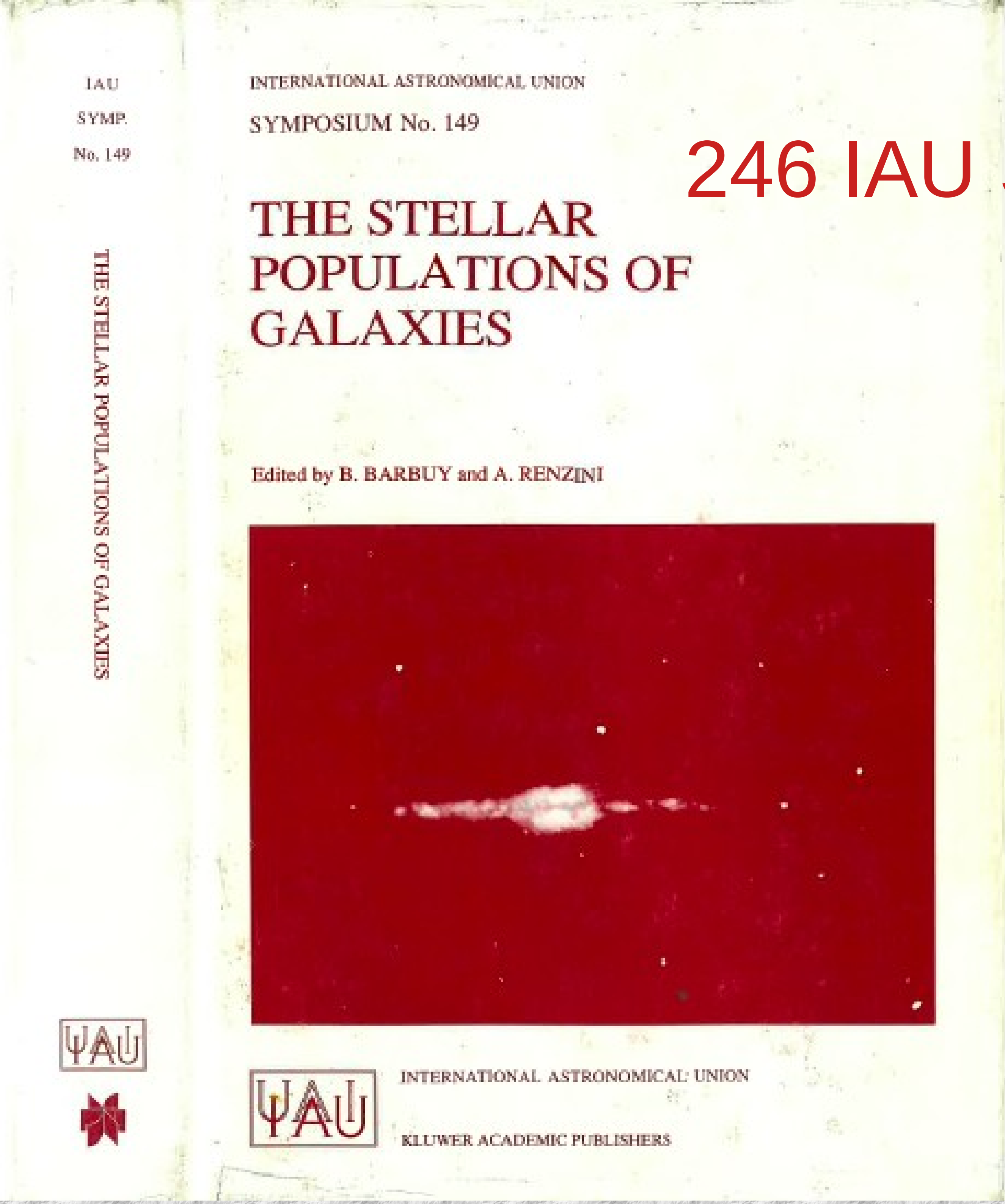
Beatriz-Fest… in the Milky Way and Beyond

Conference wrap-up

Alvio, Paraty, 11/22/2024

246 IAU Symposia ago!



The (stellar) Milky Way is made of:

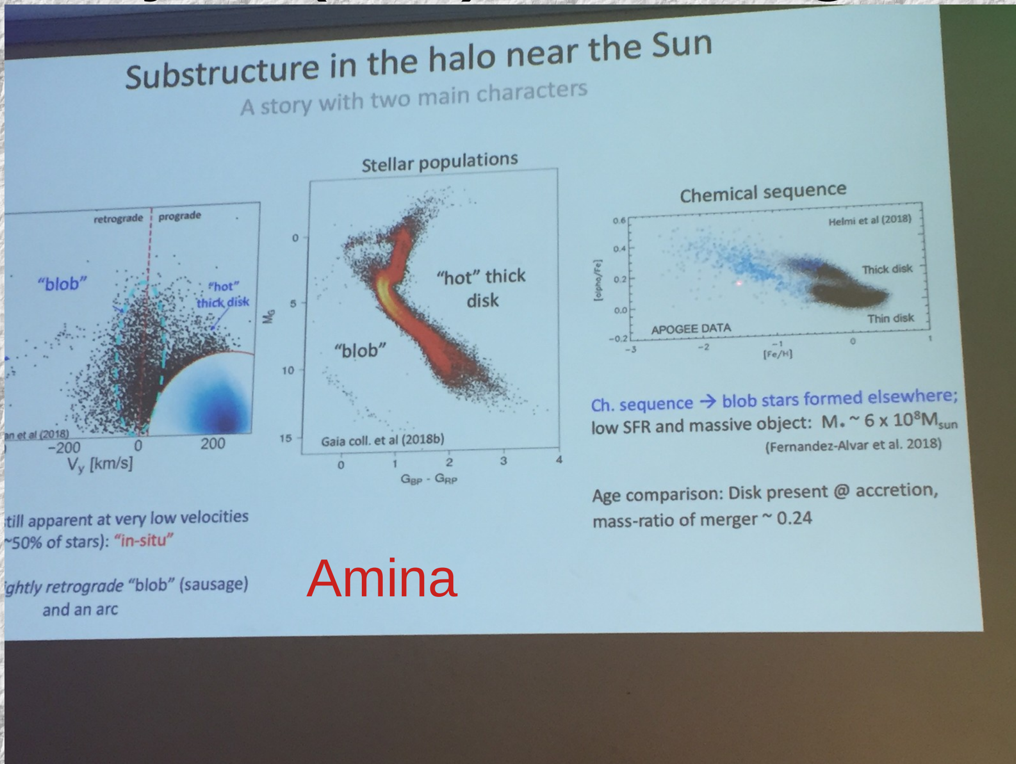
- The Halo (~10^9 $M_\odot$)
- The Bulge (~2×10^{10} $M_\odot$)

