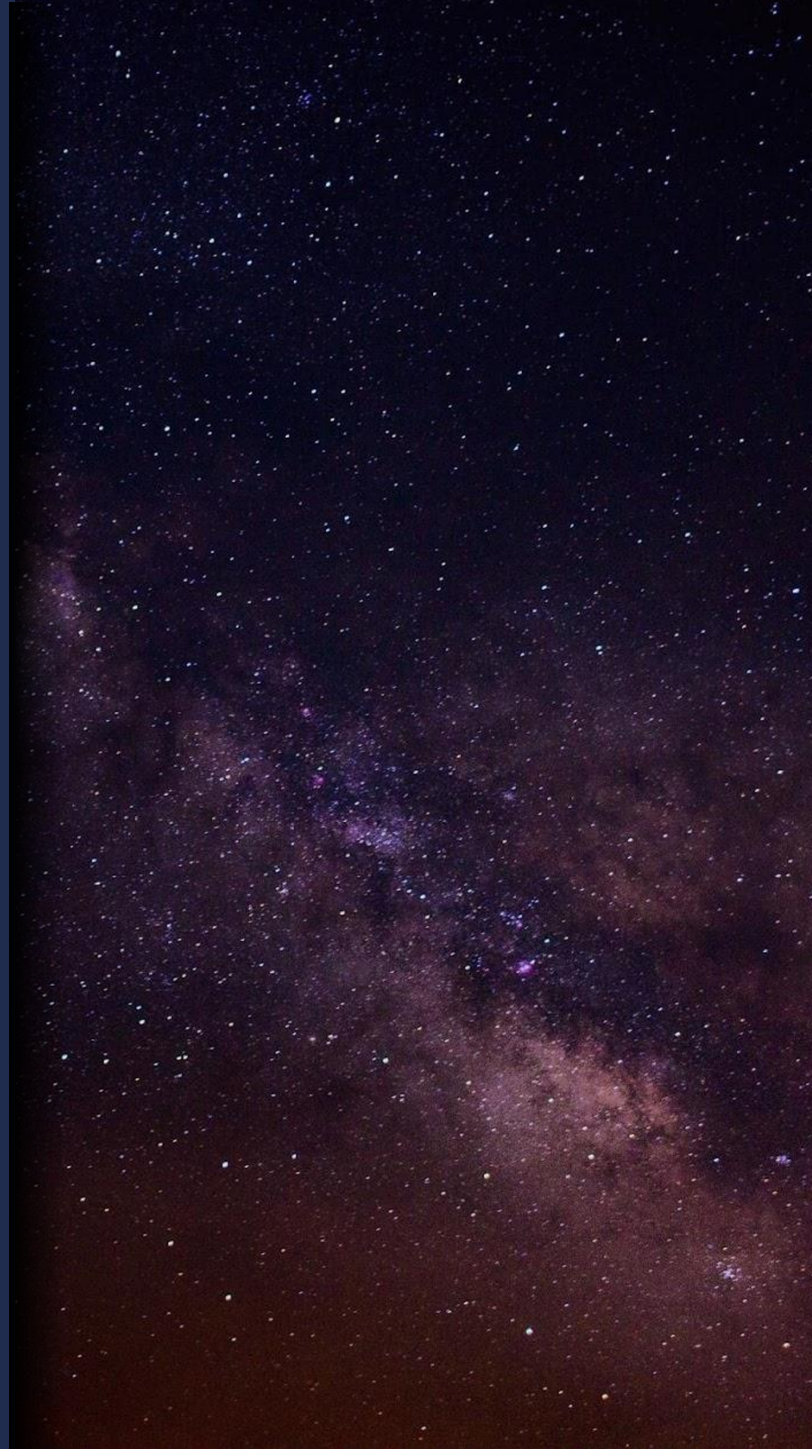
Unveiling the inner Galaxy:

Dissecting the bulge, bar and inner disk properties

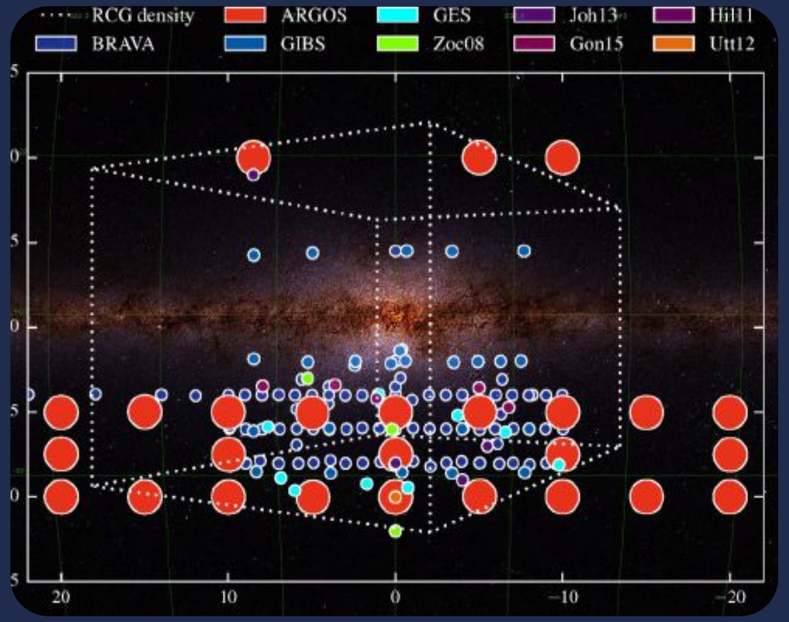
Anna Queiroz, Cristina Chiappini, Angeles Perez-Villegas, Friedrich Anders, Samir Nepal, Arman Khalatyan, Beatriz Barbuy, Carme Gallart, Tomas Ruiz-Lara, Emma Fernandez-Alvar, Basilio Santiago

IAU 395 - stellar populations in the Milky Way and beyond

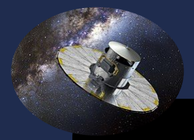


Introduction

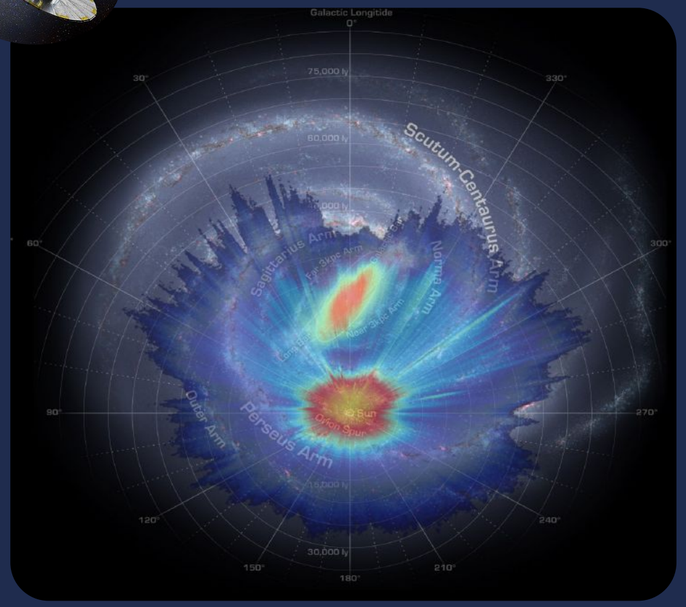
- The beginnings of our Galaxy - The inner Galaxy holds invaluable knowledge about its formation history (White+00, Starkenburg+17)
- The MW bulge is the only one we can dissect into large samples of individual stars (Barbuy +18)



Spectroscopic surveys
see Barbuy+18

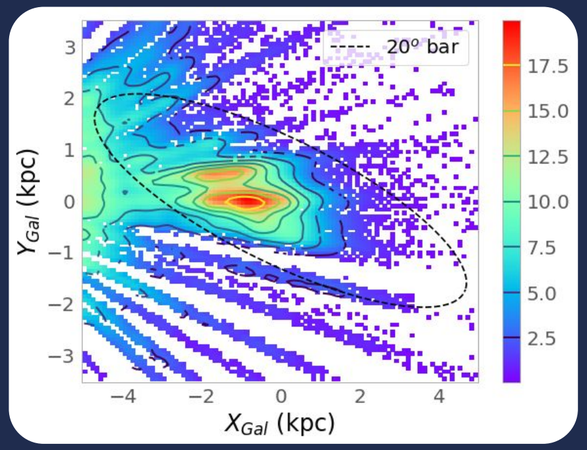


Brown Talk (this afternoon!)



