Magnetic fields of Ap stars in all four Stokes parameters

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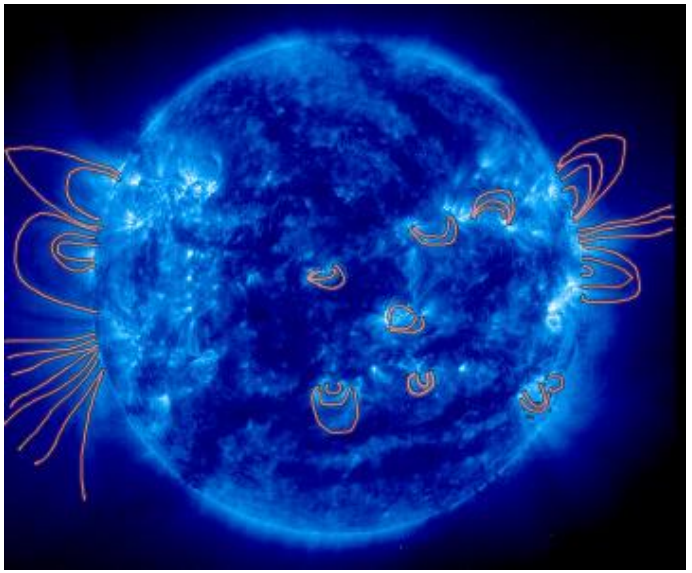
April 2014

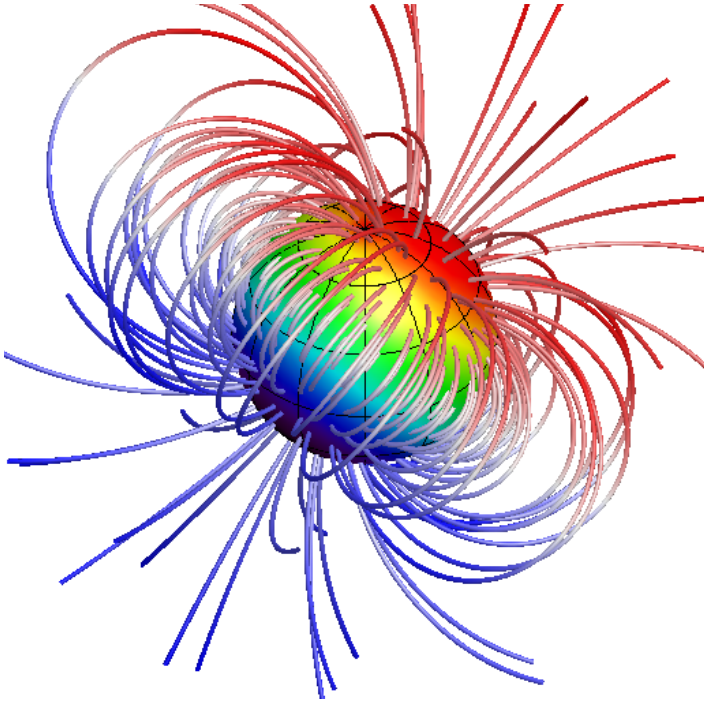
Stellar magnetism

Sun and all cool stars



- Dynamo mechanism
- Complex, rapidly evolving, weak magnetic fields
- Temperature spots
- All stars have mag. fields

Hot stars



- Fossil fields
- Simple, stable over time, strong magnetic fields
- Chemical spots
- Only 10% have mag. fields

