R. Hurt (SSC/Caltech)

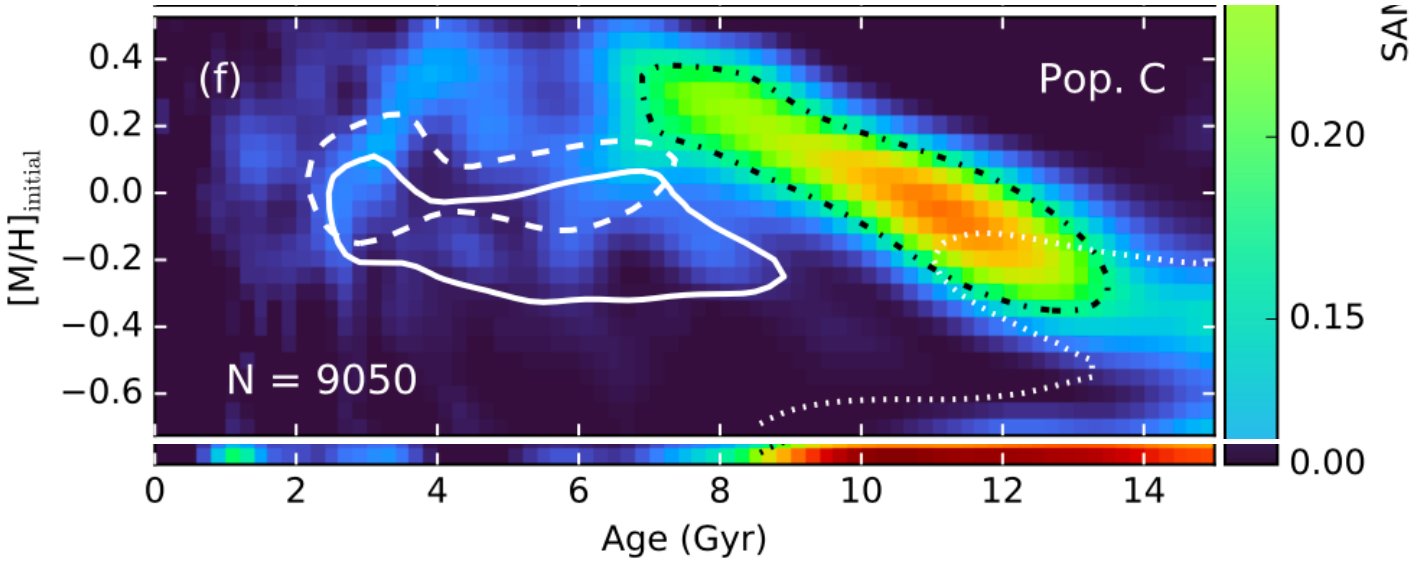
Gaia-Sausage-Enceladus
Sequoia
Thamnos
Kraken
…

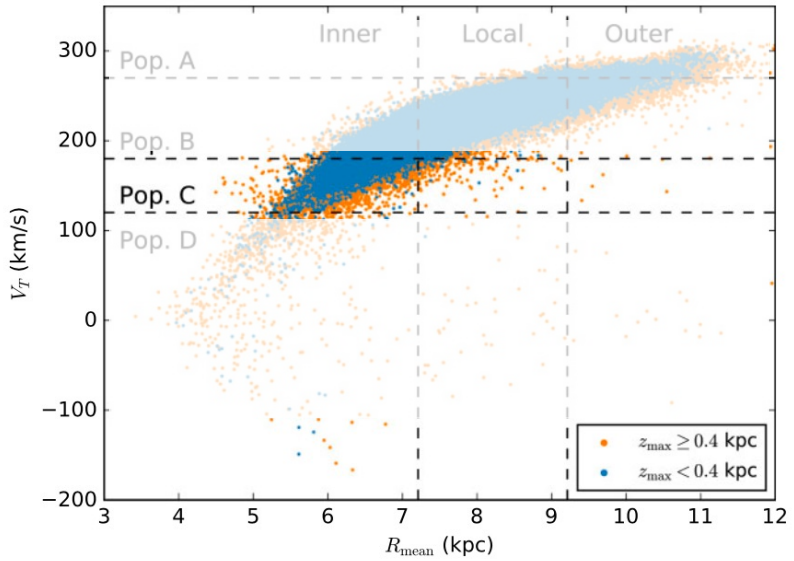
Heated existing disk
"Splash"

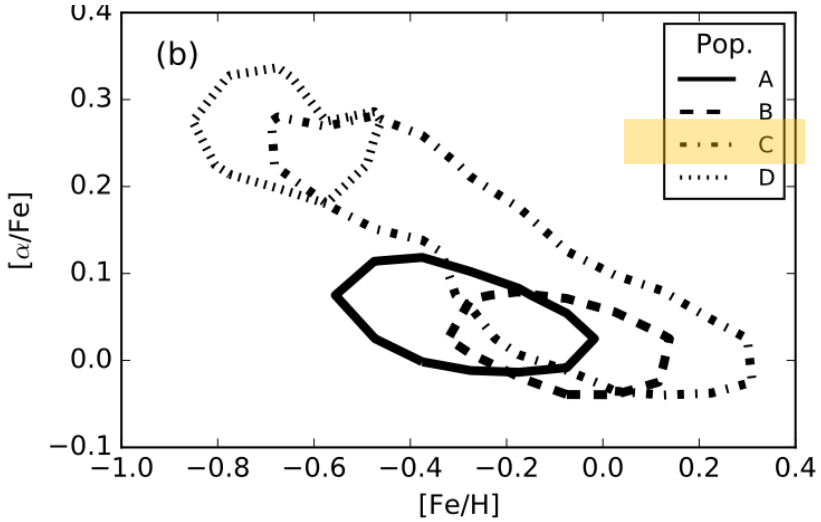


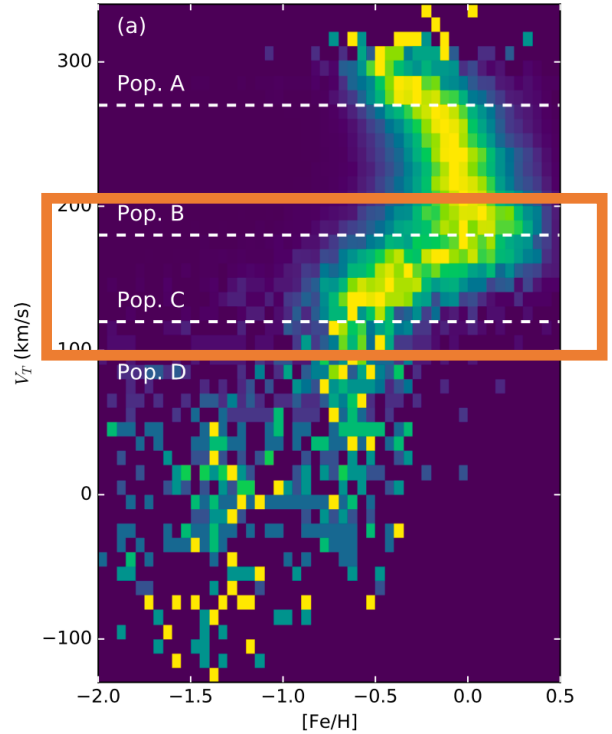


Pop C









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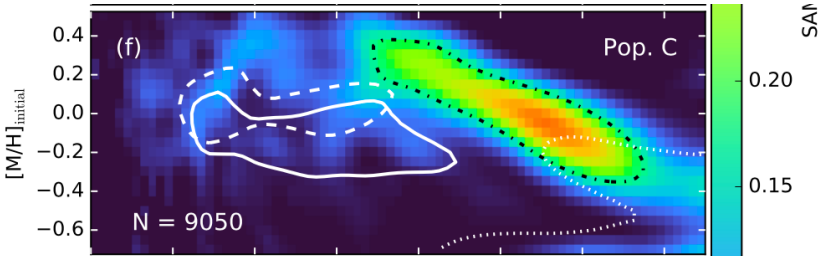
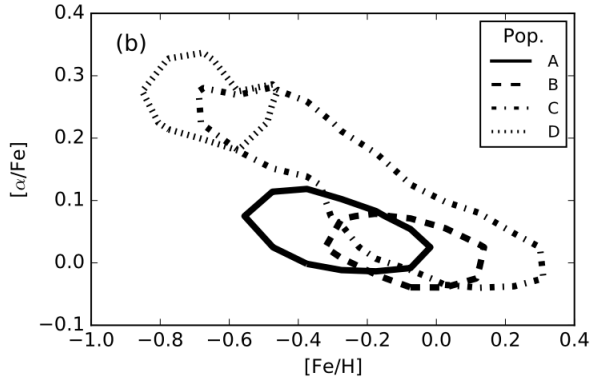
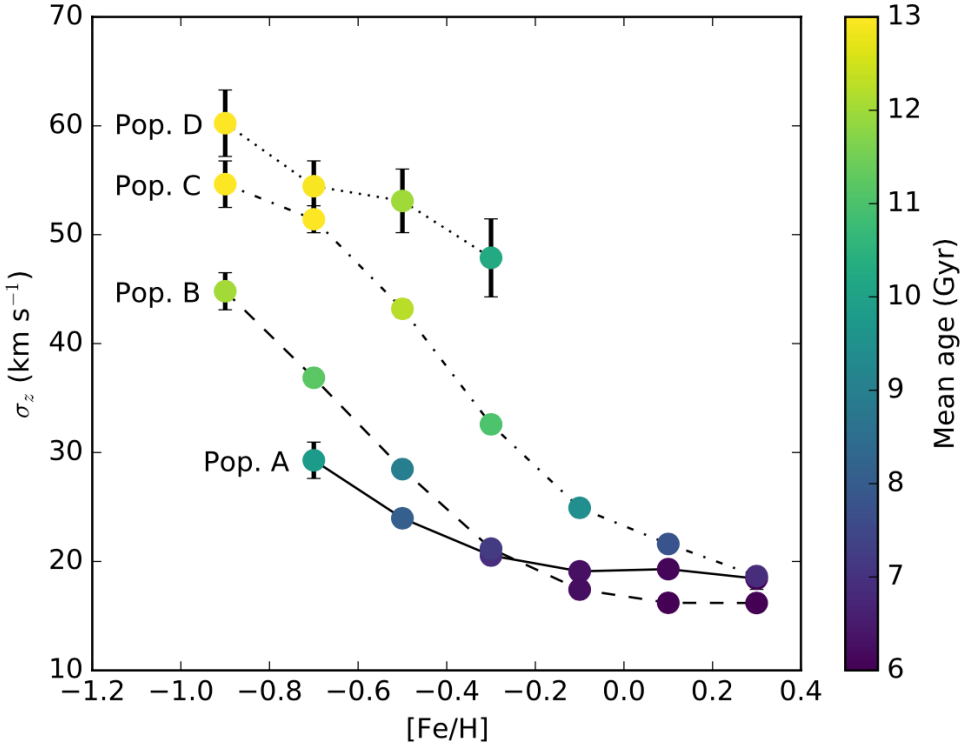
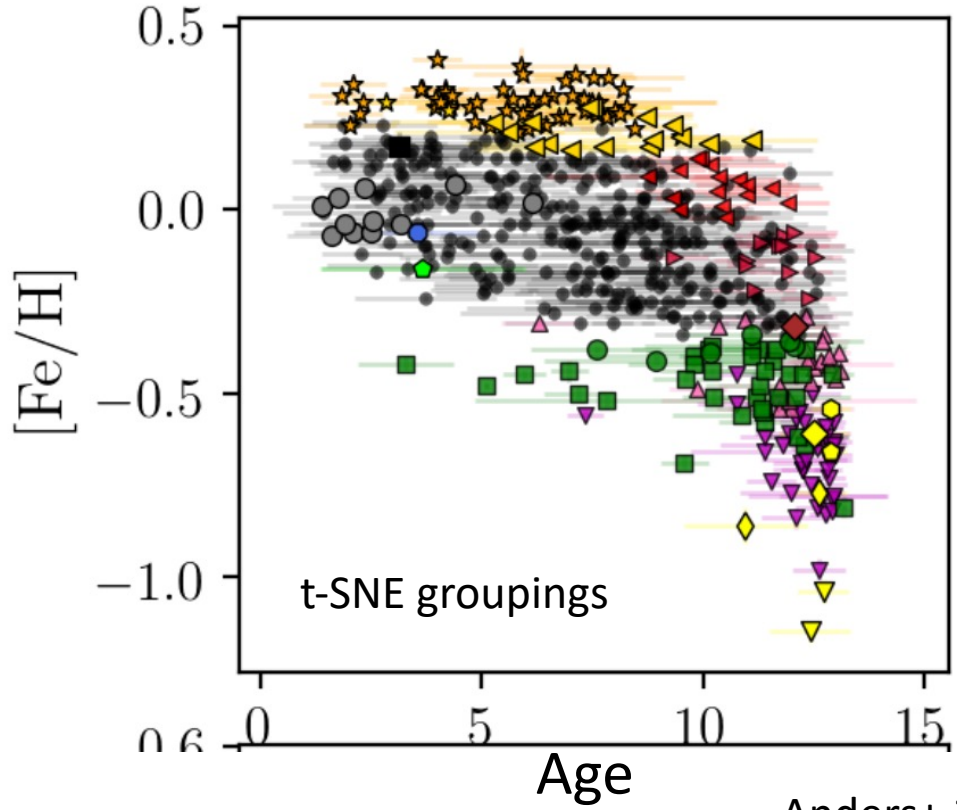
Pop C