Anders +22 - Gaia StarHorse distances

Schiavon talk: APOGEE+Gaia revolution (see tomorrow!)



Queiroz+21

Introduction

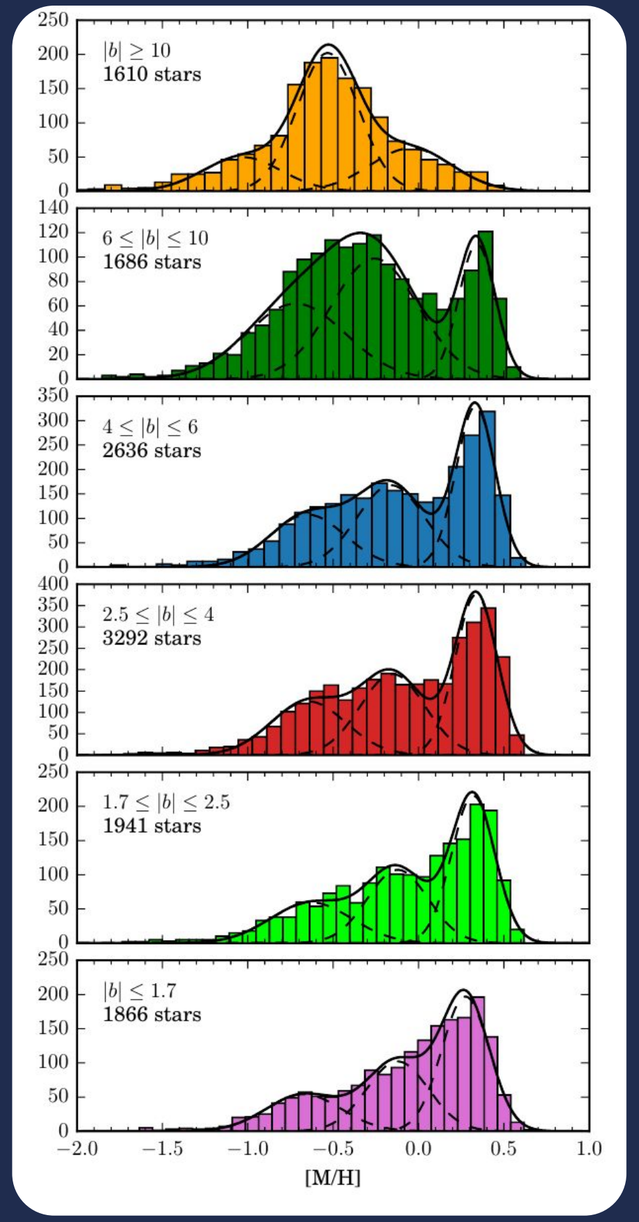
What we know about the inner Galaxy:

- Multi peaked MDF (Hill+11, Rich+12, Rojas-arriagada+20)
- Different spatial distribution for MP/MR stars (Zoccali+17, Arentsen+24 , Rix+23)
- Strong bar with boxy bulge, cylindrical rotation (Ness+16)
- Bulk of stars is old >10 Gyrs, with some young stars (Ortolani+95, Valenti+13, Bensby+17, Renzini+18, Hasselquist+20)

Challenges:

High extinction, precise distance measurements, superposition of populations

1. Boxy bulge; 2. inner disk; 3. thick disk; 4. halo; 5. globular clusters; 6. debris; 7. primordial galaxies/classical bulge.

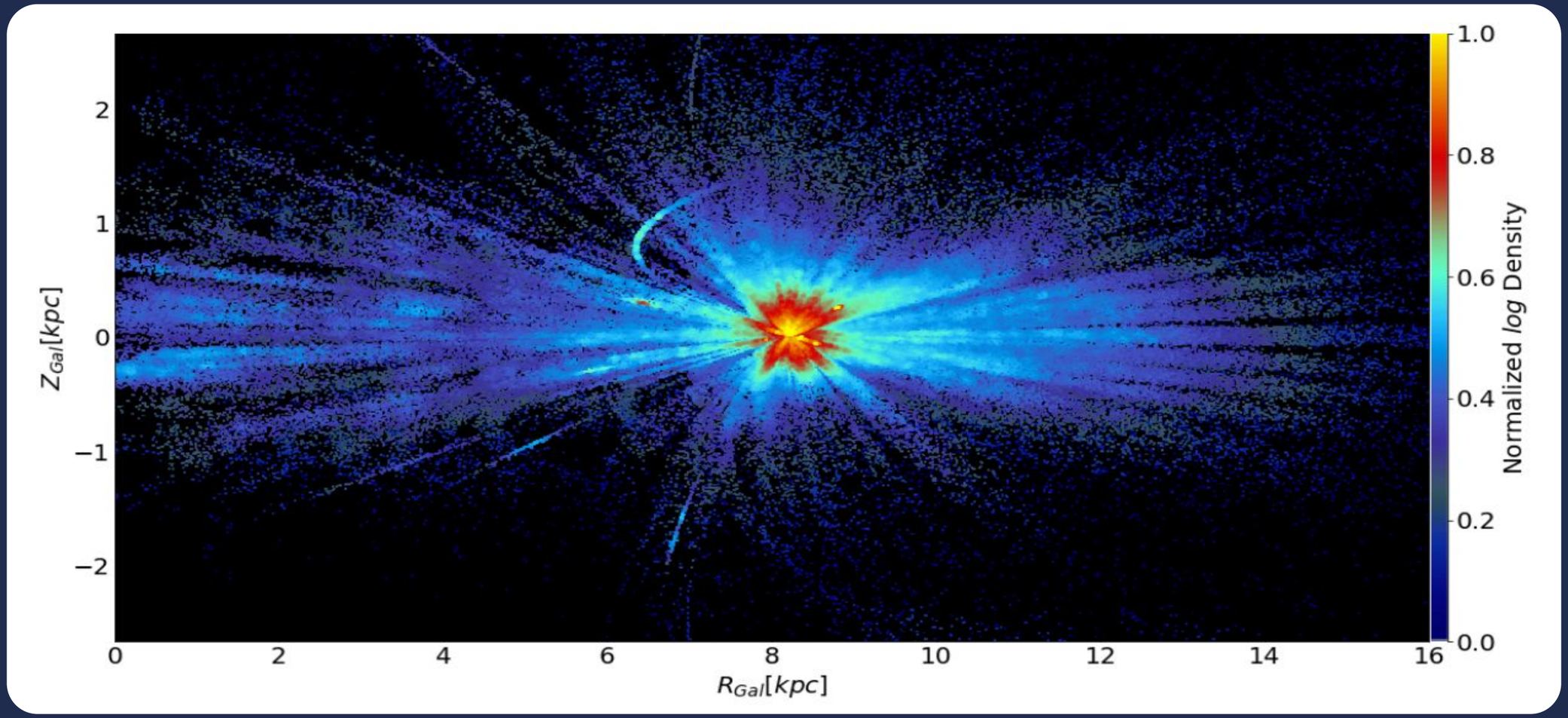


Rojas-Arriagada+20

How can we disentangle all that?

