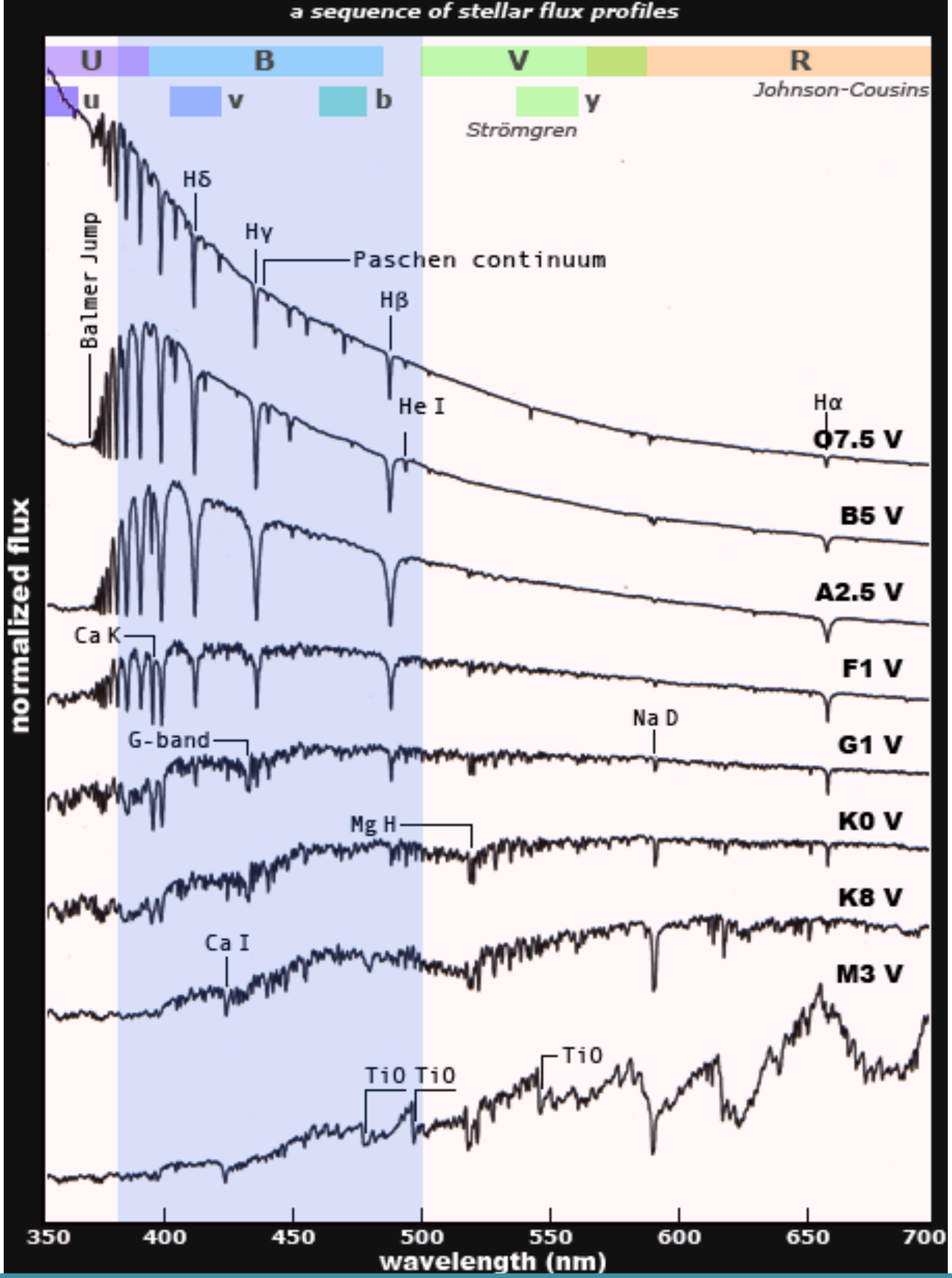
Stellar abundance ratios as population tracers

1. Basic information
2. Determination and tracer elements
3. Differences in galactic populations
    1. Galactic Disk
    2. Galactic Bulge
    3. Galactic Halo

1. Basics of measuring abundance ratios

- received by analyzing spatial & kinematical distribution function of stars in space, their age & chemical composition
  - Mostly F-/G-main-sequence stars & subgiants *(-3.0<[Fe/H]<0.4)*

- Measuring methods:
  - When reliable continuum: measuring equivalent widths
  - Fitting synthetic profil
  - Uvby-β (Strömgren)- photometry