Stellar magnetism

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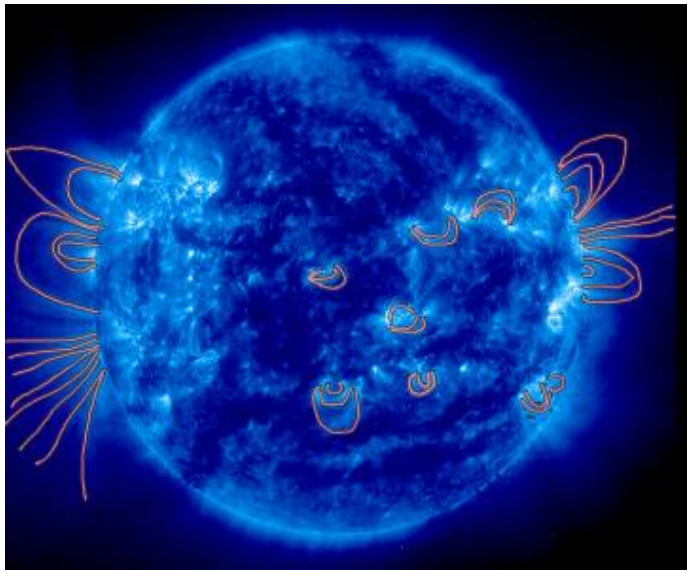

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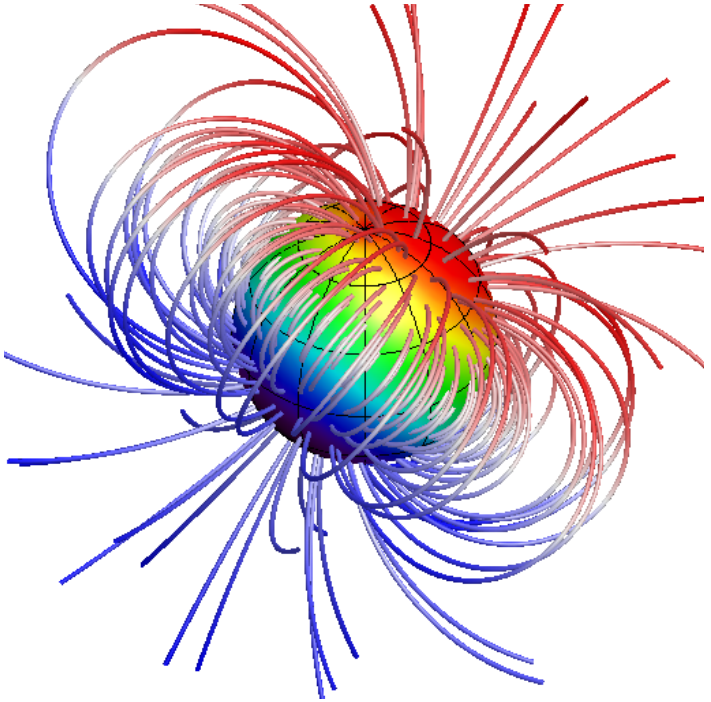

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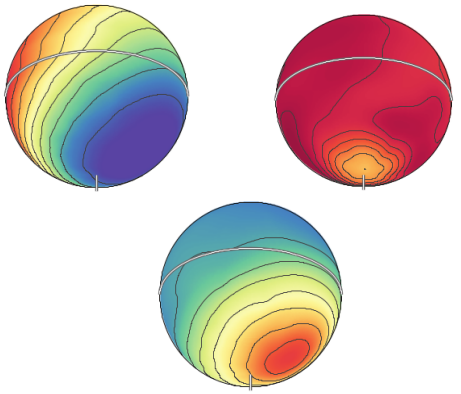
How strong?