Thick disk – Inner disk transition?





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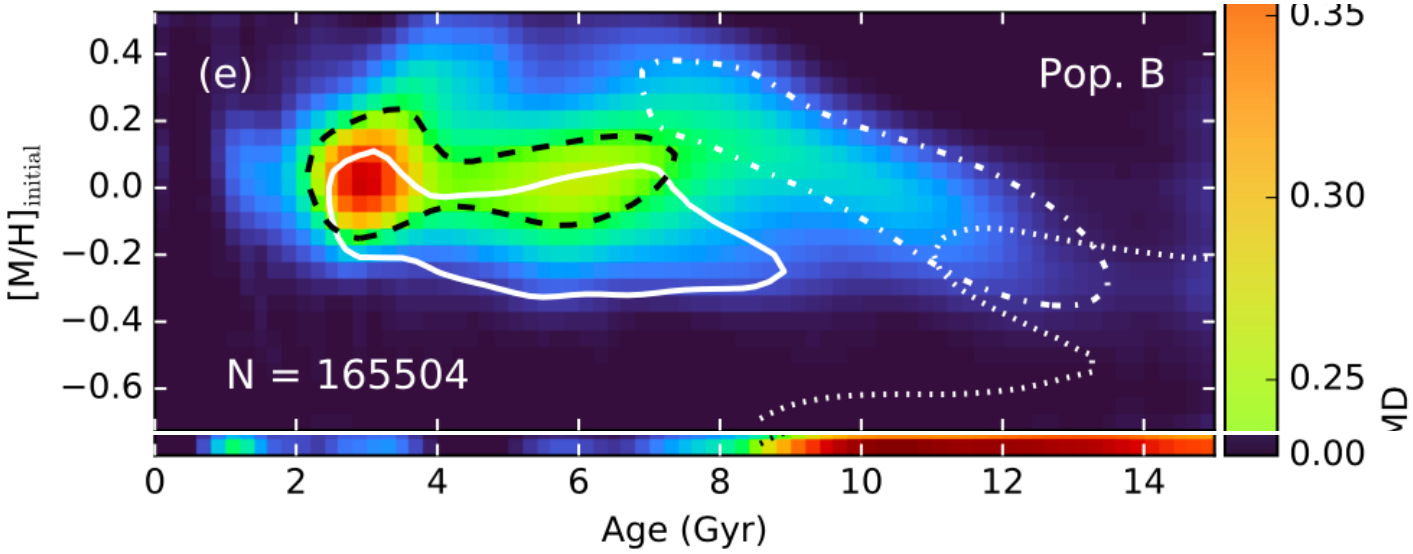
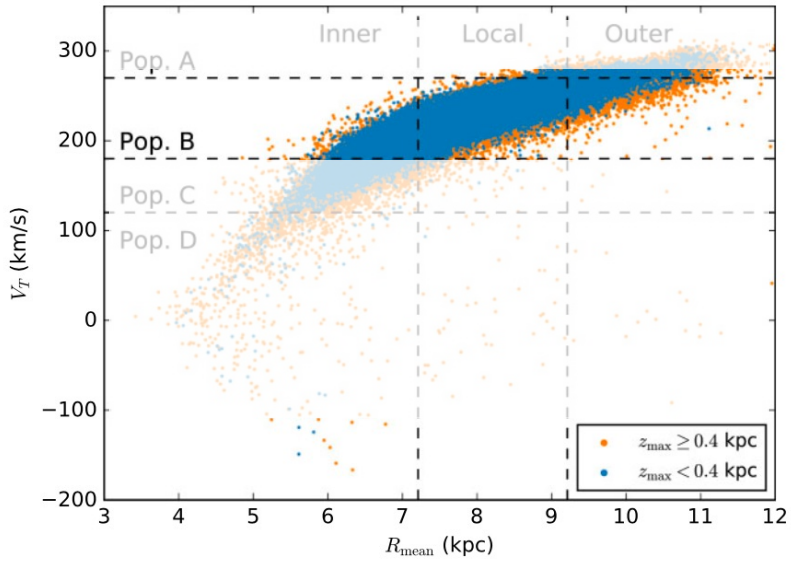
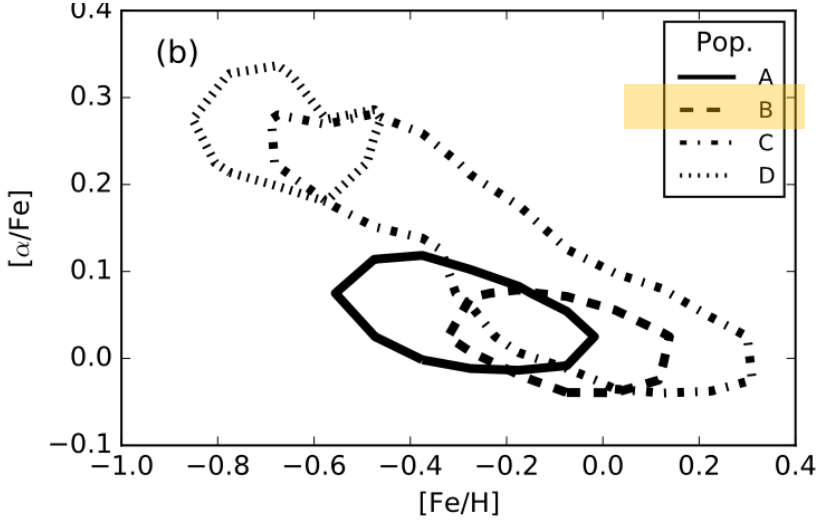
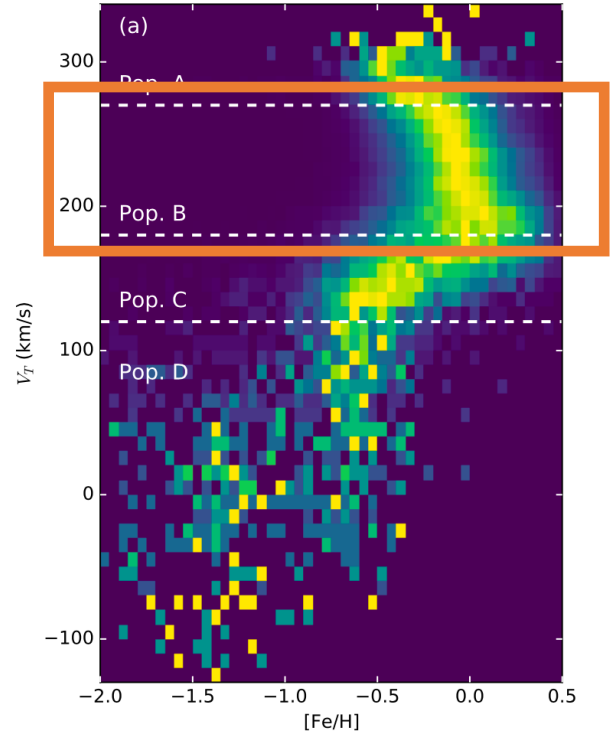
Anders+ 2018

Pop B









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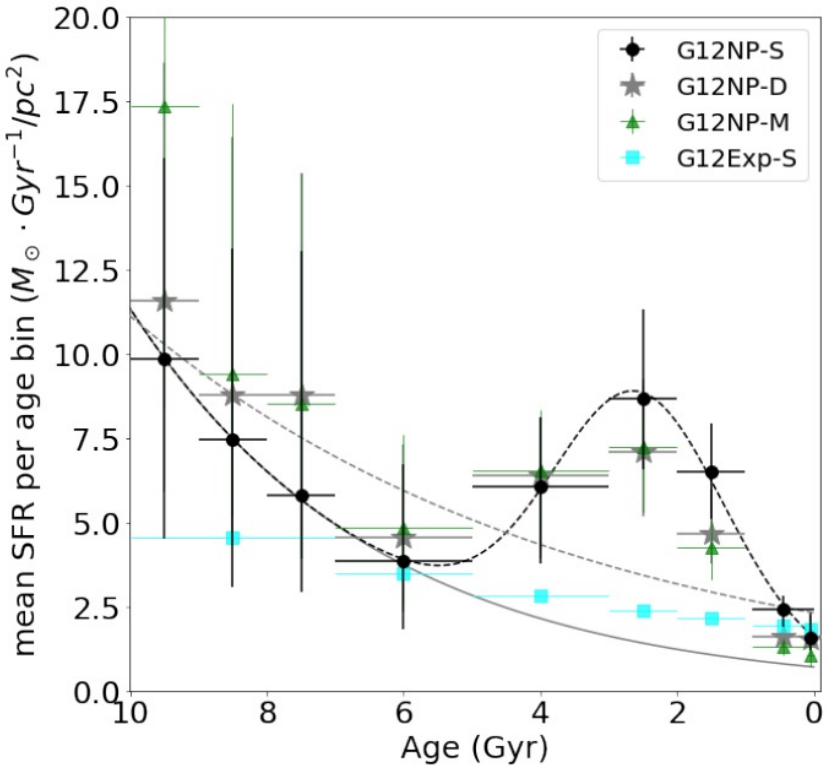
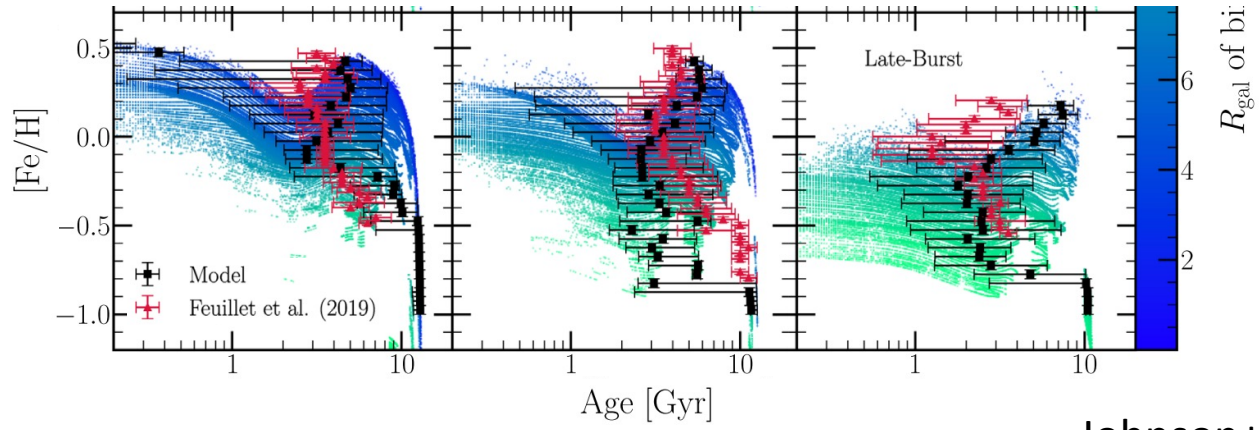
Recent Burst of Star Formation

