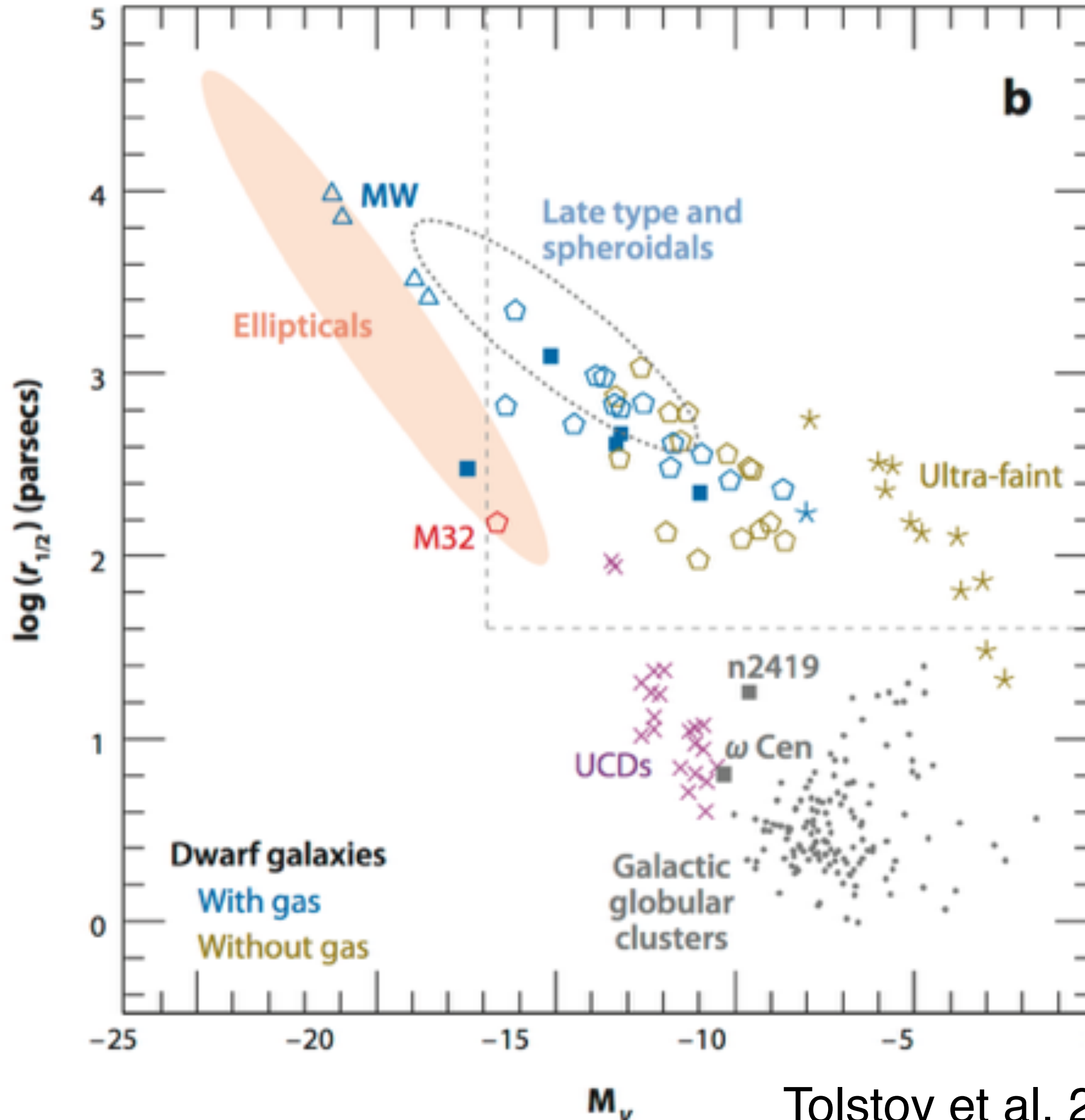
Stellar populations and Galactic archeology

The goal of this course: understand how to use stars to recostruct the evolutionary history of galaxies

Taxonomy of galaxies & their stellar content

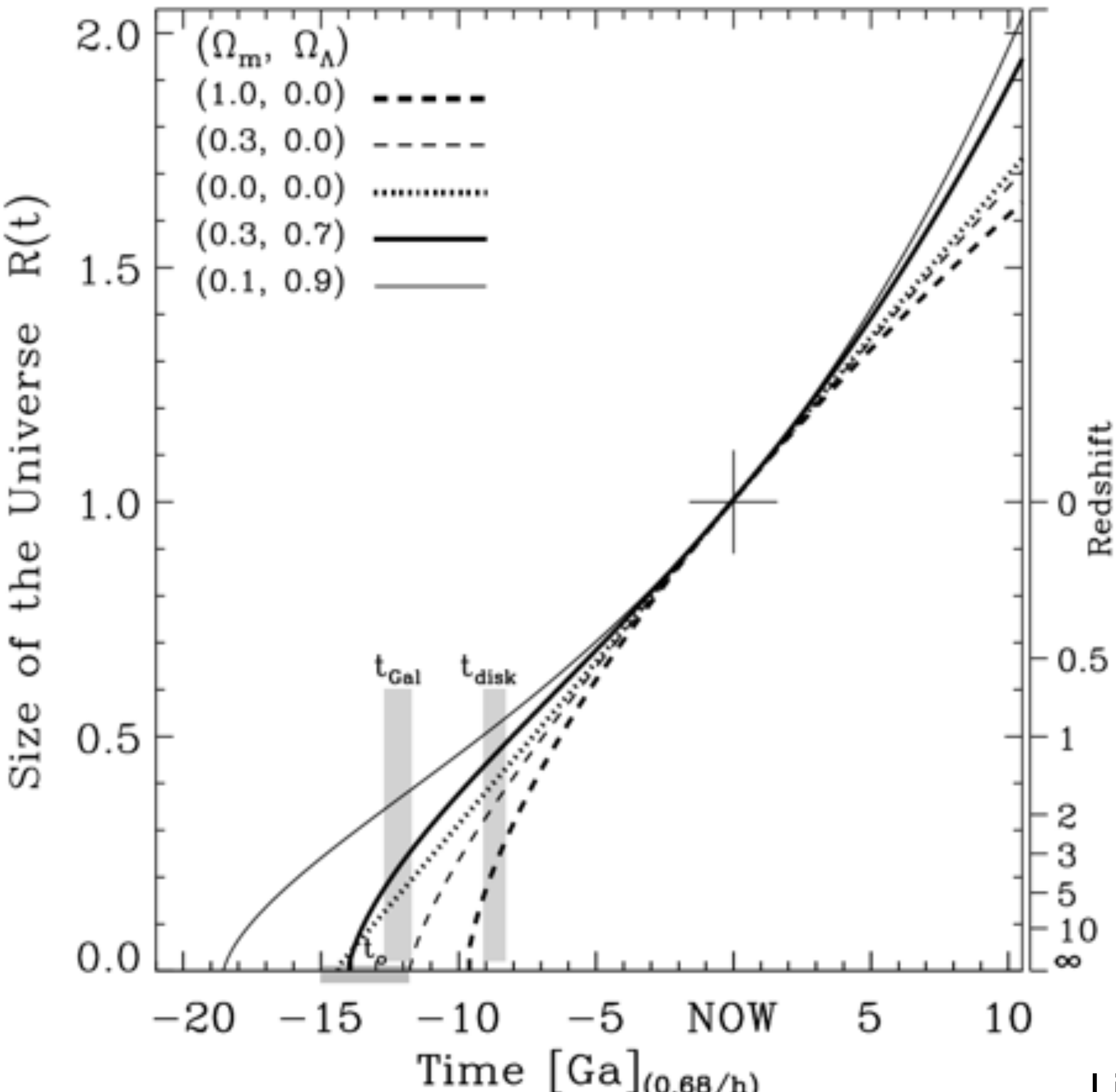
Milky Way

- a large spiral galaxy
  age ~ 13 Gyr
- dust, gas, stars, SMBH
- decomposed into:
  halo
  disc
  bulge



Tolstoy et al. 2009

Studying the Milky Way gives us:



- nucleosynthesis and GW sources
- physics of low- and high mass star formation
- stellar evolution and formation of planets
- galaxy assembly
- test of Big Bang cosmology