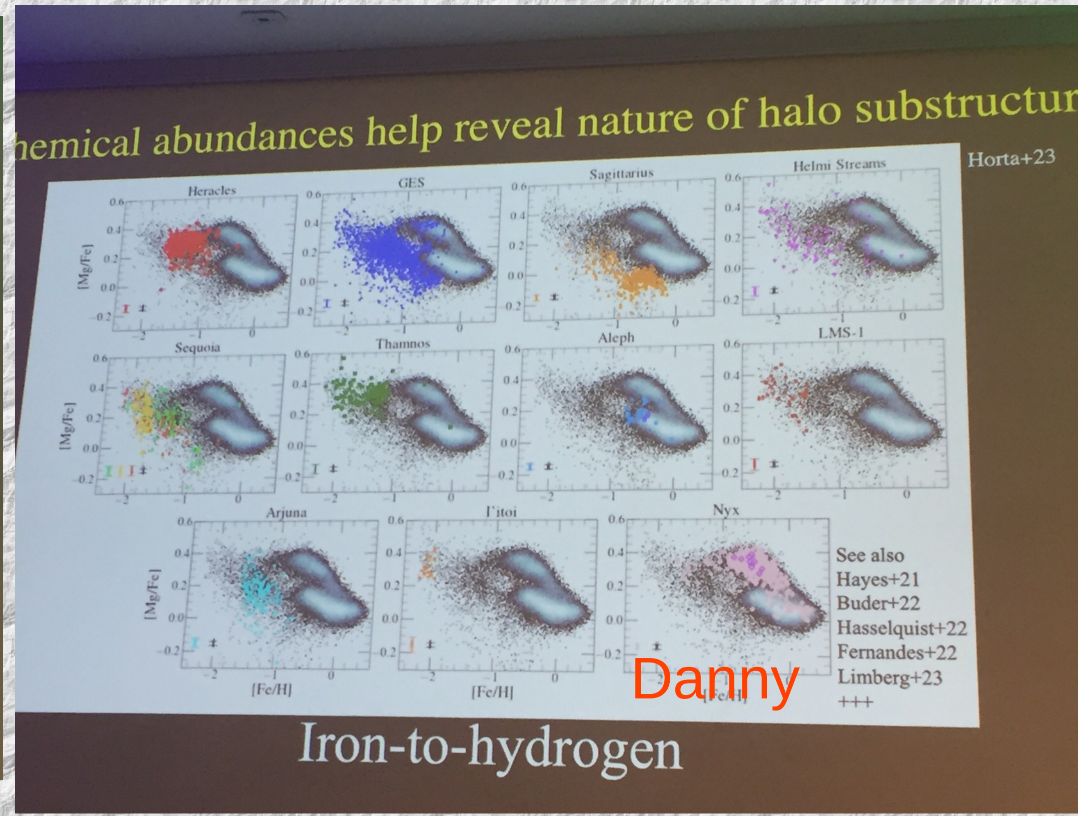
10% Thick

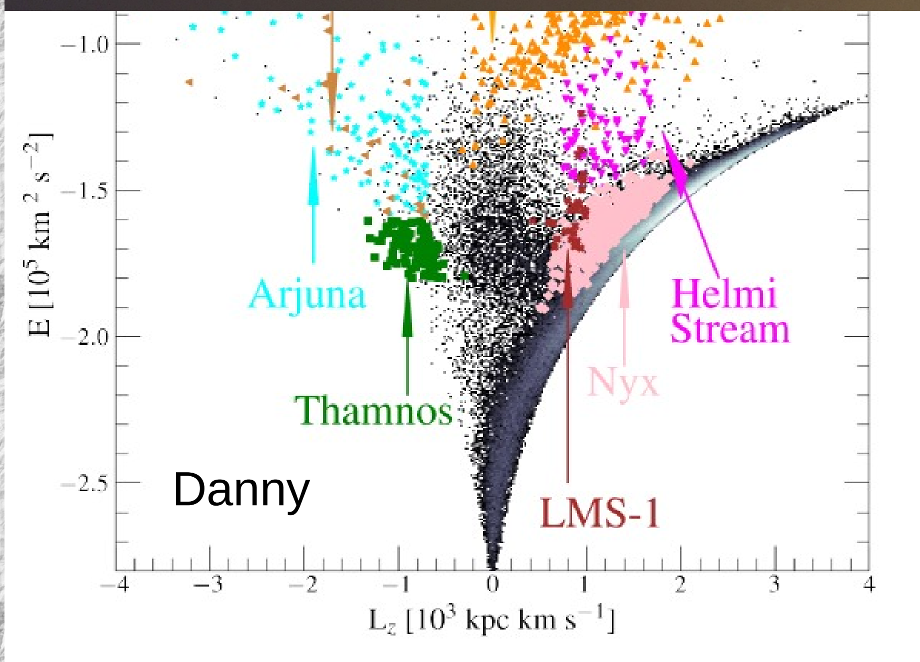
- The Disk(s) (~4×10^{10} $M_\odot$) (Else)