Gaia DR2 CMD fitting

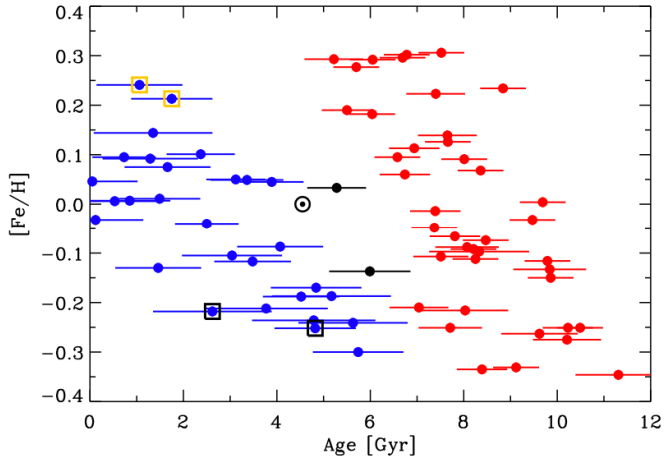


Mor+ 2019

Galactic chemical evolution model

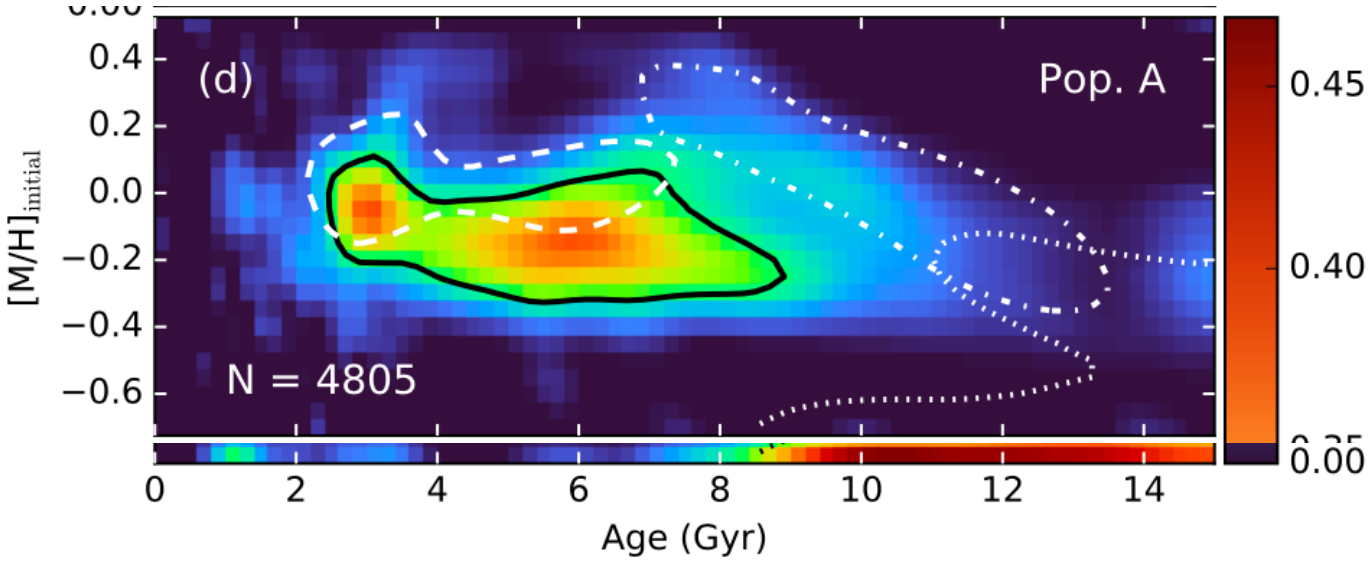


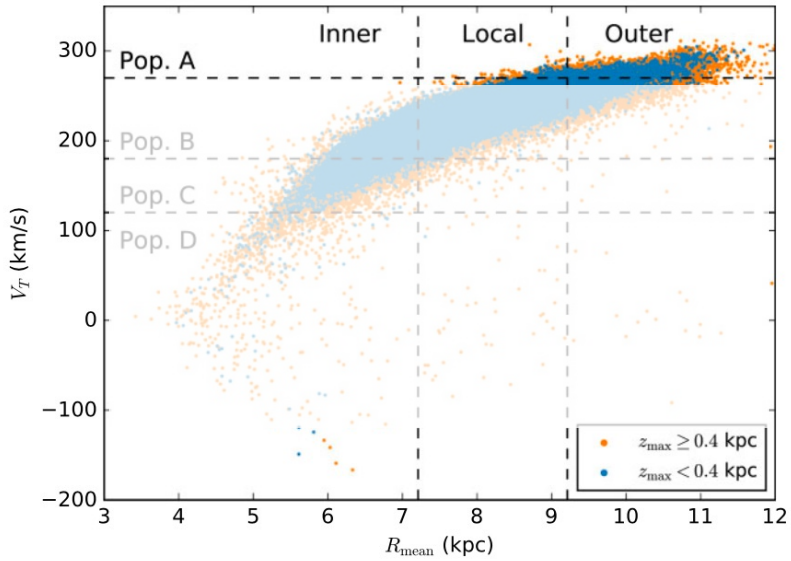
Johnson+ 2021

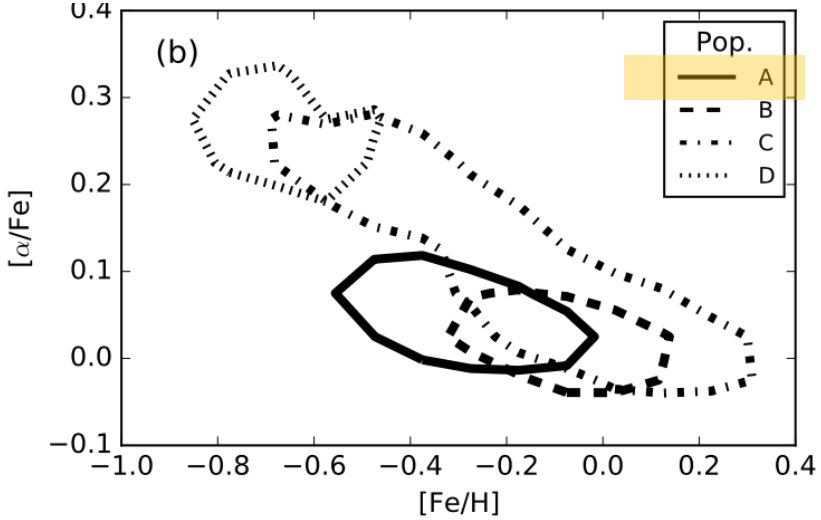


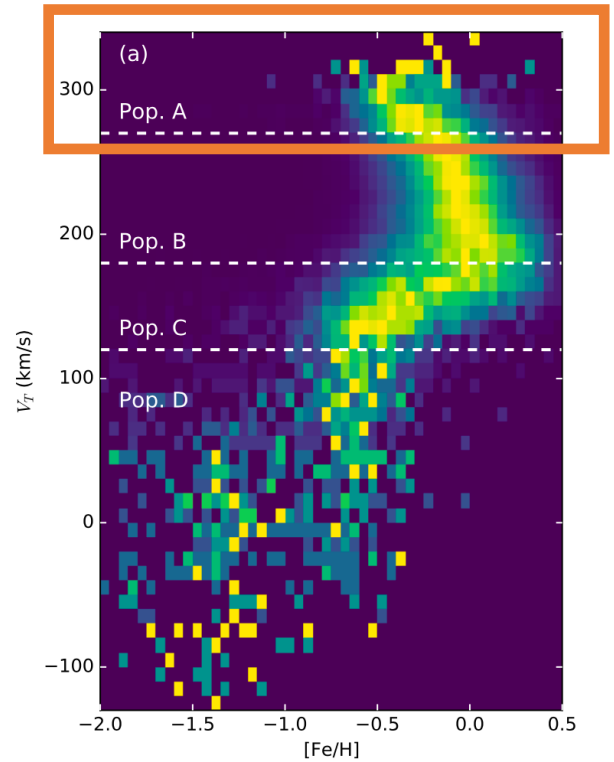
Nissen+ 2020

Pop A









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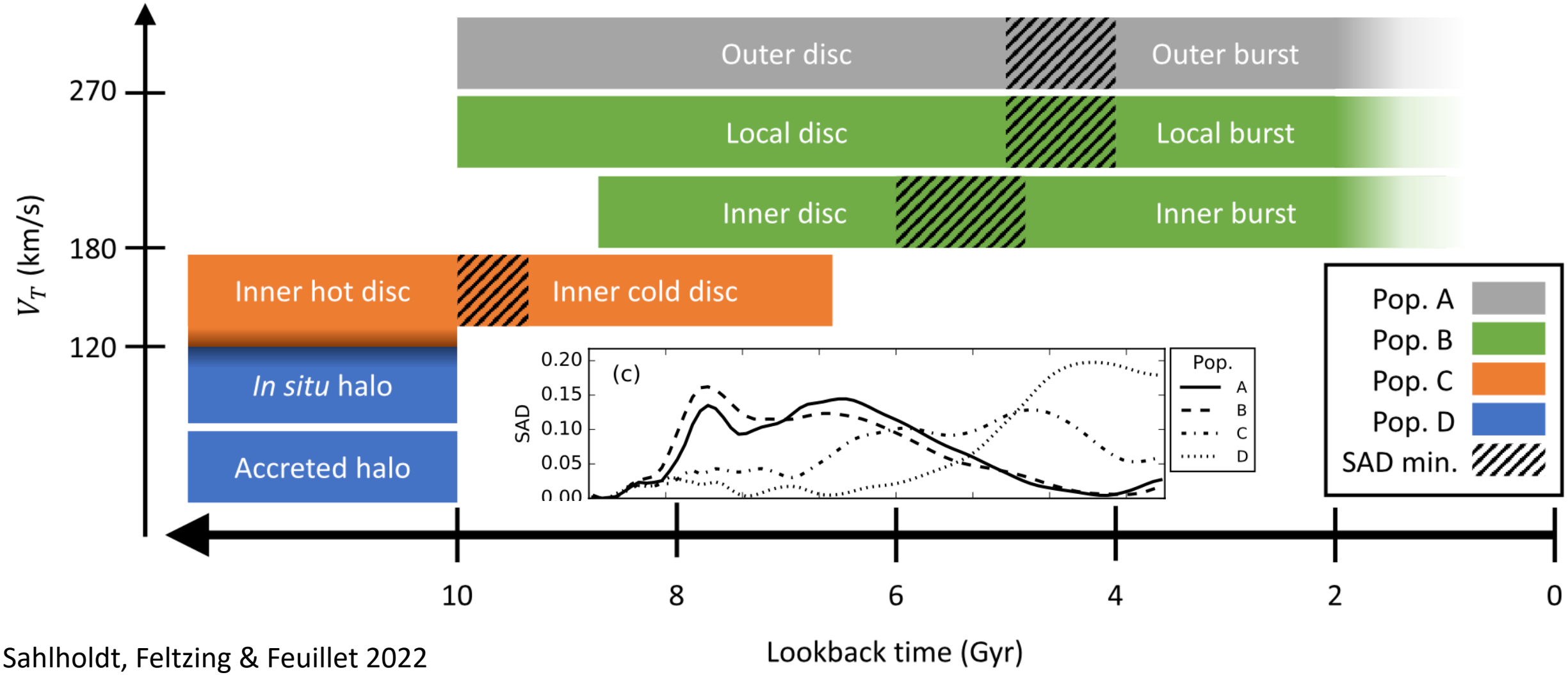
Cataloging Local Sample Components



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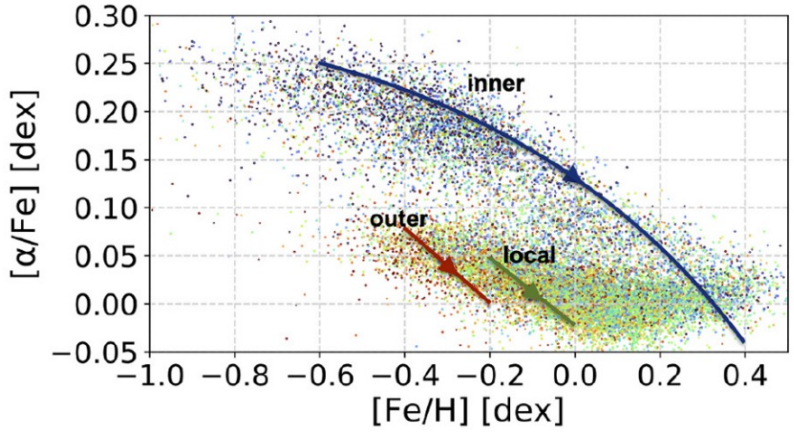
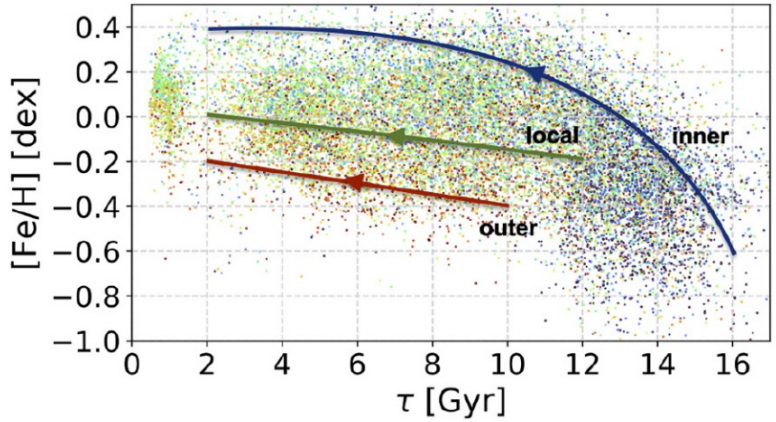
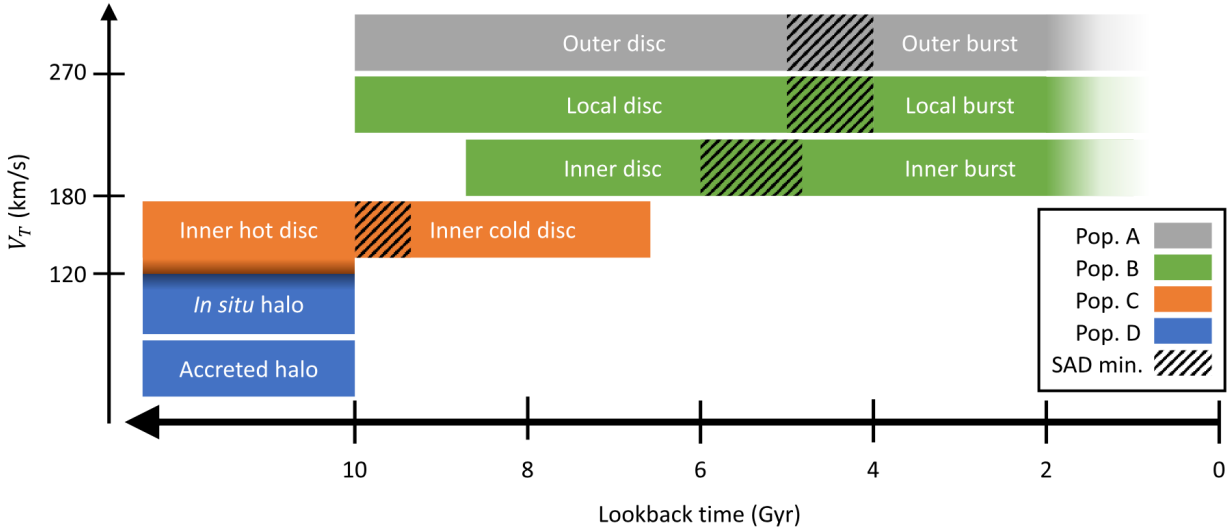