Lineweaver 1999

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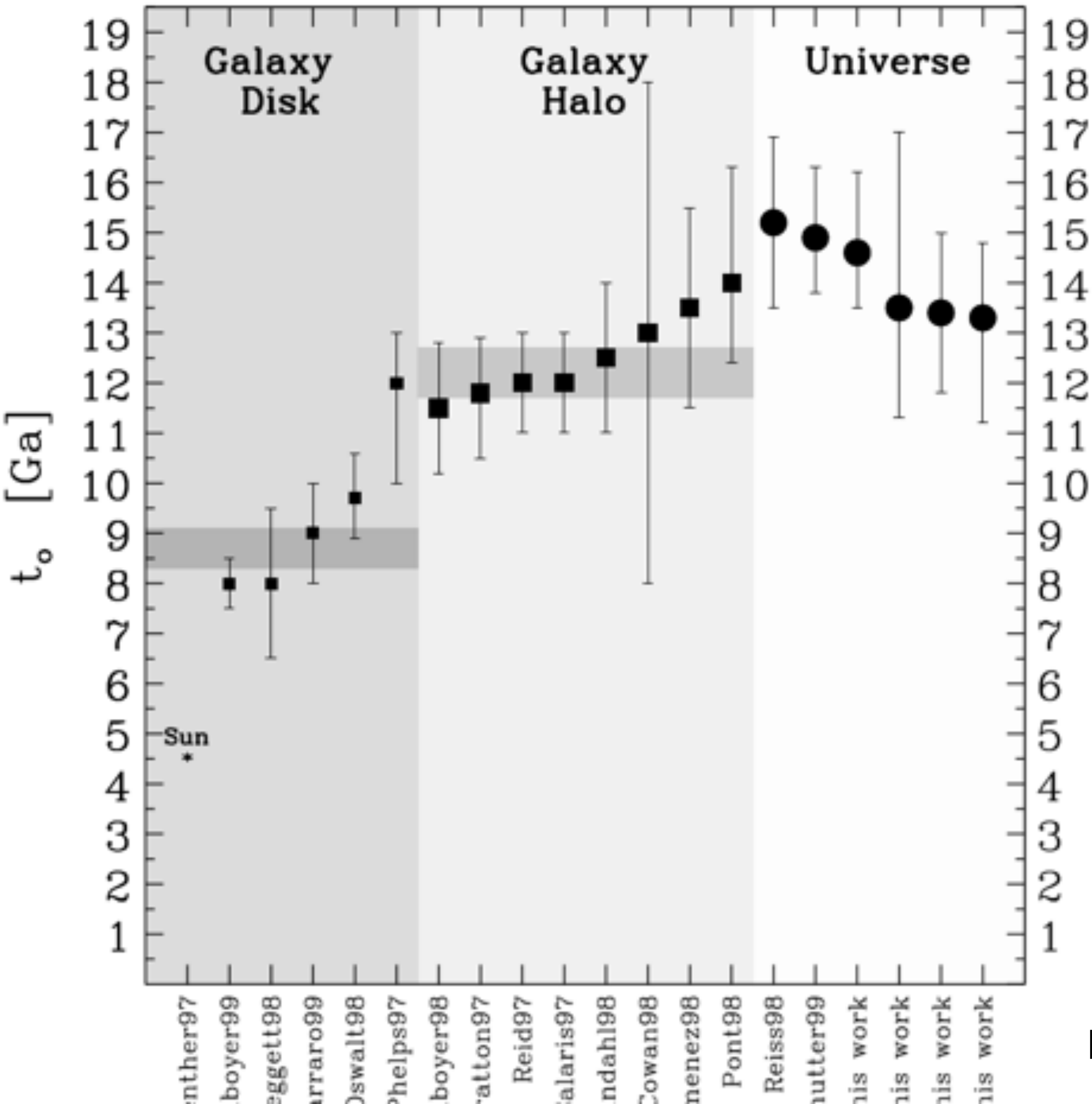

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Lineweaver 1999

Stellar populations in the Milky Way

are characterised by:

- age
- chemical composition
- stellar densities
  N stars / kpc^3
- kinematics

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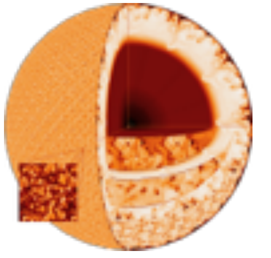
- age → stellar structure models + asteroseismology



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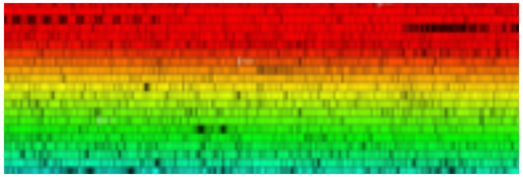

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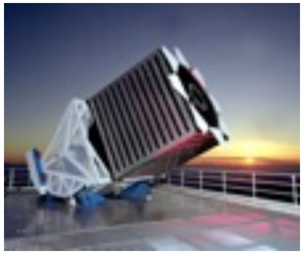