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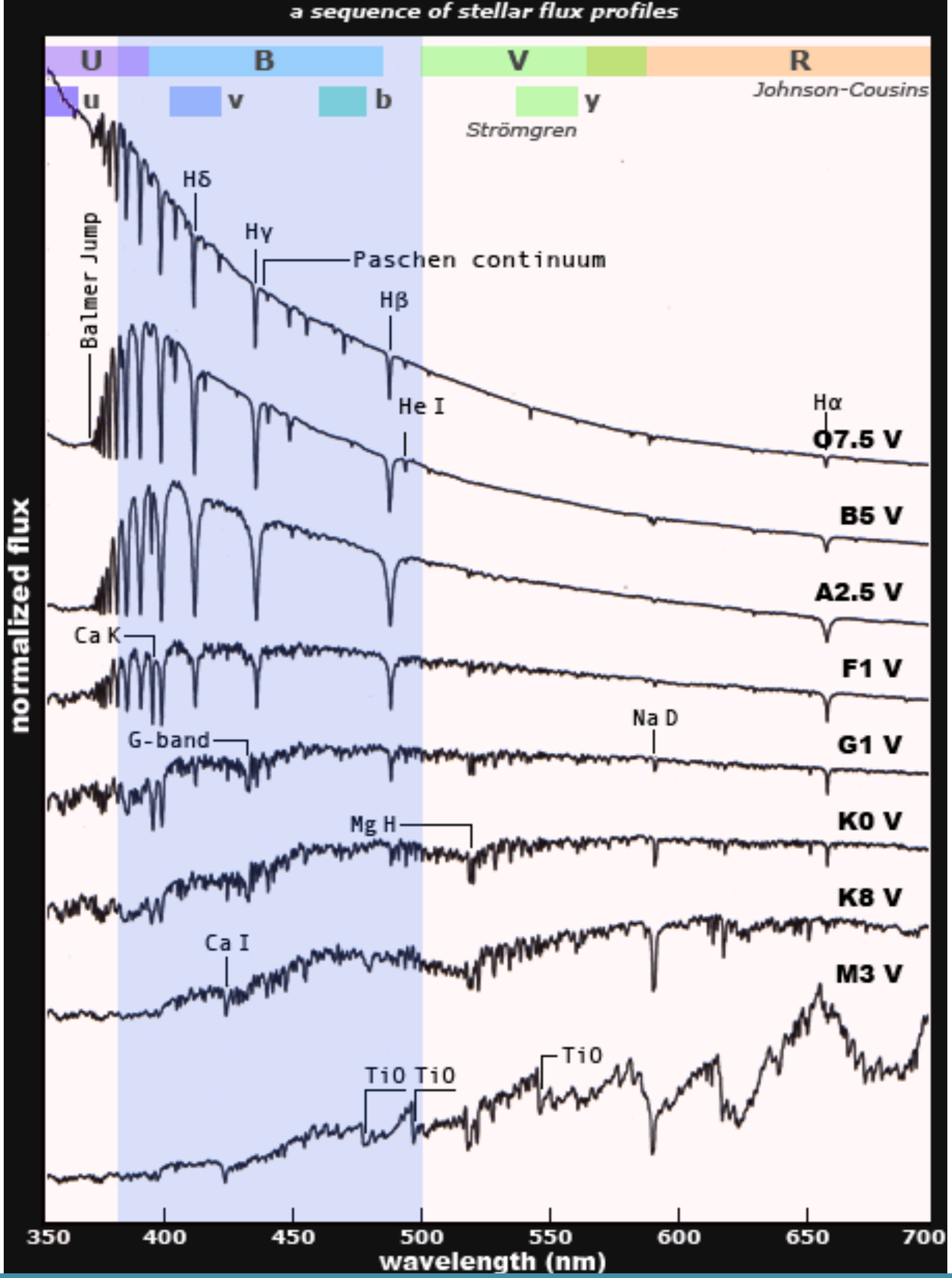

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2. Determination and tracer elements

Determination of atmospheric parameters:

- Model atmospheres assumed
  - Considering LTE (**l**ocal **t**hermodynamic **e**quilibrium)

Effective temperature: determined by colour (near stars) or spectroscopy (more distant stars)

Gravity: determined by luminosity or spectroscopially by Δ [Fe/H]

Inhomogeneous 3D- modells:

- Needed for more realistic values

  - Departures: could cause changes in abundance/metallicity

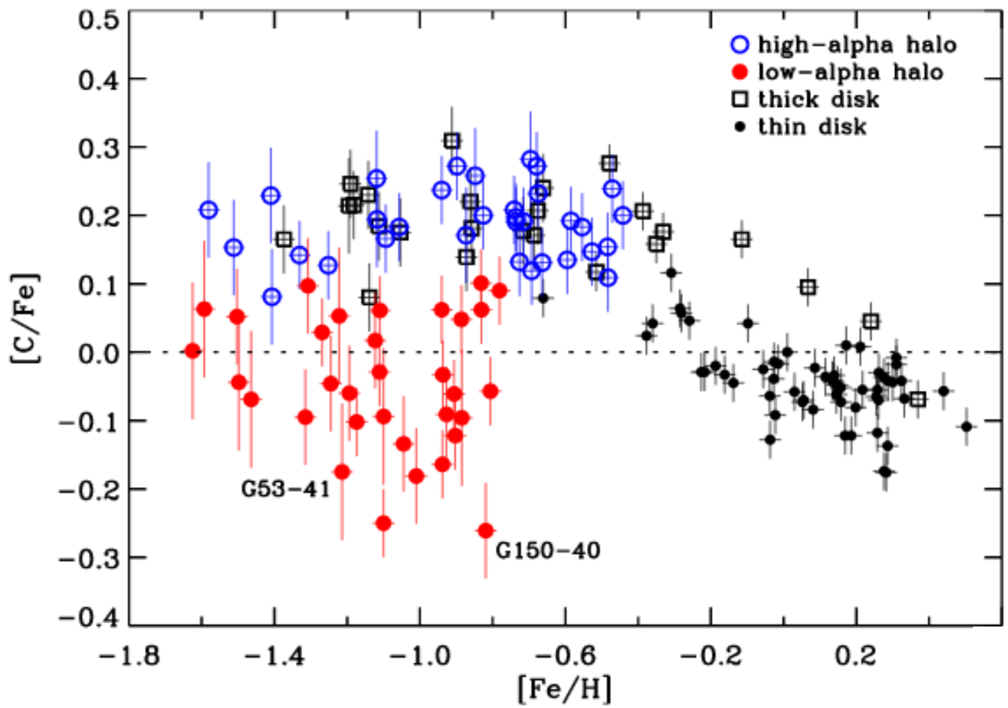
- Equation to determine population of a star:

$$n_i \sum_{j=1}^{N} (R_{ij} + C_{ij}) = \sum_{j=1}^{N} n_j (R_{ji} + C_{ji}),$$

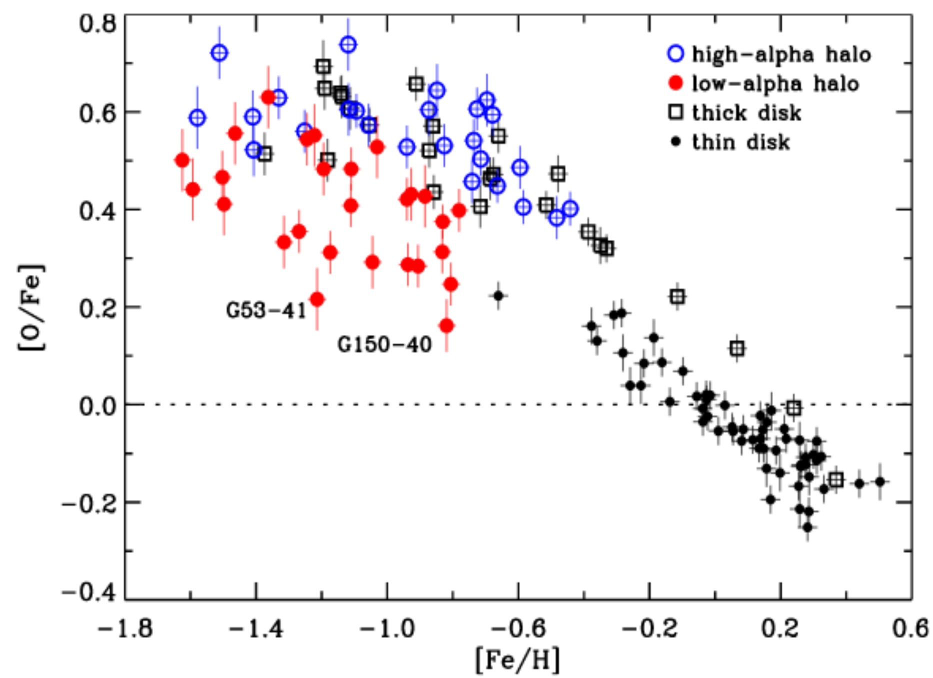
Population tracer elements:

- C & O (by forbidden lines)
- Intermediate-mass elements
  - In connection with C-/O-/N-burning by type II Sne
  - From average value metallicity is determined
- Iron elements

- Observed differences could give constraints on Sne modeling



Pic.3/4: comparison of [C/Fe]&[O/Fe] – [Fe/H] for different galactic populations

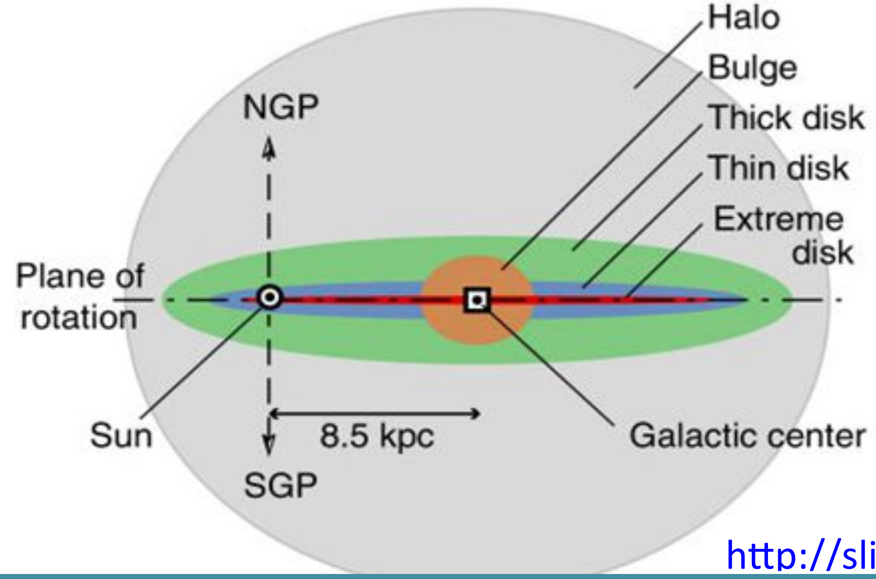


P. E. Nissen et al.: Carbon and oxygen abundances in stellar populations,2011

Different properties of single galactic parts

Modern stellar populations:

Population	*typical stars*	*velocity dispersion*	*shape of system*	*metal abundance (respect to H)*
Halo pop.	GC, red giants	130	spherical	0.003
Intermediate pop. II	high vel. stars	50	intermediate	0.01
Disc pop.	weak line stars	30	intermediate	0.02
Intermediate pop. I	strong line stars	20	intermediate	0.03
Extreme pop. I	blue supergiants	10	flat	0.04



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3.1 Galactic Disk

Thin-disk

- Height: 300pc
- Age: about 9Gyr

Thick-disk

- Height: 1.300pc
- Age: about 13Gyr

Overlapping region:

- At -0.6<[Fe/H]<-0.3
- Only few transition stars
- Seem to be connected to both types

Gap between this two disk components:

- At [Fe/H]<0.1
- Suggested systematic difference of [Mg/Fe] connected to gap in star formation between both

Kinematic/metallicity properties of disk stars

Population	σ_U	σ_V	σ_W	V_{ad}	f
	km s^{-1}	km s^{-1}	km s^{-1}	km s^{-1}	
Thin disk	43	28	17	−9	0.93
Thick disk	67	51	42	−48	0.07
Halo	131	106	85	−220	0.006