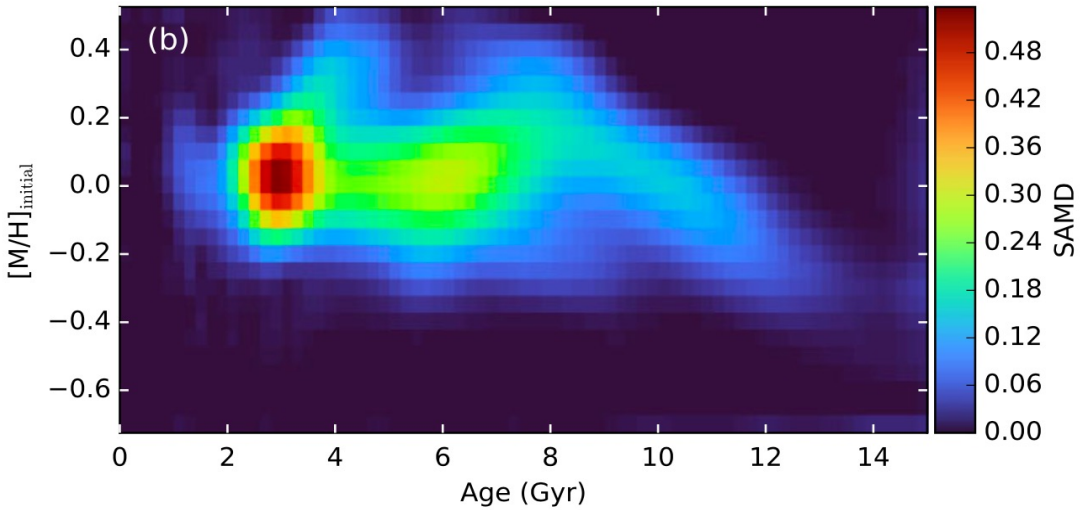


Ciuca+ 2021



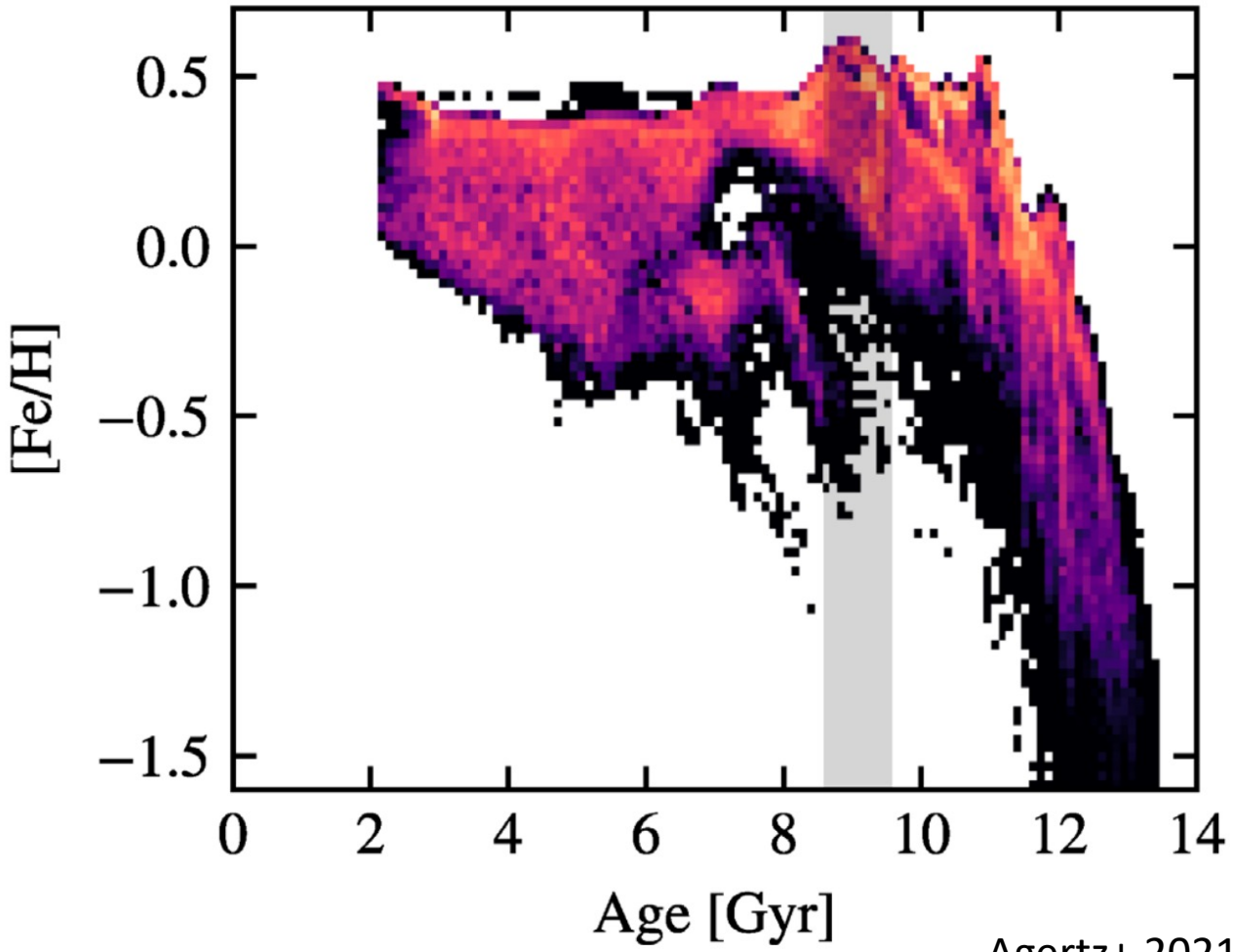
Sahlholdt, Feltzing & Feuillet 2022

GALAH SAMD



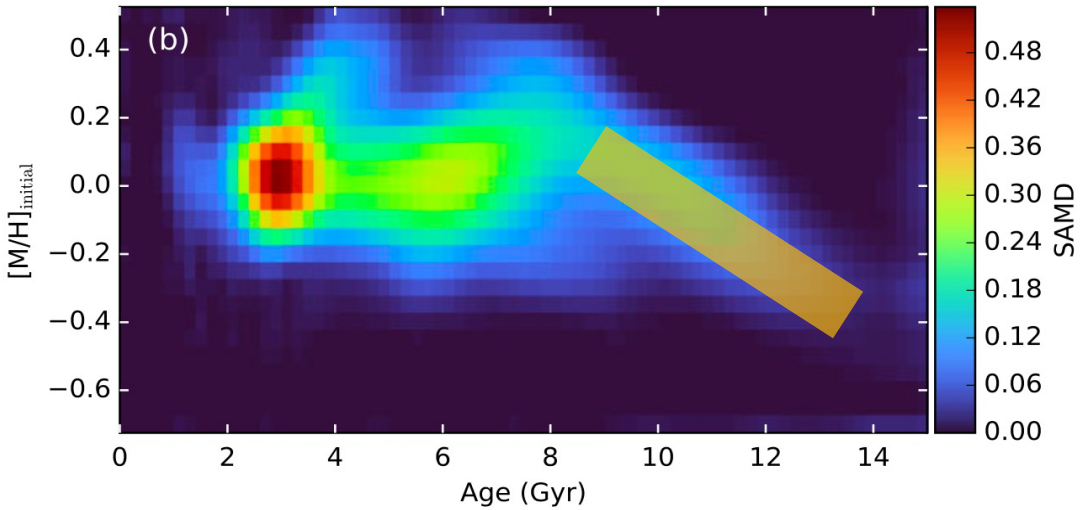
Sahlholdt, Feltzing & Feuillet 2022

Vintergatan Simulations



Agertz+ 2021

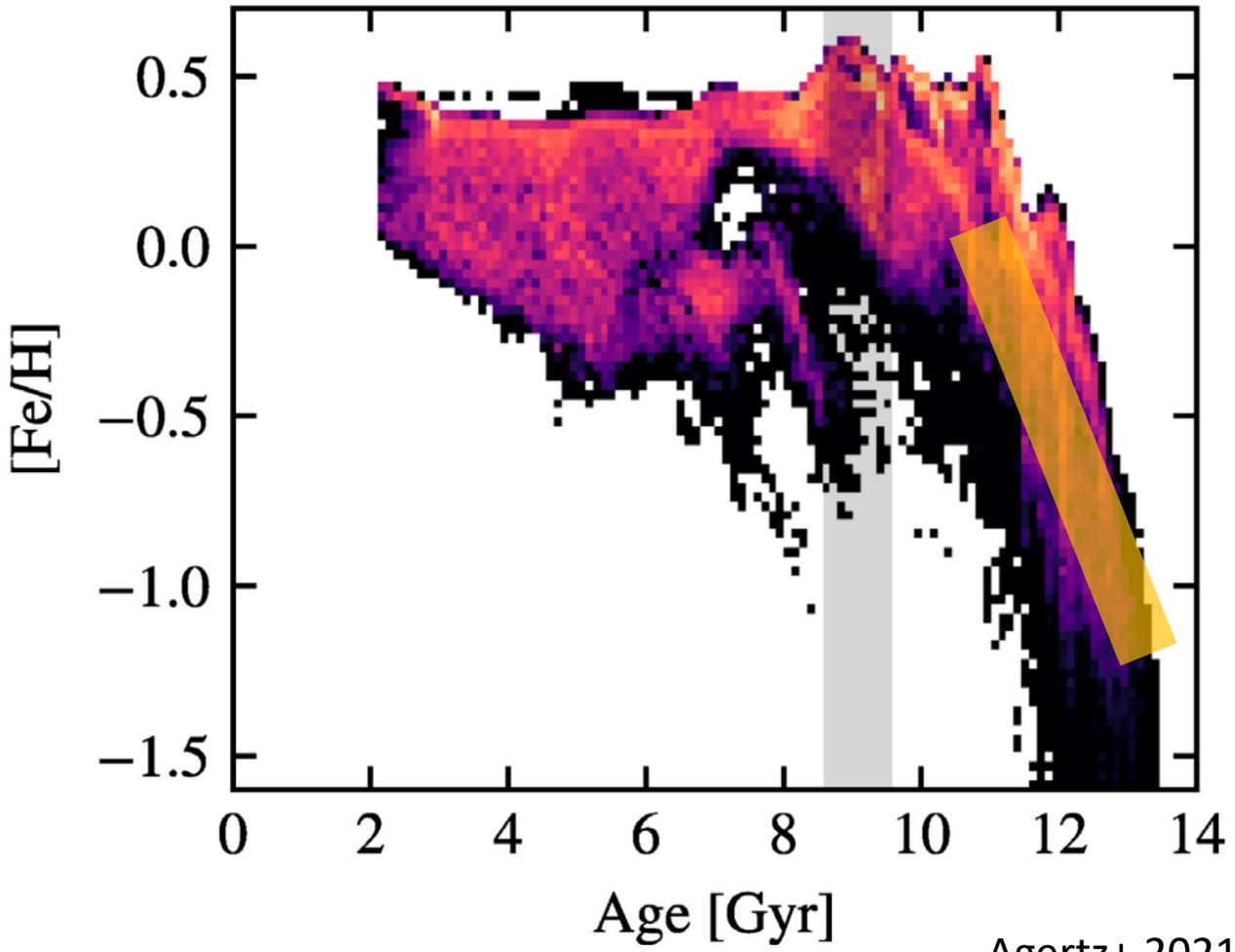
GALAH SAMD



