Chemical properties and Evolution of A- and B-type stars

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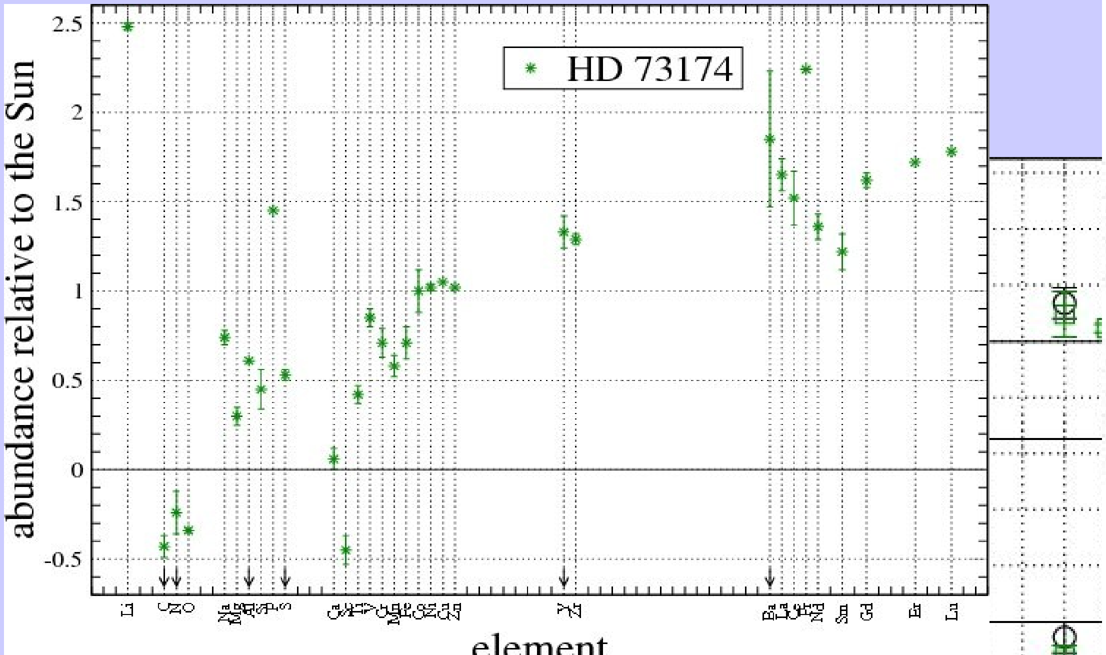
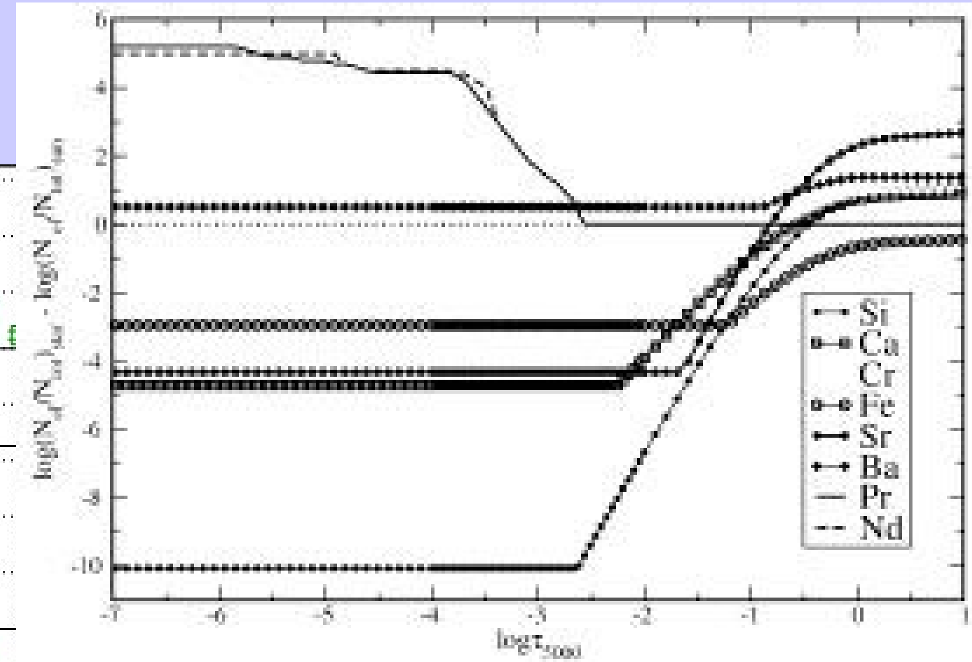
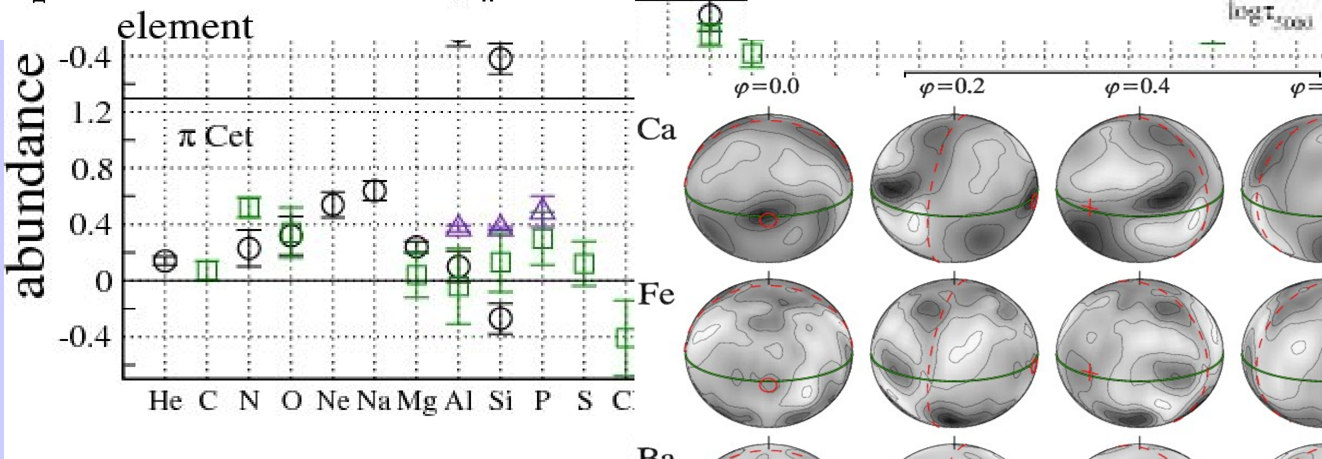
Why early-type stars?

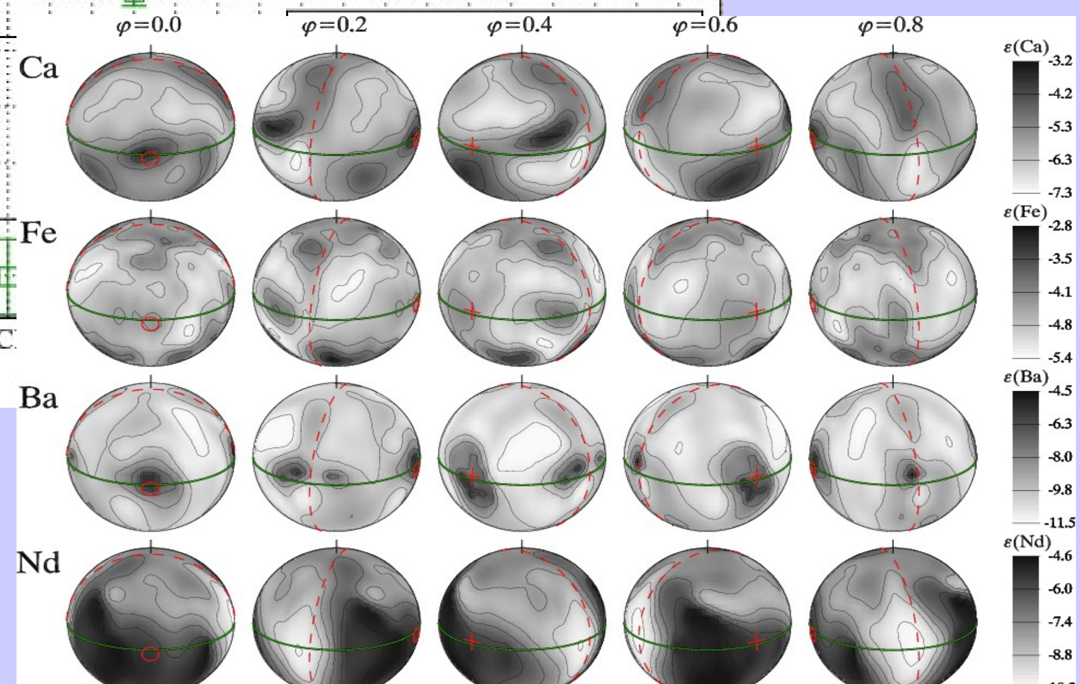
“Stars in various parts of the HR diagram often have atmospheres in which the departure from the simplest kind of plane-parallel model is largely dominated by a single physical effect. For example, massive stars ... strong winds ... . Main Sequence A stars, in contrast, appear to display the competing effects of several physical effects of comparable magnitude. The effects which can be detected by observation include ... magnetic fields, ... convection, pulsation ... , diffusion of specific species ... , ... turbulent mixing, ... winds, and non-thermal heating. This situation makes these stars extremely useful as **laboratories** to explore and to understand the physics of these various phenomena, and how these effects interact with each other.” Landstreet, J., 2004, A stars as physics laboratories, The A-Star Puzzle, Poprad, Slovakia.

