HB stars – a powerful tool in the study of the Milky Way's Halo

... or: teaching old stars new tricks

This is a Horizontal Branch

Martin Altmann

Departamento de Astronomia

Universidad de Chile

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Photo taken 2.2.2005, Fuerte Bulnes, near Pta. Arenas, XII. region, Chile

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Why are HB stars such valuable tools for Galactic studies?

- RR Lyraes and BHB/EHB are easy to find
  - RR Lyr due to variability
  - BHB/EHB due to blueness (at medium to high galactic latitudes)
- Distances readily derivable
- luminous old stars, accessible beyond the boundaries of the Galaxy
- Genuinely old stars (descendants of sun like & lower mass stars)

Why are HB stars such valuable tools for Galactic studies?

- Relatively numerous
- Abundance pattern appears to be pristine for T_{eff}<11,000 K
- globular clusters offer a testbed for issues concerning HBs
- long history of studies

→ *HB stars are an excellent tracer of old populations, eg. the Halo (see Altmann, 2006)*

Why are HB stars such valuable tools for Galactic studies?

- Down-Sides and problems:
  - RHBs hard to distinguish from some other types (Kaempf et al. 2005)
  - RR variability makes determination of distances and phys parameters more difficult
  - HBB+EHB (Teff>11,000 K): abundances severely altered!
  - HBA+HBB stars very similar to AV/BV stars (problem for solar neighbourhood)
  - high percentage of close binaries in sdB stars, these are RVV!

Kinematics of HB stars and Galactic structure

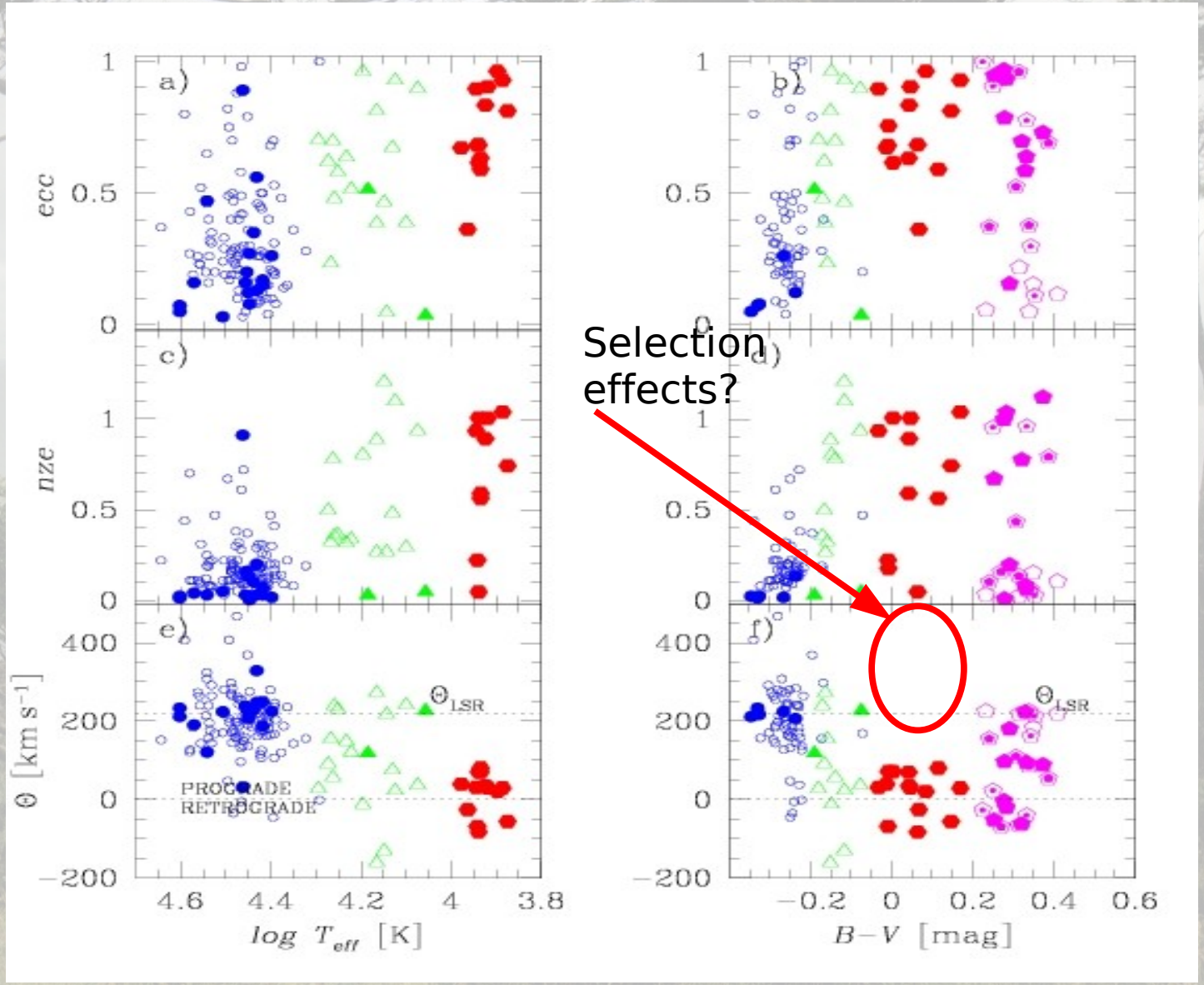
- Kinematics of the blue FHB (Altmann & de Boer, 2000)
  - EHB stars (sdb/OB) predominantly Disk/Thick Disk stars
    - minority halo population exists
  - RR Lyr mostly halo stars, minority in the Disks
    - metal rich RR s only with disk-like kinematics, more metal poor variants in all populations
  - HBA s are exclusively Halo stars
    - reason: selection effects against HBA stars with normal metallicity and kinematics, distribution of HBA star presumably similar to RR (see Maintz & de Boer, 2005)
  - HBB: inconclusive picture – too few stars with too bad kinematics (Altmann, 2002)