Early star formation in the inner disk

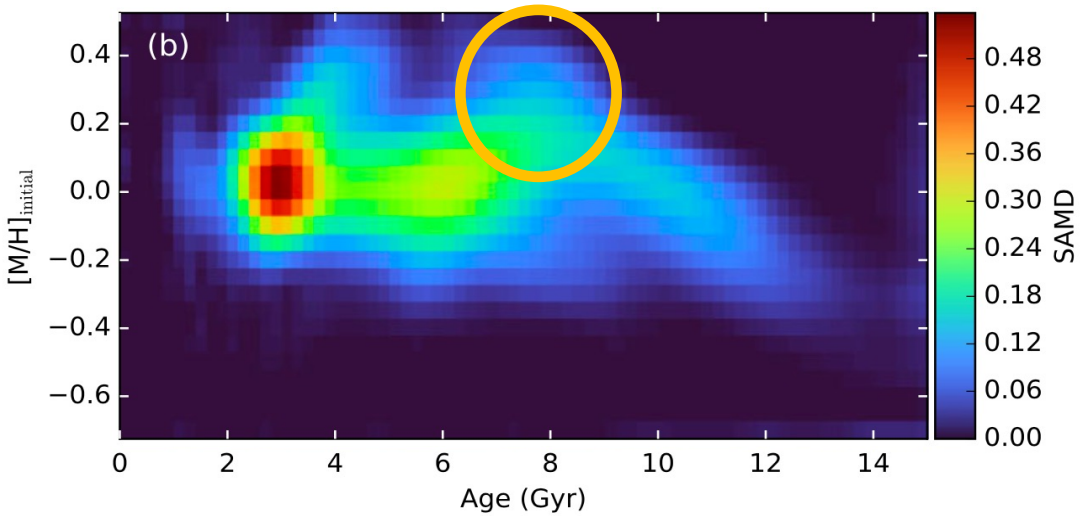
Sahlholdt, Feltzing & Feuillet 2022

Vintergatan Simulations



Agertz+ 2021

GALAH SAMD



Reaching high metallicity quickly

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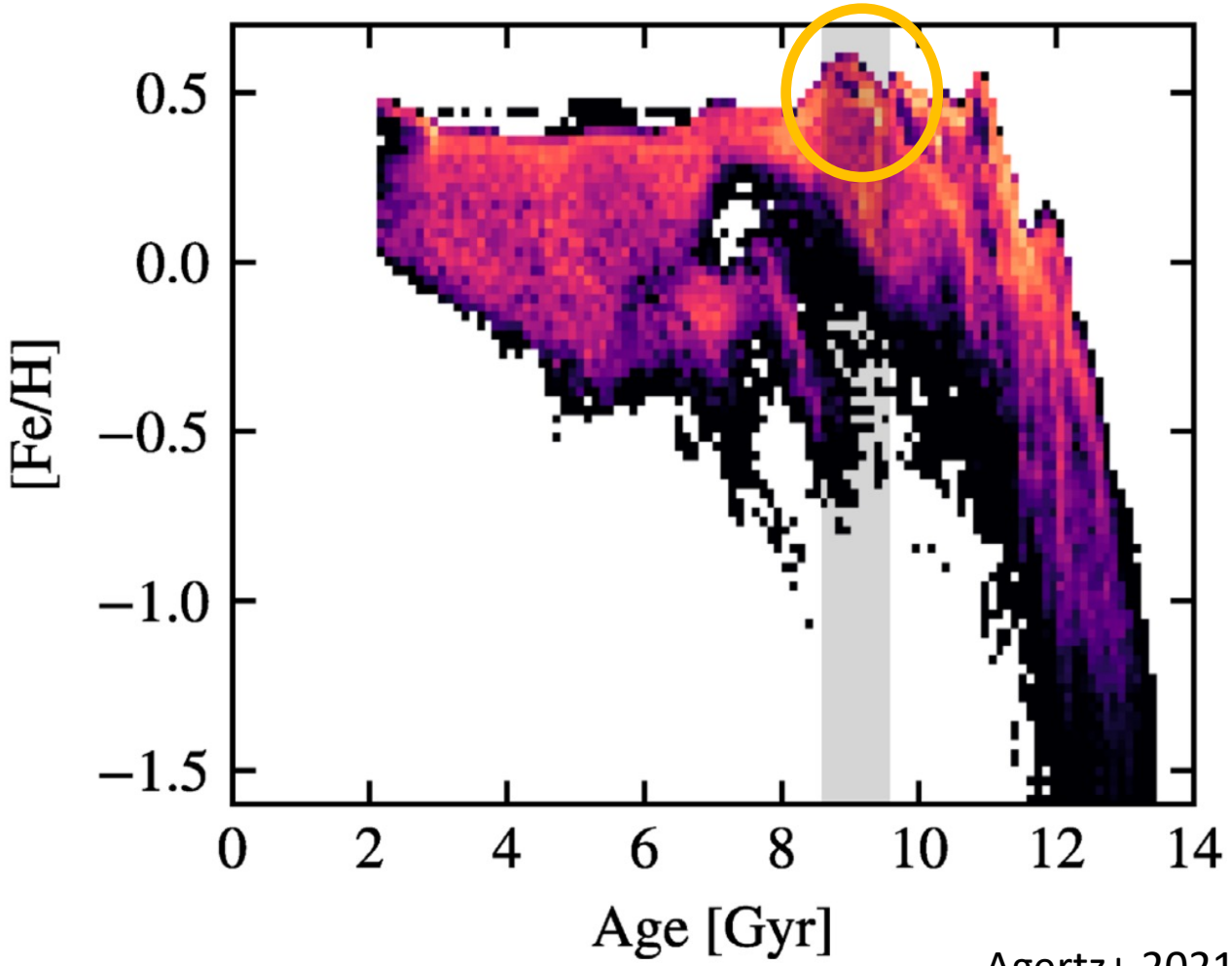
Vintergatan Simulations