Early-type star abundances









- "Normal"
- Fm/Am
- HgMn
- Ap/Bp
- roAp
- lambda Boo
- metal poor

The open cluster project

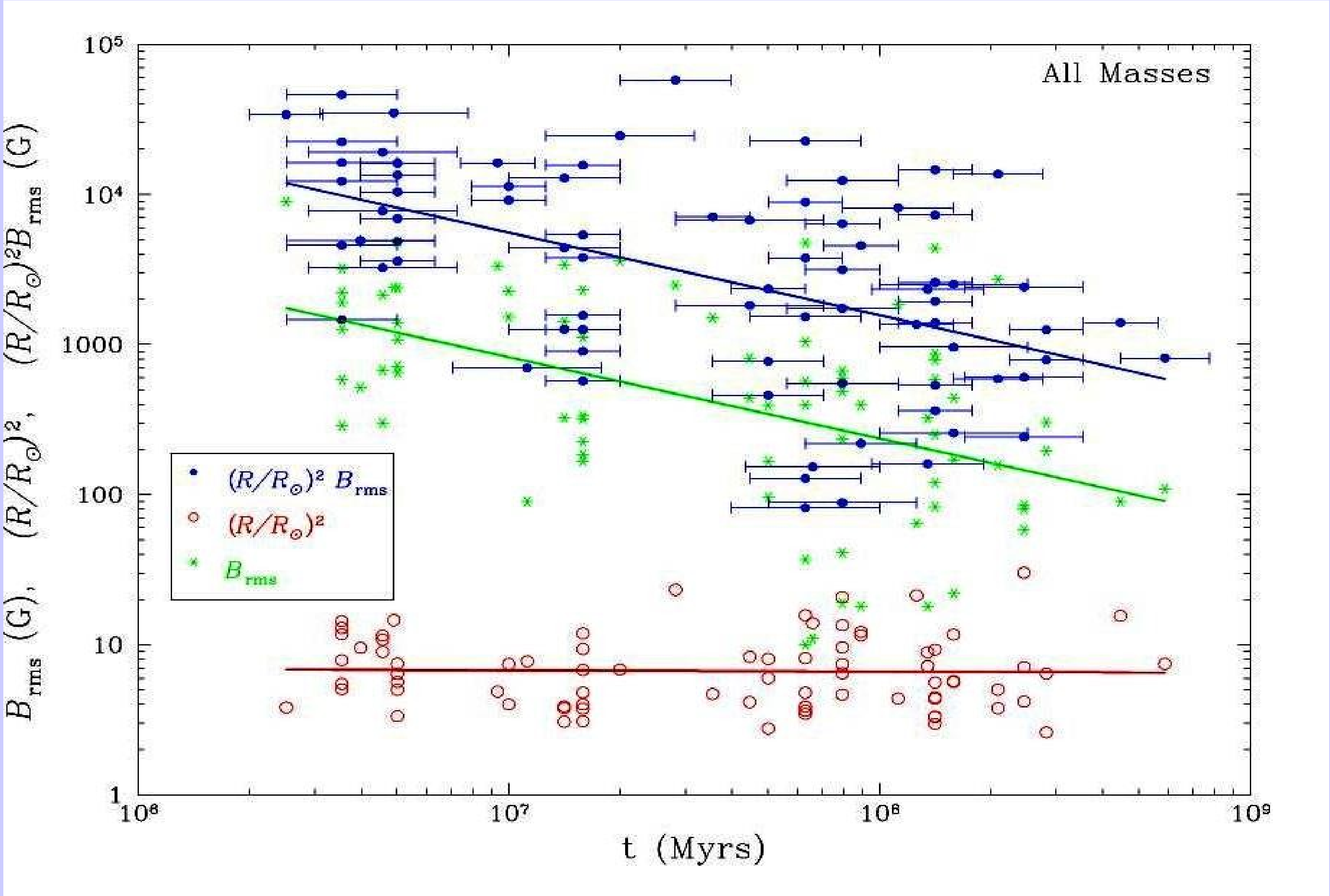
- Magnetic field measurements of chemically peculiar (CP) early-type stars in open clusters – evolution of the magnetic field

- Photometric study of CP early-type stars to measure rotational velocities – evolution of the angular momentum

→ connections between magnetic field and stellar rotation

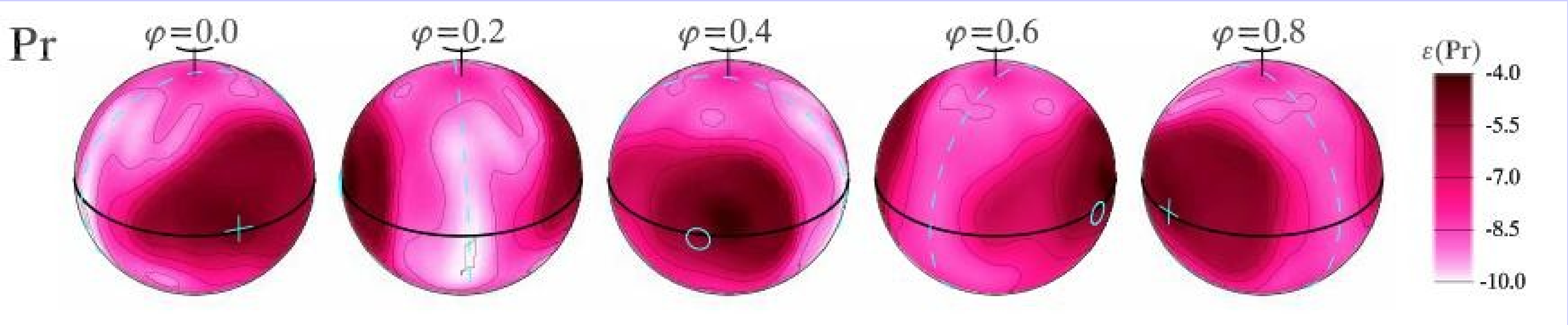
- Abundance analysis of chemically normal and peculiar early-type stars – evolution of the abundances early-type stars

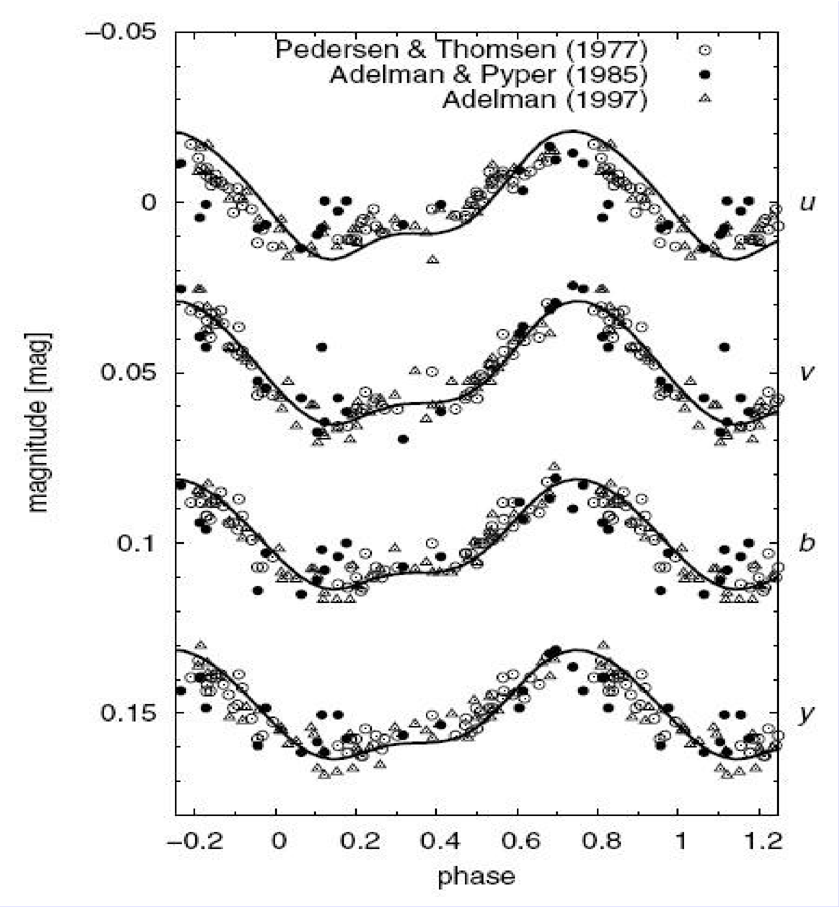
Magnetic field evolution



The magnetic field strength decreases with time (Landstreet et al. 2008)

Photometry of CP stars





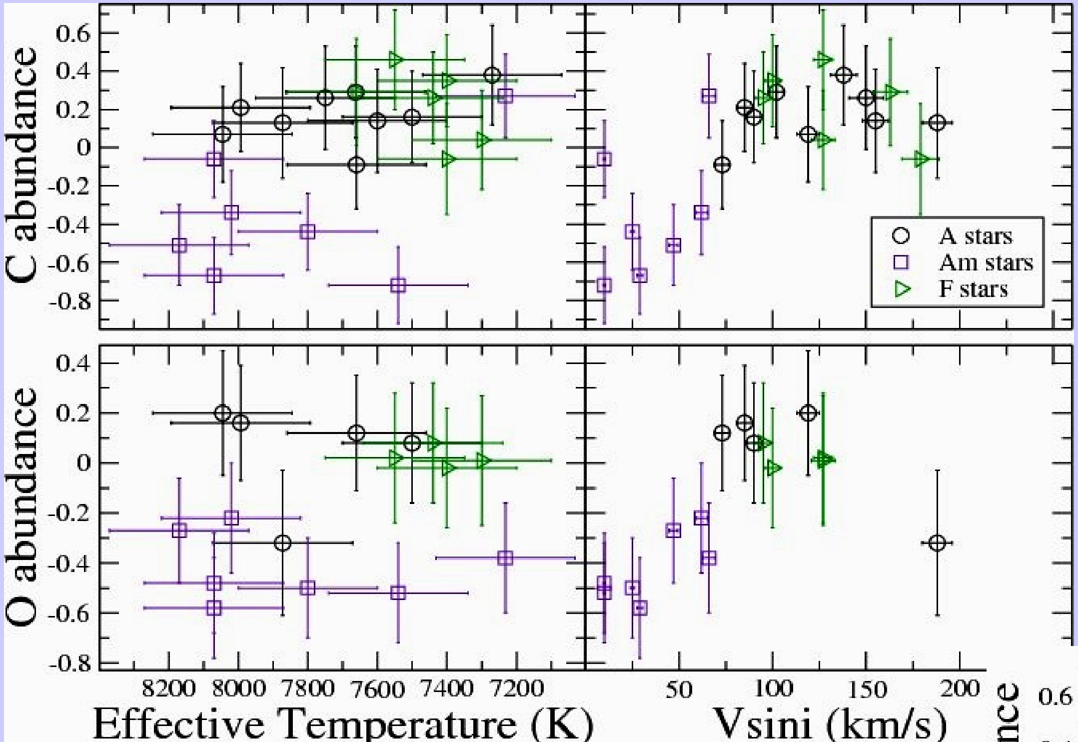
- check possible angular momentum loss during the main sequence phase
- check correlations between rotation period, light curve amplitude and magnetic field strength
- optimize future spectropolarimetric runs
- determine stellar inclination (with rotational period, Vsini and stellar radius)
- constraint model atmospheres

Observed clusters (abundances)

Cluster	Distance Modulus	**log *t***	Instrument
NGC 6193	11.8	**6.8**	FLAMES@ESO/VLT
NGC 6383	10.9	**6.9**	FLAMES@ESO/VLT
NGC 6250	10.8	**7.4**	FLAMES@ESO/VLT
IC 4665	8.3	**7.6**	FIES@NOT
NGC 6405	8.9	**8.0**	FLAMES@ESO/VLT
NGC 3114	10.0	**8.1**	FLAMES@ESO/VLT
NGC 5460	9.4	**8.2**	FLAMES@ESO/VLT
NGC 7092	7.6	**8.4**	FIES@NOT
NGC 6633	8.4	**8.6**	FLAMES@ESO/VLT
M 44 (Praesepe)	6.39	**8.9**	SOPHIE&ELODIE@OHP ESPaDOnS@CFHT