60% Thin

Day 1 (am) Making The Stellar Halo







The last major merger took place ~11 Gyr ago

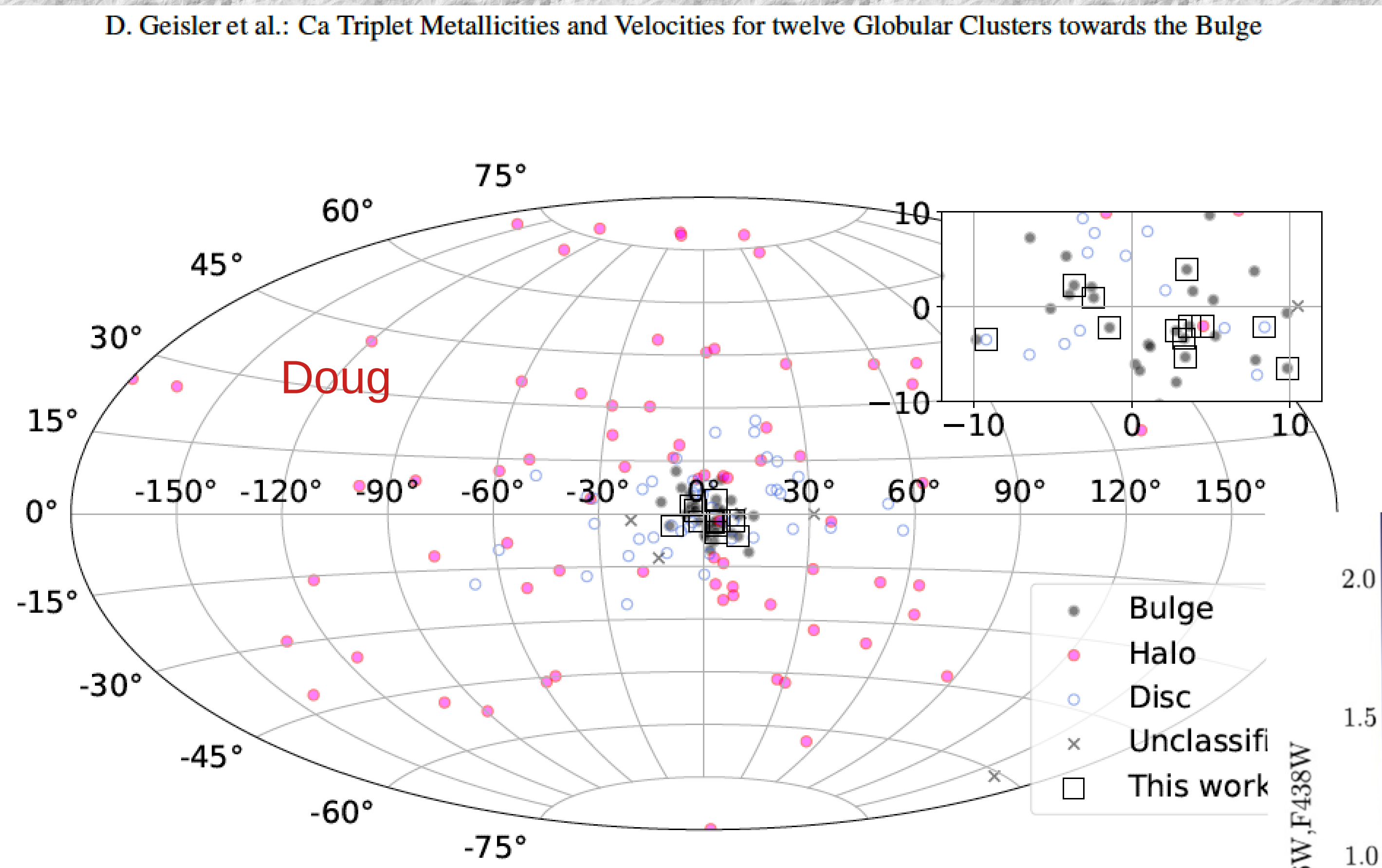
It was “major” for those early times

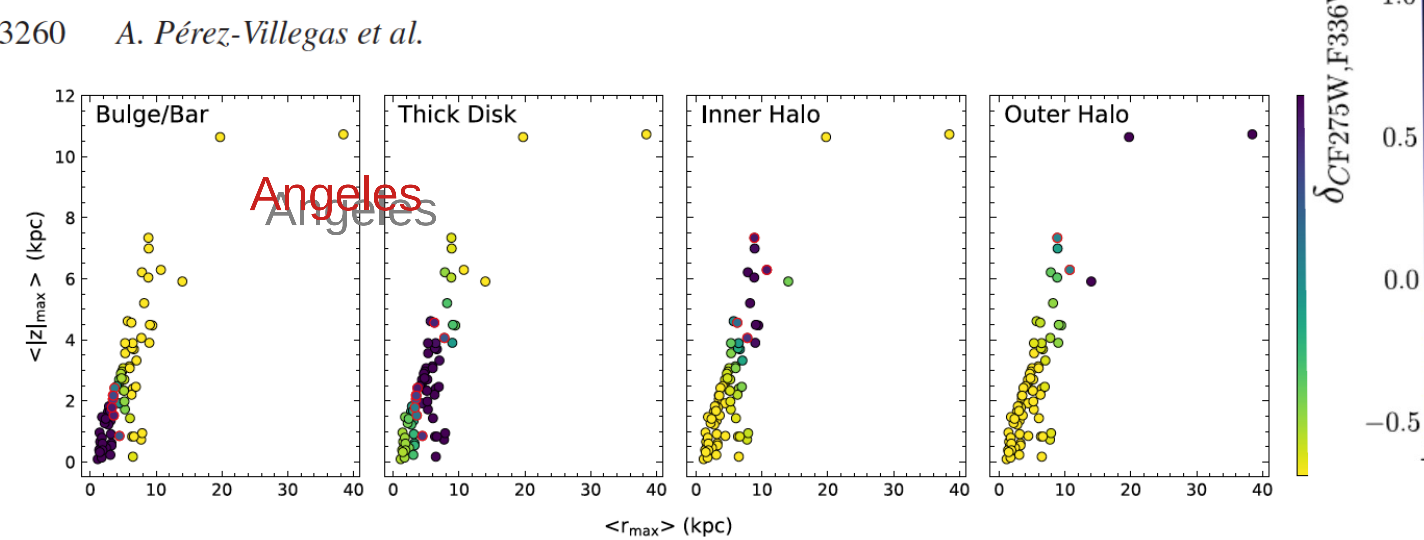
Also called **the (great) SPLASH**

Day 1 (am) Making The Stellar Halo

- ☻ It is amply demonstrated that the Halo formed by hierarchical merging of dwarfs, which became and are now the ubiquitous streams
- ☻ The Halo represents ~1% of the mass of the MW
- ☻ The rest, the Disk and the Bulge, ~99% of the MW, Did NOT form by hierarchical merging of dwarfs

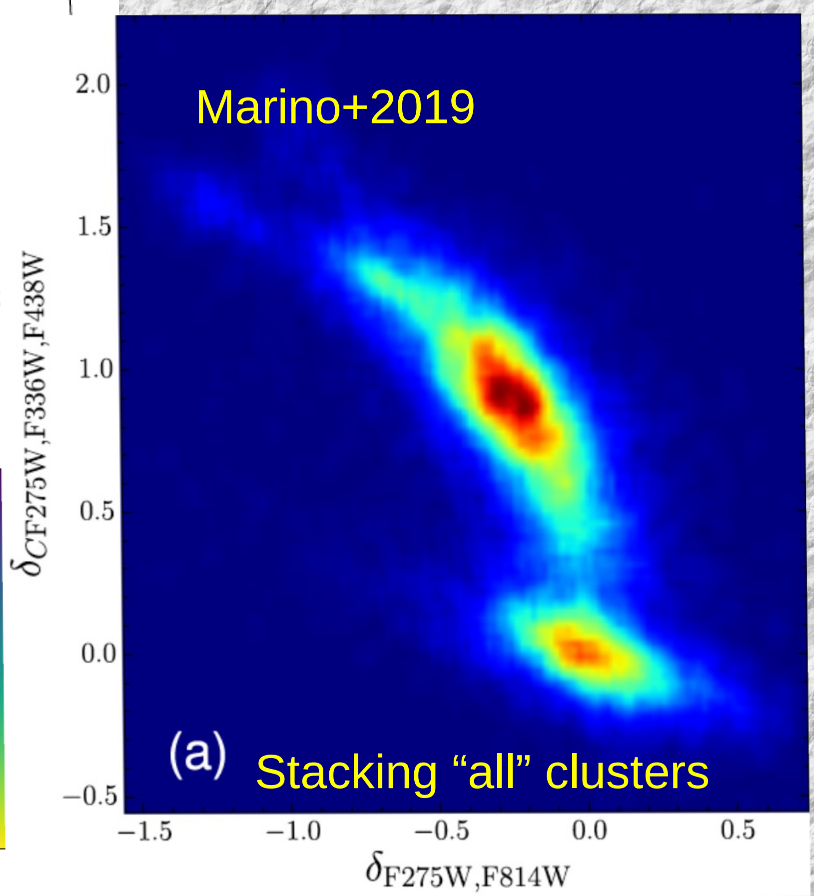
Day 1 (pm) Globular Clusters





The Chromosome Map locus results from a combination of nuclear physics (CNO cycle) and molecular chemistry (OH, NH, CH).