Chemical map of the Galaxy

StarHorse → *Gaia* + APOGEE spectra + Photometry



Queiroz+2020

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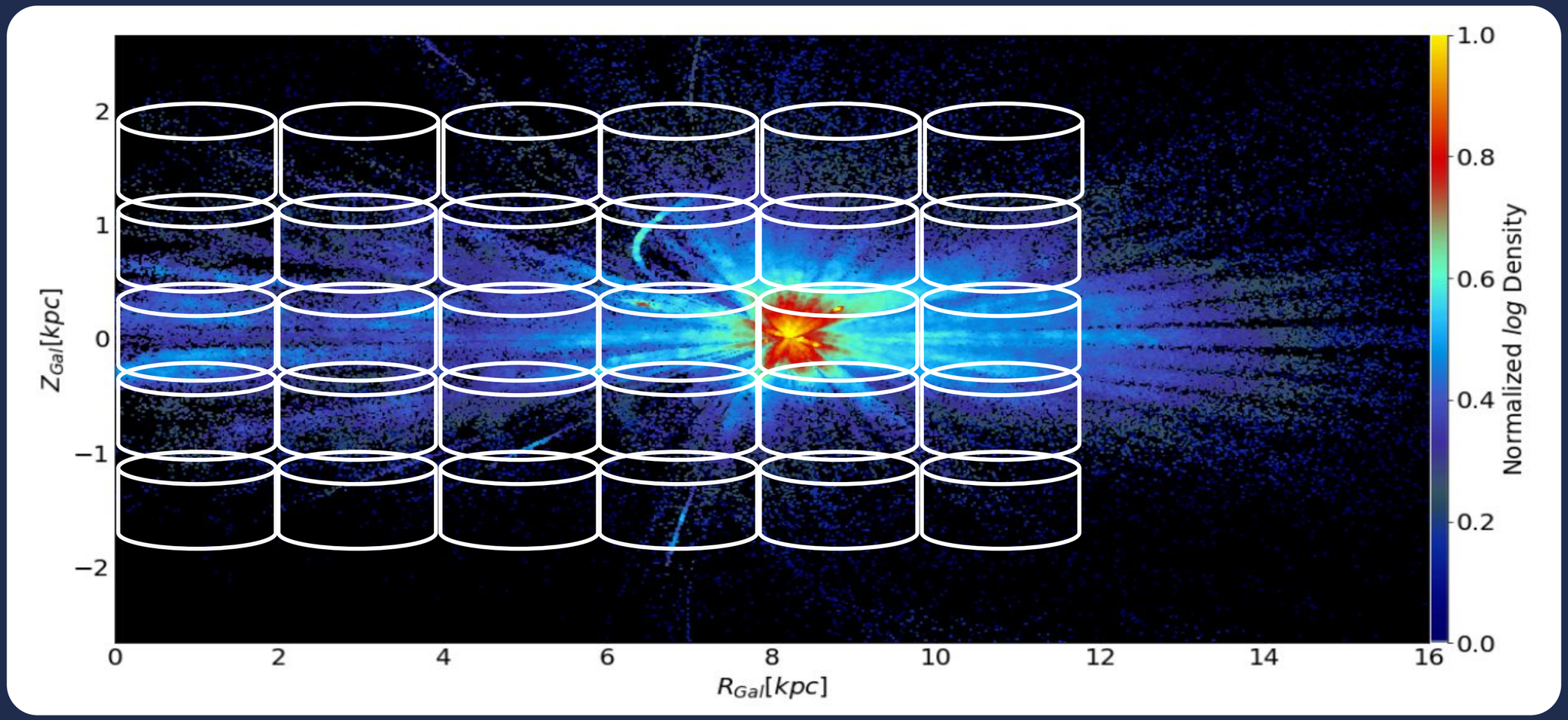
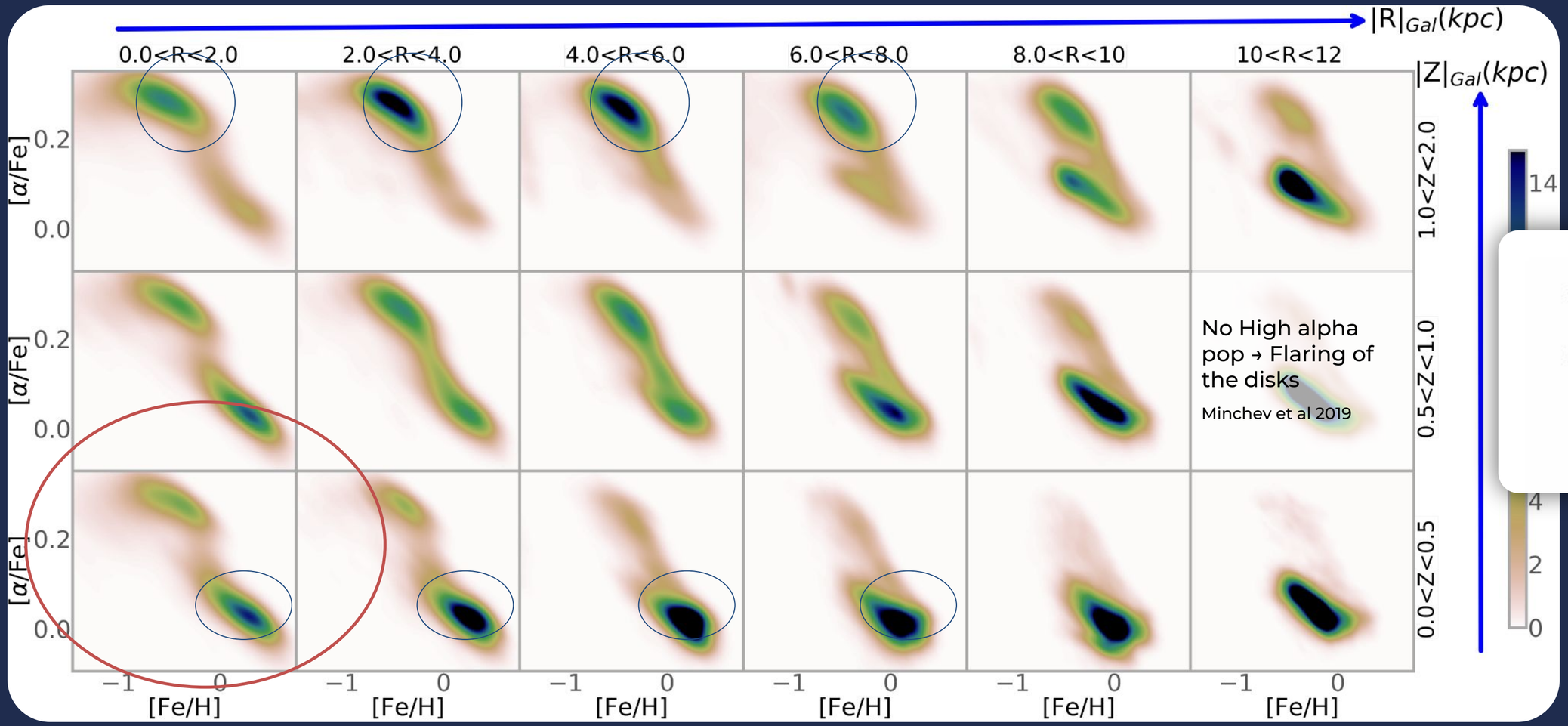


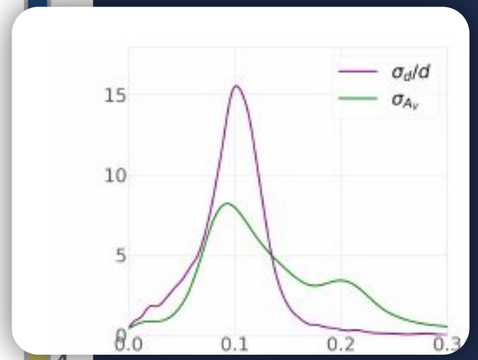
Queiroz+2020

The thin and thick disks

Many further works using apogee have confirmed the bimodality: Eilers+22; Imig+2023;