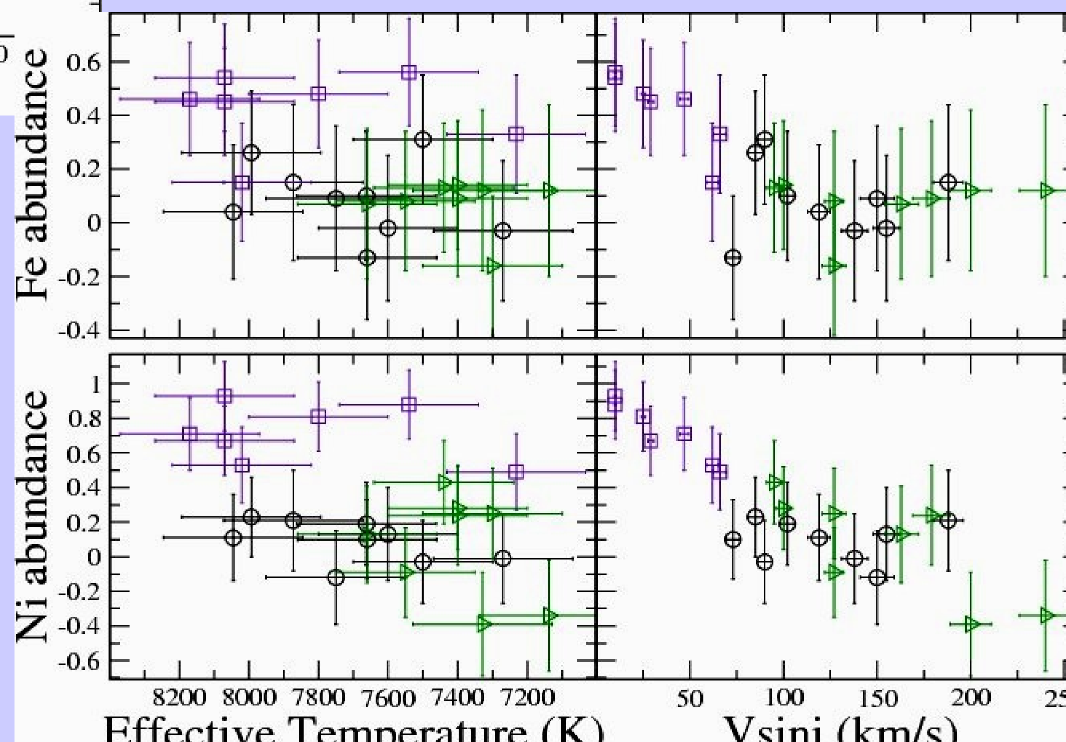
Uniform distribution in log *t*

Praesepe – abn. & Teff/Vsin*i*

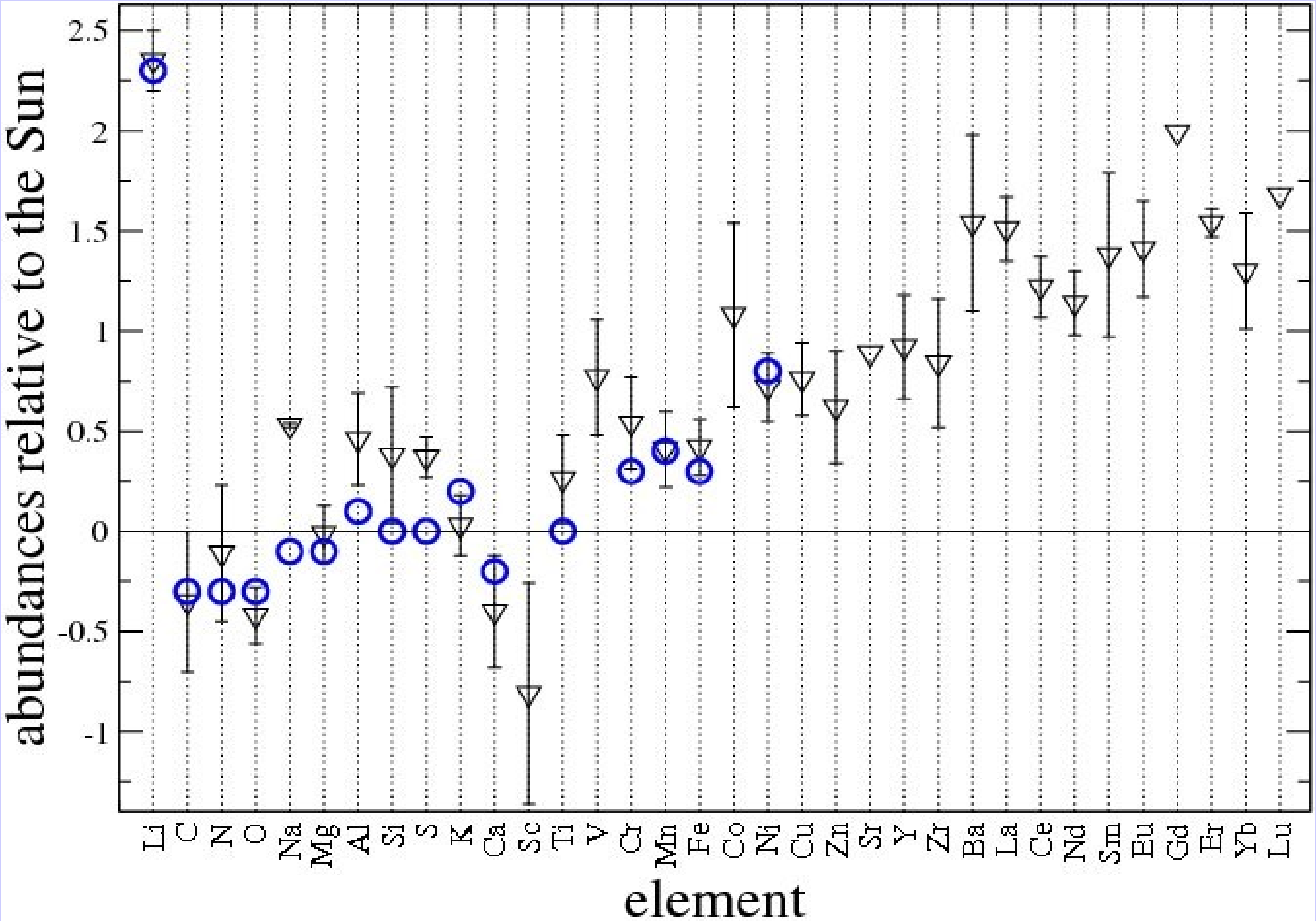


The abundance of elements *peculiar* in Am stars decrease*s* with increasing Vsin*i*.

Results in *agreement* with recent diffusion calculations:
Richer et al. 2000
Talon et al. 2006