Kinematics of HB stars and Galactic structure

Kinematics of the blue FHB:

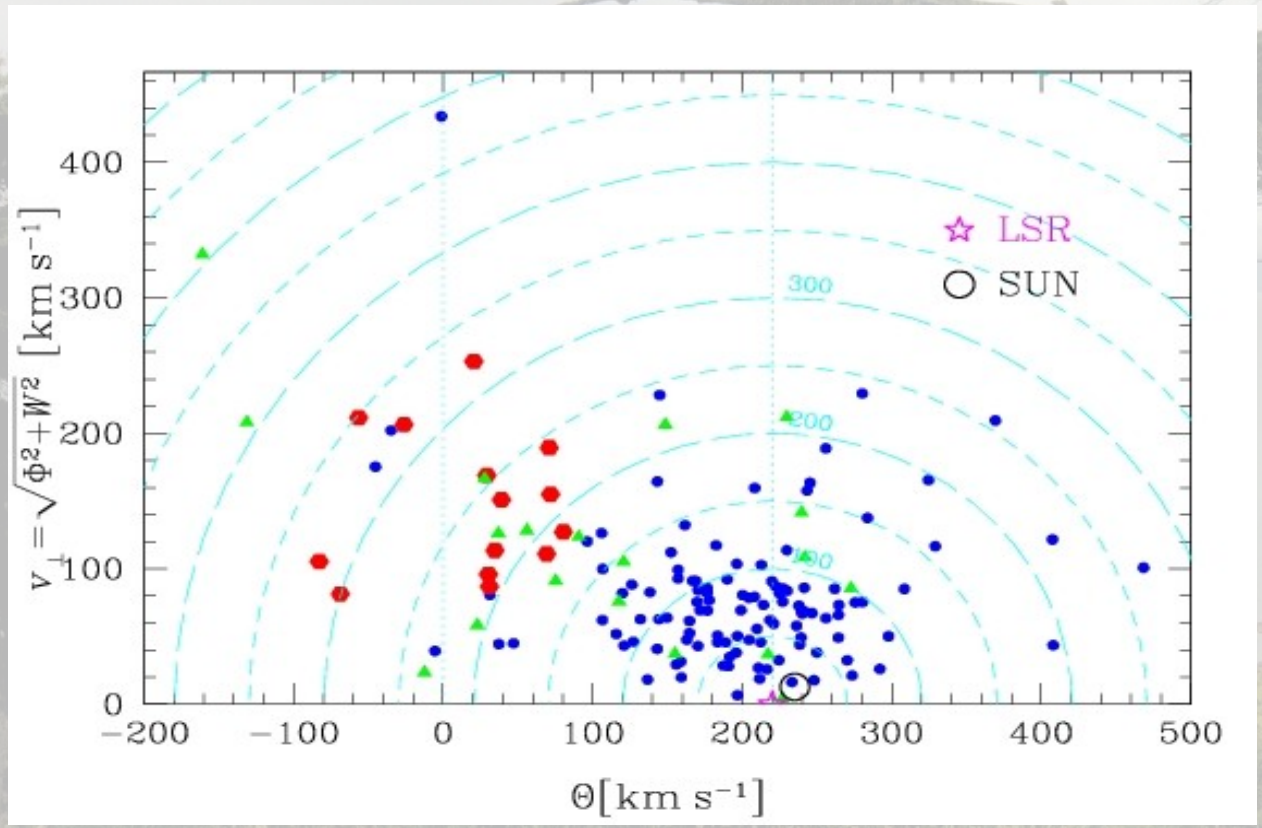
Symbols:
blue: EHB
green: HBB
red: HBA
magenta: RR
(filling of RR symbols depends on Fe/H, see Altmann & de Boer 2000)