- kinematics

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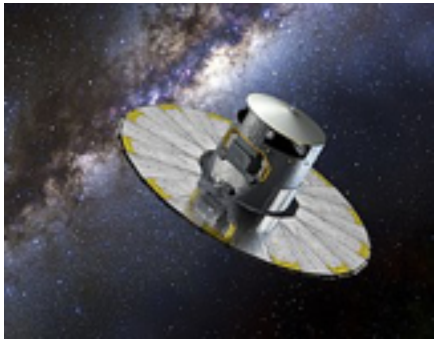
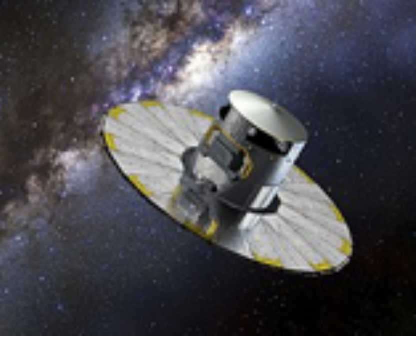
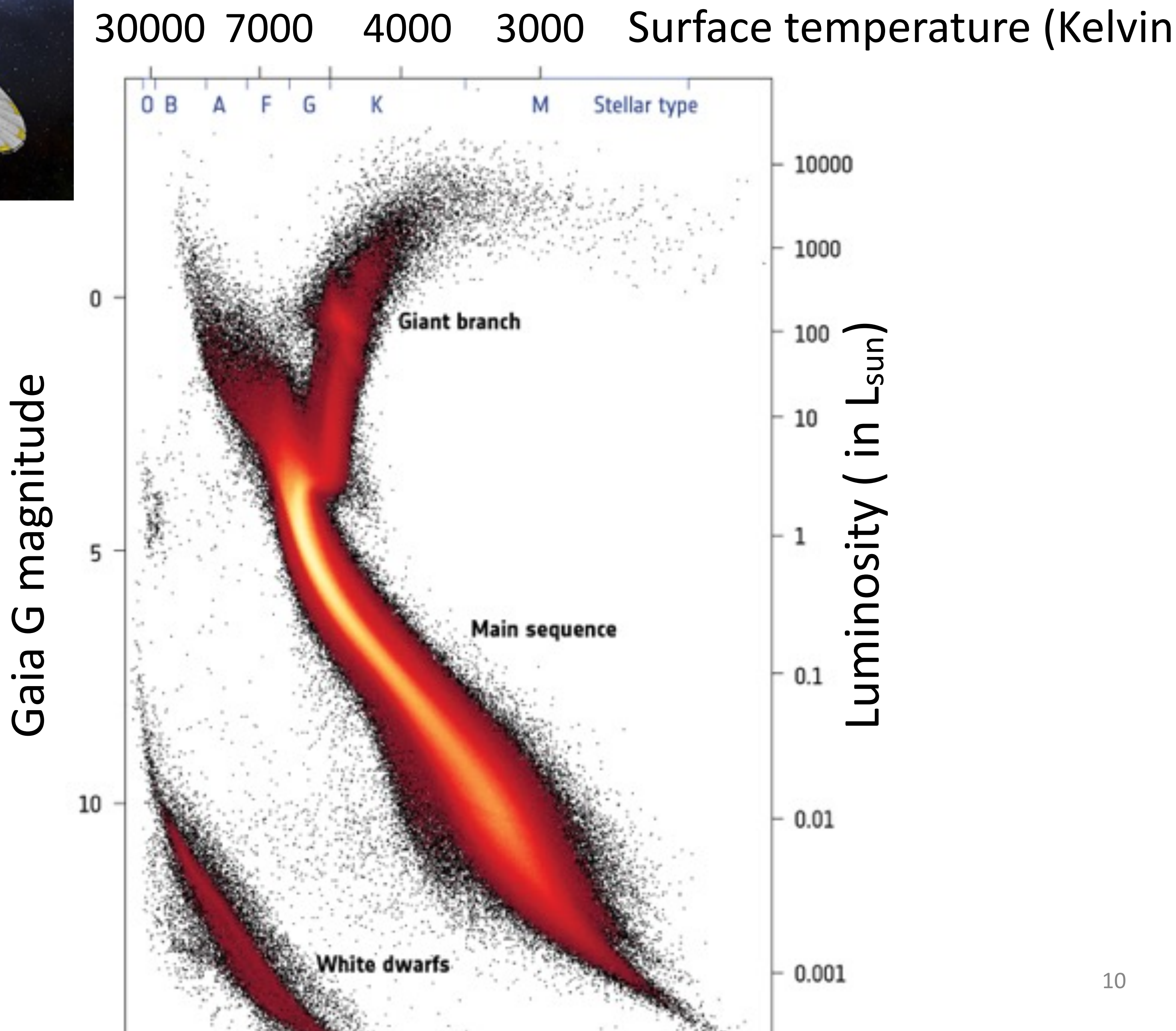
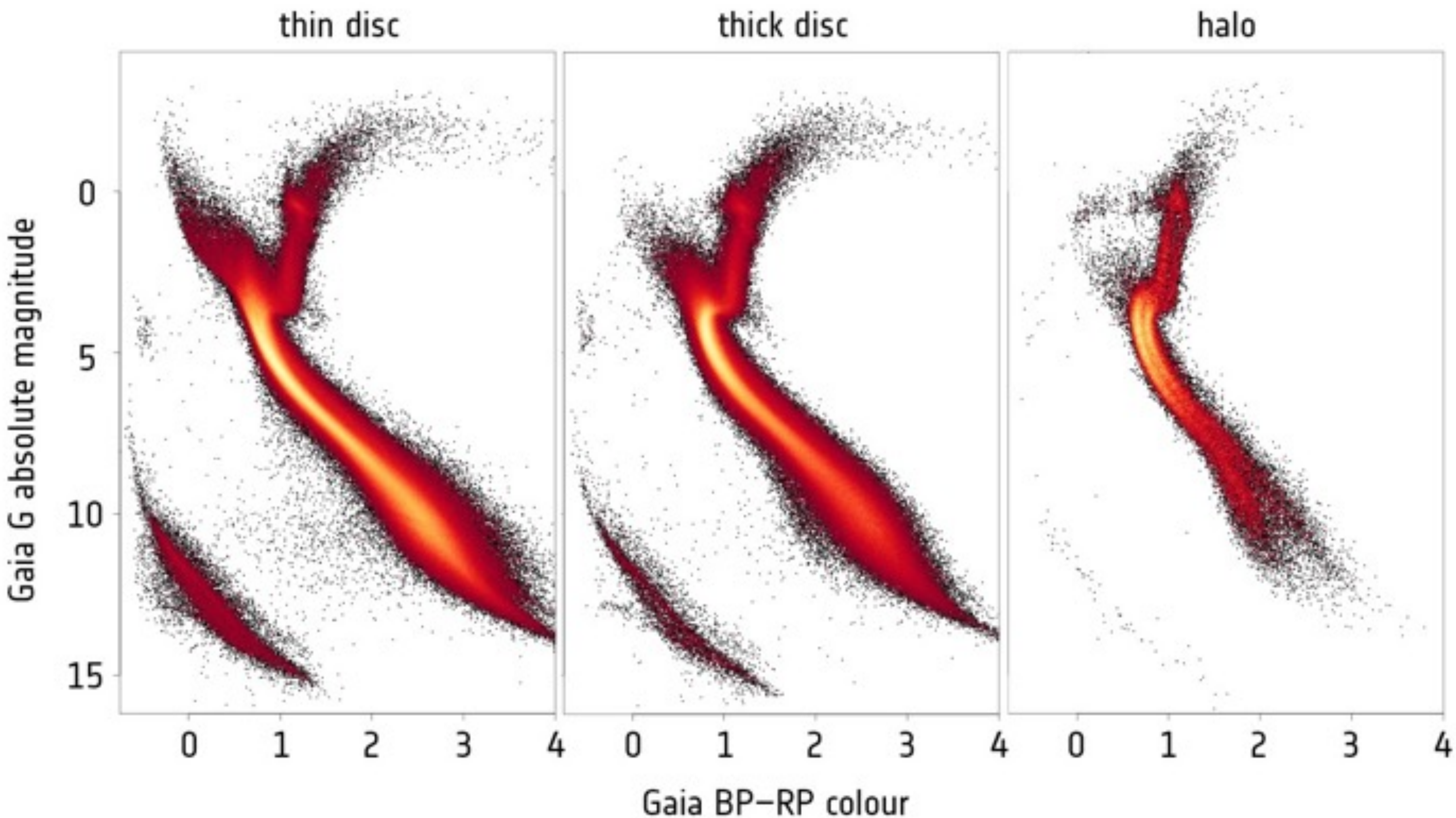
- kinematics → astrometry surveys





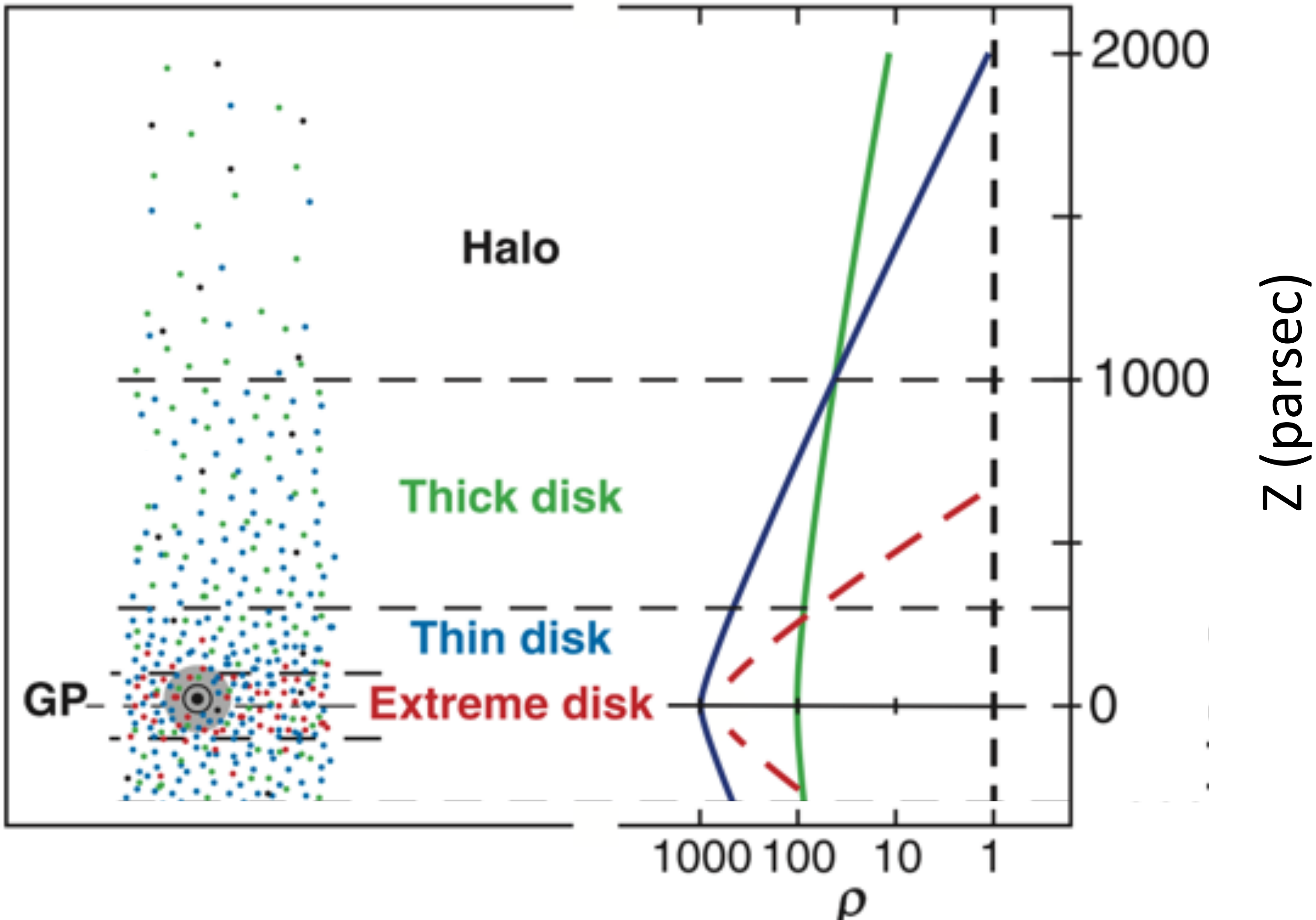

30000 7000 4000 3000 Surface temperature (Kelvin)
O B A F G K M Stellar type
Gaia G magnitude
0
5
10
Luminosity (in L_{sun})
10000
1000
100
10
1
0.1
0.01
0.001
Giant branch
Main sequence
White dwarfs