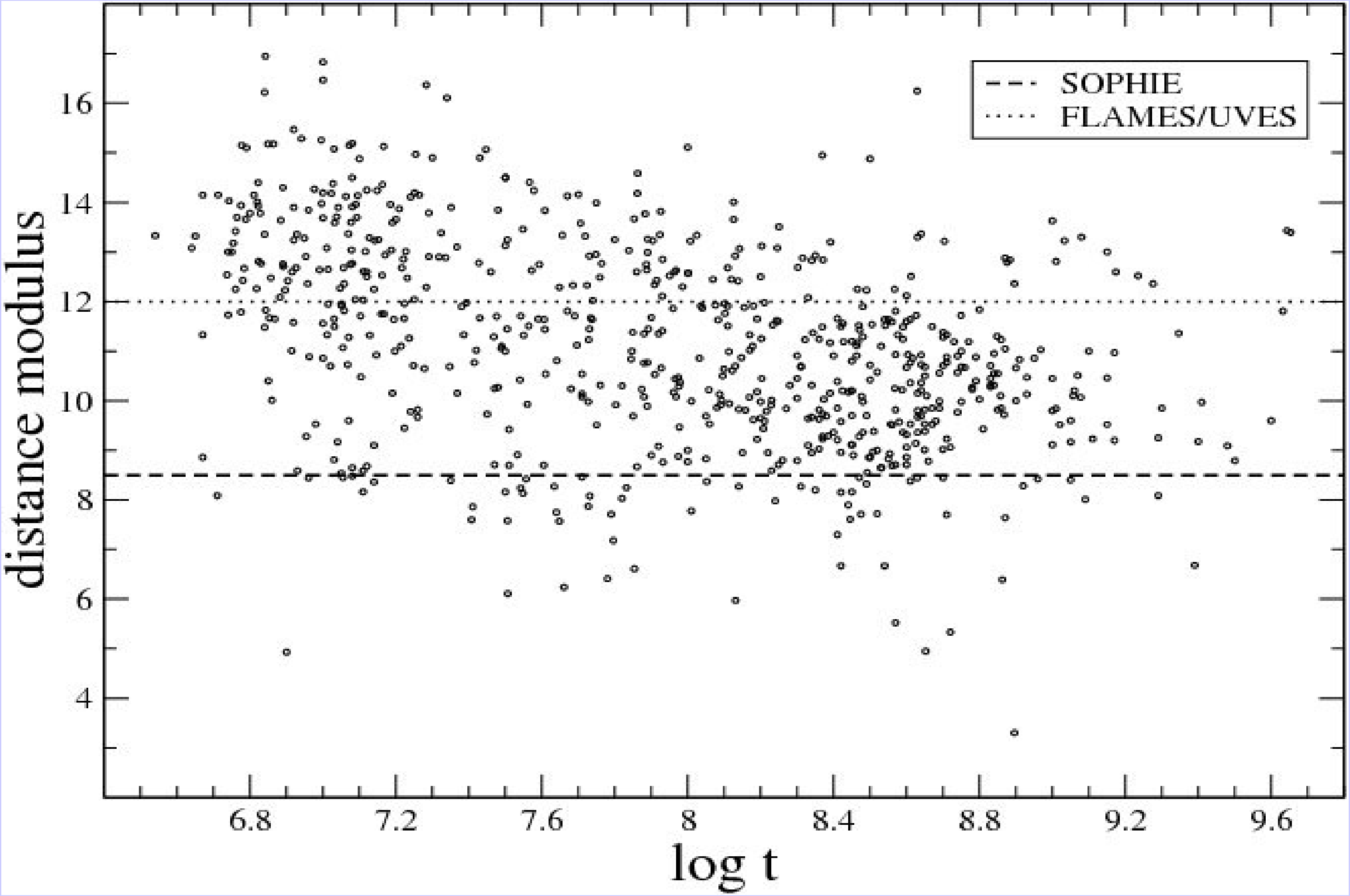
Praesepe – diffusion



Models by Richer et al. 2000

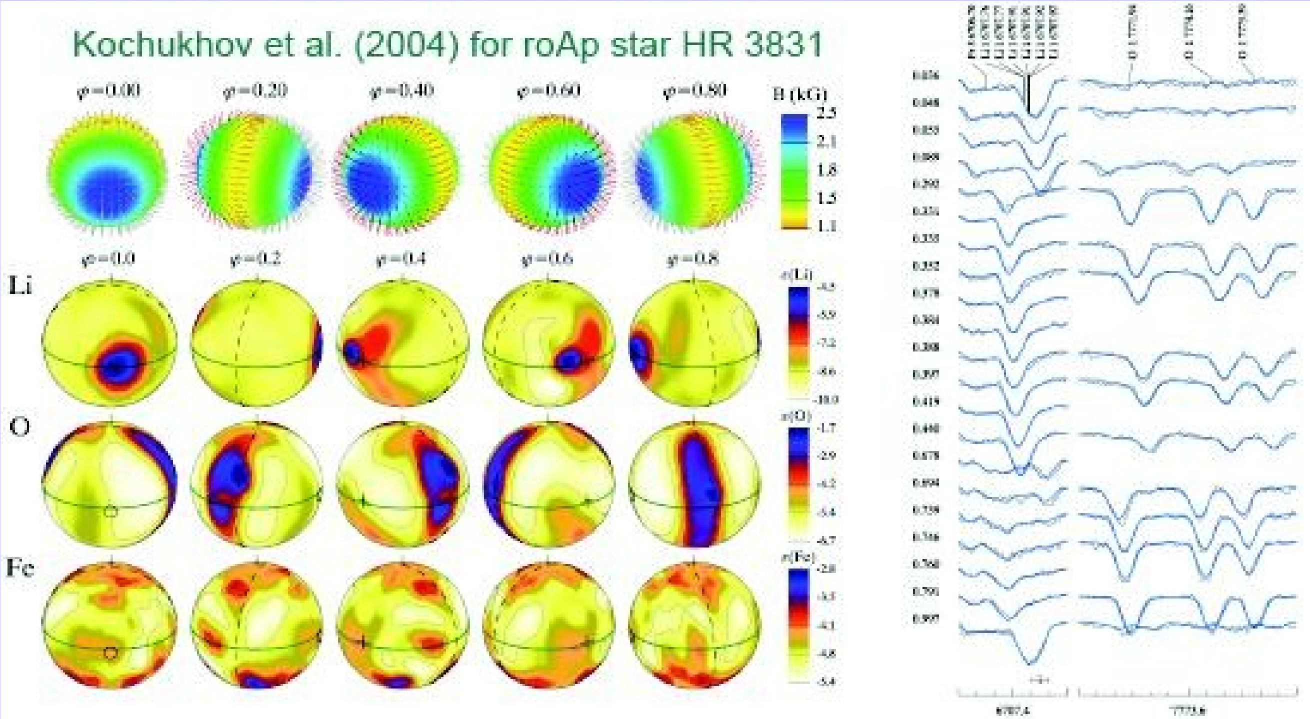
for Am star with Teff = 8000 K and log *t* = 8.82 (log *t* of Praesepe is: 8.86)