Altmann 2002

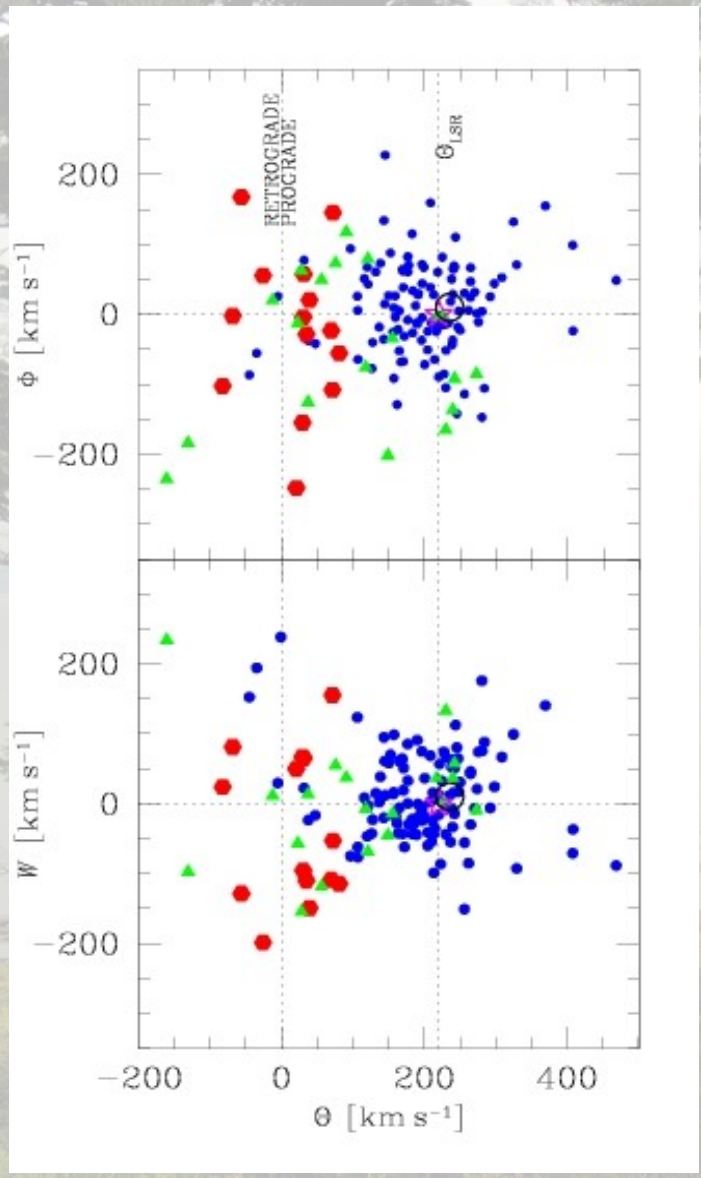


Kinematics of HB stars and Galactic structure

Kinematics of the blue FHB:



Toomre diagram Altmann 2005



Bottlinger diagram

Altmann 2005

Kinematics of HB stars and Galactic structure

Orbits of sdB (and other) stars & Galactic structure (de Boer et al. 1997, Altmann et al. 2004, Kaempf et al. 2005, Maintz & de Boer 2005):