Astrophysics determines which portion of the locus is populated by a particular GC.



Day (pm) Globular Clusters

- ☻ GCs associated to Streams (Davide)

  A confirmation that Halo GCs formed in dwarfs that later dissolved (Searle & Zinn 1978)

- ☻ This helps solving the Mass Budget problem (Carmela), as it is the host dwarf that provides the stuff to make 2G stars

- ☻ Nearly half of all GCs belong to the halo (~10^9 $M_{\odot}$)

  The other half to Bulge & Thick Disk (~2.5×10^{10} $M_{\odot}$)

  So, the Dwarfs have been ~25 times more productive of GCs than the bulge/thick disk!

But how can it be that most “bulge GCs” peak at [Fe/H]=-1.0 where there are no bulge stars (Angeles, Doug)?

I’m puzzled!

The central issue: How was the dichotomy created?

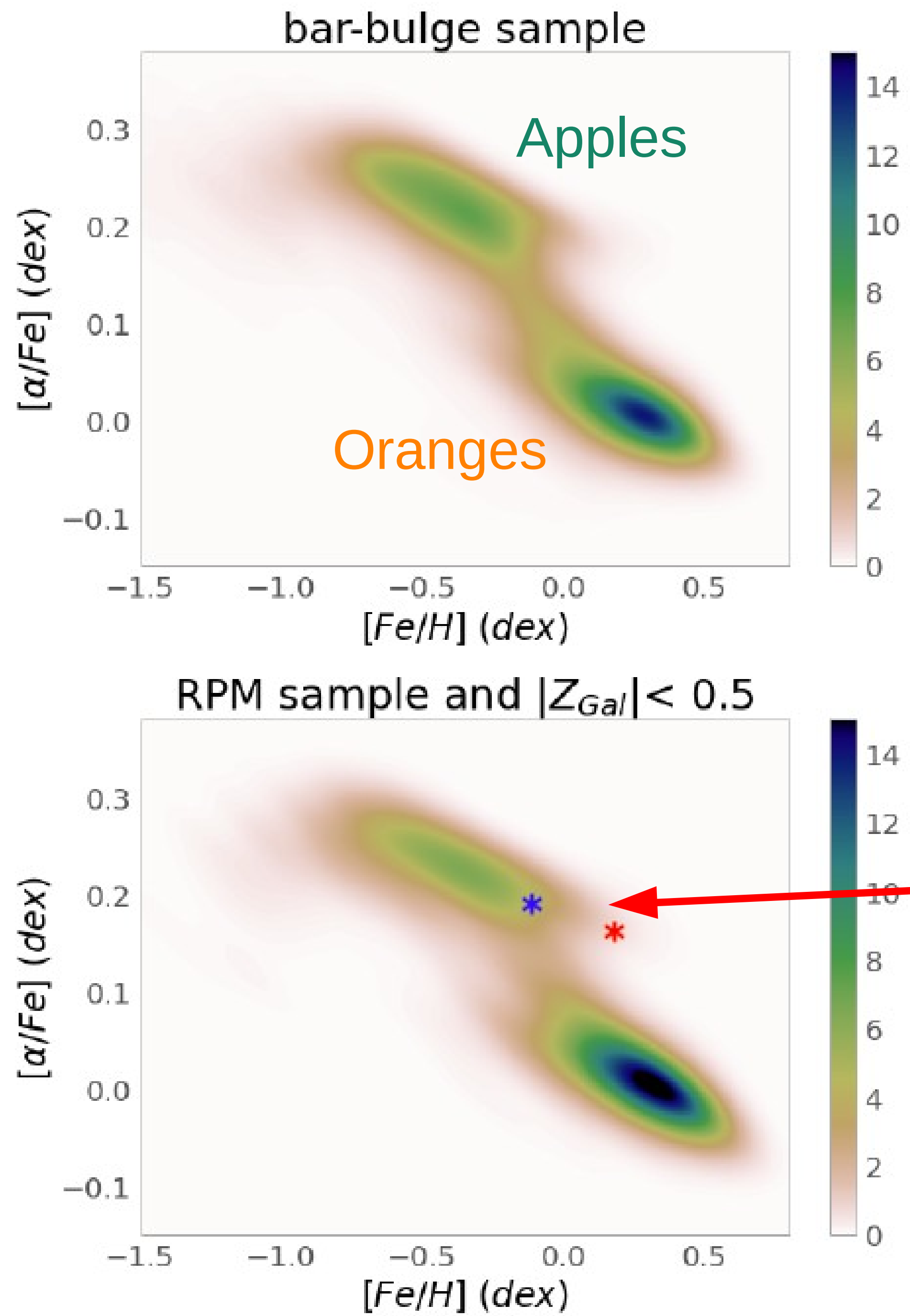
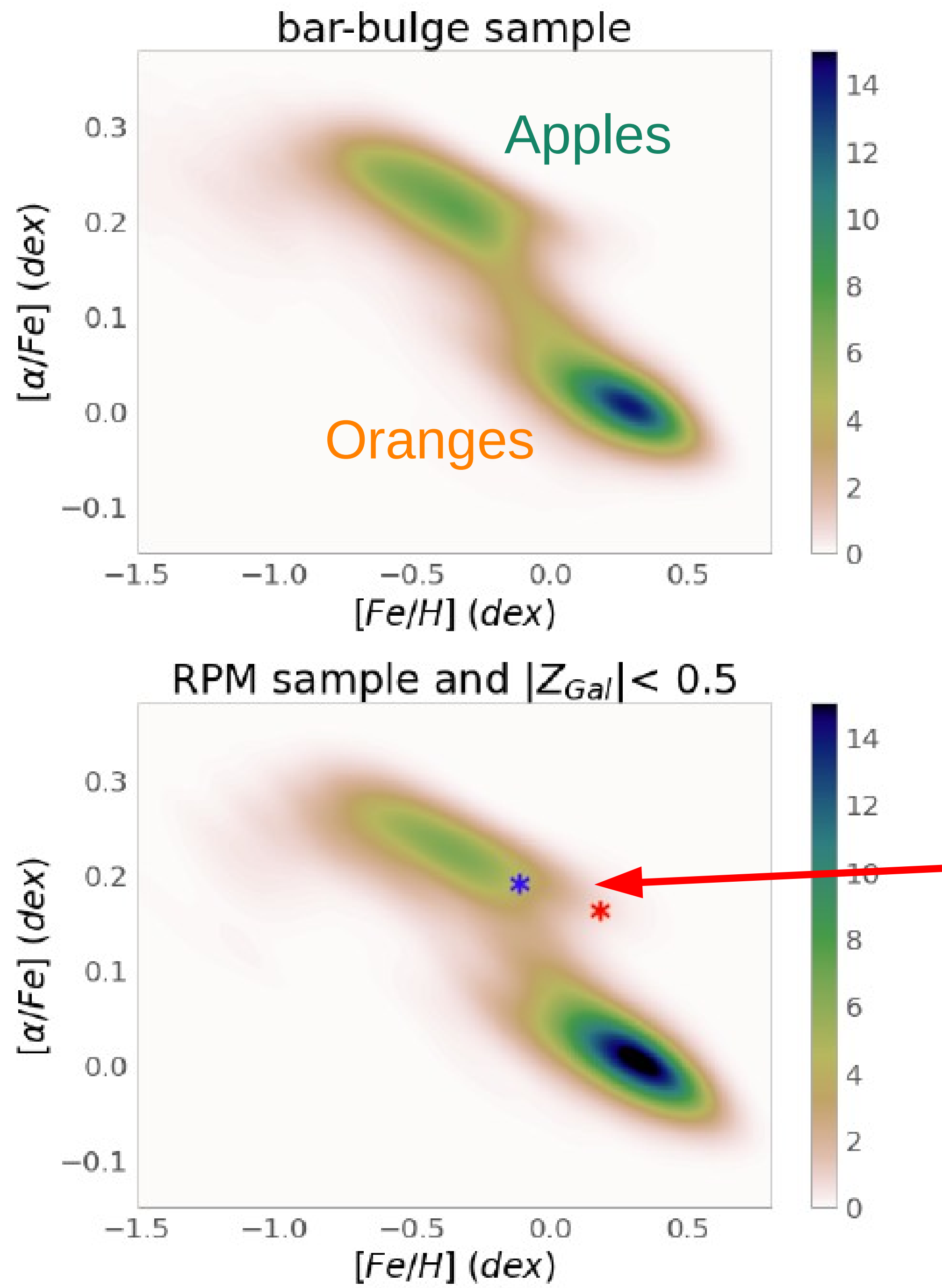