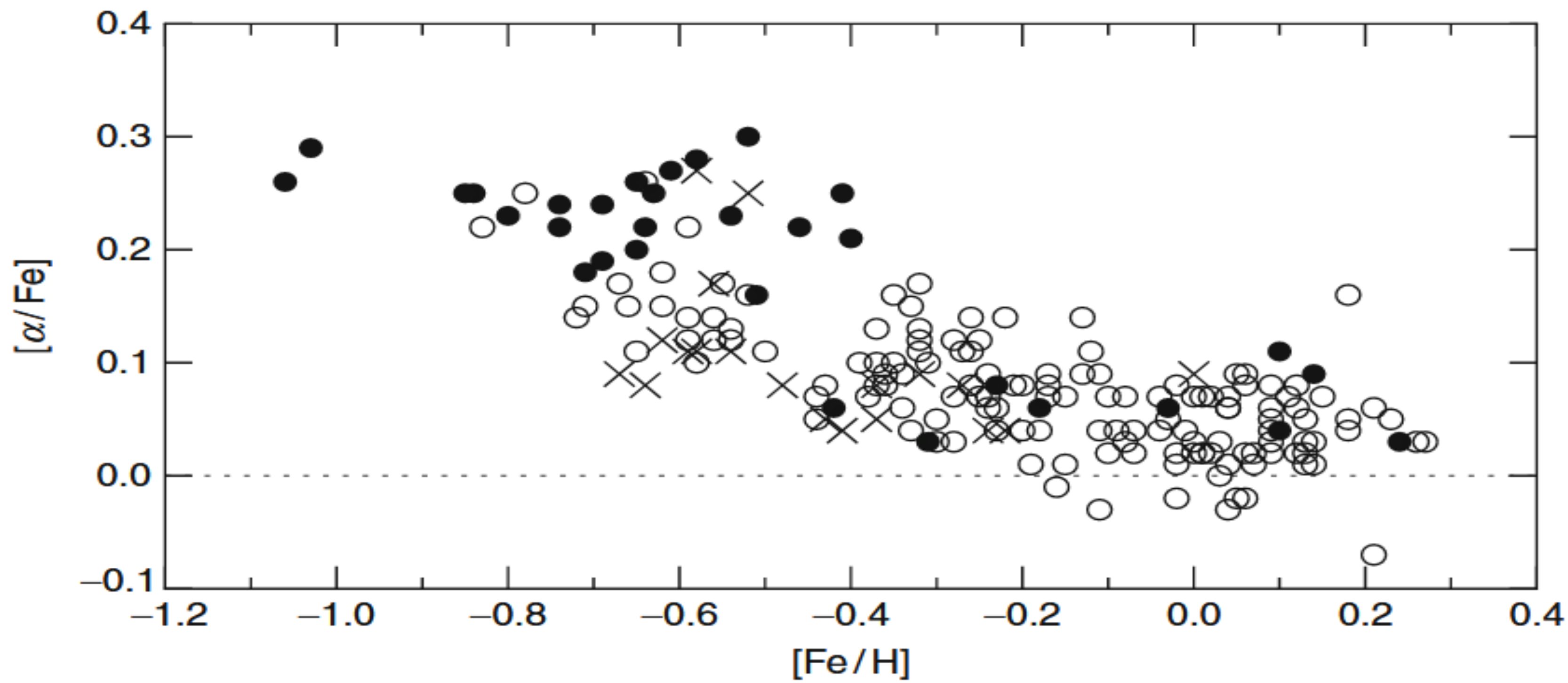


Fig.5:[α/Fe] as a function of [Fe/H] Stars with orbits Rm<7kpc (filled circles); stars (open circles) with 7<Rm<9kpc; stars (crosses) with Rm>9kpc