Queiroz et al 2020 → APOGEE DR17

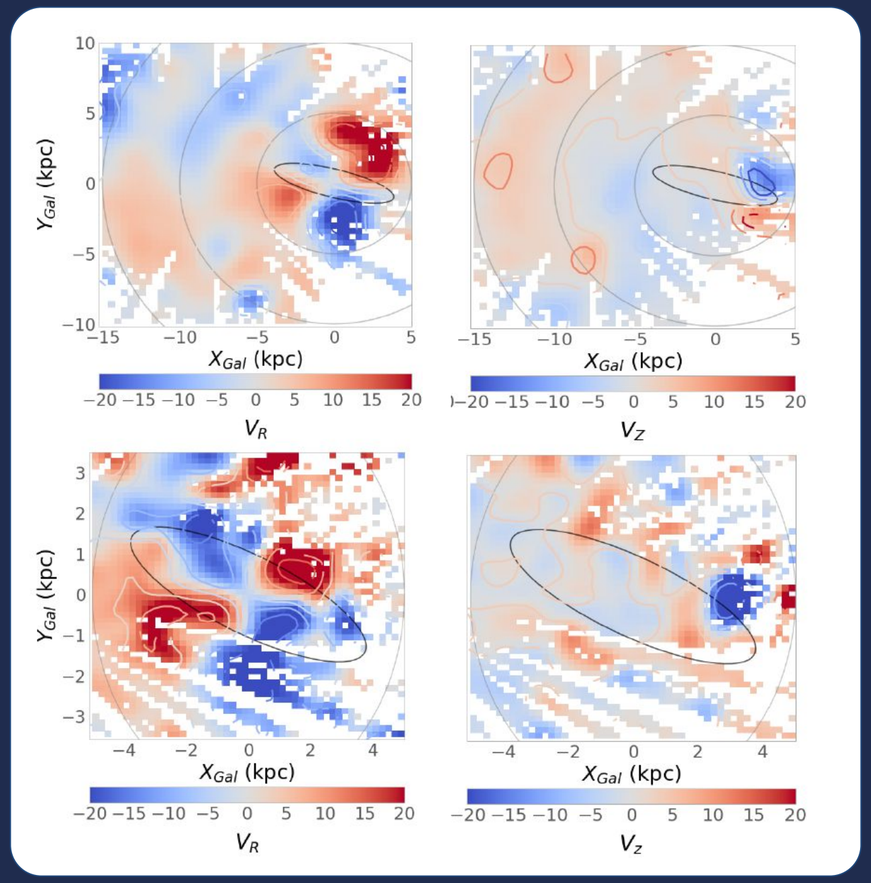




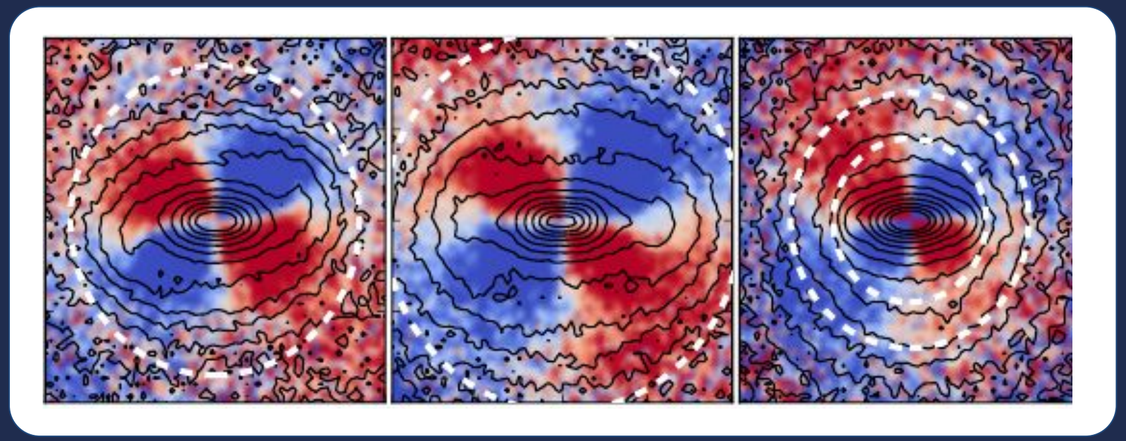
APOGEE DR17 + Gaia in the inner Galaxy (Kinematics)

The quadrupole of the Galactic bar is confirmed, reassuring distances measurements

Queiroz et al 2021

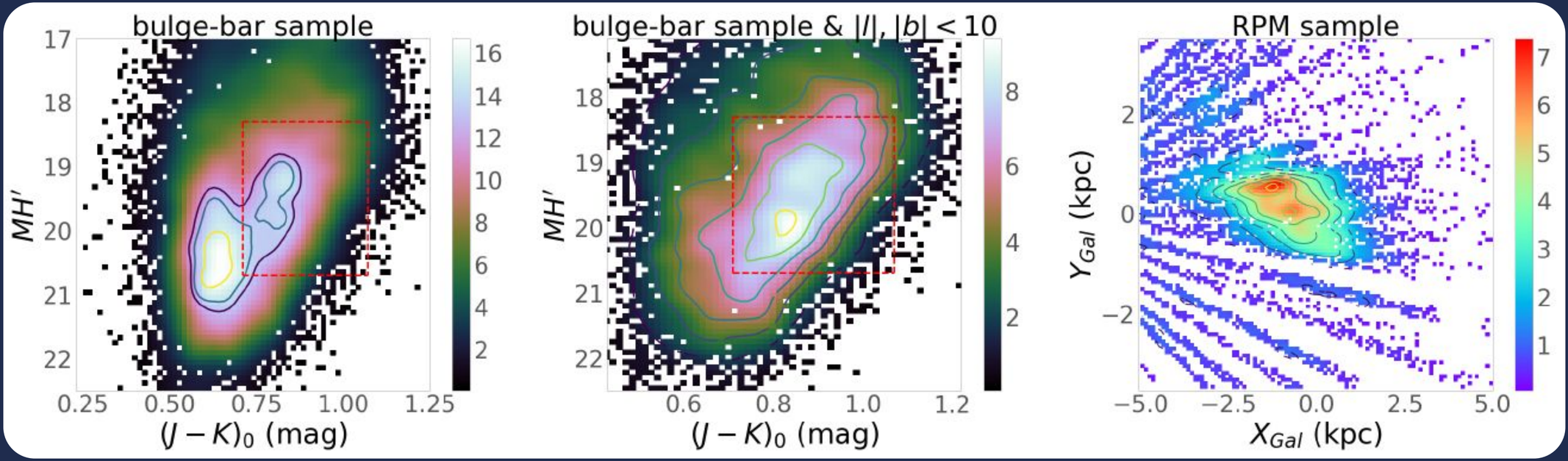


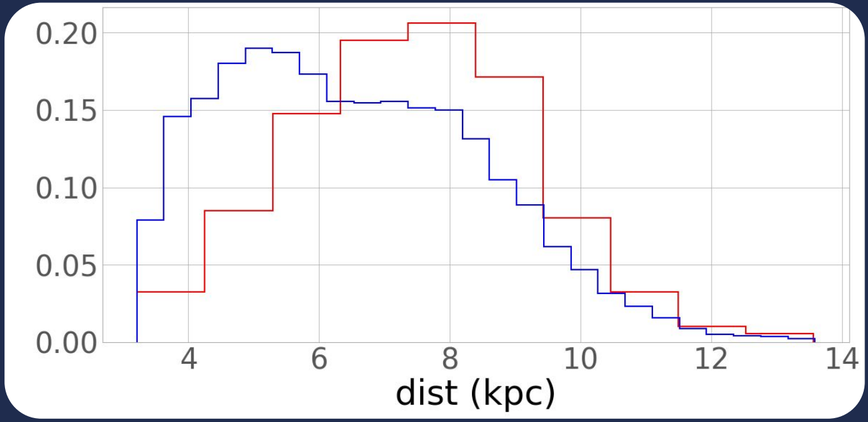
Auriga simulations Fragkoudi+19



- Later also confirmed with variable stars Hay + 2023, Zhang + 2024
- This shows alignment of the bar and inner disk
- Not a very clear structure in the vertical motion