full kinematics & Galactic potential

→ calculation of orbits

orbit → probability distribution e.g. in Z

orbits of a sample of stars

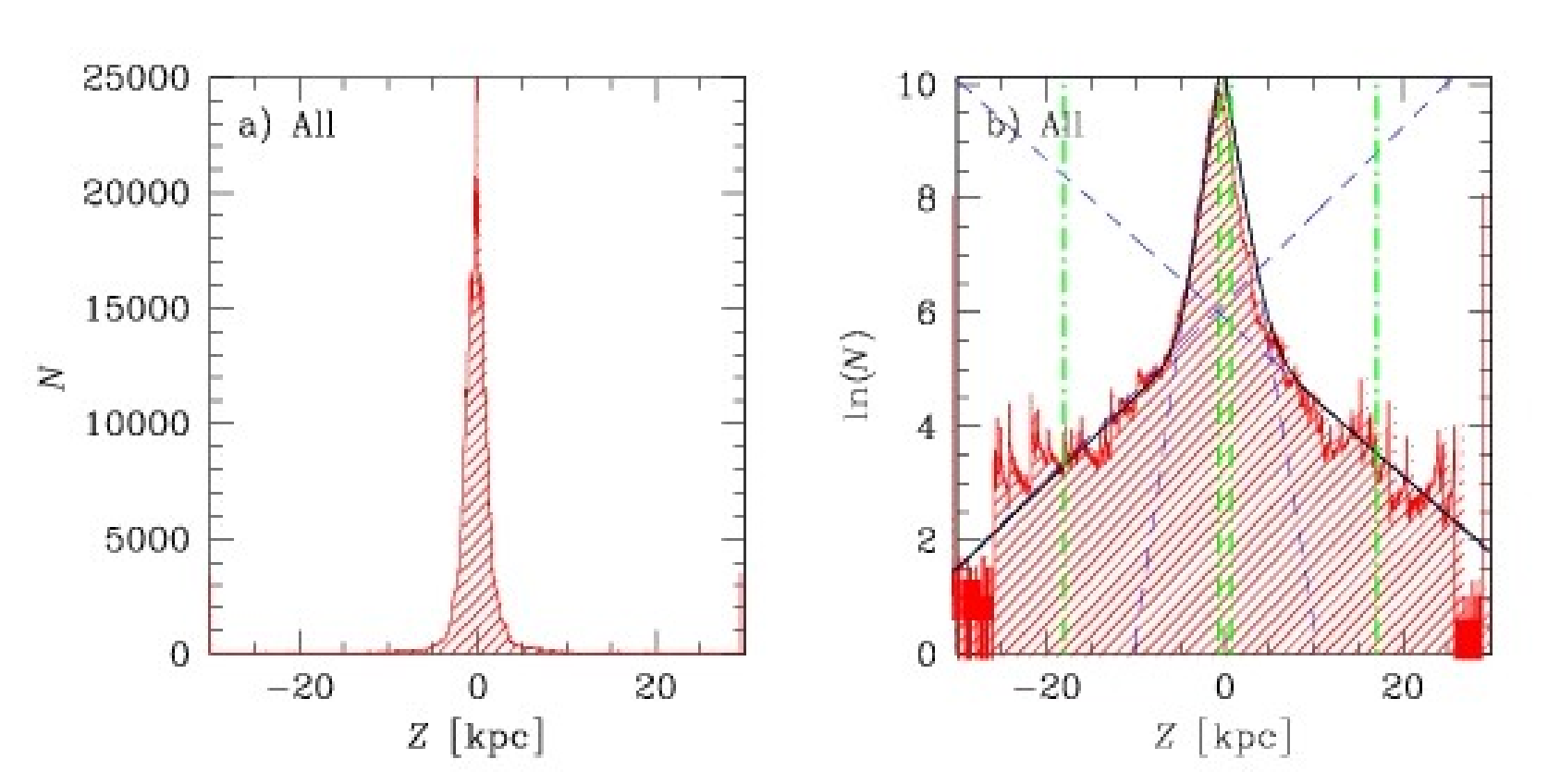
→ Z-probability distribution of sample

→ assuming exp distr. → logarithmise

→ scale height(s) of sample

Kinematics of HB stars and Galactic structure

Orbits of sdB (and other) stars & Galactic structure (de Boer et al. 1997, Altmann et al. 2004):



Altmann 2002, Altmann et al. 2004

Kinematics of HB stars and Galactic structure

Orbits of sdB (and other) stars & Galactic structure:

- Results: scaleheight for Thick Disk: 0.9 kpc, for the Halo 7kpc (not really an exponential distr., Altmann et al. 2004)
- RR-Lyr (Maintz & de Boer, 2005), RHB (Kaempf et al., 2005) deliver similar values.
- Range for TD: 0.5 --- 1.7 kpc, more recent studies converge more and more at about 1 kpc, e.g. the star count results of MUSYC (Altmann et al. 2007 , in prep, see poster No. 7)

Kinematics & Abundances of local HBA stars

- Preliminary study of kinematics and abundances of 30 local HBA stars to find objects within the OCen debris kinematics-abundance parameter space.
  - OCen is retrograde & has very distinct & unusual abundance pattern
  - Abundances for the stars from literature, other quantities from recent HB-studies (Altmann & de Boer (2000), Kinman et al. (2000), Behr (2003), Hipparcos (ESA, 1997)