Decomposition by kinematics



(c) Gaia Data Processing and Analysis Consortium (DPAC);
Carine Babusiaux, IPAG – Université Grenoble Alpes / GEPI – Observatoire de Paris, France

Decomposition by number density



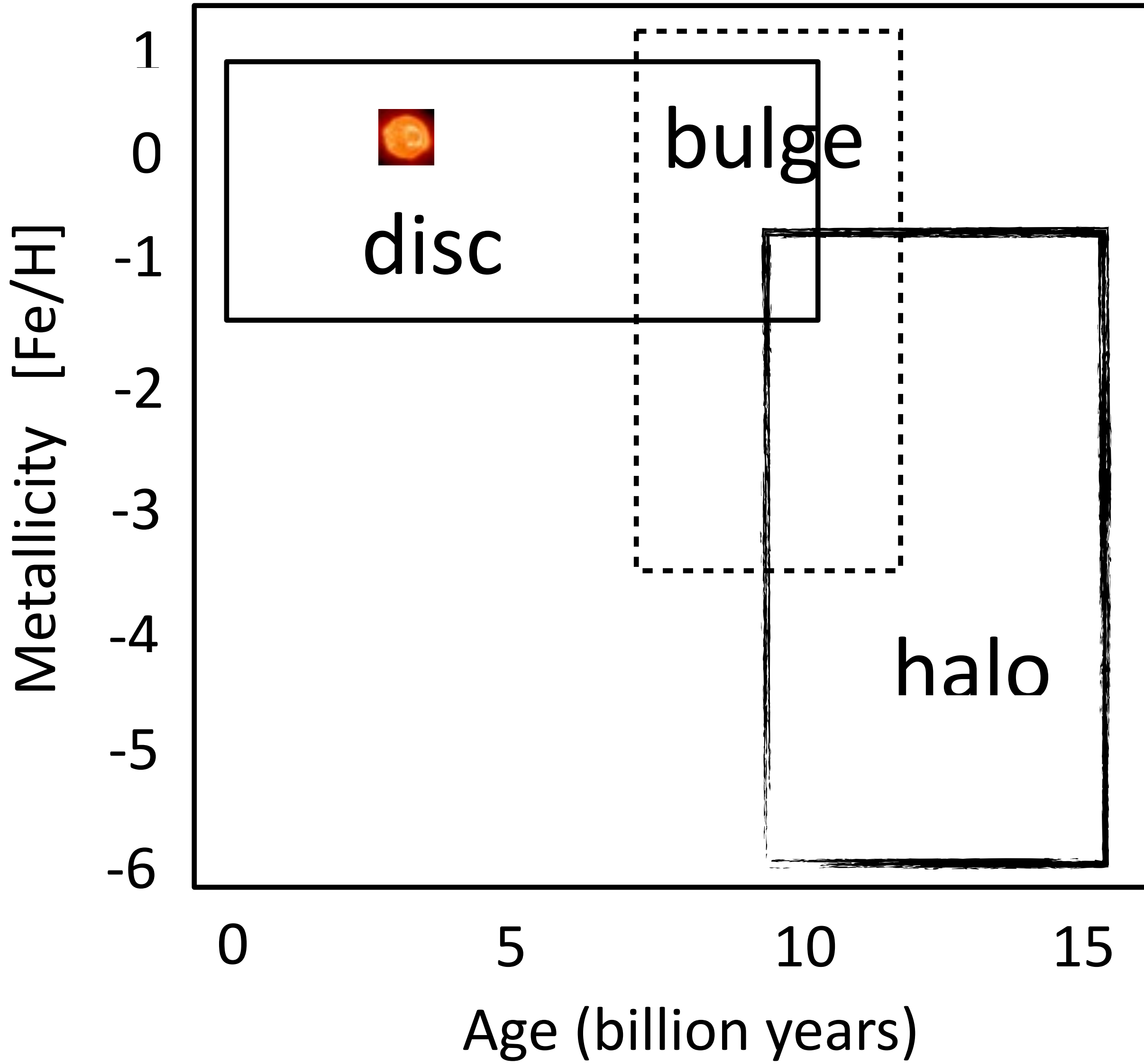
Density of stars (per 1 halo star)