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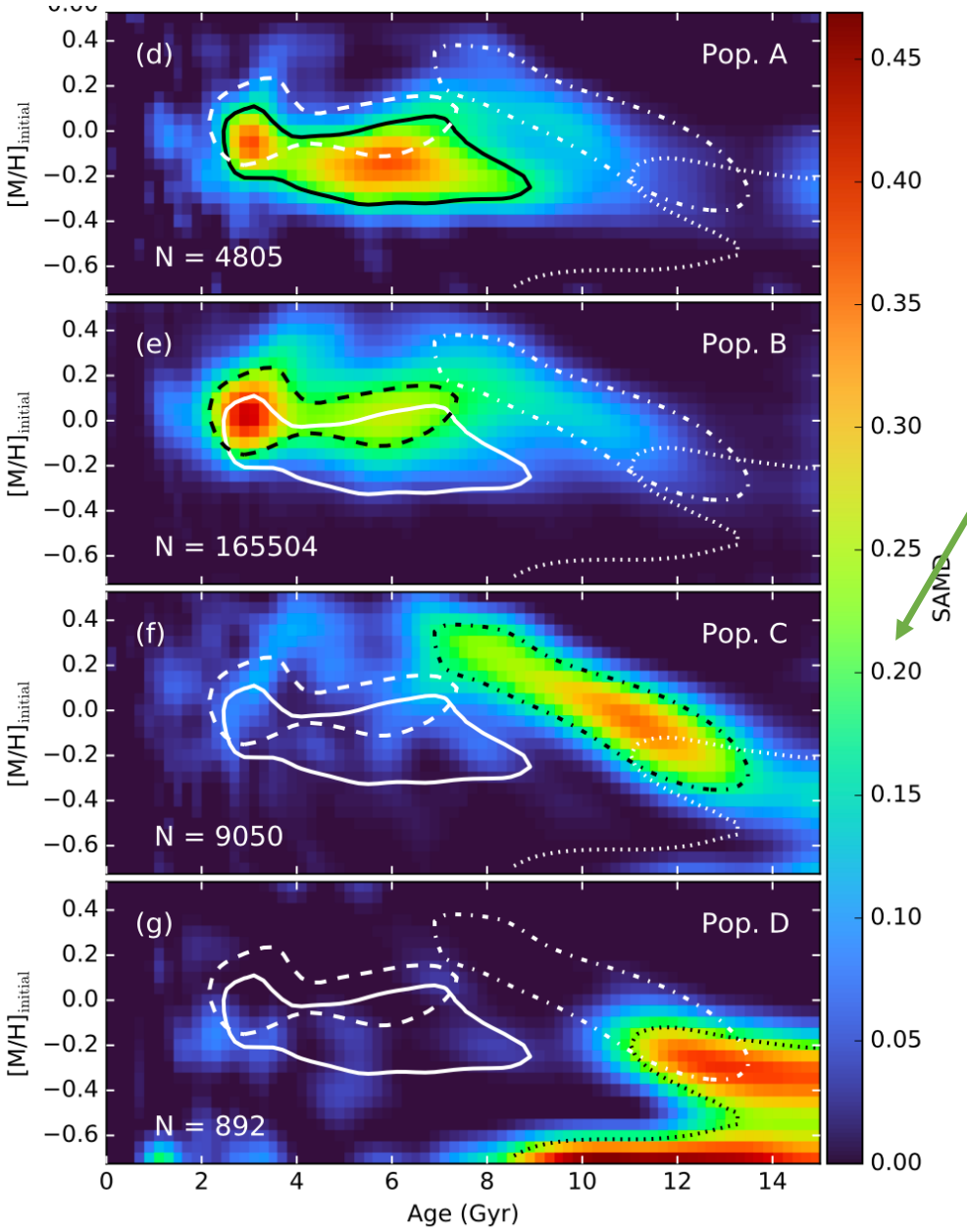
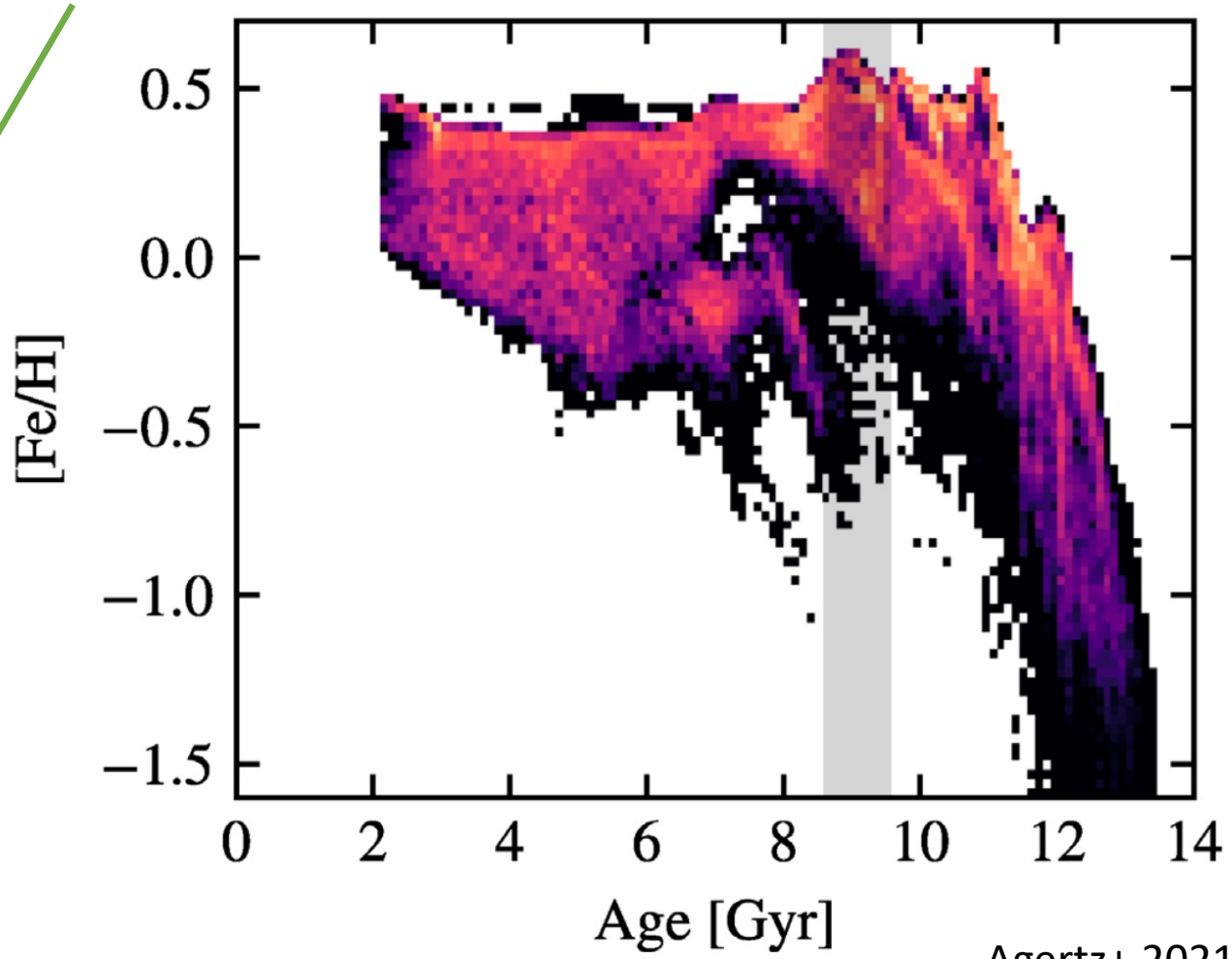


Early star formation in the inner disk



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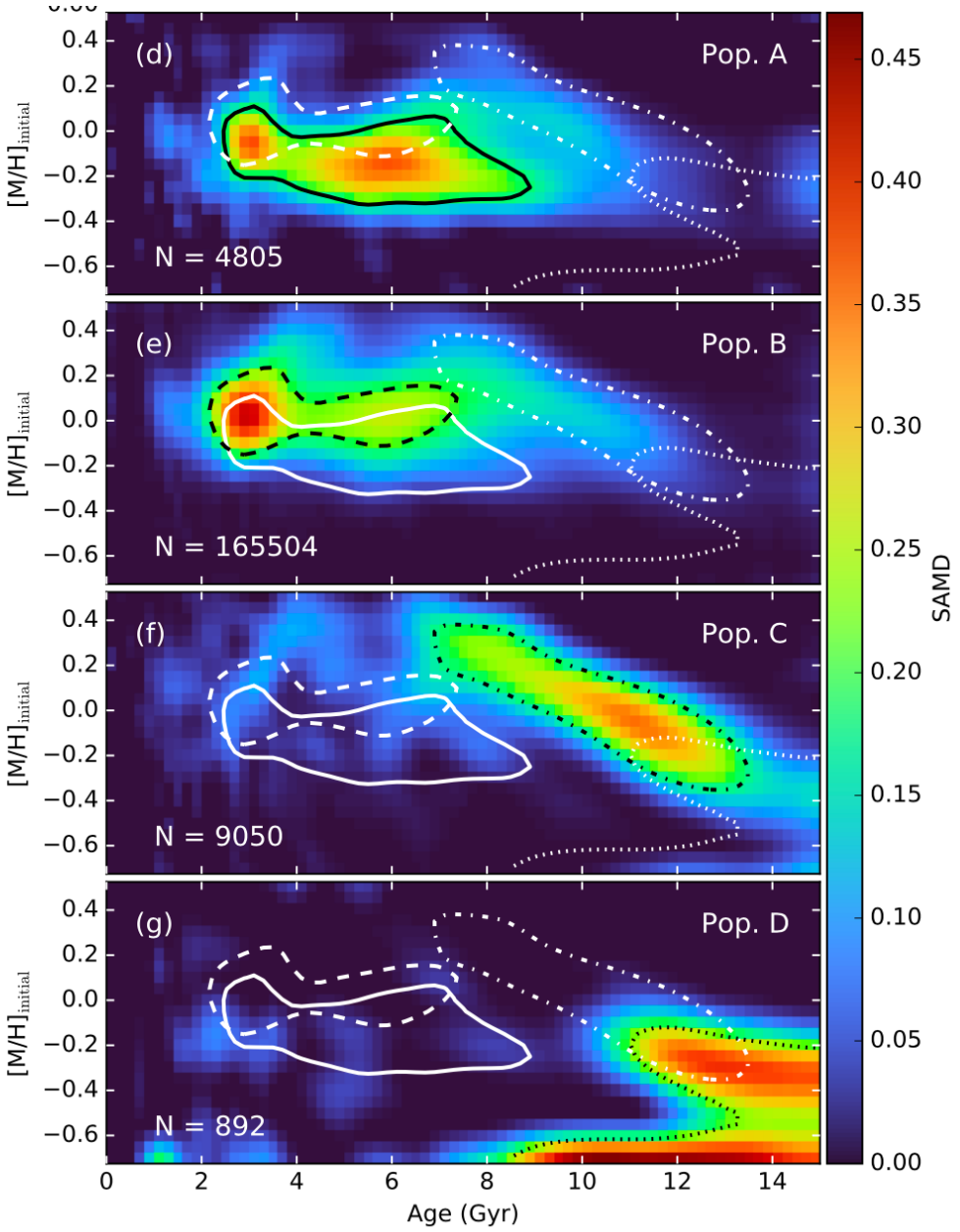