Observed clusters

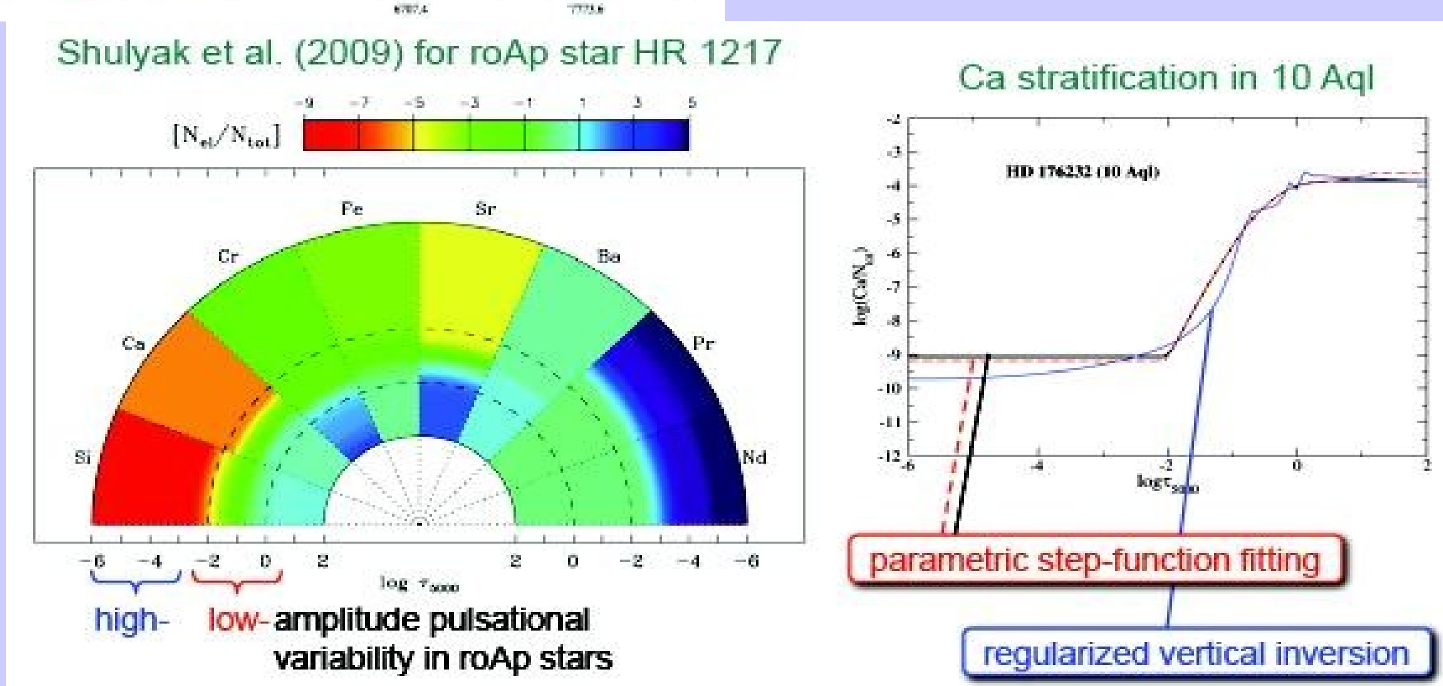


Magnitude limit reached assuming 30 min. exposure time and 200 SNR

Magnetic Doppler Imaging



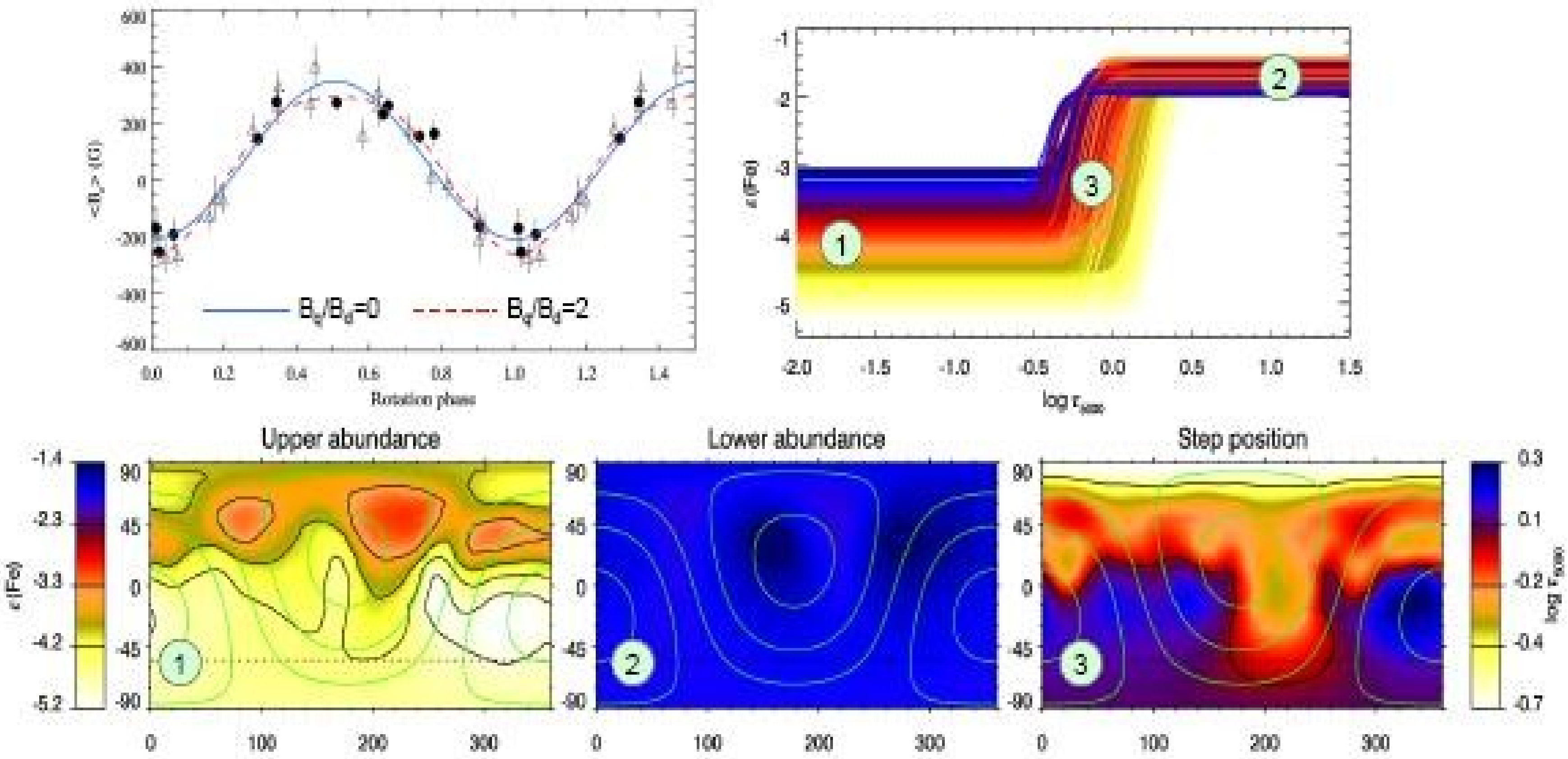
Horizontal inhomogeneities



Vertical inhomogeneities

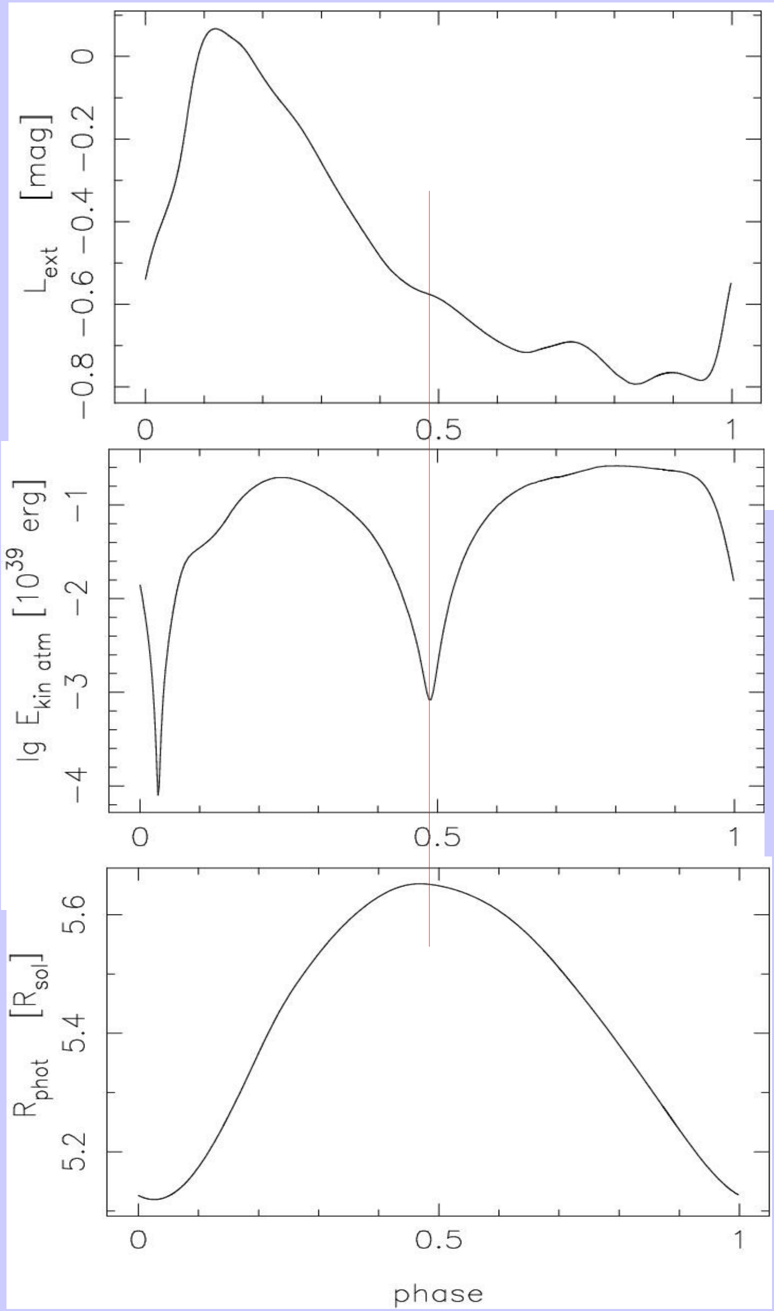
Magnetic Doppler Imaging

- A0pSi, $T_{eff} \approx 10500$ K, $V_e \sin i$ = 54 km/s, B_d=1.3 kG
- 20 BOES spectra, $S/N \approx 300$, 16 Fe I and Fe II lines



There is a desperate need of target stars and observational data:
Doppler imaging: fast rotators, rotational phase coverage
Stratification analysis: slow rotators, wide spectral coverage

Abundance analysis of RR Lyrae stars



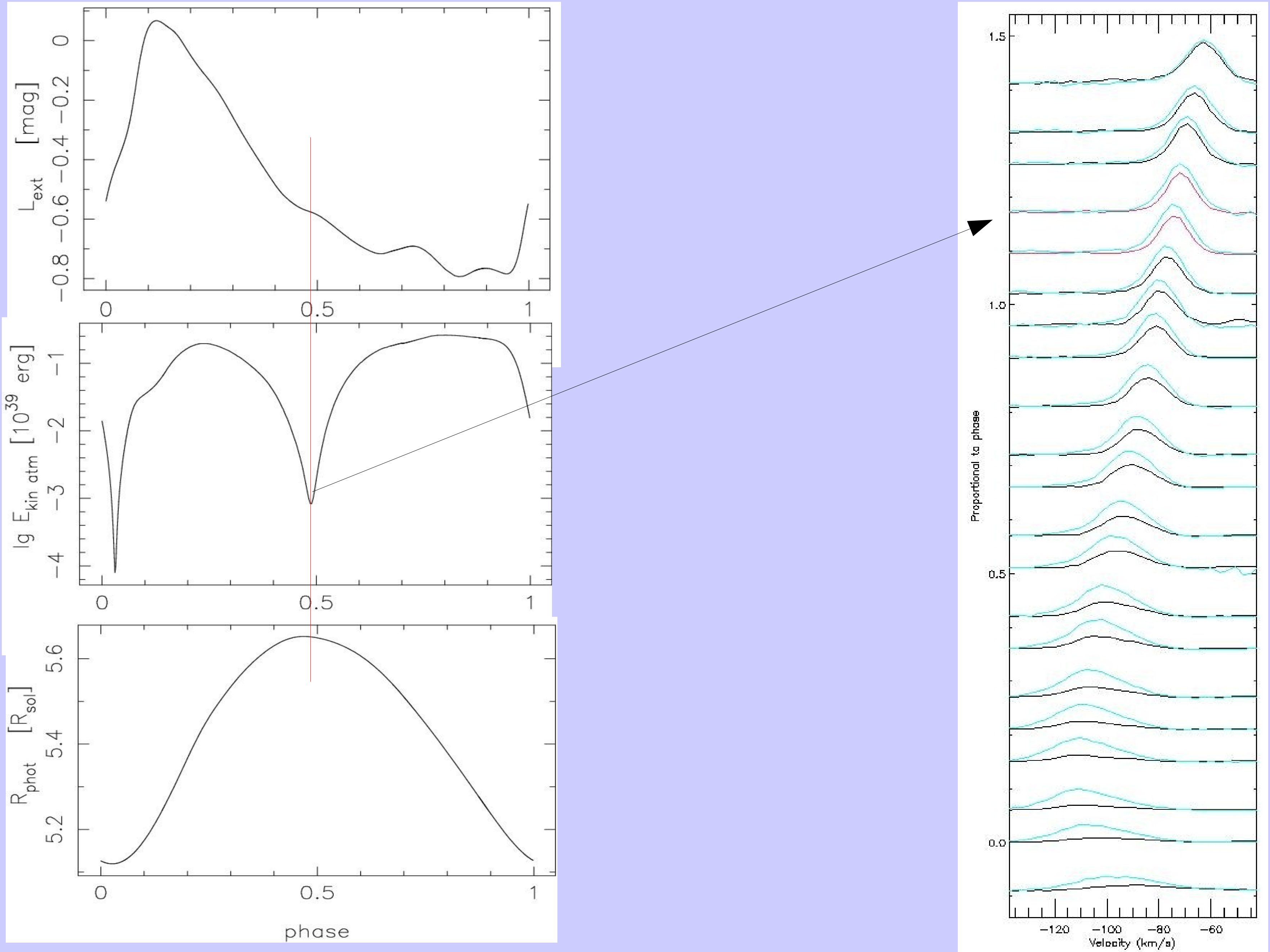
Two different Phases:
Pulsational Phase about 0.6 days
Blashko Phase about 40 days

Previous analysis:
- static model atmospheres
- phases around minimum light

Our analysis:
- static model atmospheres with individualised abundances
- phase of maximum radius
- non-grey dynamic model atmospheres with individualised abundances

Line profiles: always broadened and very much distorted, but not at maximum radius

Abundance analysis of RR Lyrae stars



Conclusions

Both magnetic field and angular momentum evolution projects are based on statistics and more observations of more open clusters are needed.

Open clusters containing several Am stars need to be discovered to be able to study any abundance anomaly evolution. What about HgMn stars?

In general there is the need to observe the young far open clusters and to discover and observe more old open clusters.

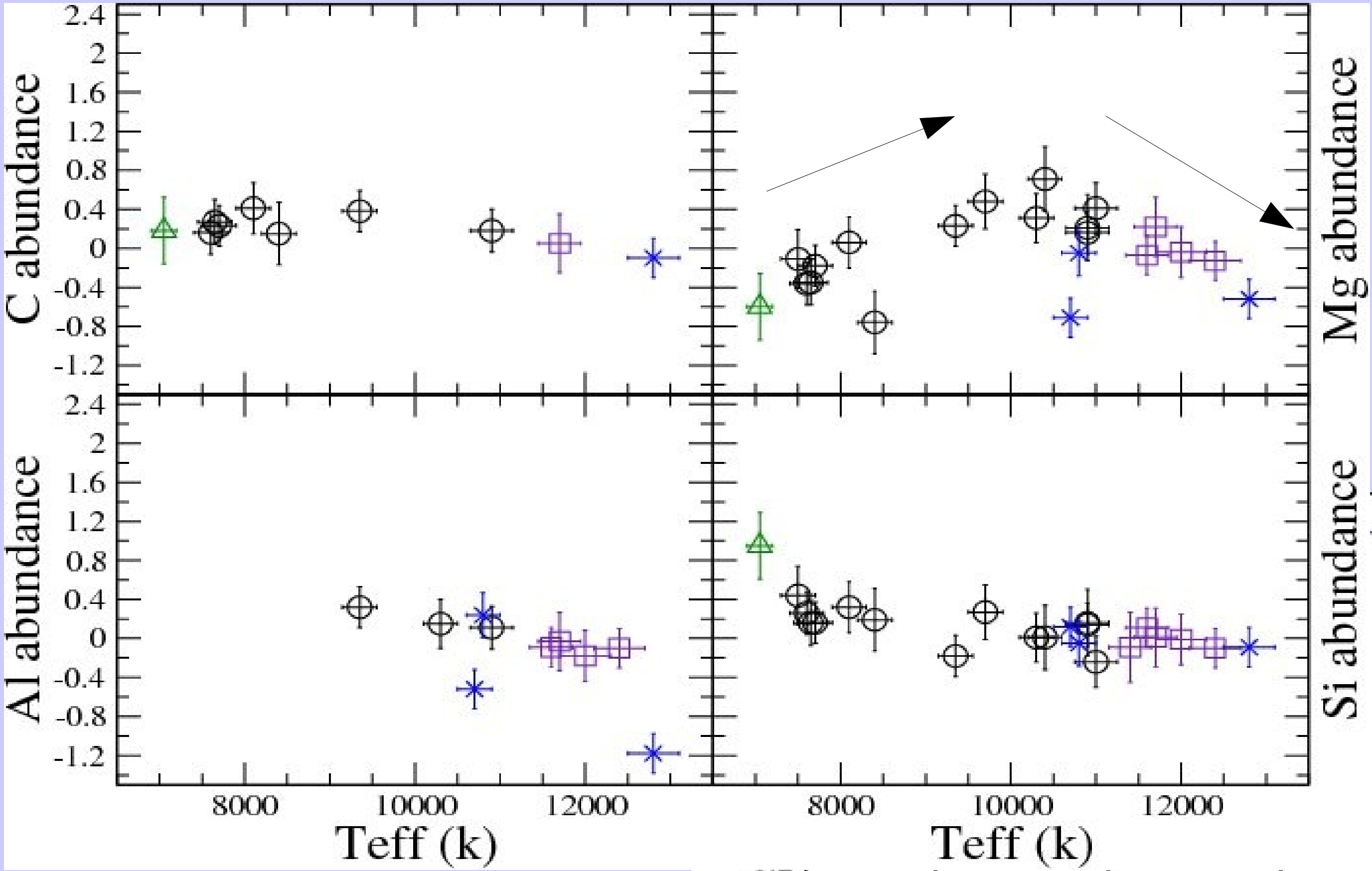
The 3D mapping of CP stars requires the discovery of suitable objects.

A realistic abundance analysis of Blashko stars goes through extensive observational campaigns requiring high SNR spectra obtained with the shortest possible exposure time.