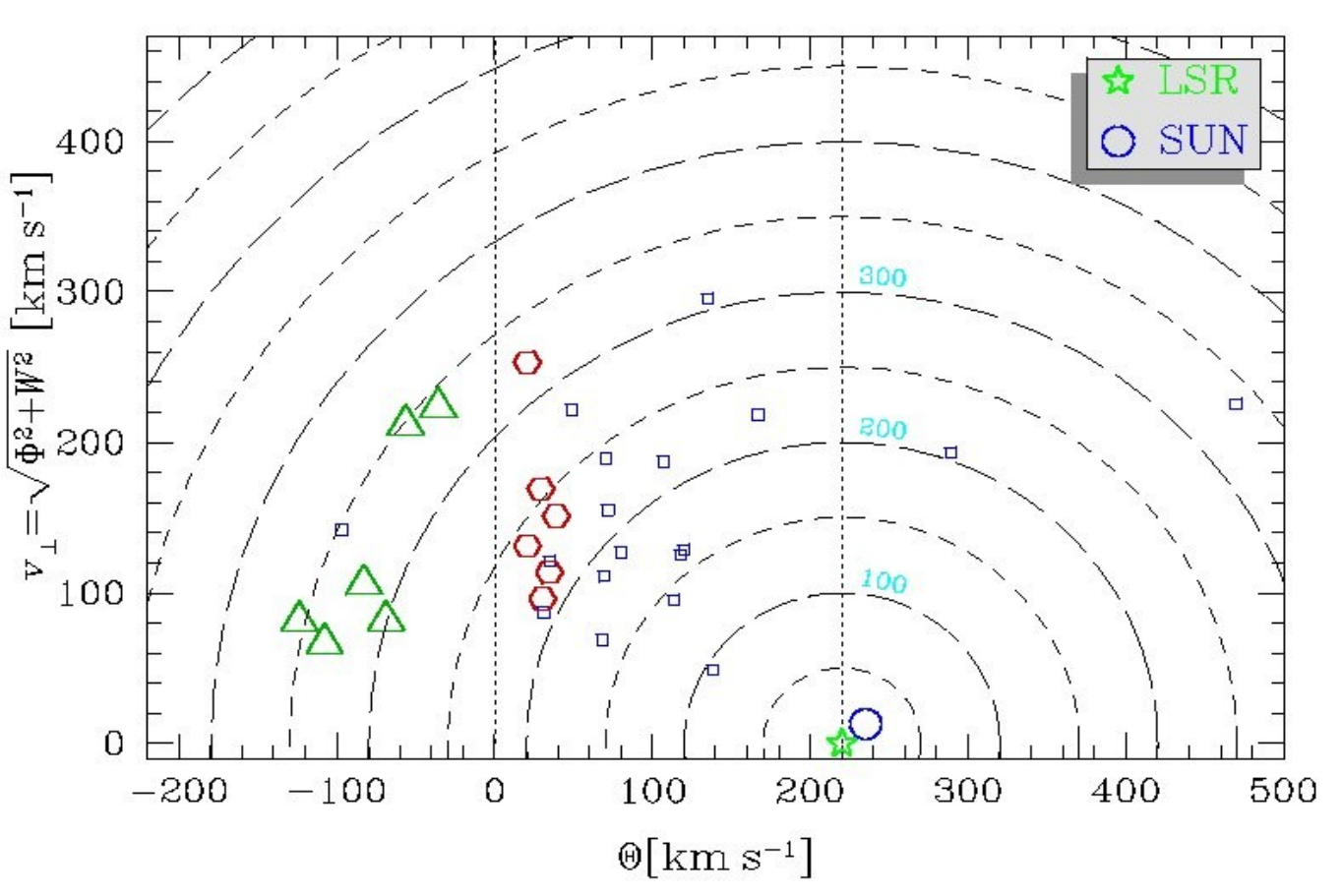
Kinematics & Abundances of local HBA stars

- Preliminary result: Yes, some stars fit into the parameter space for OCen debris
- Surprise result: Among the prograde objects (about 75% of the sample) 5-6 share very similar abundances in several elements and very similar kinematics
  - These venture very close to the Galactic centre