Defining a bulge bar sample





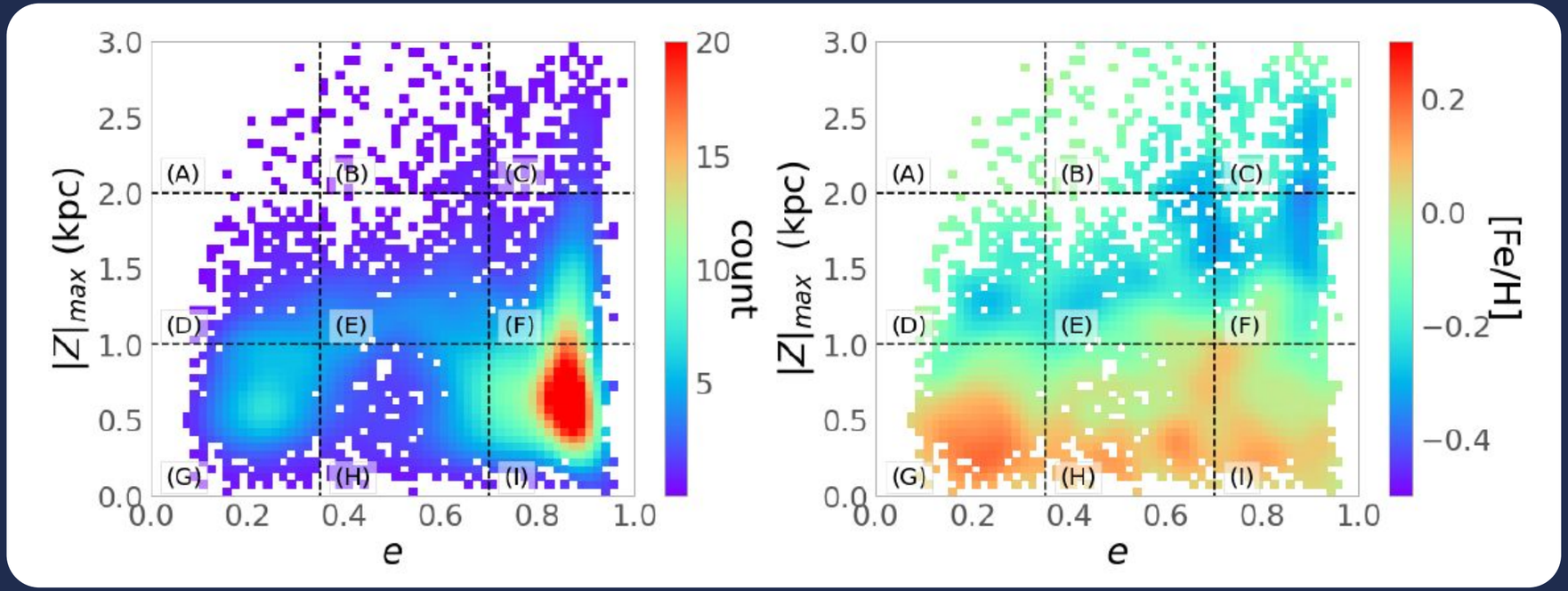
This sample selection has been used in many works studying the bulge chemical properties.
Razera+22, Barbuy+23, Barbuy+24

Orbital analysis

Proper motions depends on Gaia availability

Orbit-metallicity analysis

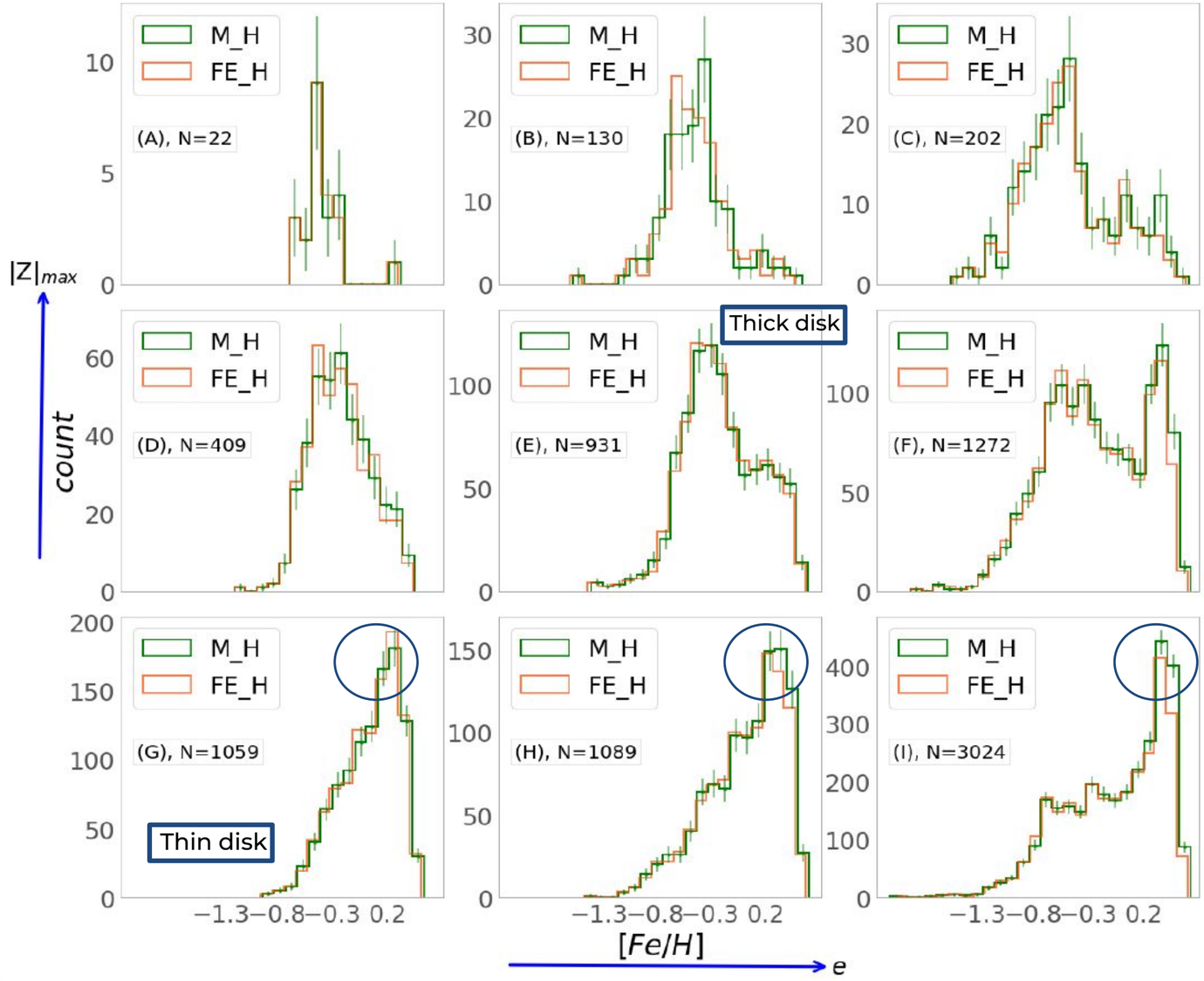
Queiroz+2



- (MW-like potential) = (MN-disks + NFW DM halo + triaxial Ferrer bar)
- Integrate forward for 3 Gyr
- 50 monte carlo realizations