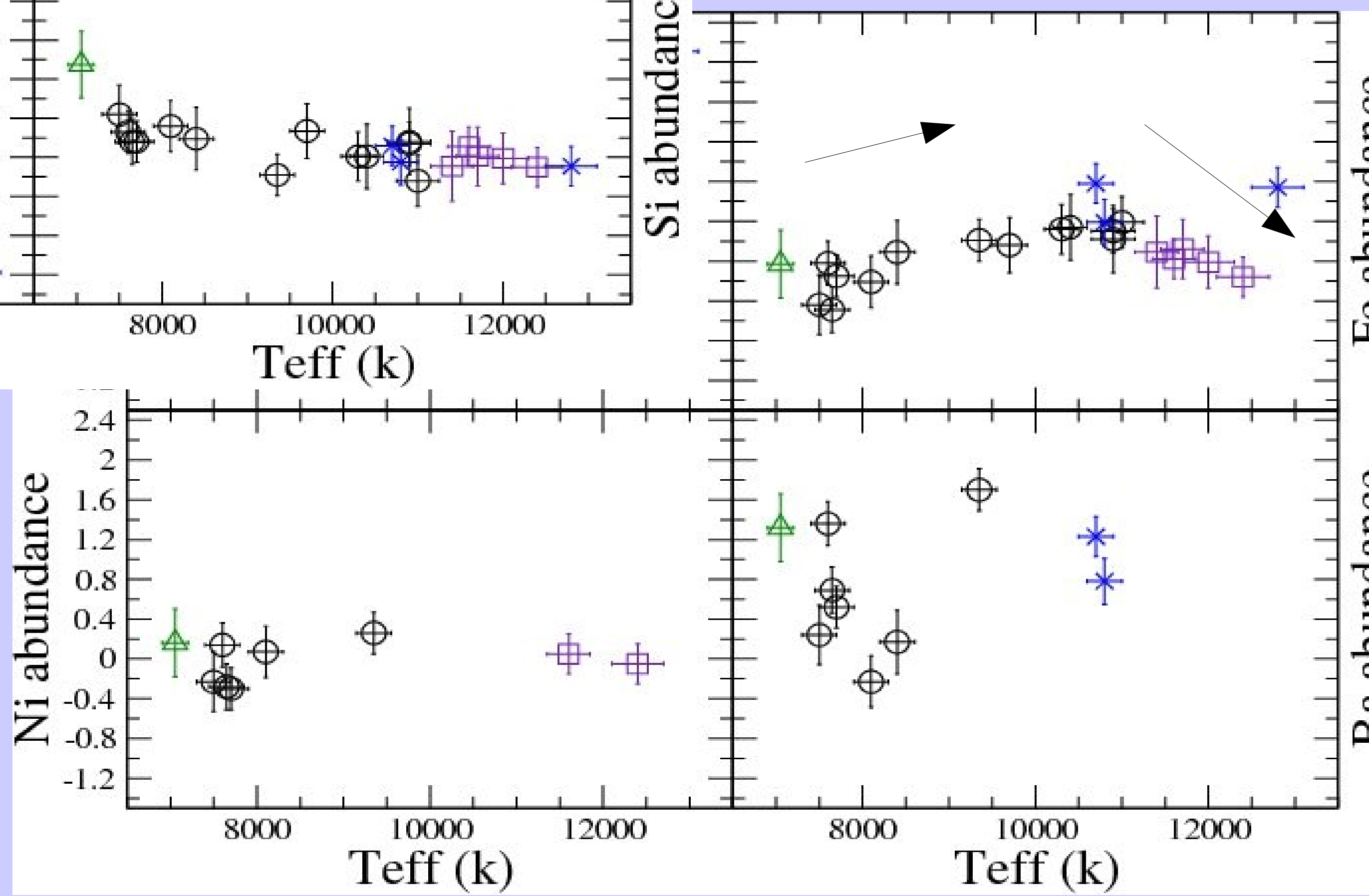
E-ELT can provide all the necessary observations / information

Thank you
for your
attention.

RESULTS: NGC 5460 – abundance & Teff

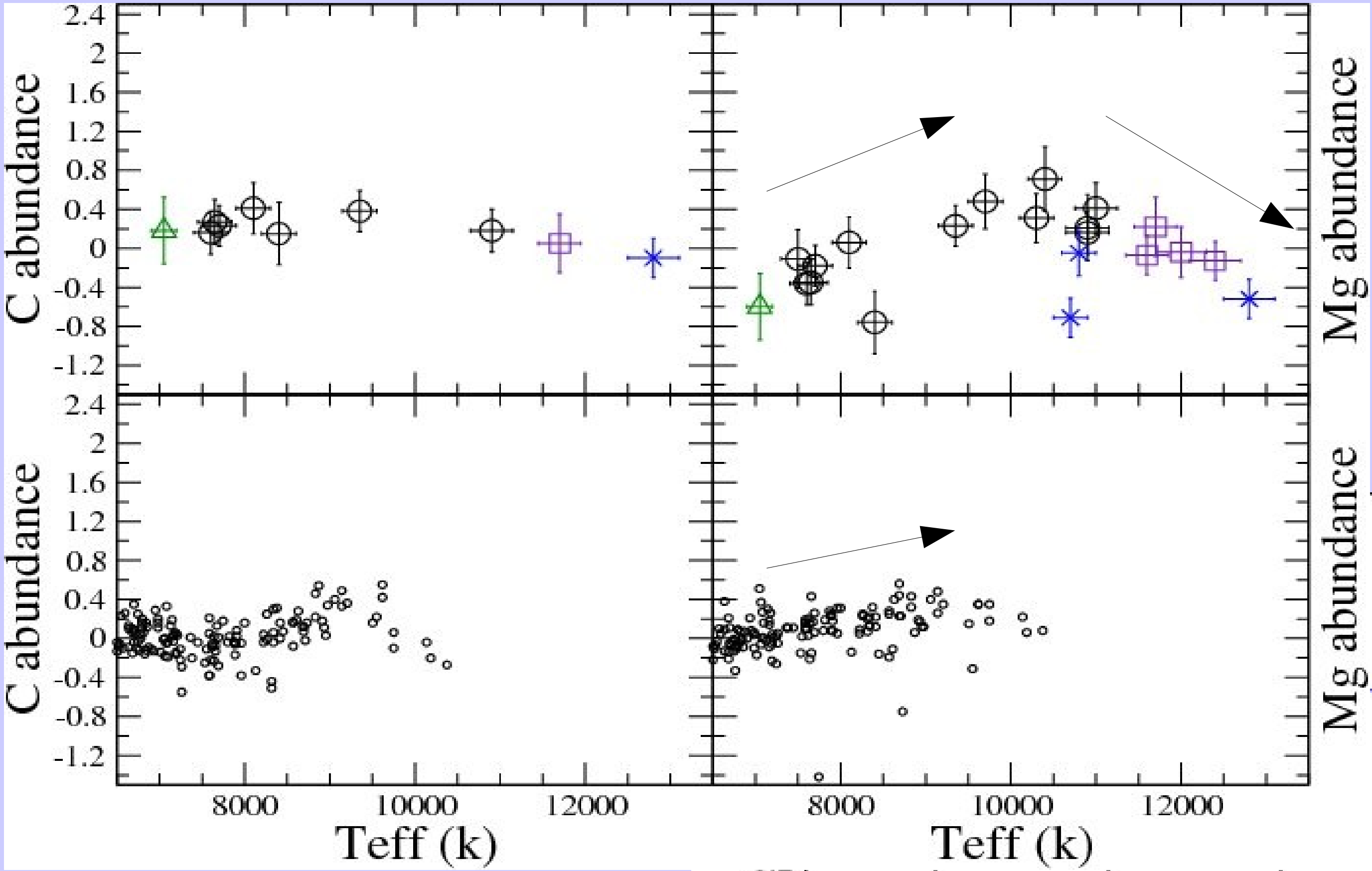


Square & violet: B-type
Circle & black: A-type
Triangle & green: F-type
Cross & blue: He-weak



Hint of trends for Mg and Fe?