Chemical Abundances as Population Tracers,Poul Erik Nissen, 2013

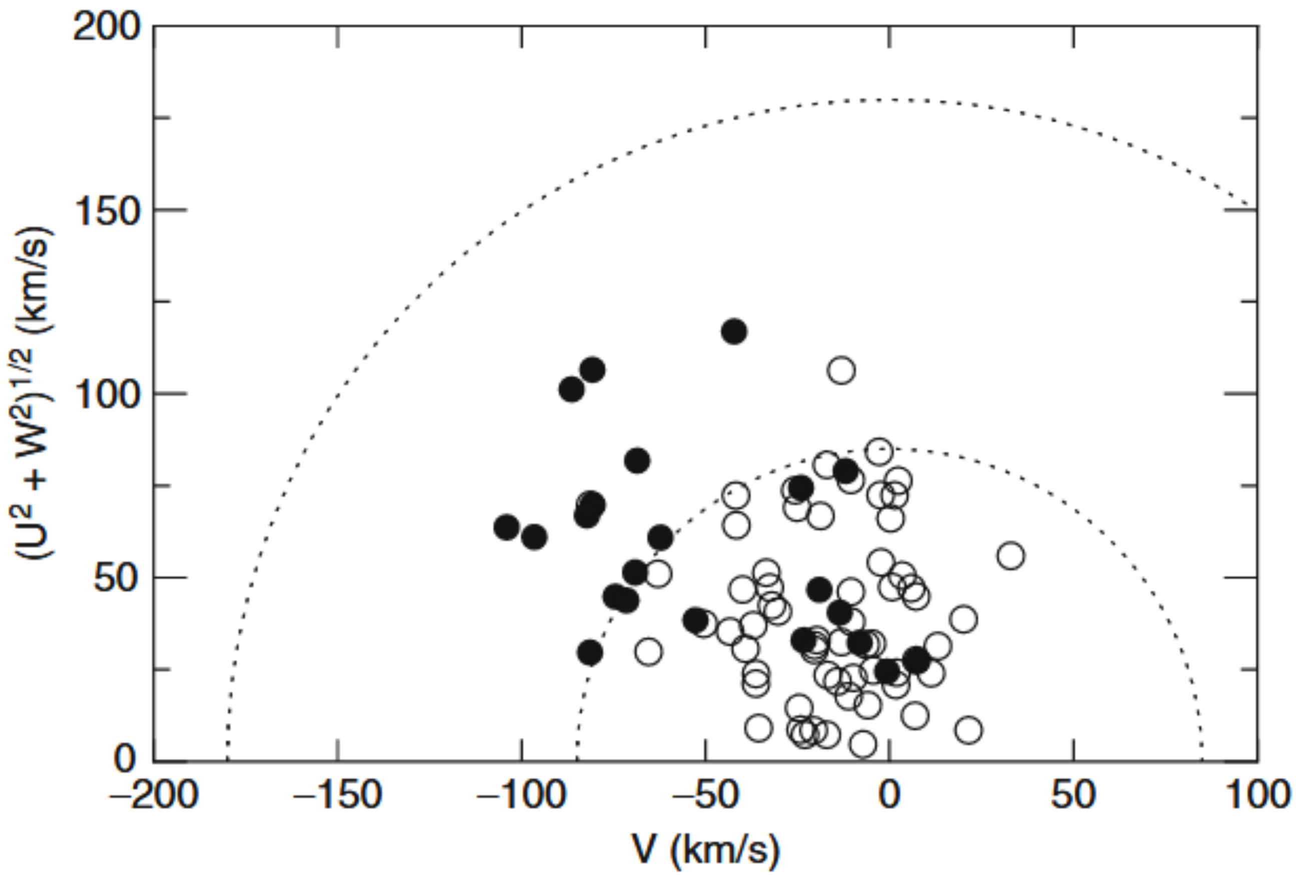


Fig.6:Toomre-energy diagramm of stars

Chemical Abundances as Population Tracers,Poul Erik Nissen, 2013

Scenarios of disk development

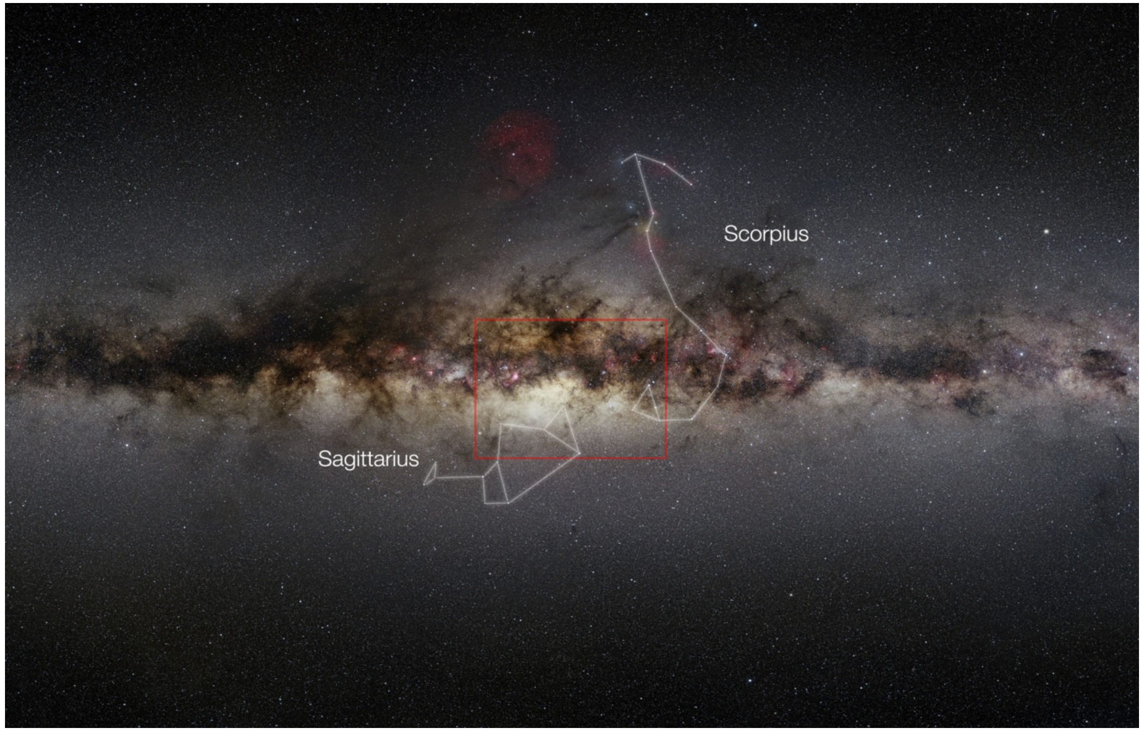
- At first period of rapid star formation
  - Interrupted by merging satellite galaxies
    - Already fromed stars heated to thick-disk kinematics
- Hiatus in star formation (metal-poor gas was accreted)

-->first thin-disk stars were formed

Model of chemical evolution of galactic disk:

- Star formation decreases monotonically ,including radial migration & gas flows
- predicts bimodal distribution of [α/Fe]

3.2 Galactic bulge



Pic.8: view of milky way bulge

2 classical formation scenarios:

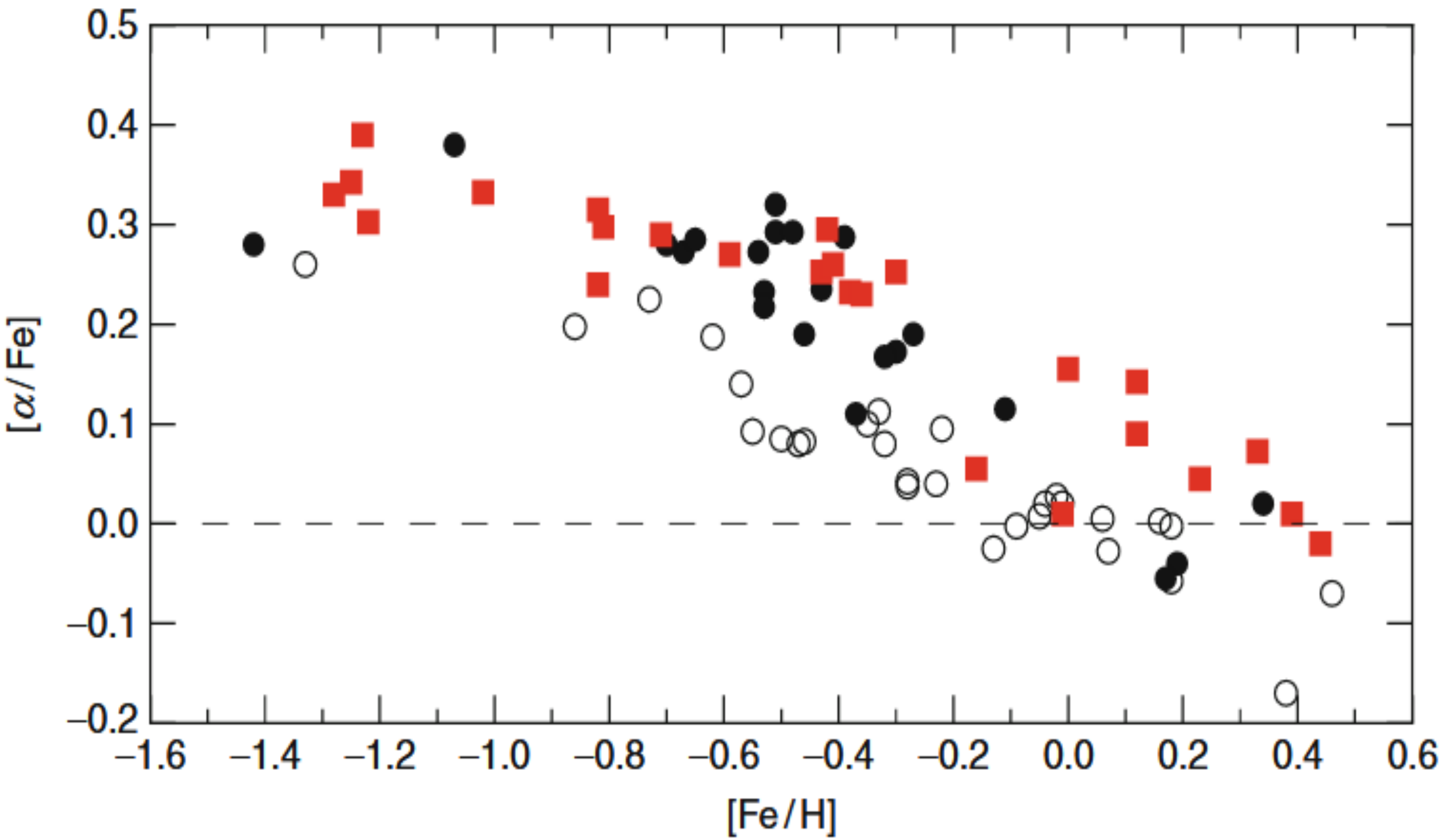
- Coalescence of star-forming clumps
- Development of `pseudobulge` over long time through dynamical disk instabilities

2 tendencies of regions in the galactic plane:

1. metal-poor region:
    - Behave like thick-disk stars
    - Average age: 11.2 Gyr

2. metal-rich group
    - Similiar properties to thin-disk stars
    - Average age: 7.6 Gyr

- This assymetric distribution was also derived by comparing this stars by gravity- Teff



Pic.9: visulization of the [α/Fe]/[Fe/H] for K bulge stars compared to stars with thick-disk & thin-disk kinematics

Chemical Abundances as Population Tracers,Poul Erik Nissen, 2013

3.3 Galactic halo

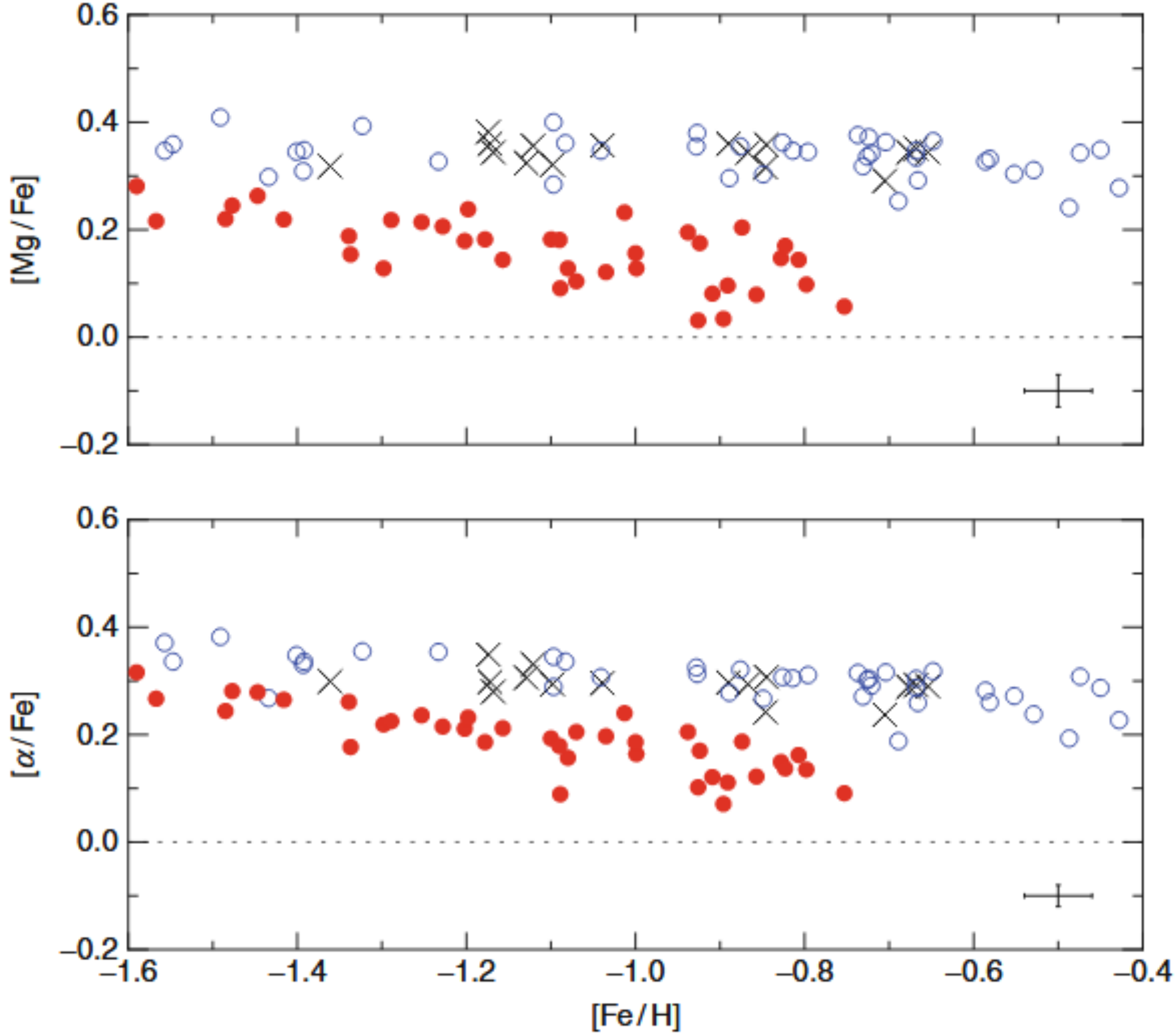
- Separation of halo populations:

I. population:

- Inner, older ,flattened
- Prograde rotating(more bound to galaxy)
- Formed during dissipative collapse
    - In high rate chemical evolution regions (by Sne II)
- [Fe/H]=-1.6
- Special that [Mg/Fe] constant

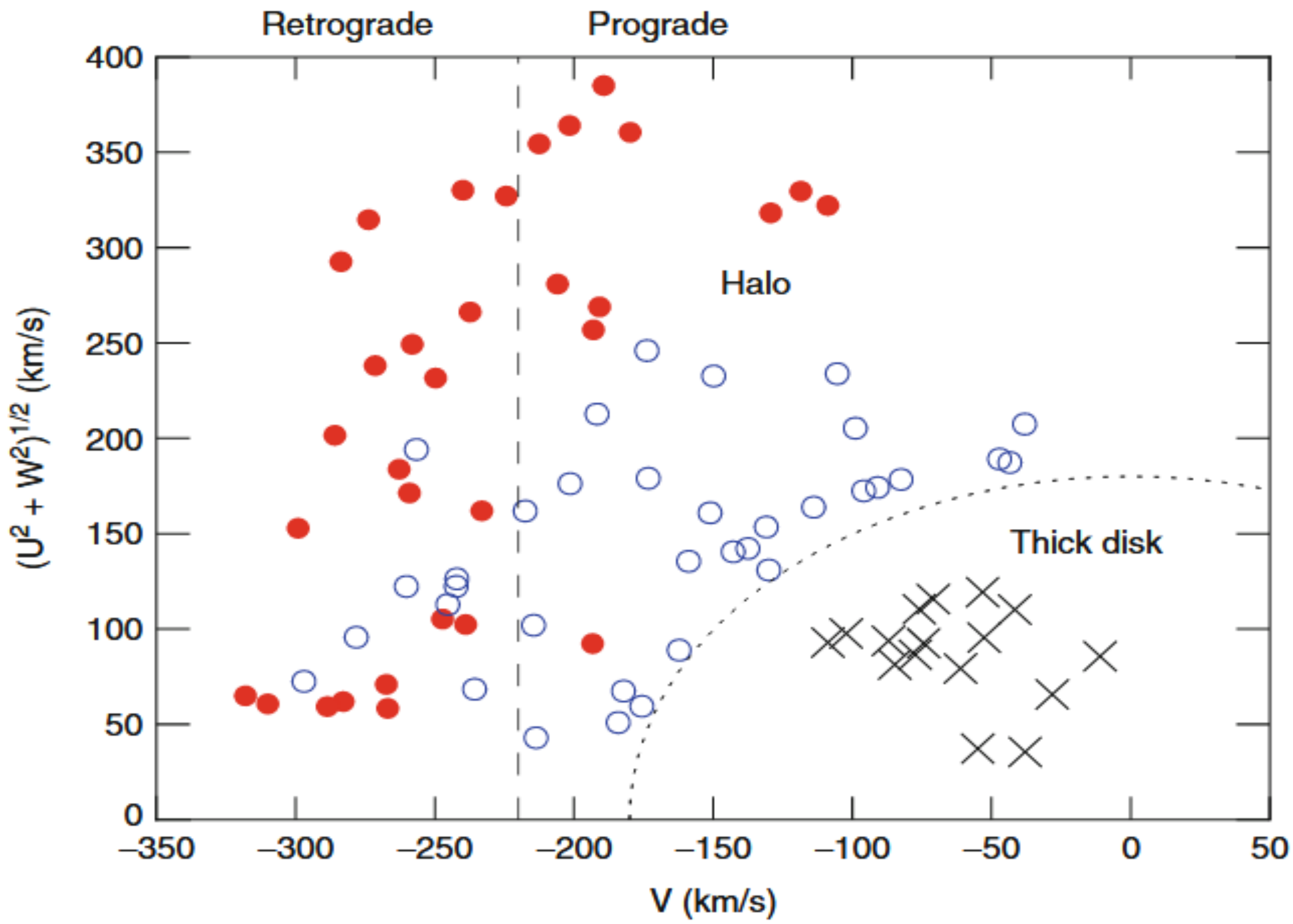
II. population:

- Outer, younger, spherical
- 2/3 retrograde rotating (less bound to galaxy)
- Accreted by satellite galaxies
    - In slow rate chemical evolution regions (by Sne Ia)
- [Fe/H]=-2.2
- Declining [Mg/Fe]



Pic.10: [Mg/Fe] & [α/Fe] vs. [Fe/H] halo stars devided in low-α (filled red circles) & high-α (open blue circles)

Chemical Abundances as Population Tracers,Poul Erik Nissen, 2013



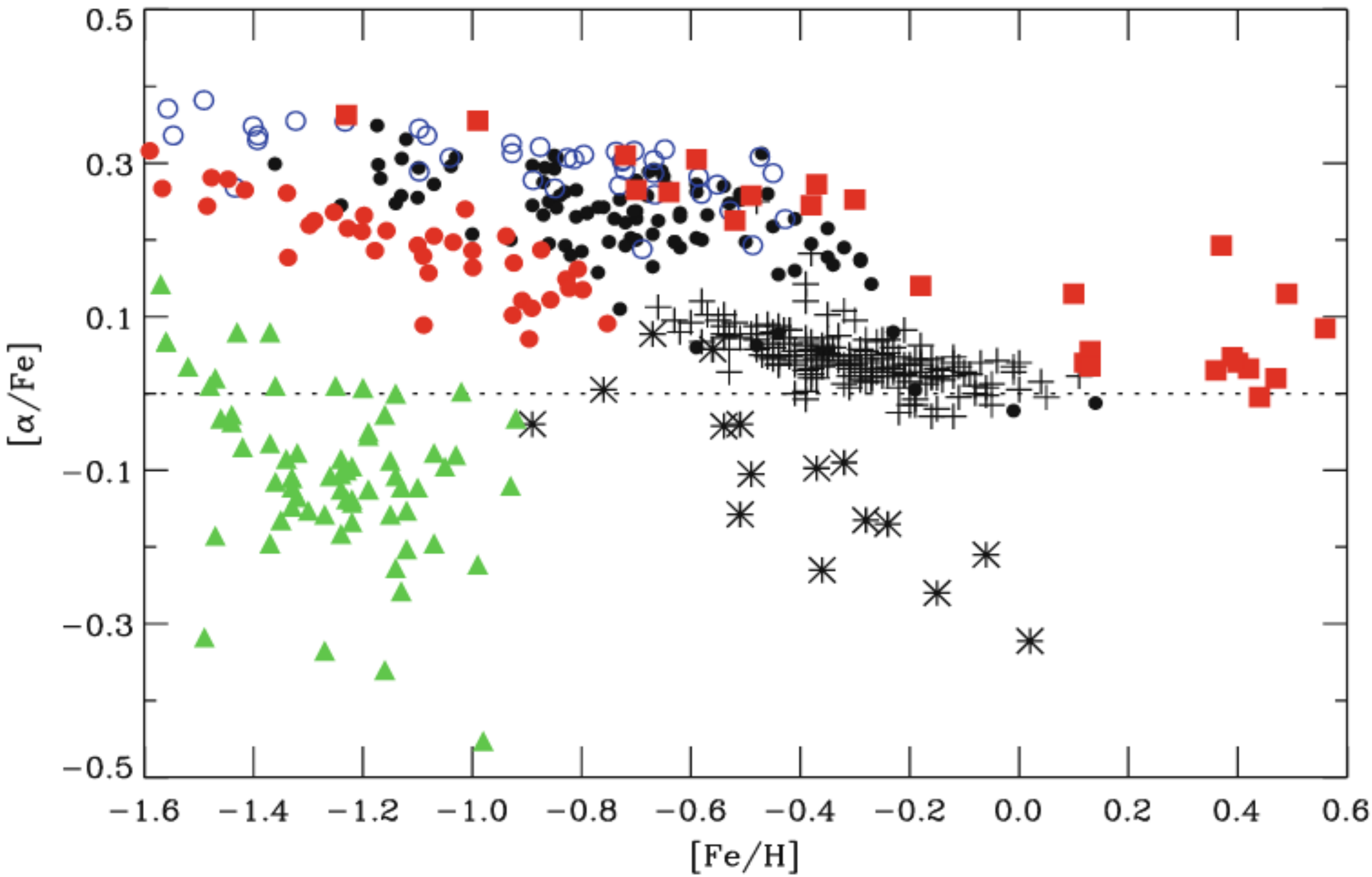
Chemical Abundances as Population Tracers,Poul Erik Nissen, 2013

Summarization

- There were actually a lot of unexpected properties found
- There exist subclasses to normal population I/II

In future:

- More data needed
- Better understanding of 3D-/non-LTE effects, nucleosynthesis
- Seperate diferent spectral and luminosities classes, dwarfs- giants



[α/Fe] vs. [Fe/H] for various stellar populations {Thin-disk stars: plus symbols; thick-disk stars: filled circles; microlensed bulge stars: filled red squares; high-α: open blue circles and low-α halo stars: filled red circles; stars in the Sculptor dSph galaxy: filled green triangles and stars from Sagitarius galaxy: stars}

References

Source:

- T.D. Oswalt, G. Gilmore (eds.),Planets, Stars and Stellar Systems. Volume 5: Galactic Structure and Stellar Populations, 2013
- P. E. Nissen, Chemical Abundances as Population Tracers, 2013
- P. E. Nissen et al.: Carbon and oxygen abundances in stellar populations 2011
- http://icc.dur.ac.uk/~tt/Lectures/Galaxies/TeX/lec/node27.html

Pictures:

- https://www.handprint.com/ASTRO/specclass.html
- http://slideplayer.com/slide/5189502/
- https://www.planet-wissen.de/technik/weltraumforschung/astronomie/pwieunsereheimatgalaxiediemilchstrasse100.html