Fig. 9. [α/Fe] vs. [Fe/H] distributions for the bulge-bar region (~ 26 500 stars), and RPM sample (~ 3 800 stars with $|Z_{Gal}|$ < 0.5 kpc), colour-coded by the probability density function.

The two most metal rich globular clusters NGC 6522 and 6553 (~10 Gyr old)



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The two most metal rich globular clusters NGC 6522 and 6553 (~10 Gyr old)

All globulars are Apples!

(no thin-disk GCs exist)

Day 2 (am) The Central Parts of the Galaxy (also known as the Bulge)

A. Queiroz et al.: New StarHorse stellar parameters, distances, and extinctions for spectroscopic surveys

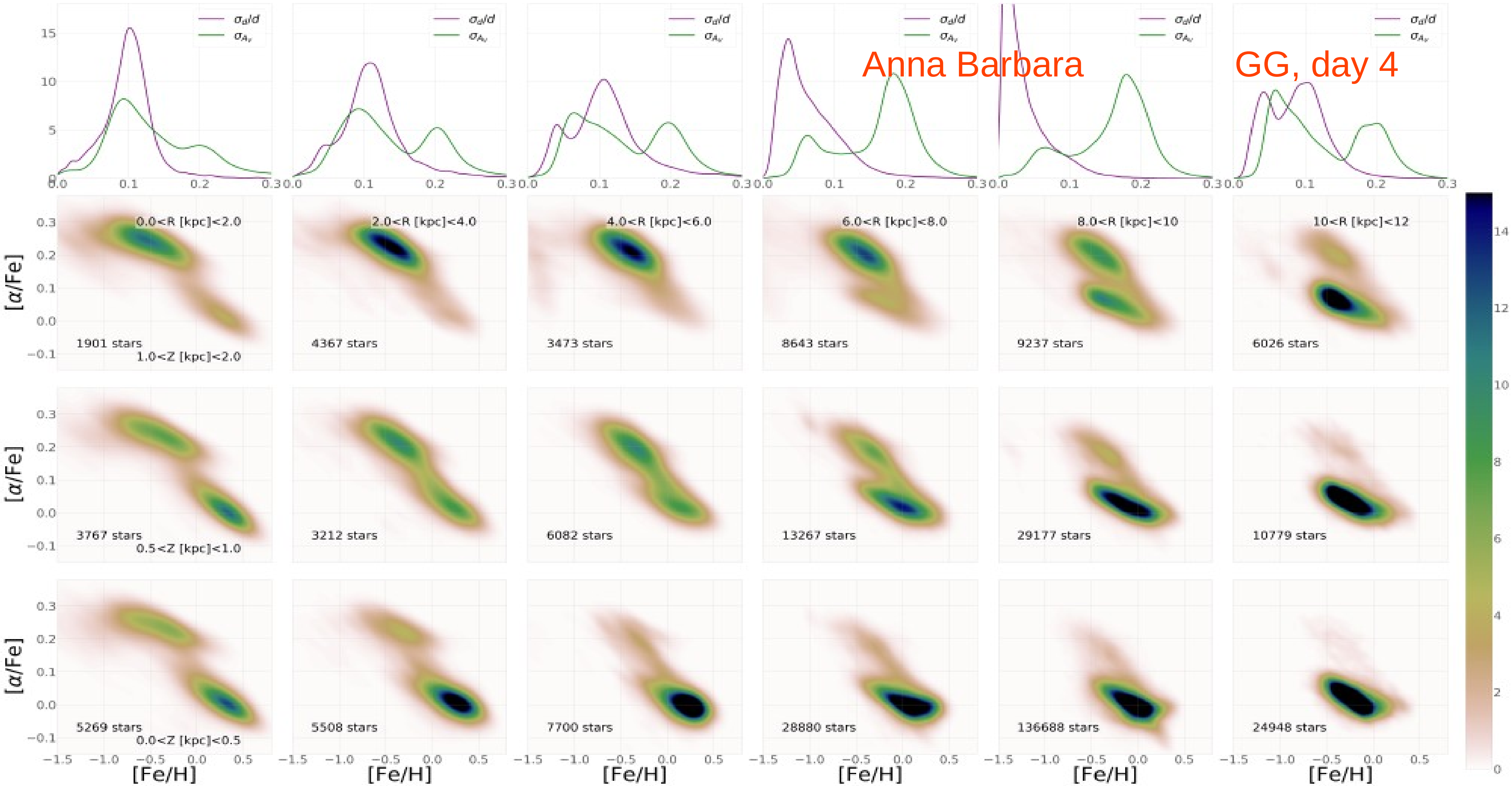

Fig. 6. APOGEE DR16 [α/Fe] vs. [Fe/H] diagrams in bins of Galactocentric cylindrical coordinates, similar to the chemical maps presented in Hayden et al. (2015), but extending further into the inner Galaxy. The upper panels show kernel-density estimates of the uncertainties distributions in StarHorse extinctions and distances, for each Galactocentric distance bin (including all Z_{Gal} bins).