Orbit metallicity dissection

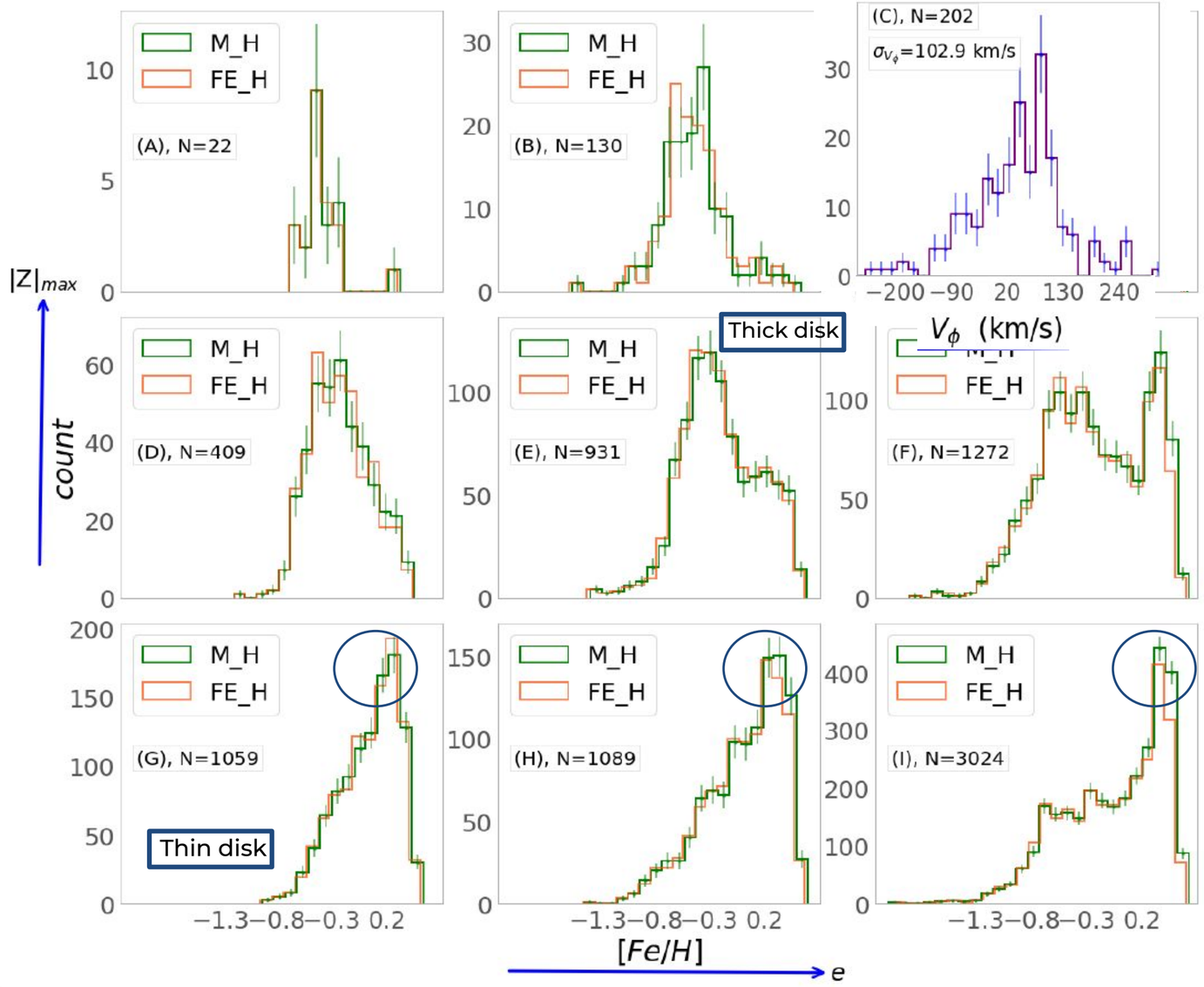
Queiroz+21



- High e, slowly increases metallicity
- Radial migration can explain super metal rich stars in the SN
- Contribution of inner thin / thick disks is decomposed by orbital analysis

Orbit metallicity dissection

Queiroz+21



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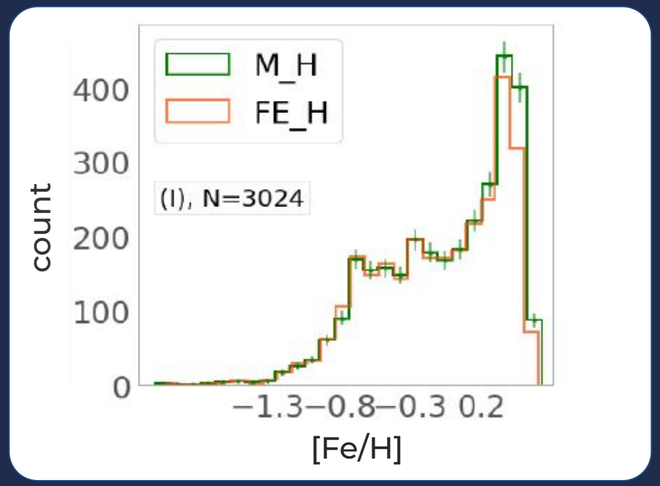
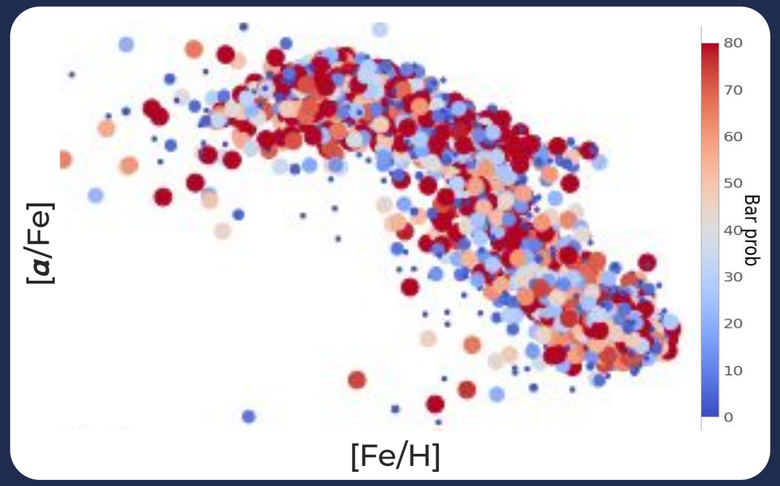
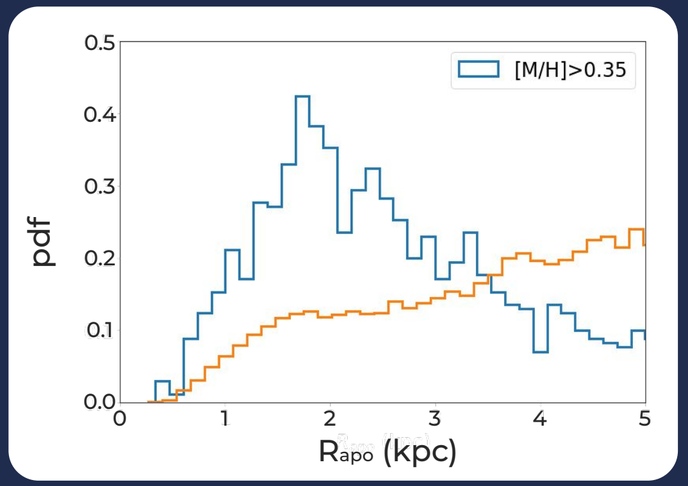
A reservoir of super metal rich stars