Buser 2000

Decomposition by age and metallicity

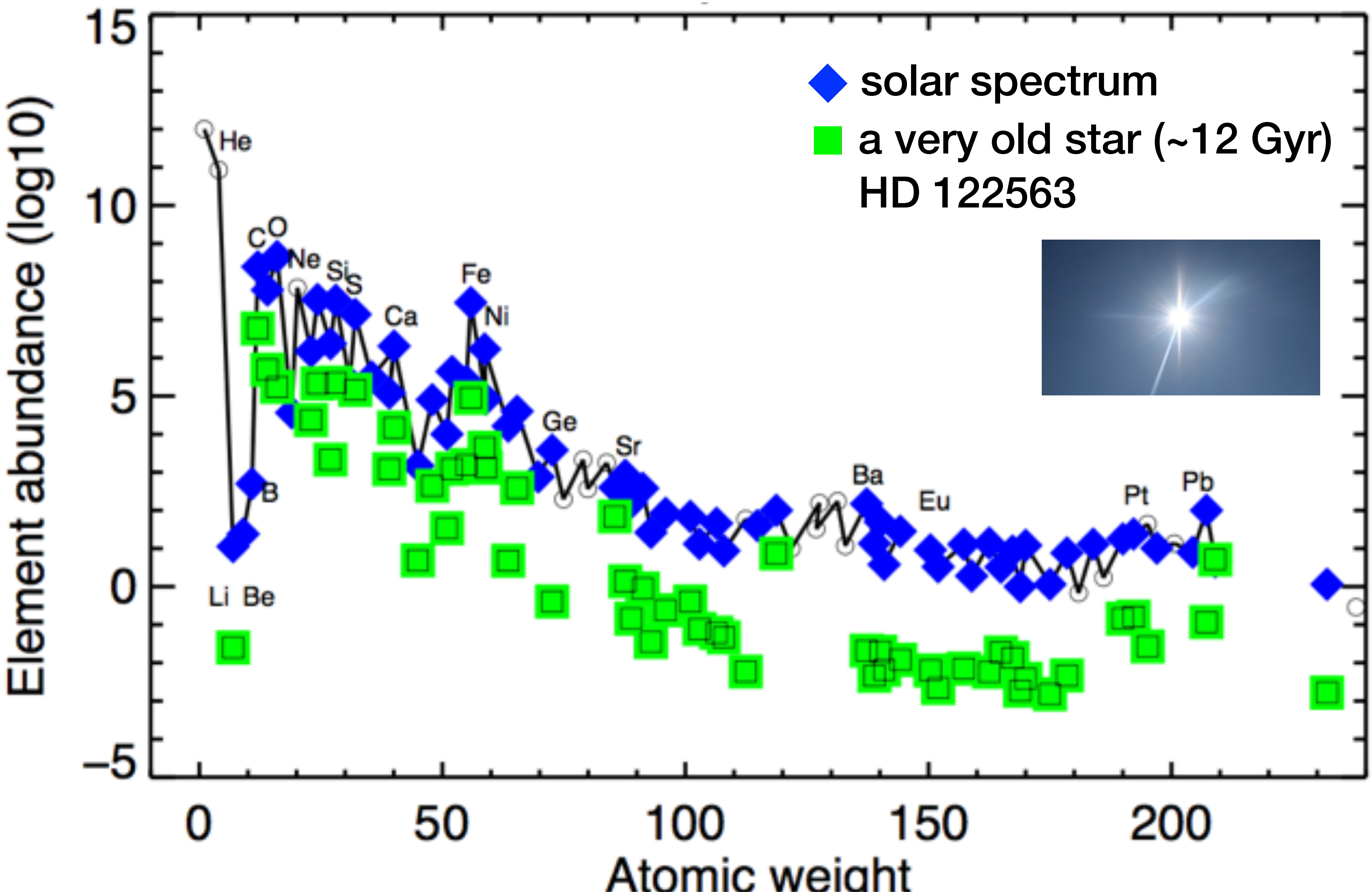
Definition of metallicity in astronomy

[Fe/H] =
$(Fe/H)_{Star} - (Fe/H)_{Sun}$



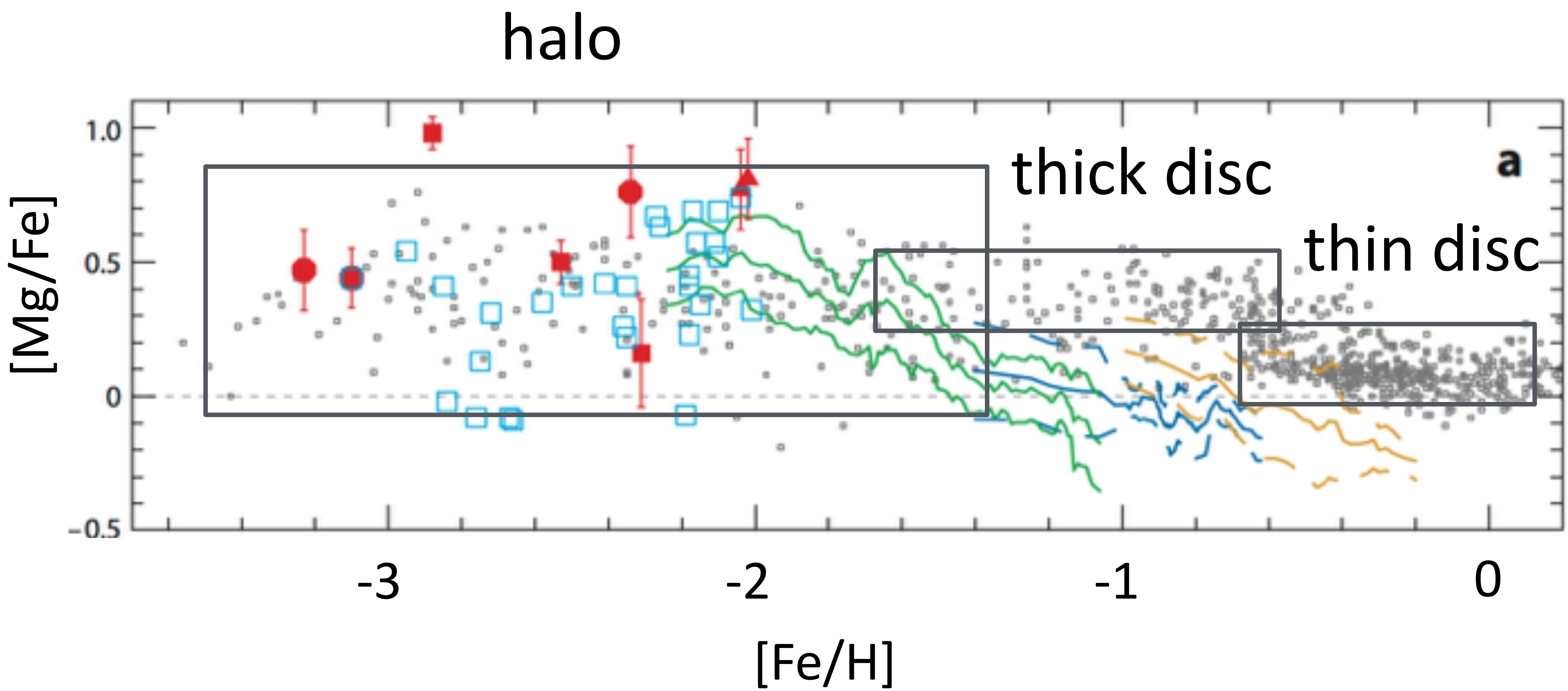
Freeman & Bland-Hawthorn 2000

Decomposition by chemical abundances



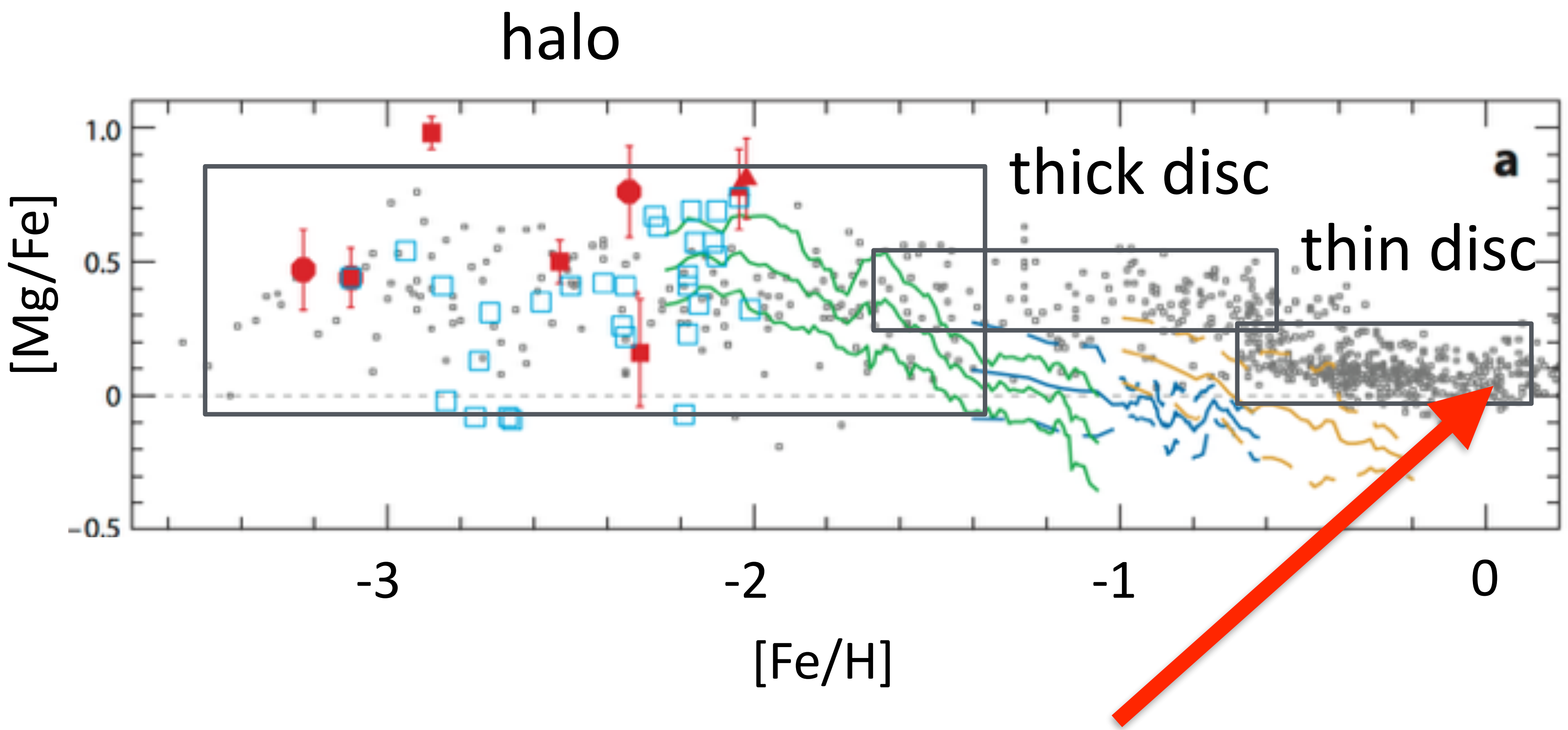
Lodders et al. 2009,
***Bergemann, Hansen**, and Beers (2019, in press)*

Decomposition by chemical abundances



Tolstoy et al (2009)