→ ***Cometary orbit group***

Kinematics & Abundances of local HBA stars

Toomre Diagram of 30 local HBA stars



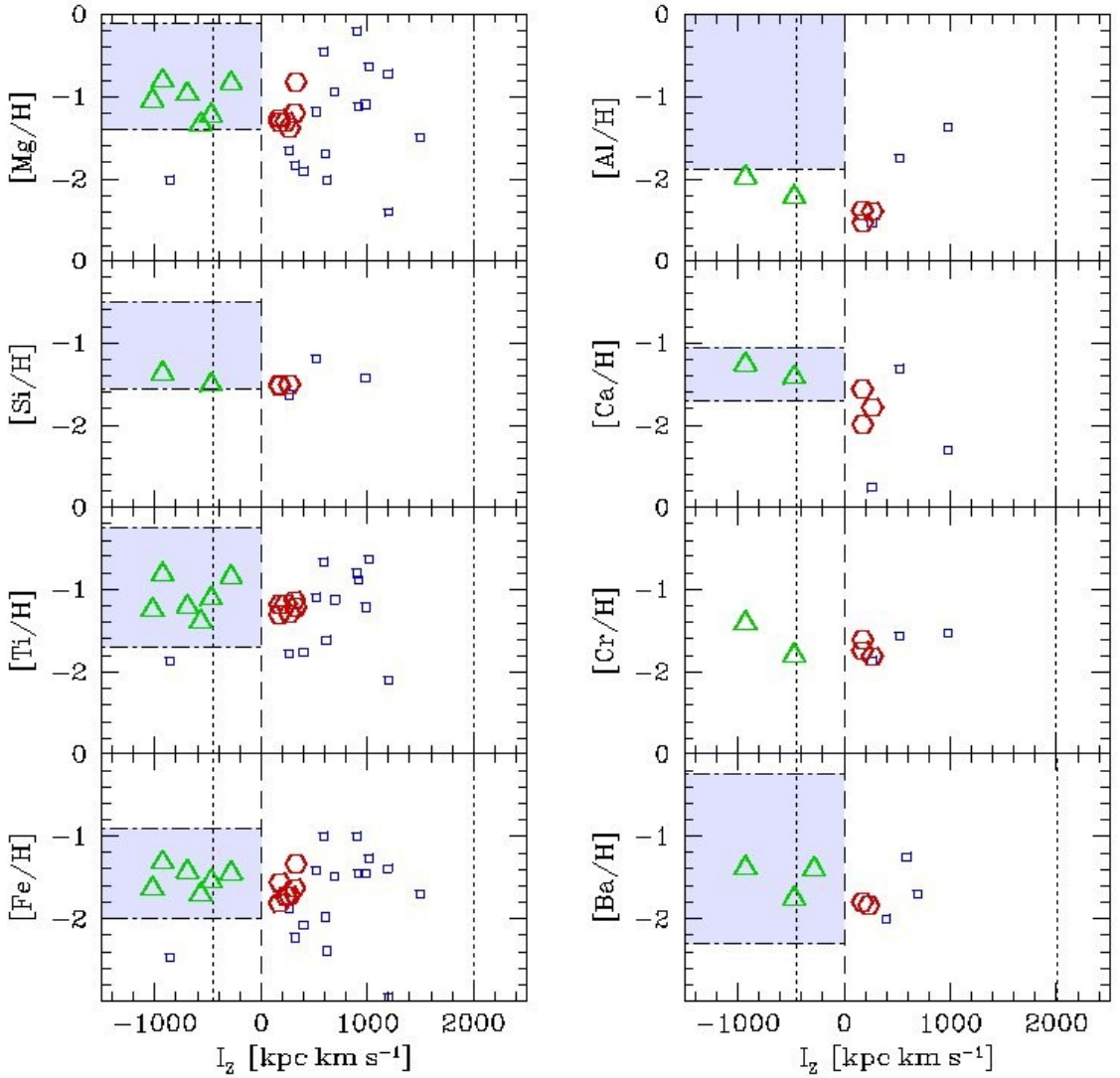
green triangles: possible. Ocen debris candidates