High ecc and low Zmax





APOGEE DR17 full bulge bar sample

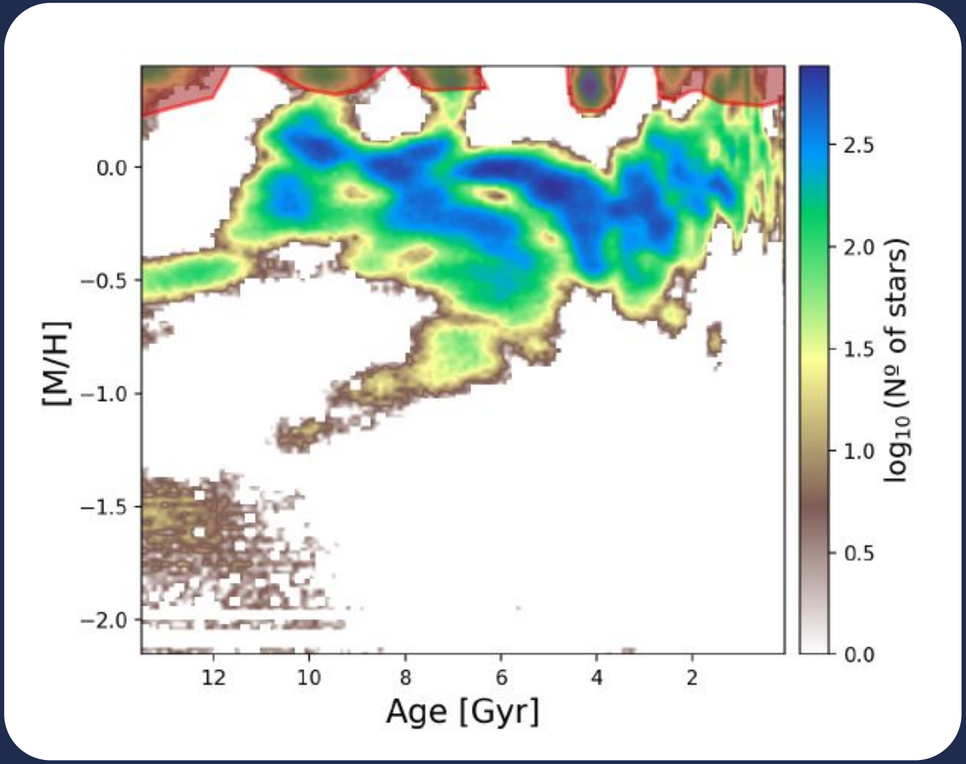


- Super metal rich stars are abundant in the inner Galaxy, this is very clear with APOGEE!
- They can also be found in the solar neighborhood via radial migration (mostly old 8 gyrs Miglio+21)
- The age of SMR stars is a good tracer for the age of the inner Galaxy and bar activity
  See talk by Samir Nepal this afternoon → bimodality on Rg (Nepal+24a, Khalatyan+24)

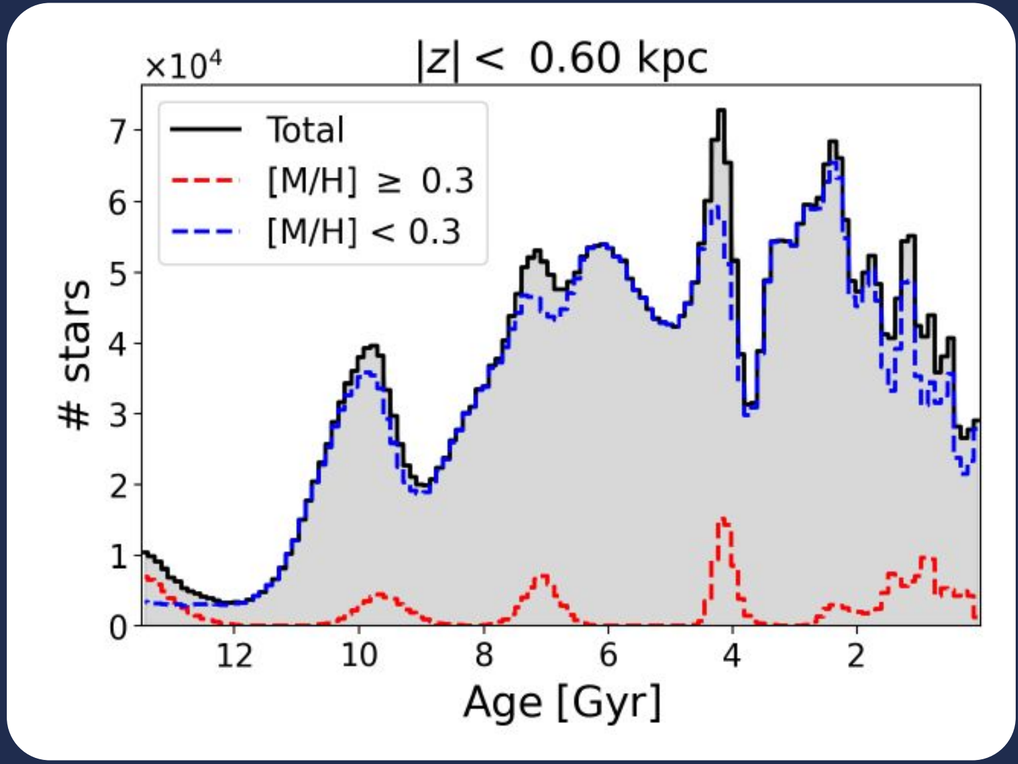
A reservoir of super metal rich stars

Gaia CMD-fitting of local disk - shows SMR events of star formation
Ruiz-Lara+25 in prep

Gallart's Talk & Fernandez-Alvar Poster!



Ruiz-Lara et al in prep.

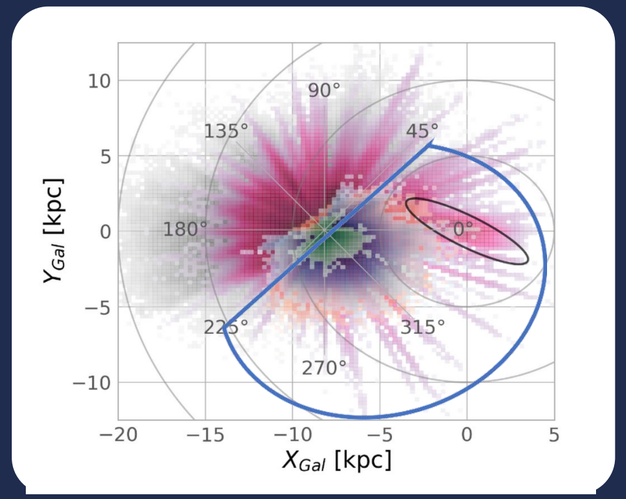


These stars can tell us about the age of the inner Galaxy!
See also Recio-Blanco+24

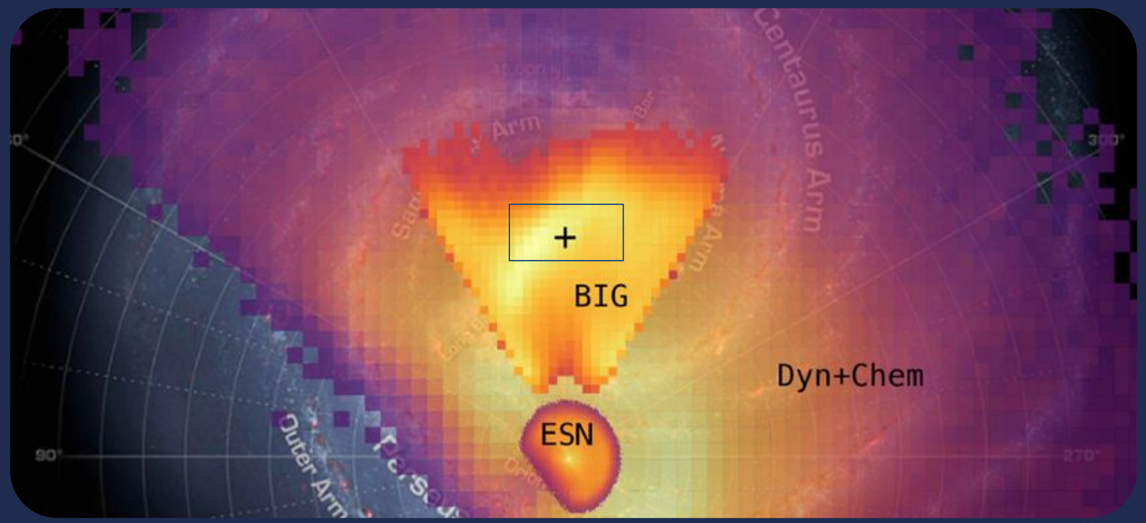
Further surveys in the Galactic bulge

- Great progress thanks to large photometric surveys e. g. BDBS (Rich's talk)
- Future spectroscopic surveys are promising! e. g. Moons, 4MOST