Decomposition by chemical abundances



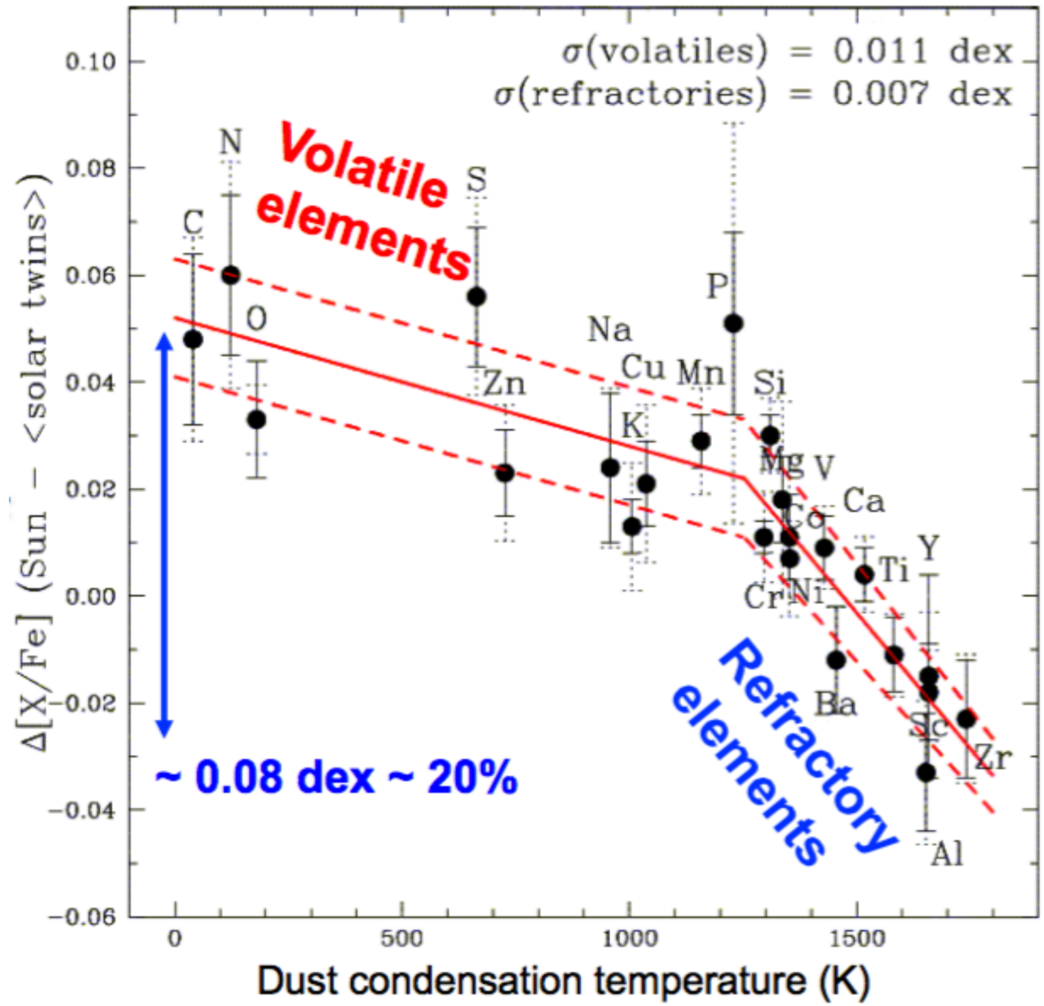
Tolstoy et al (2009)

Sun and solar twins

Solar Chemical Composition is a fundamental reference in astronomy

Solar-like stars (“twins”)

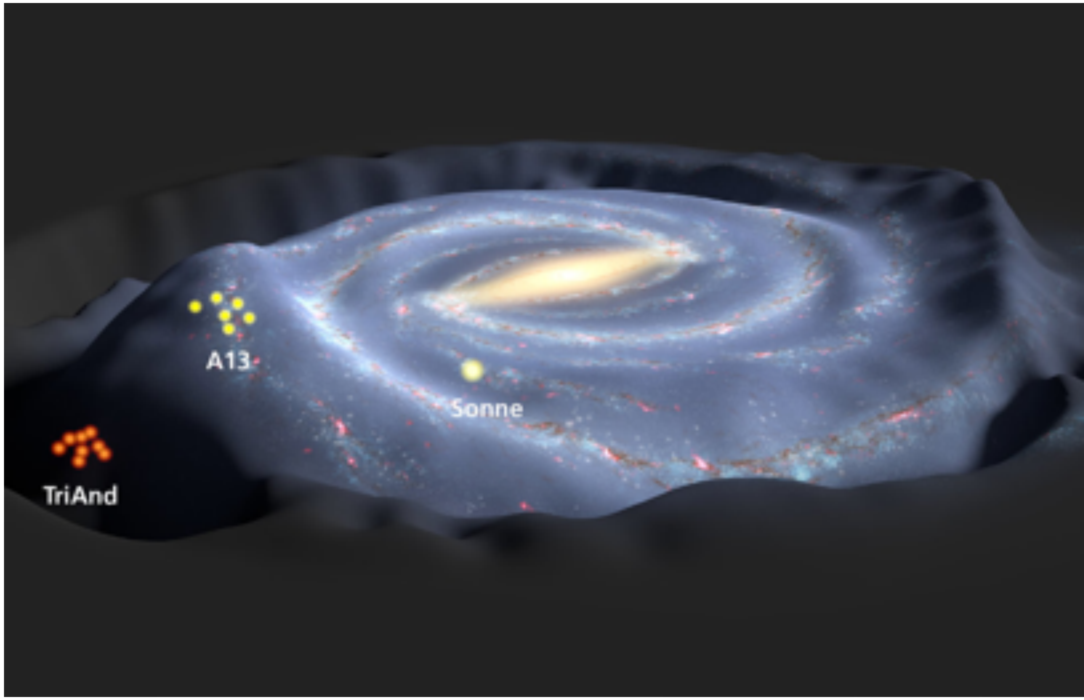
- best candidates for the **2nd Earth**
- Signatures of planet formation in their chemical abundances



Meléndez, Asplund, Gustafsson, Yong 2009, ApJ Letters

Key properties of the disk

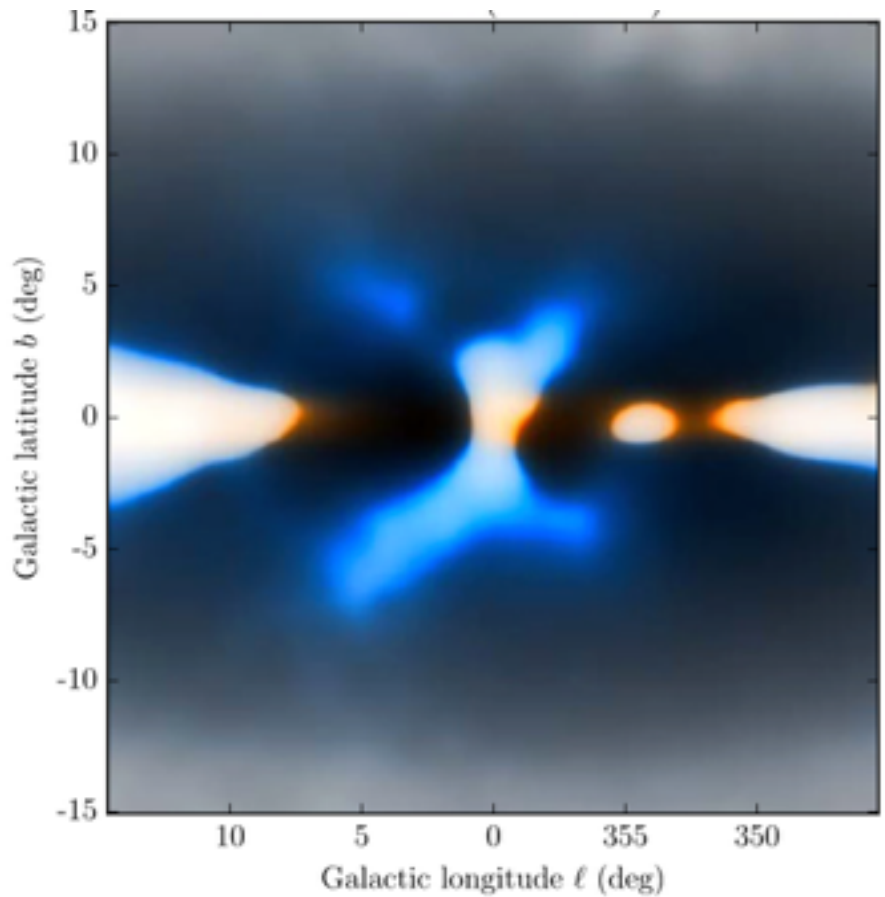
- most massive stellar component
- most stars are on nearly circular orbits
- lots of dust
- stars of all ages; diversity of chemical compositions
- spiral arms, warp, global oscillations



Bergemann et al (2018)

Key properties of the bulge

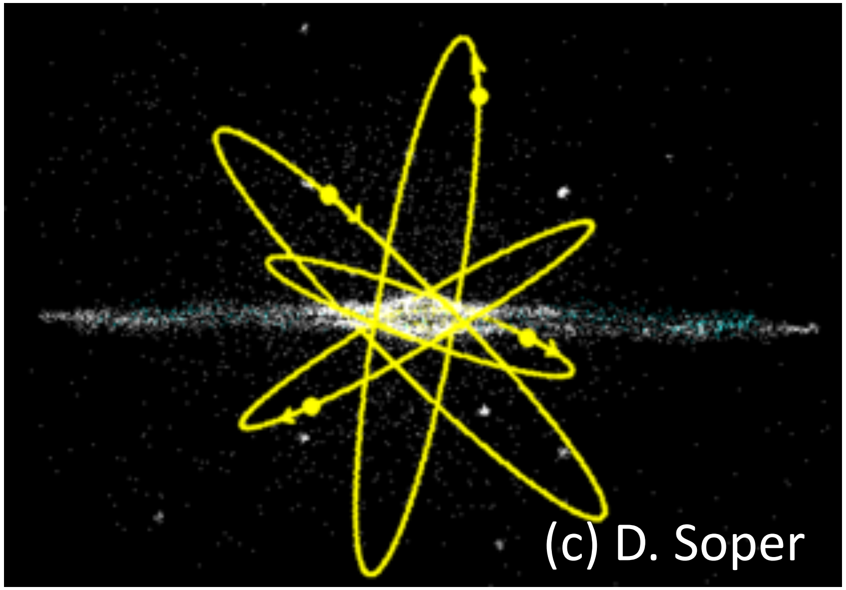
- main stellar body: barred and X-shaped
- core: nuclear star clusters + super-massive black hole
- inner region: young stars, active star formation
  outer region: old stars with diverse chemical abundances