Day 2 (pm) The Bulge

"Near-coeval formation of the Galactic bulge and halo inferred from globular cluster ages"

Sergio Ortolani, Alvio Renzini, Roberto Gilmozzi, Gianni Marconi, Beatriz Barbuy, Eduardo Bica & R. Michael Rich

Nature, 377, 701 (1995)

But the bulge is rather a continuation of the disk, not of the halo!

The Key issue remains (as from Beatriz' review):

What is the age distribution of bulge/bar stars, separately in various metallicity bins?

Day 2 (pm) The Bulge

We all agree that Oranges (supersolar) must be younger than Apples (subsolar). The question is "by how much"?

Two methods of getting Bulge ages:

Photometric (from CMD and classical MSTO luminosity)

Spectroscopic on lensed stars (g, T_{eff}, Z)

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  - Advantages: many stars, not much model-depended, pm
  - Disadvantages: no individual distances, photo-Z, no v_r

- ☻ Spectroscopic on lensed stars (g, T_{eff}, Z)
  - Advantages: distance independent, Spec-Z
  - Disadvantages: few stars, more model-depended, no pm

e.g. theoretical g and T_{eff} depend on the adopted "mixing length" and with different stellar models Joyce+2023 obtain a narrower age range for the oranges, using the same data

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The solution: use the photometric method with input spectroscopic metallicities for stars around the MSTO

What we do not understand yet:

- How was the galactic dichotomy created?
  - Early quenching, followed by a SF gap and rejuvenation? (Lian+2020) Apples first, then Oranges (Carme)
  - High-α stars form in SF clumps, low-α stars out of clumps? (Clarke+2019): Making Apples and Oranges together
  - A result of the Great Splash? (Amina?)
  - or else? (a glitch in the pipeline?)

- How to make α-poor bulge stars (Oranges) at z~2? This would contradict the rule of thumb that high sSFRs makes α-rich stars.

➔ Bulge Oranges are not so old, how much younger than Apples are they? Bulge Oranges did not form in a burst, but it took a few Gyr to make them. Yes, but how many??

Day 2 (pm) The Galactic Disk (both thick and thin)

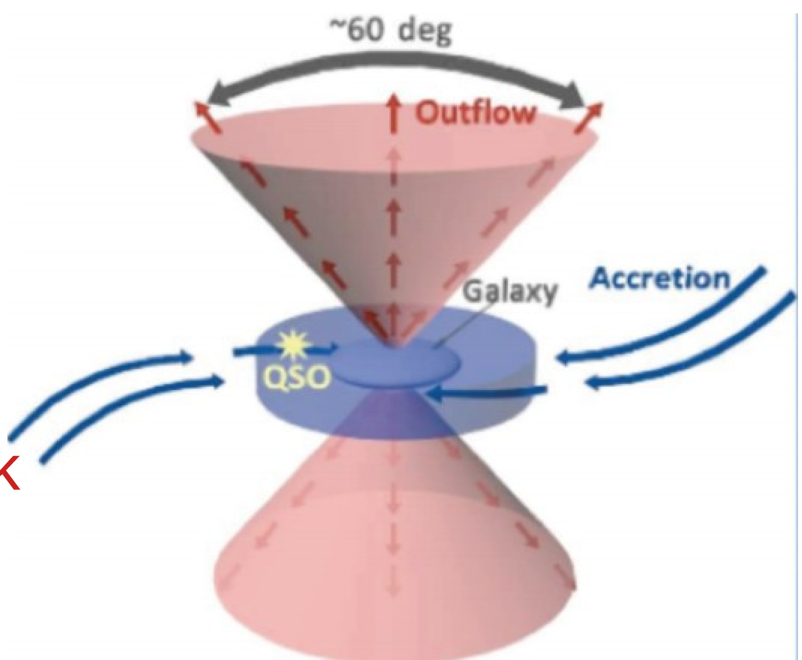
The Thick > 10 Gyr The Thin < 10 Gyr (e.g., Carme)

The key issue: HOW DID IT/THEY FORM?

Here, it is critical to look at high-z galaxies (Samir)

Most SFGs at z up to 3 (and beyond) are rotationally supported disks, fed by co-planar co-rotating gas accretion followed by radial flow in the disk

(Andrew in Day 4)



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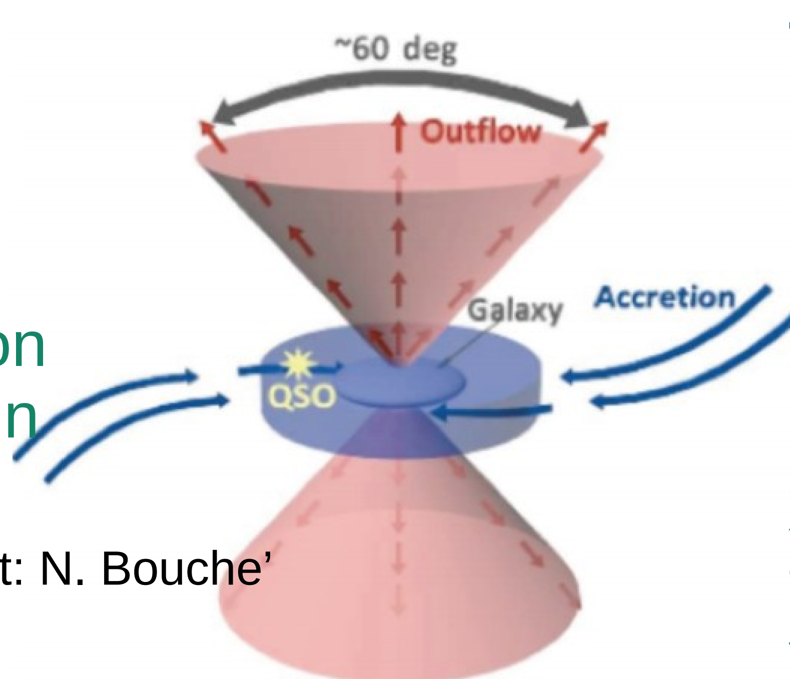


Credit: N. Bouche'