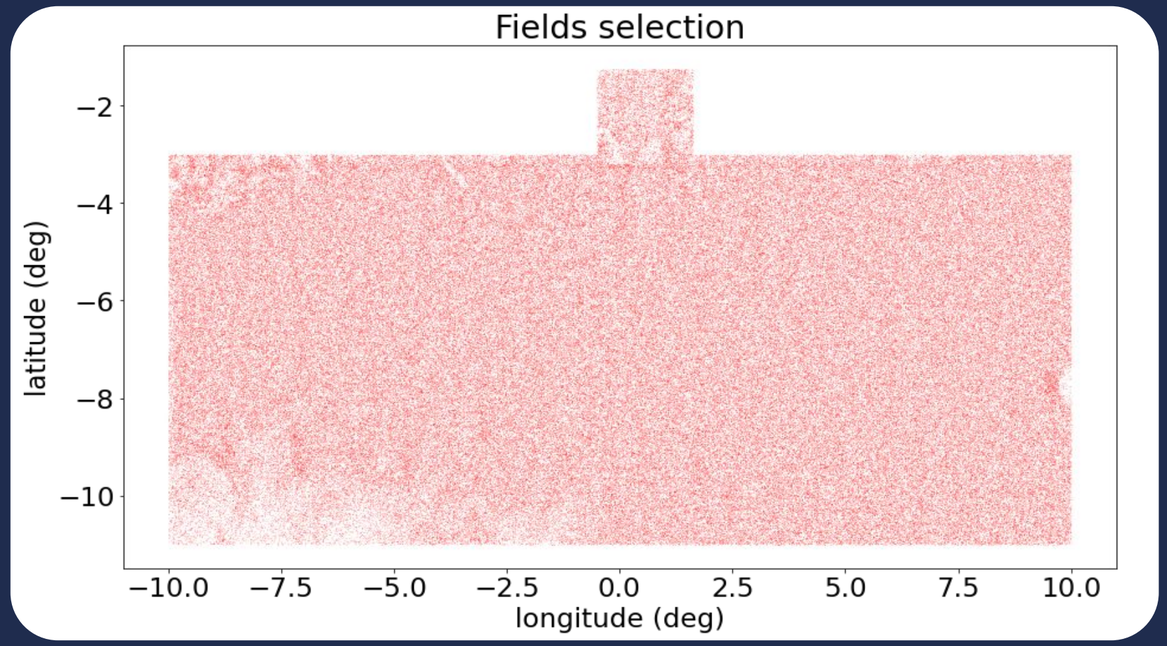
4MOST will cover a significant missing part with spectroscopy on the visual range and southern hemisphere



4midable Low-R Chiappini+17

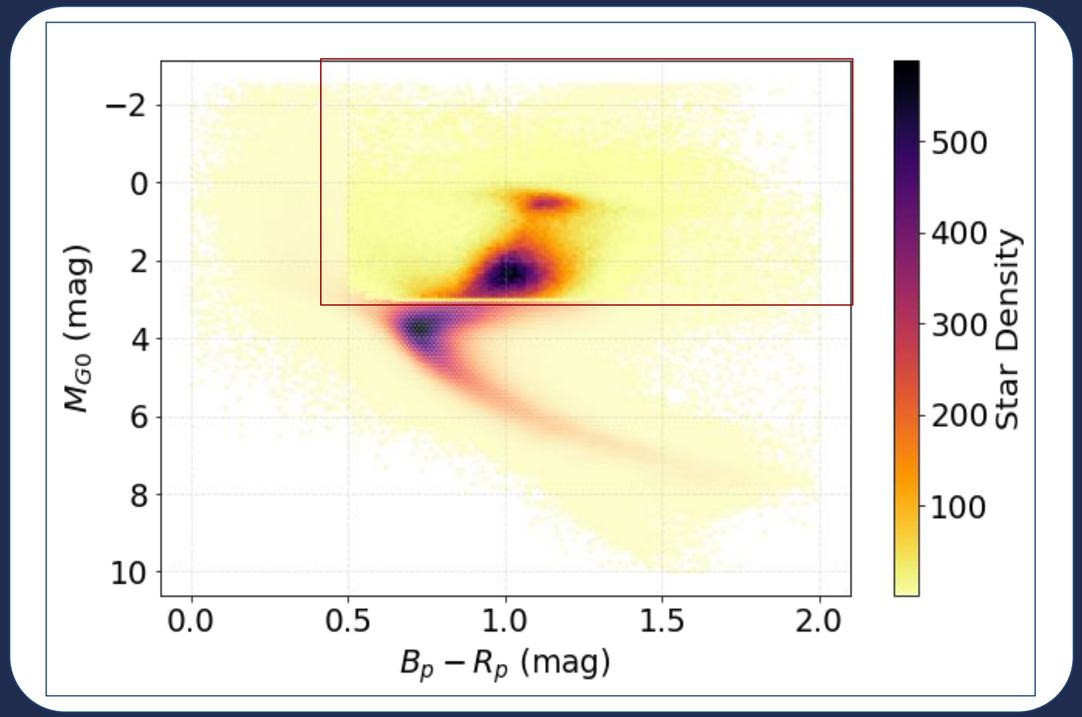


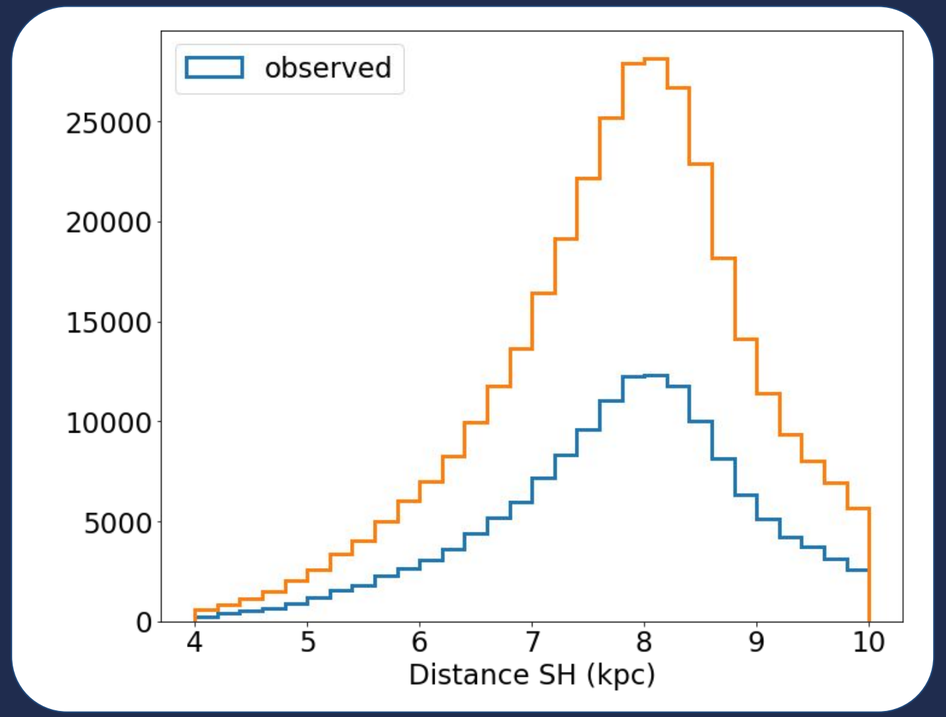
Bulge deep 17 < G_{mag} < 18 mag



Further surveys in the Galactic bulge

- Going deep may present a challenge for the target selection, but a valuable gain on age determination
- selection on parallaxes, color and absolute magnitude





Impact in Galactic archeology

- The bimodality in chemical elements in the inner Galaxy and beyond indicates different formation processes
- The bar orbits and distances are well determined through the detection of the quadrupole in Vr and the chemical bimodality of bar-shaped orbits → secular evolution of the bar, both thin-disk and thick-disk stars can get trapped in the bar resonances; (Agreement with RR lyrae works Kunder et al. 2020)
- Metal rich stars are found in abundance in the inner Galaxy and in bar orbits, their counterpart in the solar neighborhood suggests distinct epochs of formation (See Ruiz-Lara in prep.)
- The chemical homogeneity of the genuine thick disk indicates that this population had a fast homogeneous formation scenario
- Metal-poor stars in the inner Galaxy suggest the presence of a pressure supported component. (Arentsen+24)

An Inspiration of a Brazilian, Professor and woman

"Creio que as mulheres têm de fazer alguma coisa mais que os homens para serem bem reconhecidas como profissionais"