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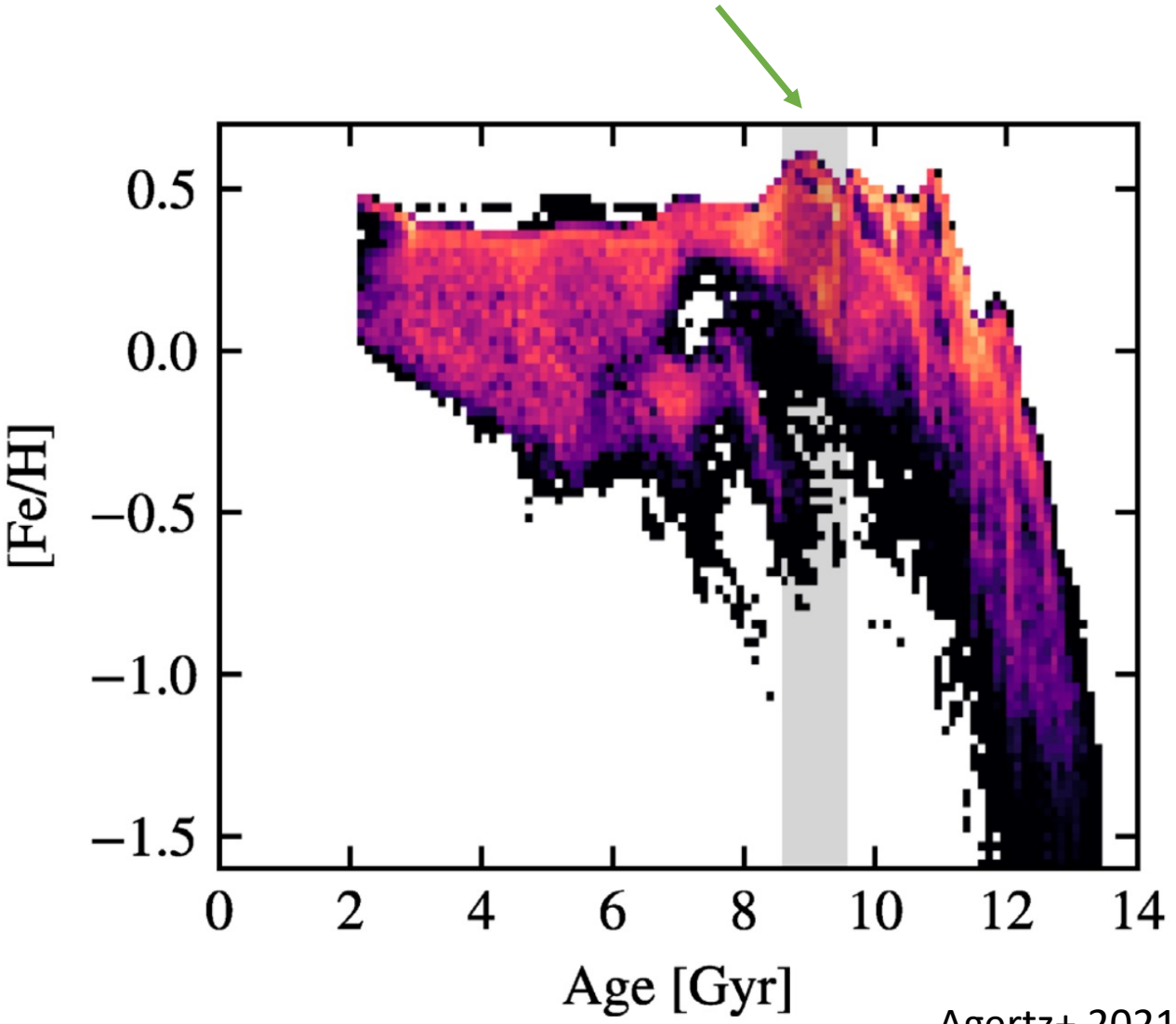
Merger deposits gas in the outer, misaligned disk



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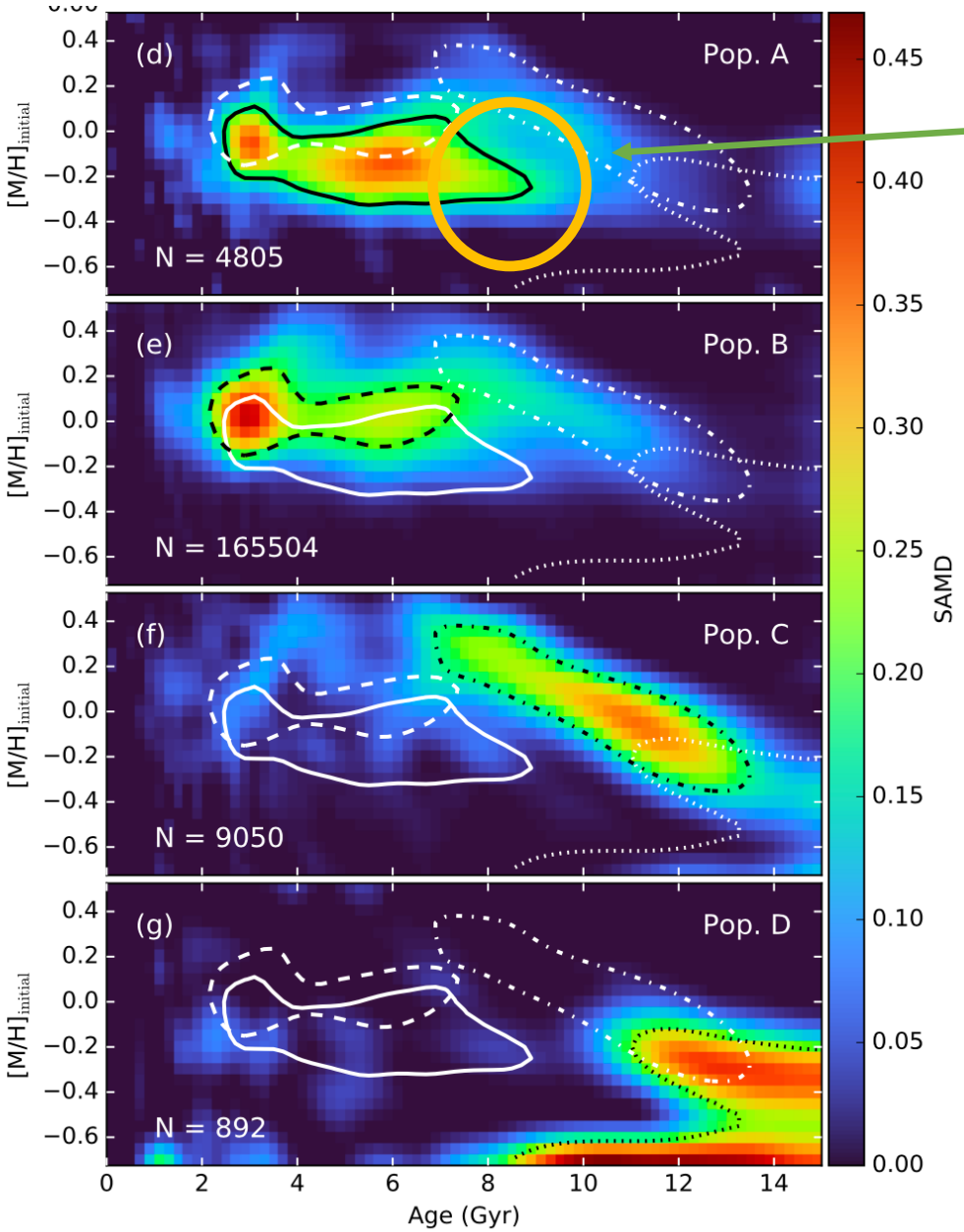
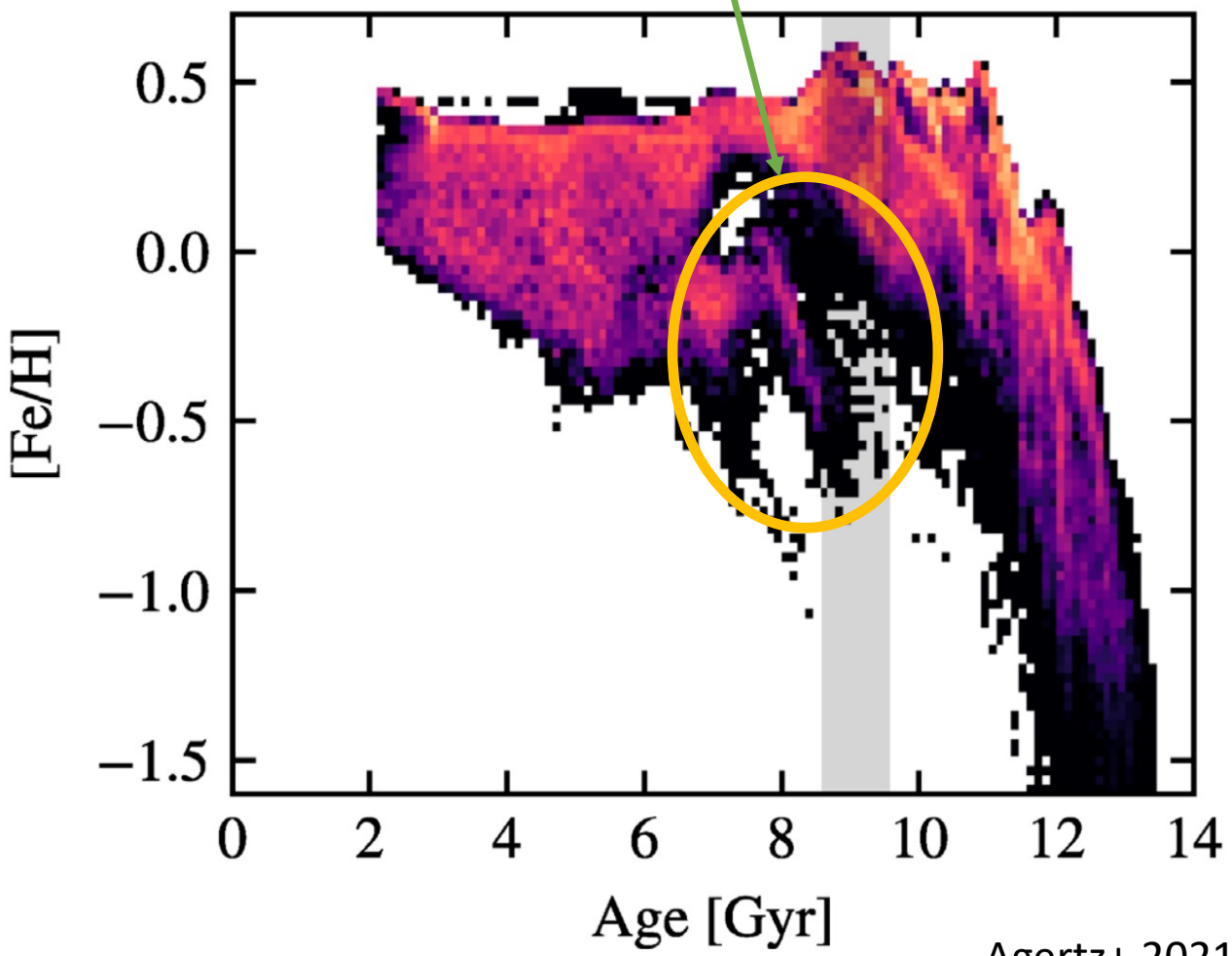
Outer disk feature