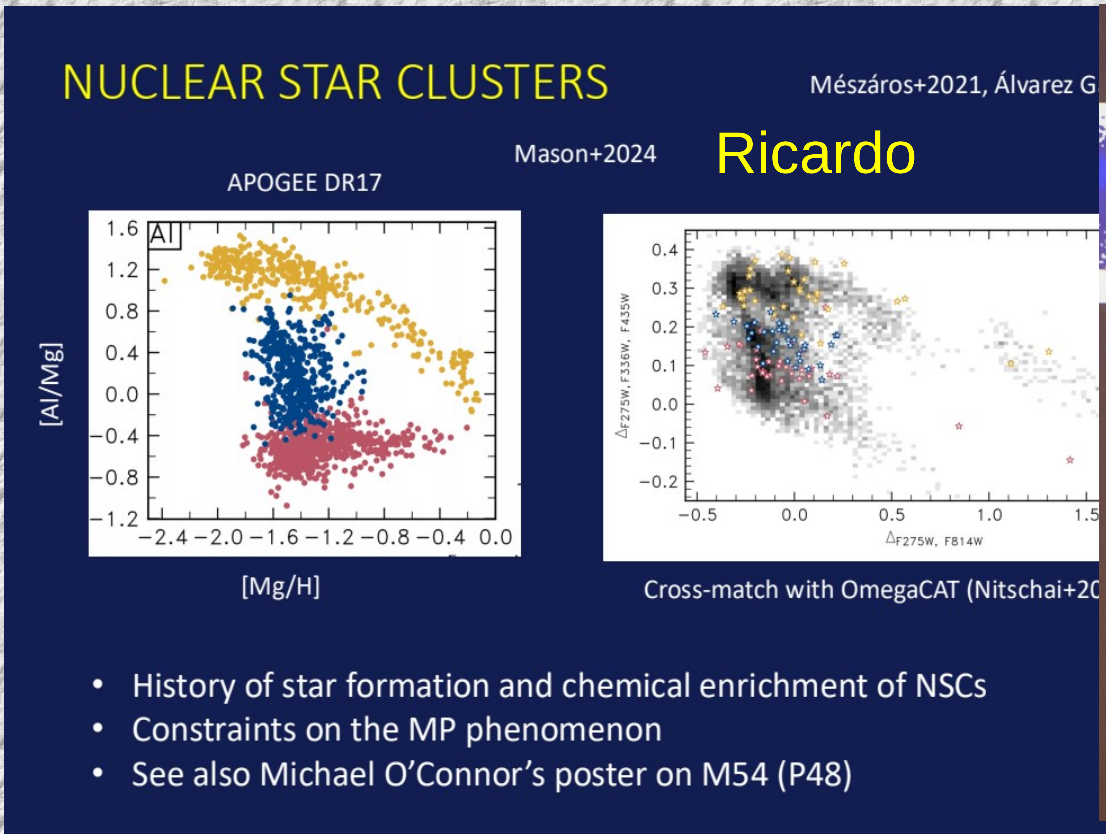
To which extent archaeology and lookback time-travel match each other?

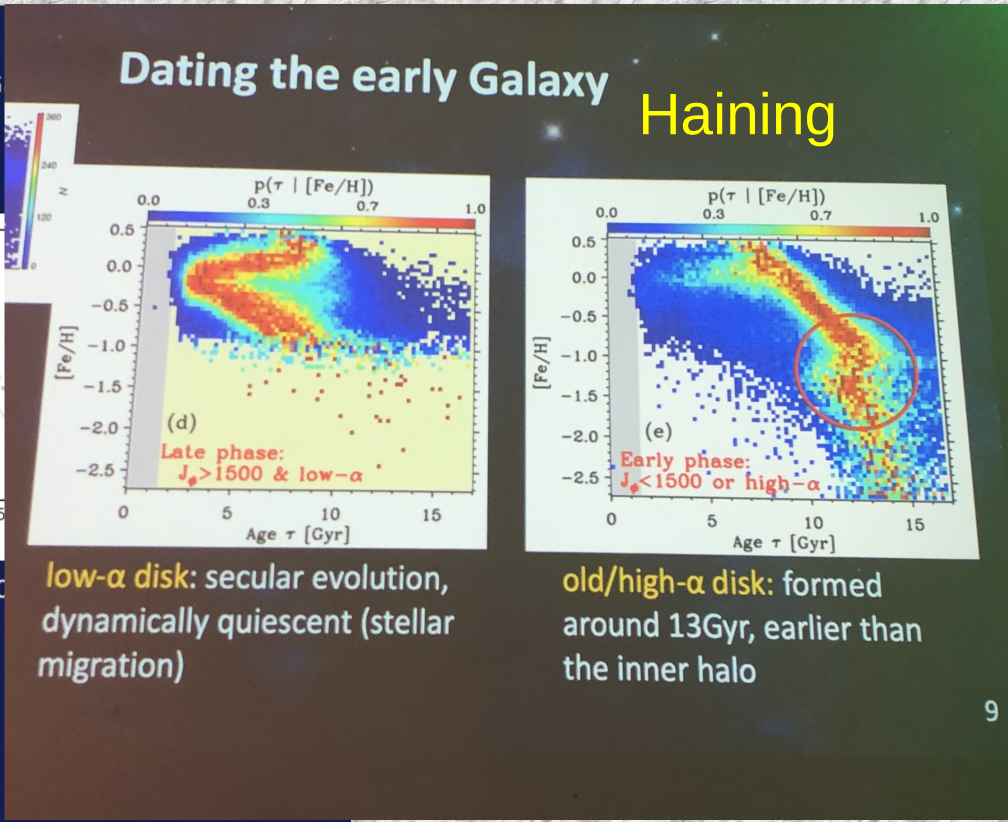
Xiang, Rix+2024 find a ~13 Gyr old disk in the solar vicinity...

Day 3 (am) Surveys

Hard to summarize….

Just from fully survey-dedicated ground-based telescopes:





Day 4: Methods & Population Synthesis
(the kichen tools)

Theoretical vs empirical spectral libraries (Paula):
model atmospheres are unavoidable either way

ISM from Sodium lines (Alexander, Francesco):
it is very insensitive to the number of M stars, so one needs very many of them to change the Na line by 1-2% of the continuum and needs very high Na too!!

Zoom-in simulations are starting to show signs of the Apples/Oranges bimodality (Francesca, Chiaki)

UFDs (Nitya, Mario) formed at ERI, along with ultracompact globulars and ultracompact galaxies