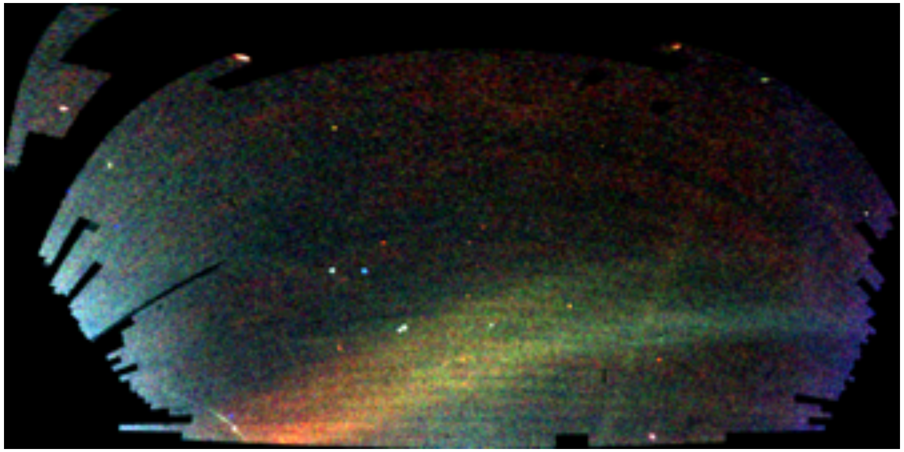


Ness & Lang 2016
Barbuy et al. 2018

Key properties of the halo

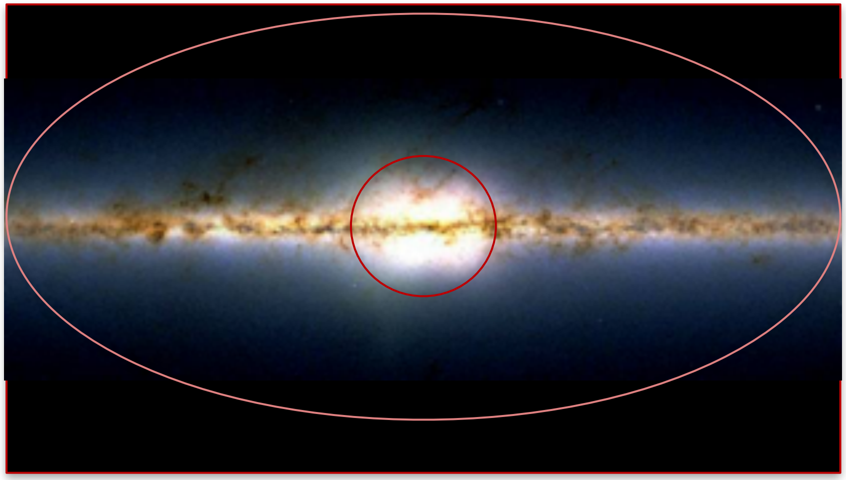
- most mass in Dark Matter
- most stars are on highly-<u>eccentric</u> orbits
- <u>sub-structure</u>: stellar streams and overdensities
- host to the <u>old(est)</u> stars with ages of >10 Gyr





Belokurov et al (2006)

Extremely metal-poor stars

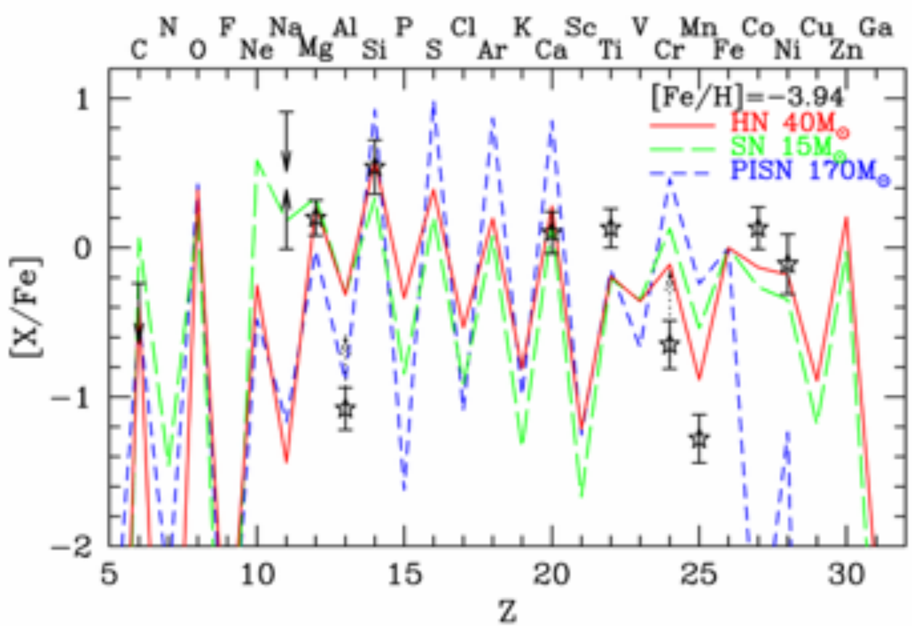


probably the oldest …

best candidates for probing the physical state of <u>very early Universe</u> (few 100s Myr)

Cosmological simulations: oldest stars in the <u>bulge</u> and <u>halo</u>

White & Springel (2000)



Keller et al. (2014)