RESULTS: NGC 5460 – abundance & Teff



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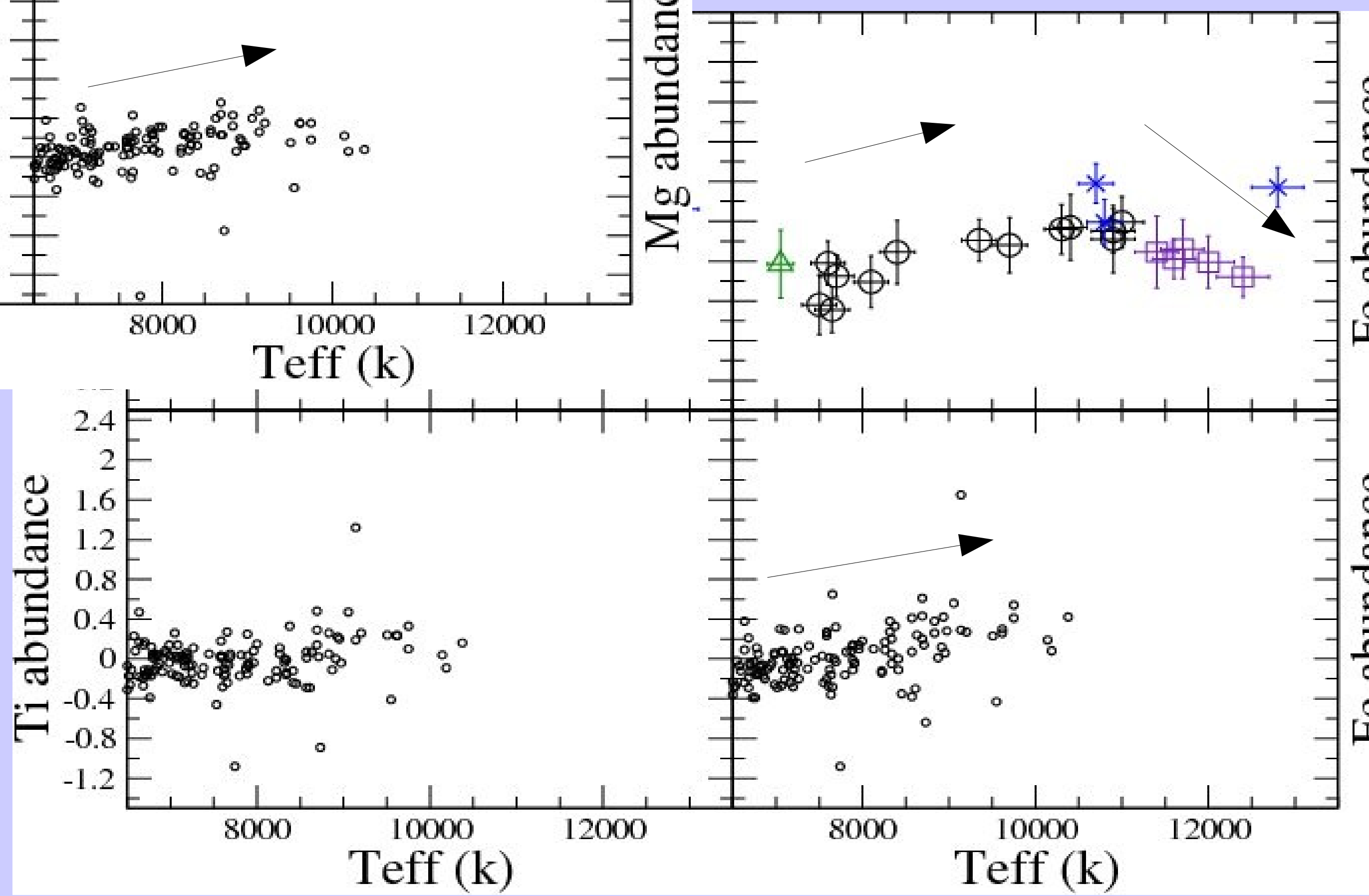
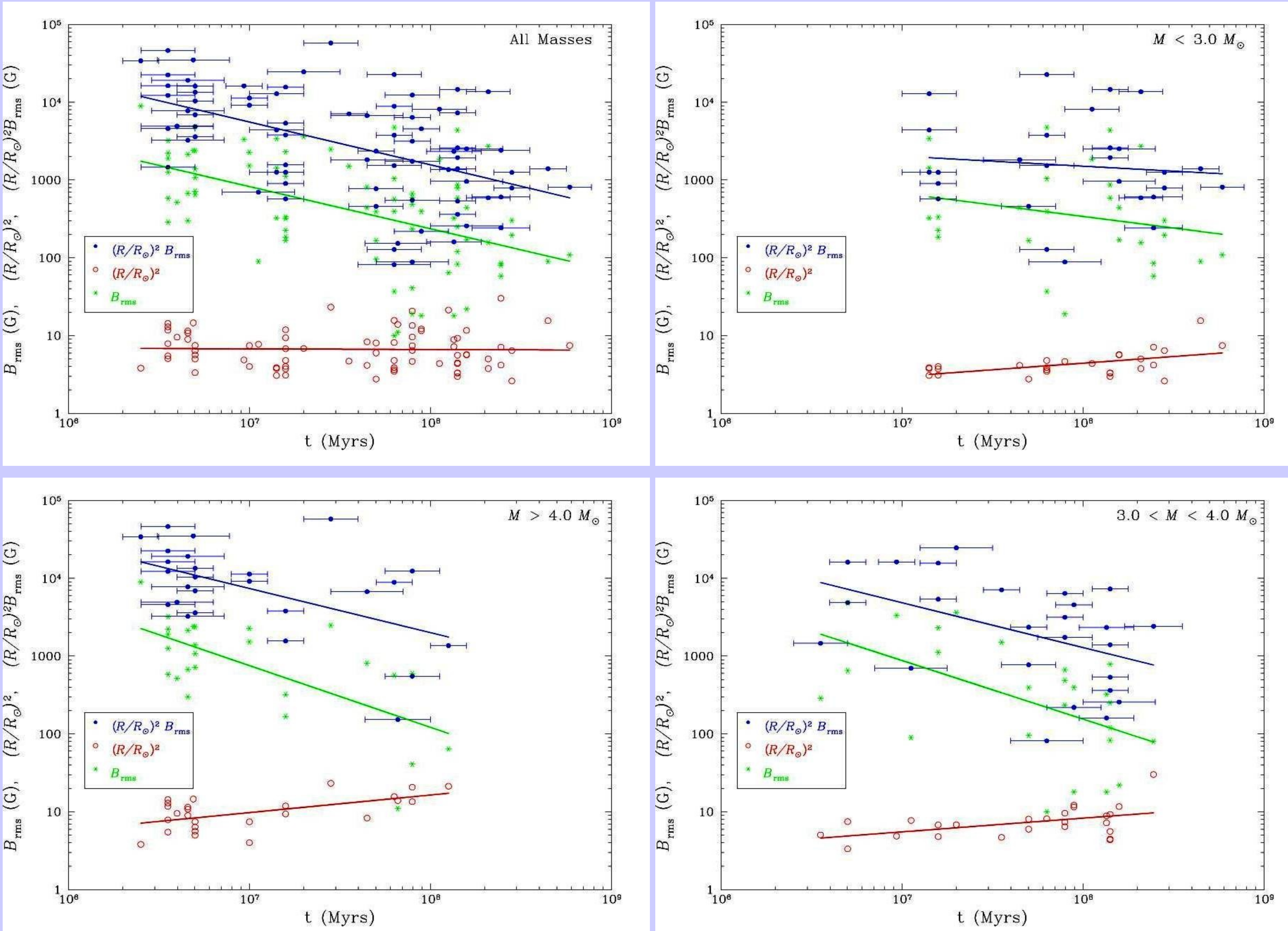


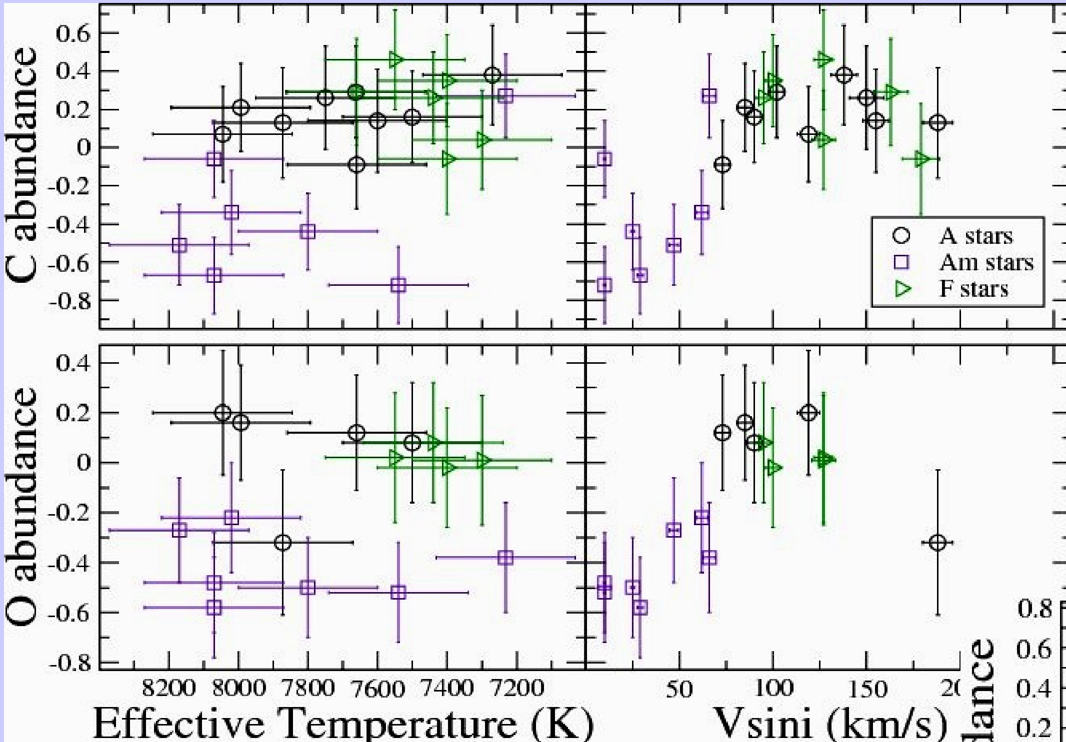
Comparison with Erspamer & North 2003

- Diffusion?

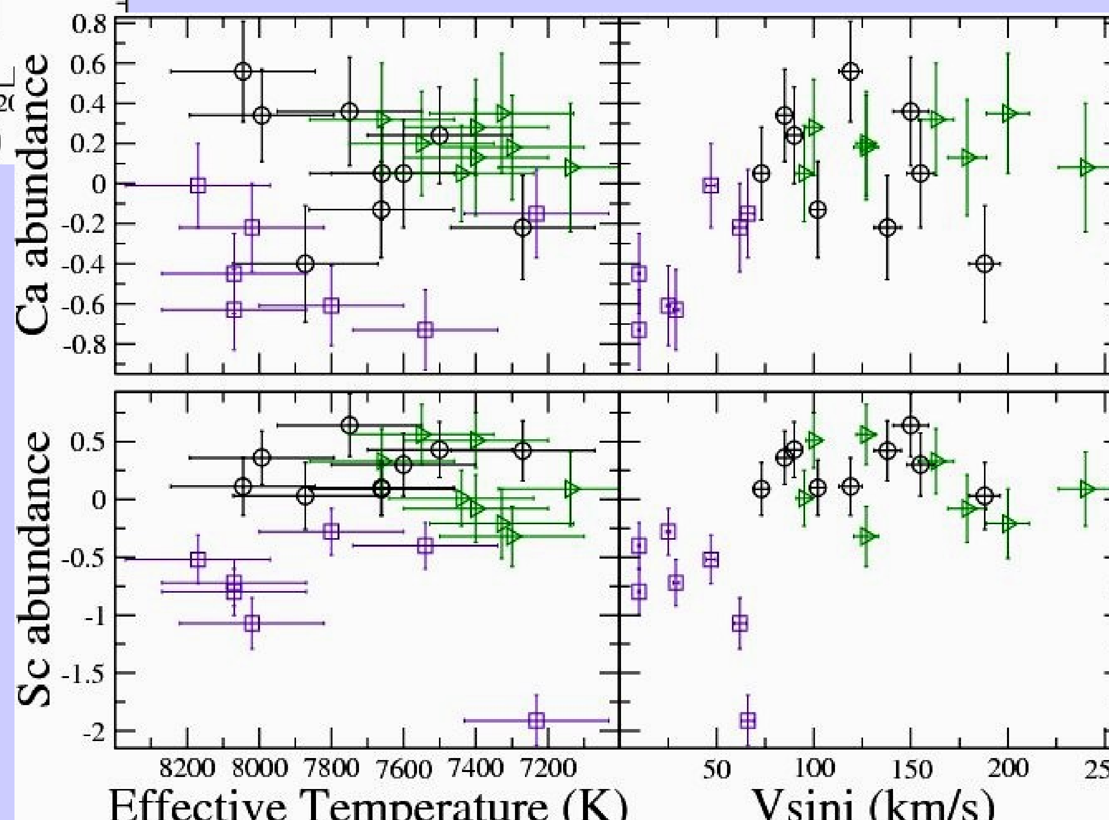
Magnetic field evolution



Praesepe – abn. & Teff/Vsin*i*



The abundance of elements *underabundant* in Am stars *increases* with increasing Vsin*i*.