Day 5 (am) Un/resolved Populations & High-z

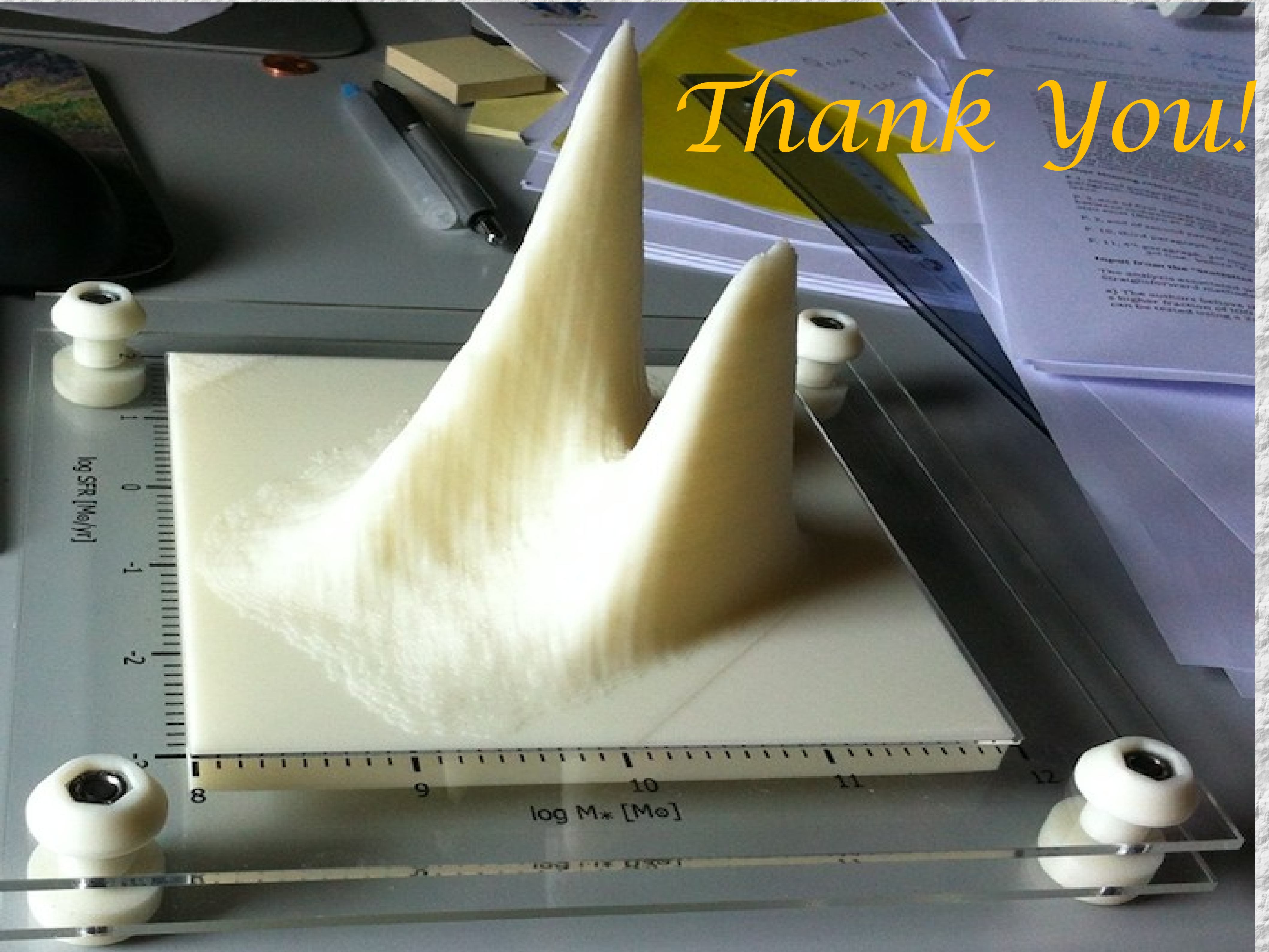
JWST opening the very high redshift window
But data are too good for the models to fit (Gustavo)

Post-AGB is not enough for LIERS (Grazyna)

Zwicky 18 is still an outlier, like Fritz… (Giacomo)

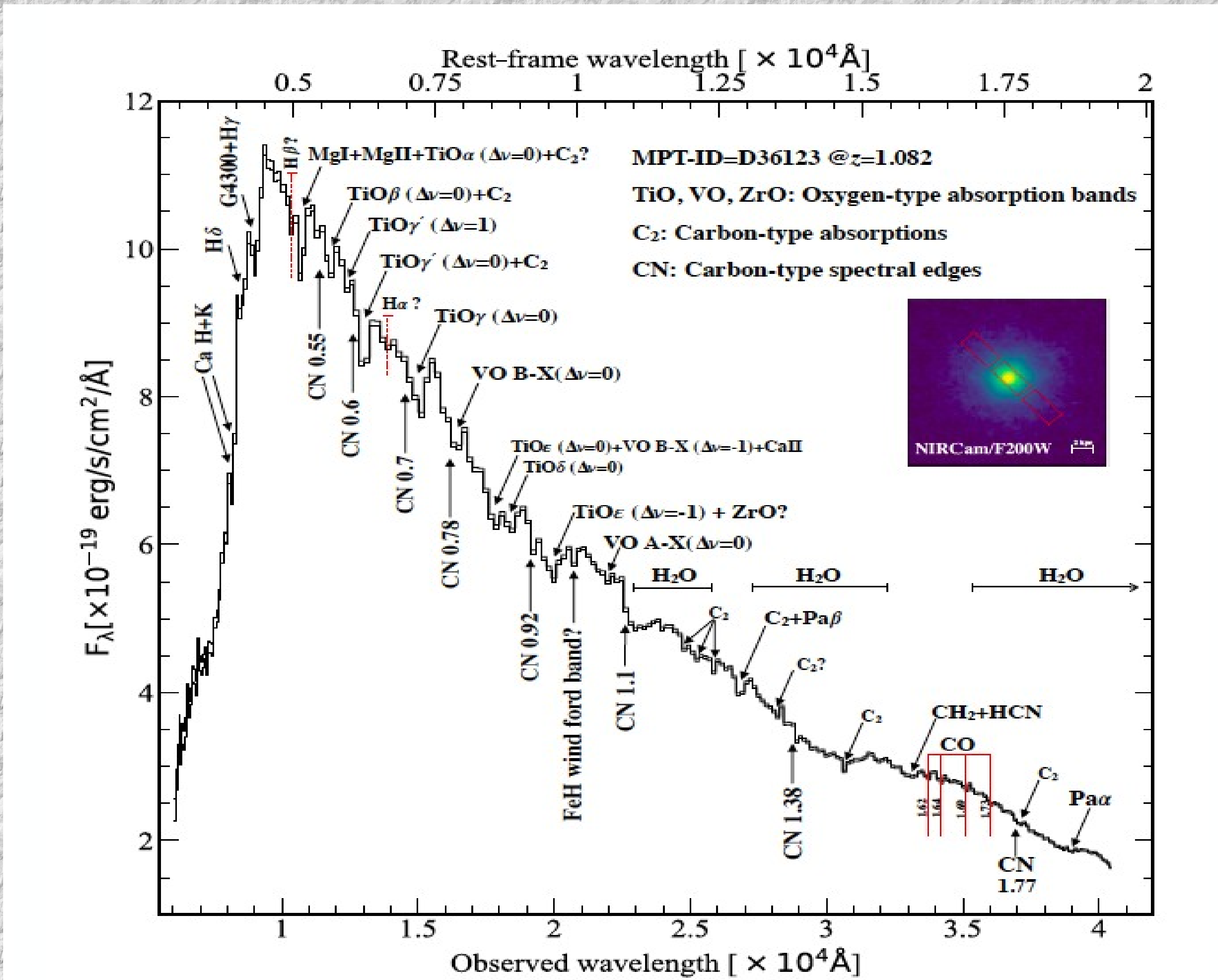
Euclid can make a great deal of good for stars within ~5 Mpc (Jess)

Thank You!



Lu, Daddi, Maraston et al. 2024

The JWST/NIRSpec spectrum of a quenched galaxy at z~1 showing features of both AGB Carbon stars and AGB M-type stars




Thank You!