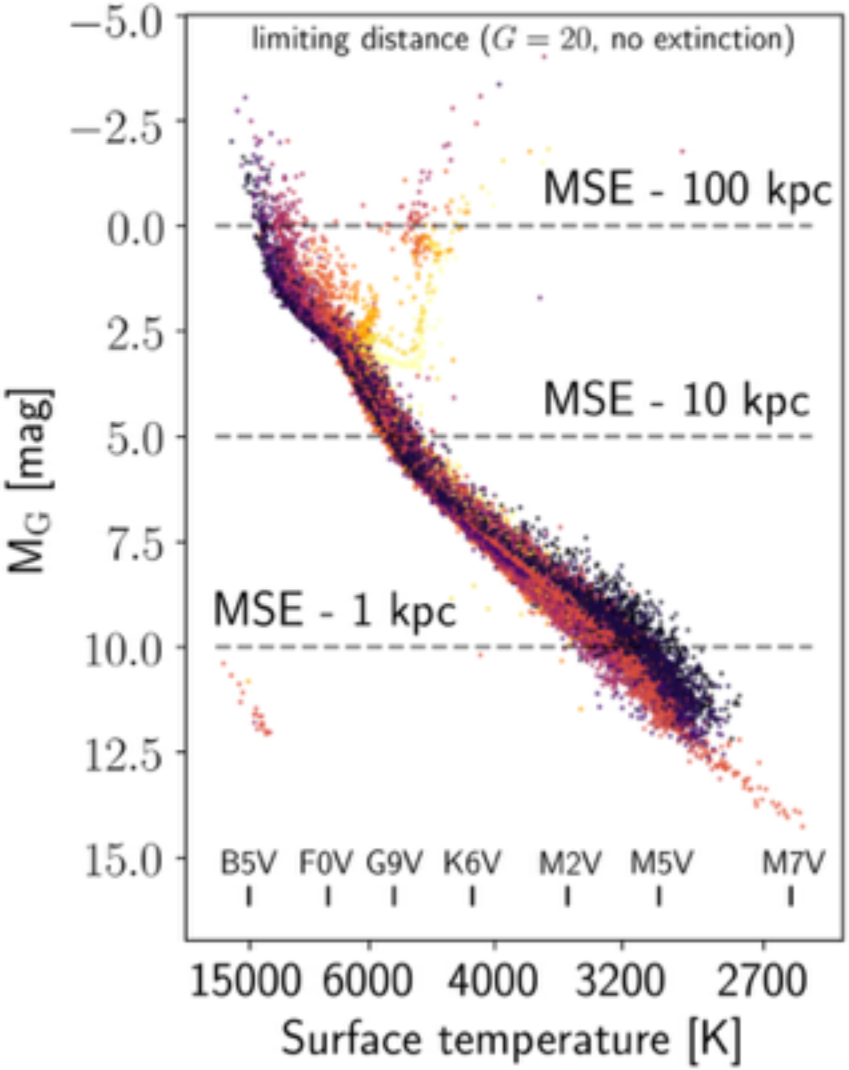
Open Clusters

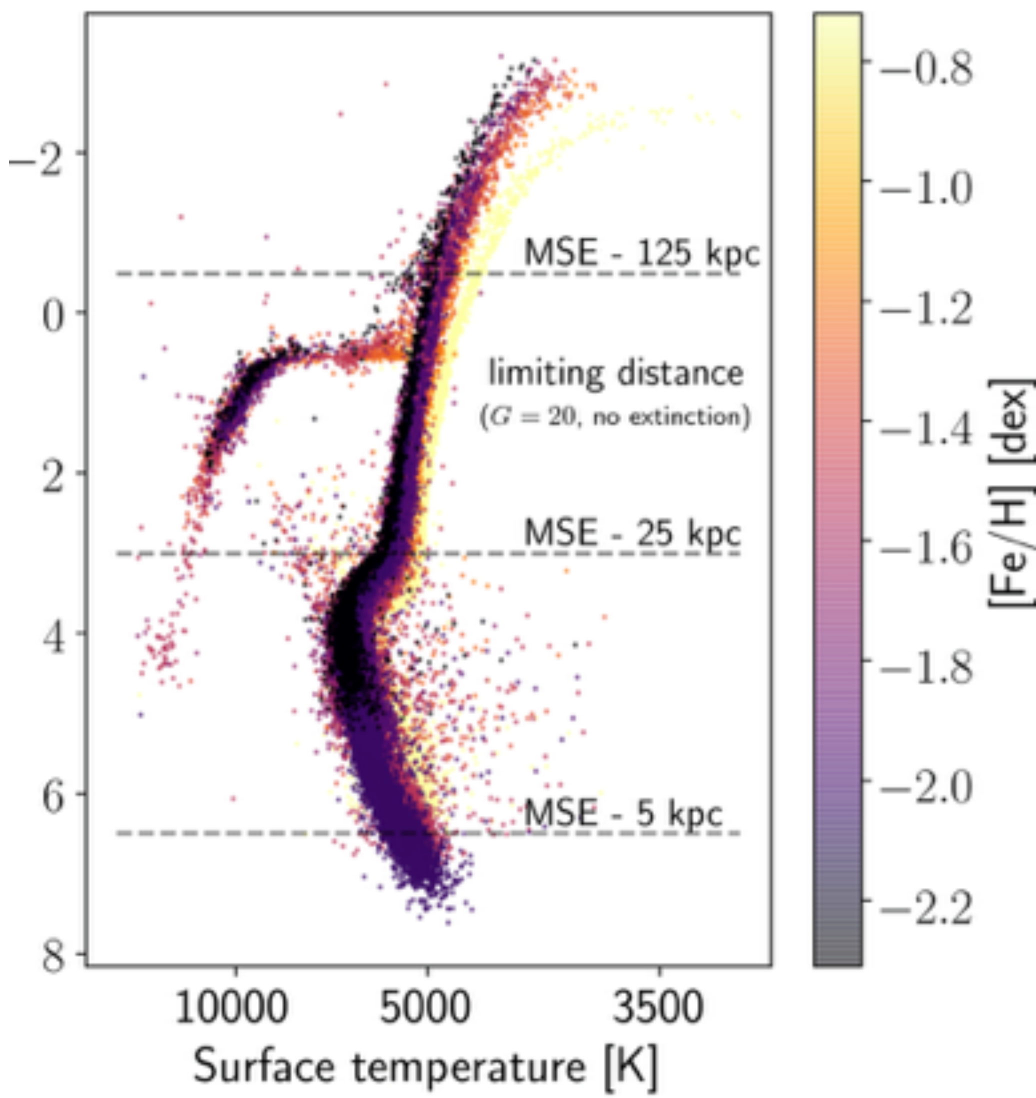
- 10^2 to few 10^3 stars
- irregularly shaped
- young, continue forming
- disk

Globular Clusters

- 10^4 to 10^5 stars
- spherically symmetric
- old, no longer forming
- halo / bulge

Open Clusters   Globular Clusters

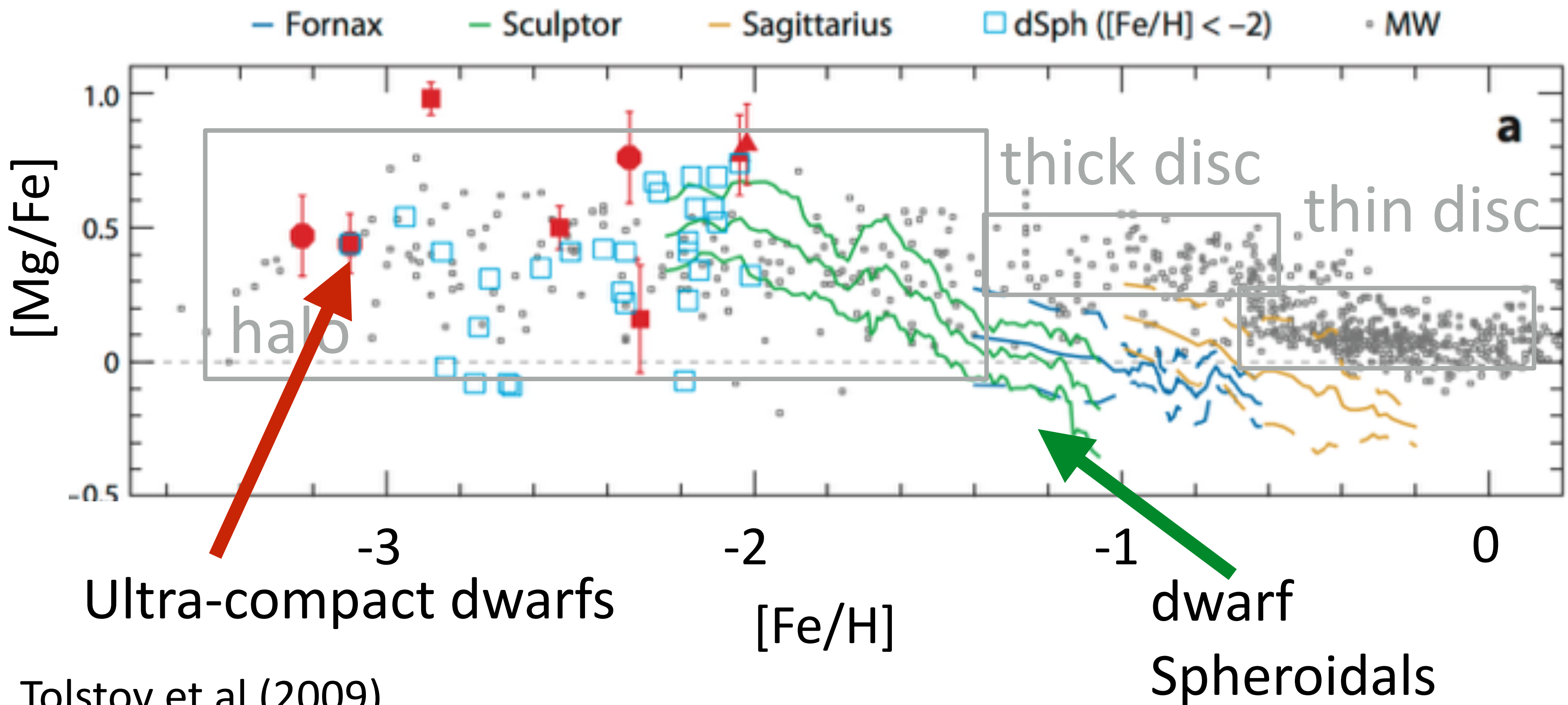




Bergemann et al (2019) https://arxiv.org/abs/1903.03157

Key properties of dwarf Spheroidals

- first objects to form stars
- smallest DM dominated systems in the Universe
- early heating and gas loss
- abundances similar to the halo



Tolstoy et al (2009)

How to give a good talk

(c) H.-W. Rix

How to give a good talk

1) Spend 20 min conveying the most new / important / promising insights to be gained from the paper

2) Briefly set the stage and expose the scientific issue:
What's the question, puzzle, observation to be understood?
Why is it interesting?

3) What are the “punchline(s)” / key insight(s)?
Is that based on new calculation / data / ideas / technology?

4) What are the broader implications?
.... based on the authors written view, filtered by your judgement

- Think about your audience first: What do they already know?
- The first & last slides are most important: spell out your first 5 and last 5 sentences verbatim.
- Practice each talk 3 times all the way before you give it
- One transparency / 3 minutes
- Use figures extensively, but annotate them: Legible axes If there are several lines, label them
- Explain everything on the slide - or don't put it on the slide
- If a slide has no bearing on your conclusion, omit it
- Talk to the audience
- Keep it simple but not simplistic