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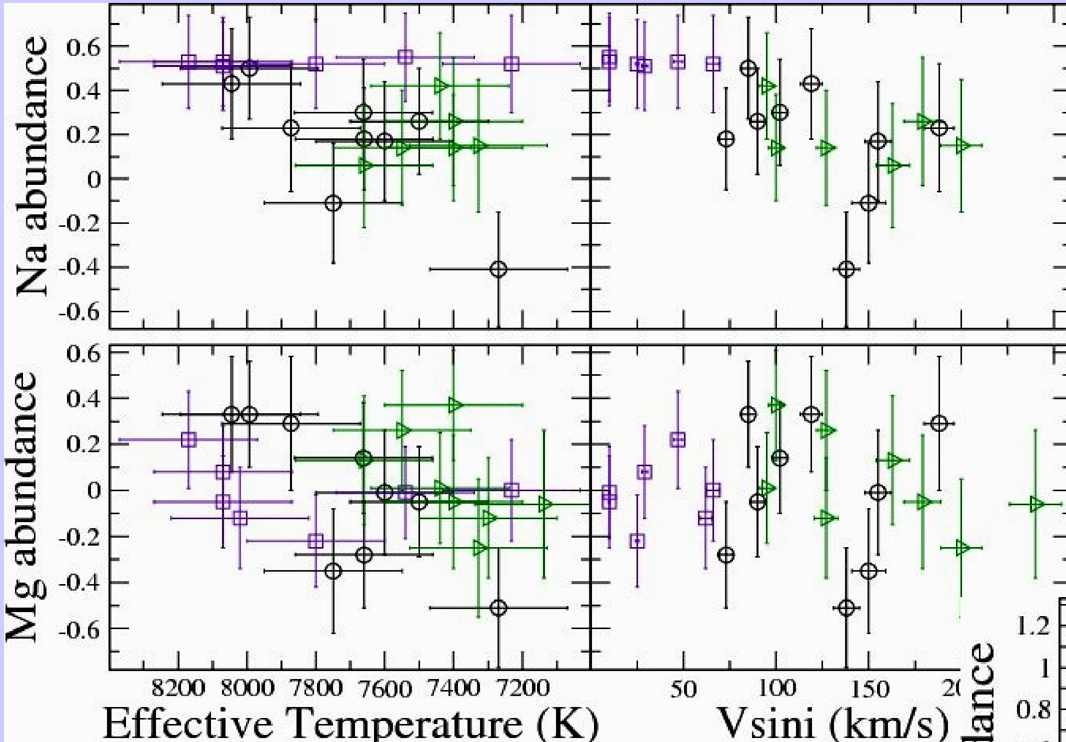
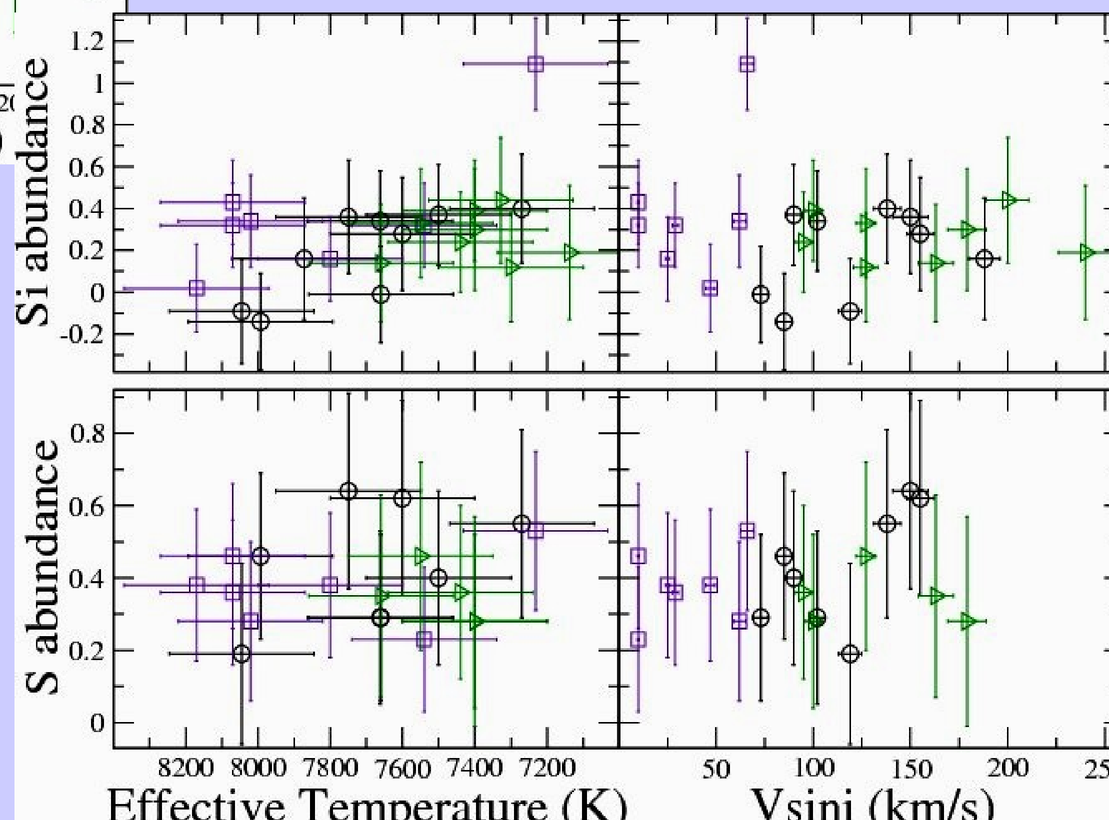
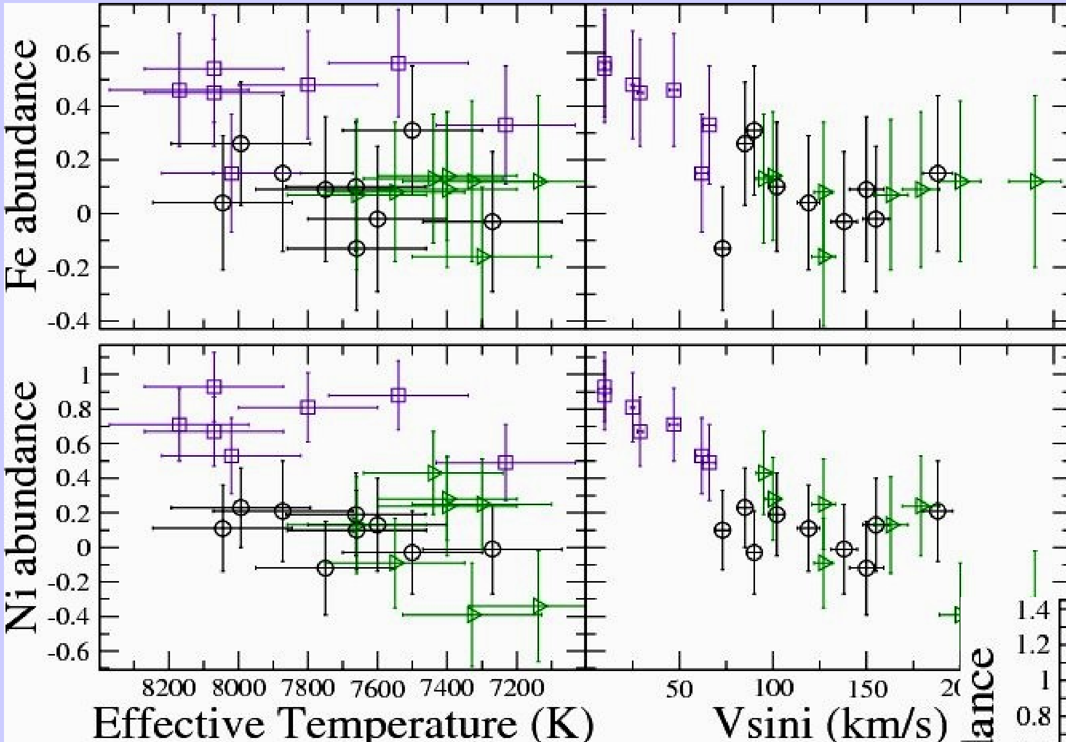


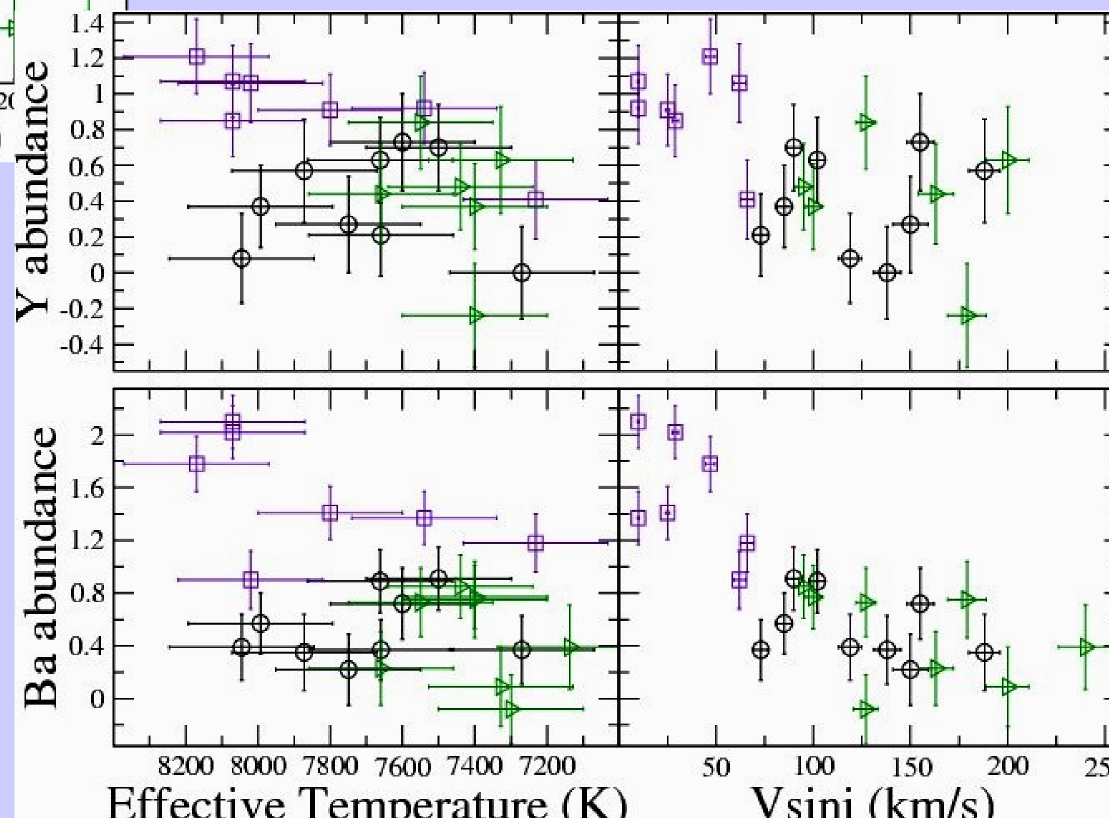
The abundance of elements *not peculiar* in Am stars do *not show* any trend with Vsin*i*.



Praesepe – abn. & Teff/Vsin*i*



The abundance of elements *overabundant* in Am stars *decreases* with increasing Vsin*i*.



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Blue Stragglers – the example of HD73666

Most of the known Blue Stragglers in open and globular clusters are early-type stars

HD73666

RA: 08 40 24

DEC: +19 40 00

Distance: 180 pc

Reddening: 0.009mag

Distance modulus: 6.30mag

Log t: 8.85

[Fe/H]: +0.14,   Z:0.024

Mass: ~600 solar masses

Radius: 3.5 pc

Members: ~573 stars

Blue Stragglers – the example of HD73666

- Horizontal Branch confusion (*Sargent, 1968*) NO
- Second or third generation stars NO
- Stars with extended main sequence life due to internal mixing (chemically peculiar stars) NO
- Stars formed by collision of two single stars
- Stars with current or past mass transfer from a close companion UNLIKELY
- Stars formed by the merging of the components of a binary system
- Stars formed after the collision of two or more binary systems

between 5 and 350 Myr (50 Myr if HD73666 is an intrinsic slow rotator)