red symbols: COG stars

Altmann et al. 2005

Kinematics & Abundances of local HBA stars

Altmann et al. 2005



Abundance vs. angular momentum

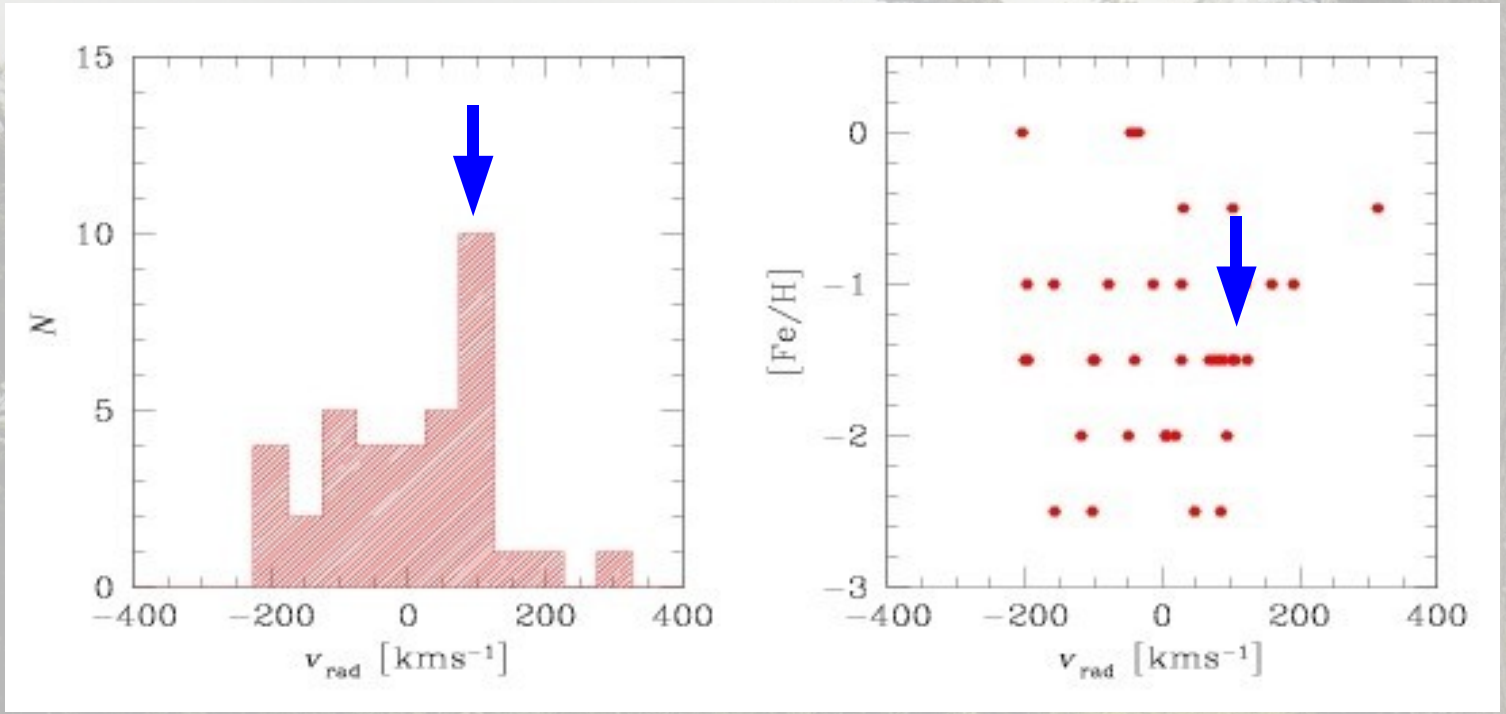
green triangles: possible. Ocen debris candidates

red symbols: COG stars

Note the close abundance range of the COGs!

Kinematics & Abundances of local HBA stars

Sample of Gal. Centre Window HBA stars (Peterson et al. 2001):



Altmann, 2002

Hints of overdensity of HBA stars of certain (Fe/H) and v_{rad}

(Fe/H) of COG is about -1.6, i.e. similar to this peak

Kinematics & Abundances of local HBA stars

- There is a clear indication of an overdensity of local HBA stars at very low prograde rotation and (Fe/H)=-1.6 - -1.7
- Further study required to substantiate this finding
  - new hi-res spectroscopy over the whole optical range to complete and extend the abundance measurements and verify the COGs and determine the nature of the Ocen debris candidates
    - data set aquired, evaluation currently pending
  - extend study to larger samples, spanning a larger volume,
  - e.g. those of Beers et al. (1996), HQS (Hagen et al. 1995), etc.

Kinematics & Abundances of local HBA stars

These results are at current insecure and mere hints of what is going on in the inner Halo, however:

preliminary results published in Altmann et al., 2005, A&A 439, L5

- Results show that a galactochemical analysis (i.e. kinematics and differential abundances) can be a valuable tool in the study of old stars
- HBA stars are very suited tracers for this kind of work

HB stars of various kinds will continue to be one of the premier tool in the study of old populations

Outlook

Apart from continuing this project, we can expect a wealth of new insight using **HB** stars with **GAIA** data (distances, proper motions, v_{rad}s, abundances, etc.) for just about all **HB** stars in the Galaxy.

GAIA will certainly revolutionise our view of the Milky Way in an unprecedented way

HB stars will significantly contribute to this "revolution"

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