Triggers new star formation isolated from inner disk





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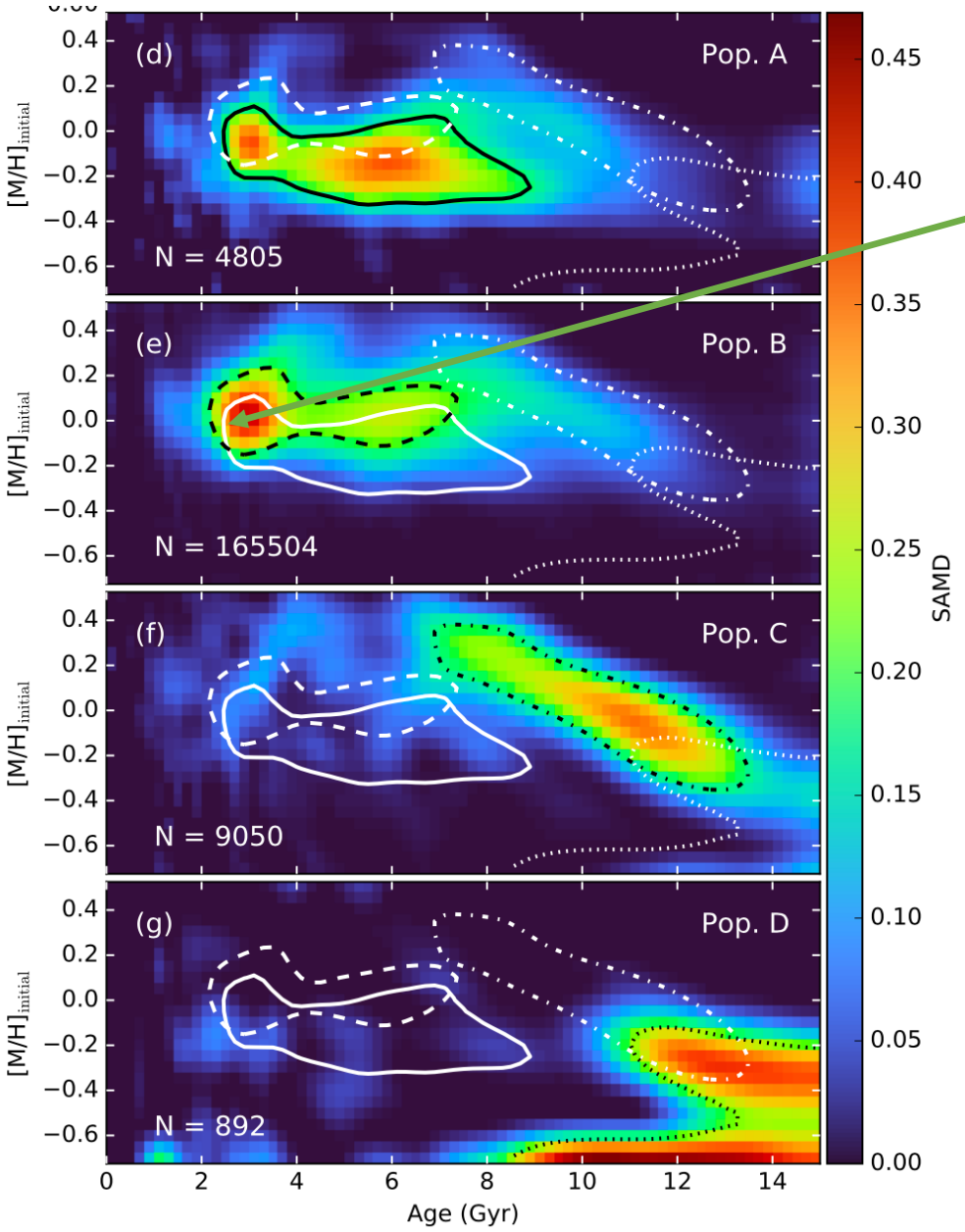
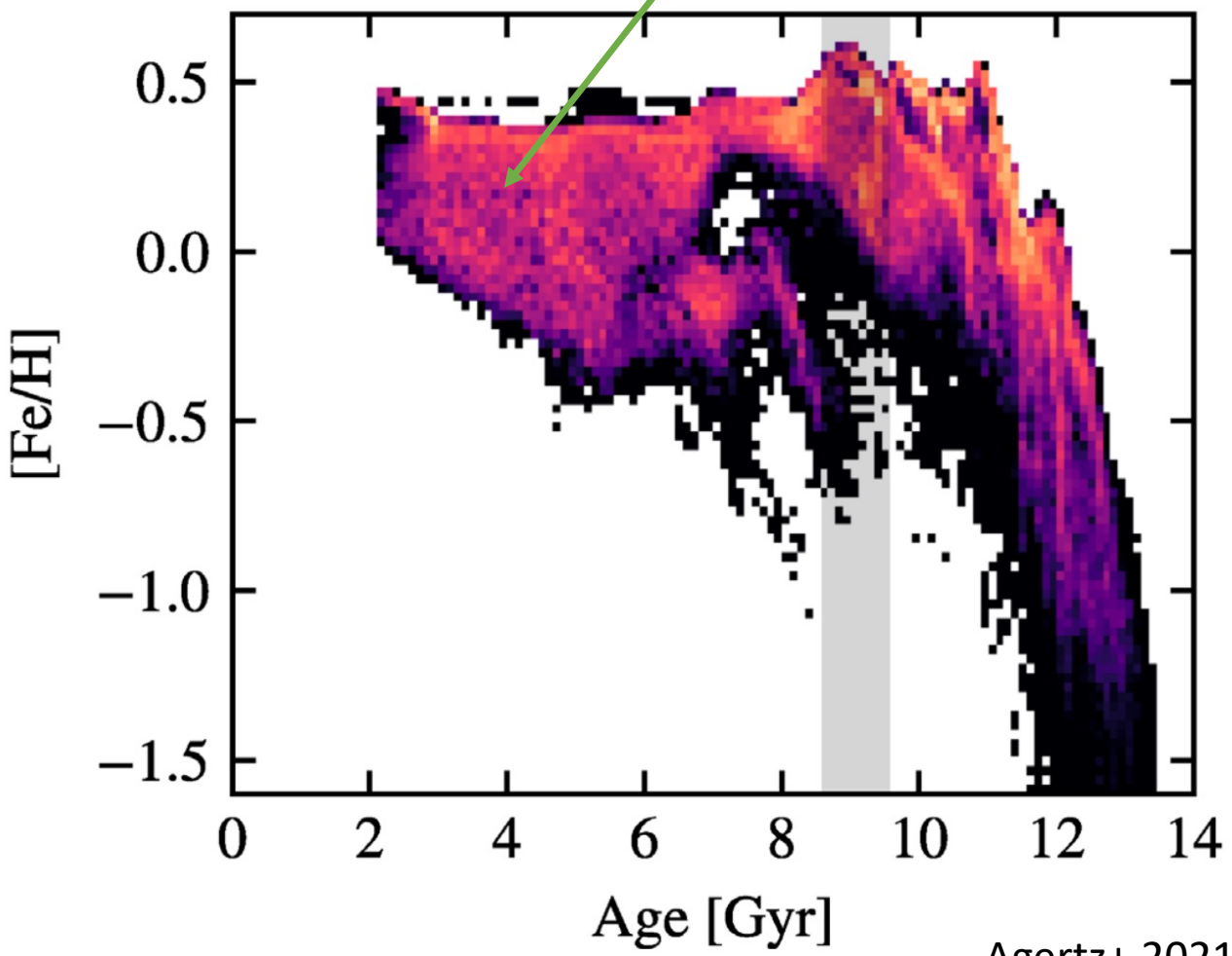


No recent starburst
No Sagittarius merger



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Conclusions

- The MW age-metallicity distribution is complex.
- Different velocity/spatial samples have large variations in the distribution.
- Interesting population in the inner disk with continuous age-metallicity sequence.
- Suggests three phases of star formation
- Different sequences in the inner and outer disk
- Plans to further test methodology and expand

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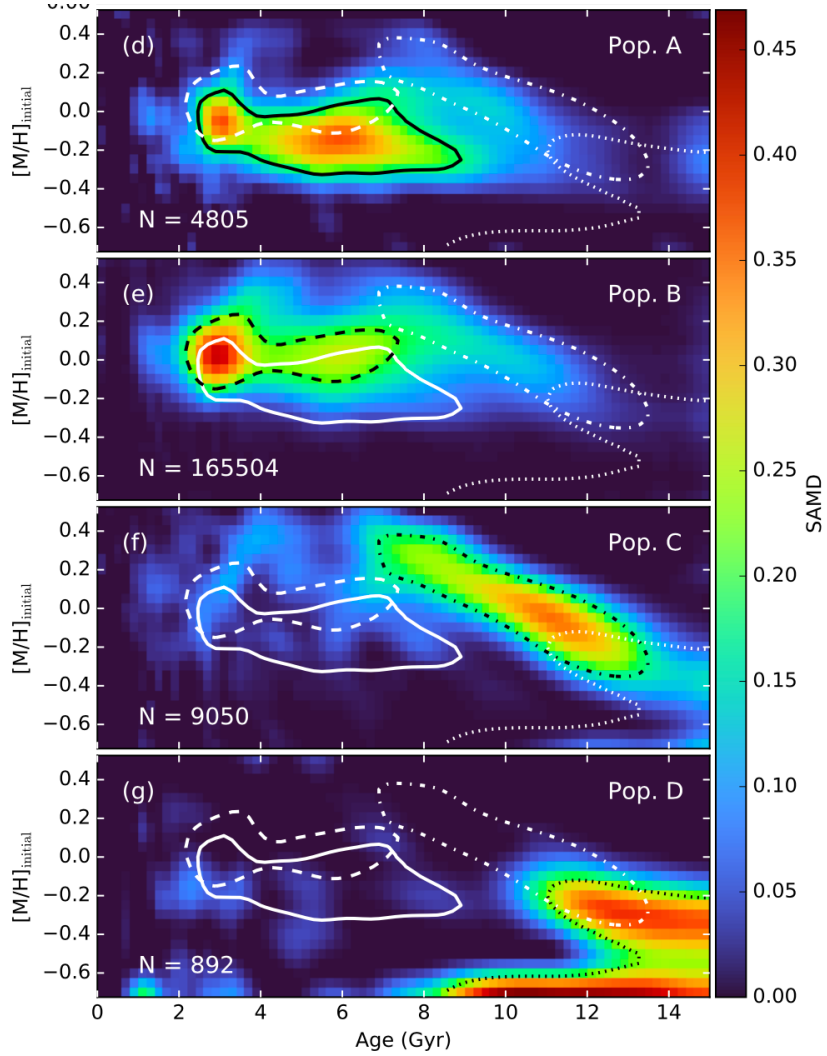

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