Field strength ~ 1-30 kG

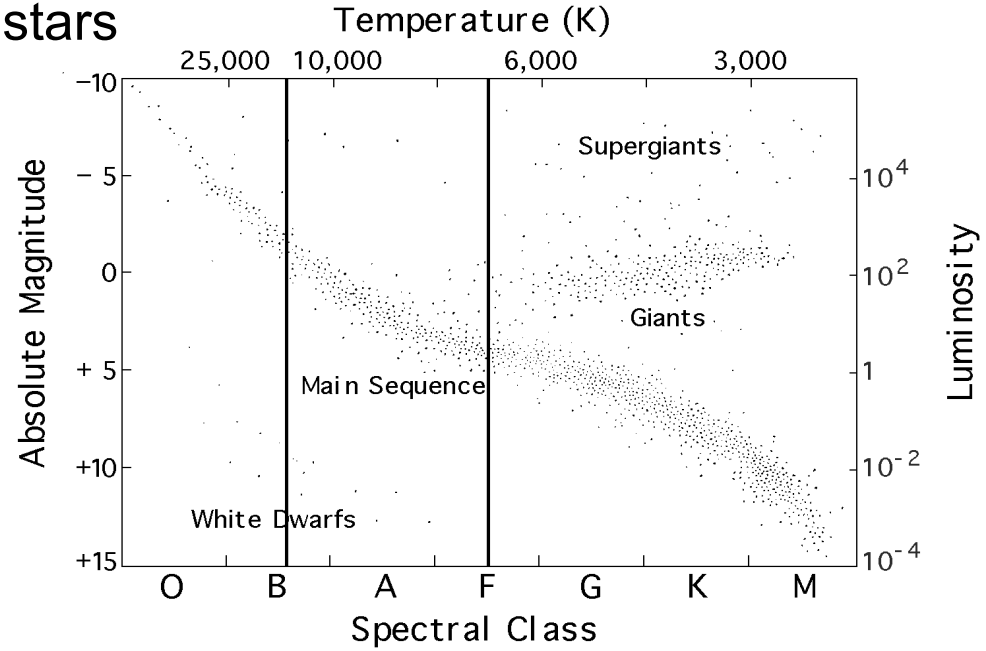
How spotty?



Several orders of magnitude

Ap and Bp stars

- Main sequence A and late B type stars
- Spectral Types: B6 – F4
- Teff range: 7 – 16 kK
- Simple, stable over time, strong magnetic fields
- Enhancements in Si, Sr, Cr, Eu,...
- Slow rotation



roAp (rapidly oscillating) stars: short-timescale, milimagnitude photometric variations and variations in radial velocities of spectral lines with periods P ~ 5-24 min.

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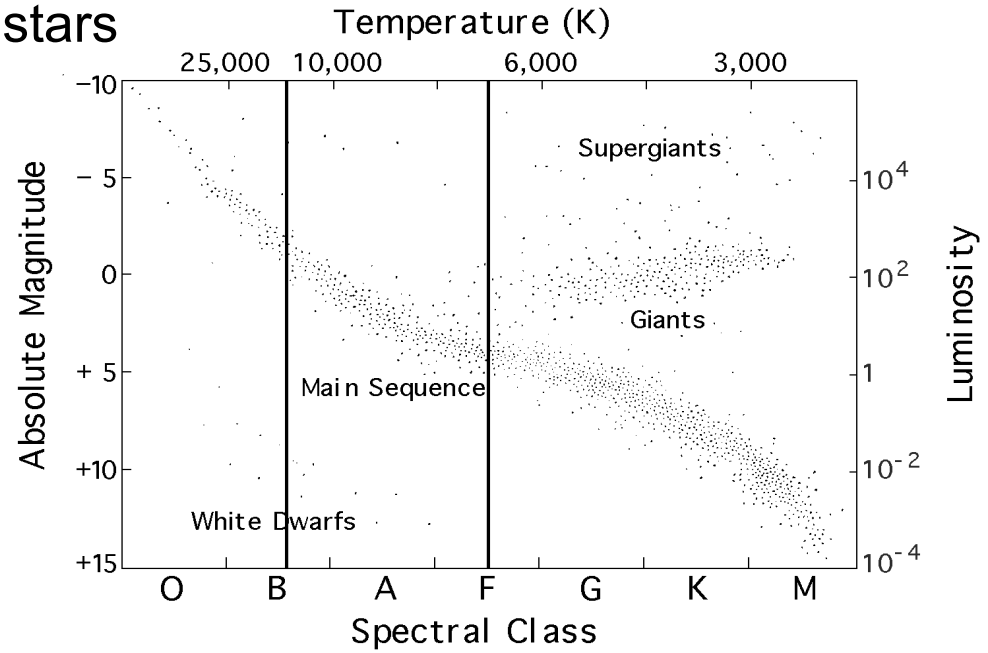

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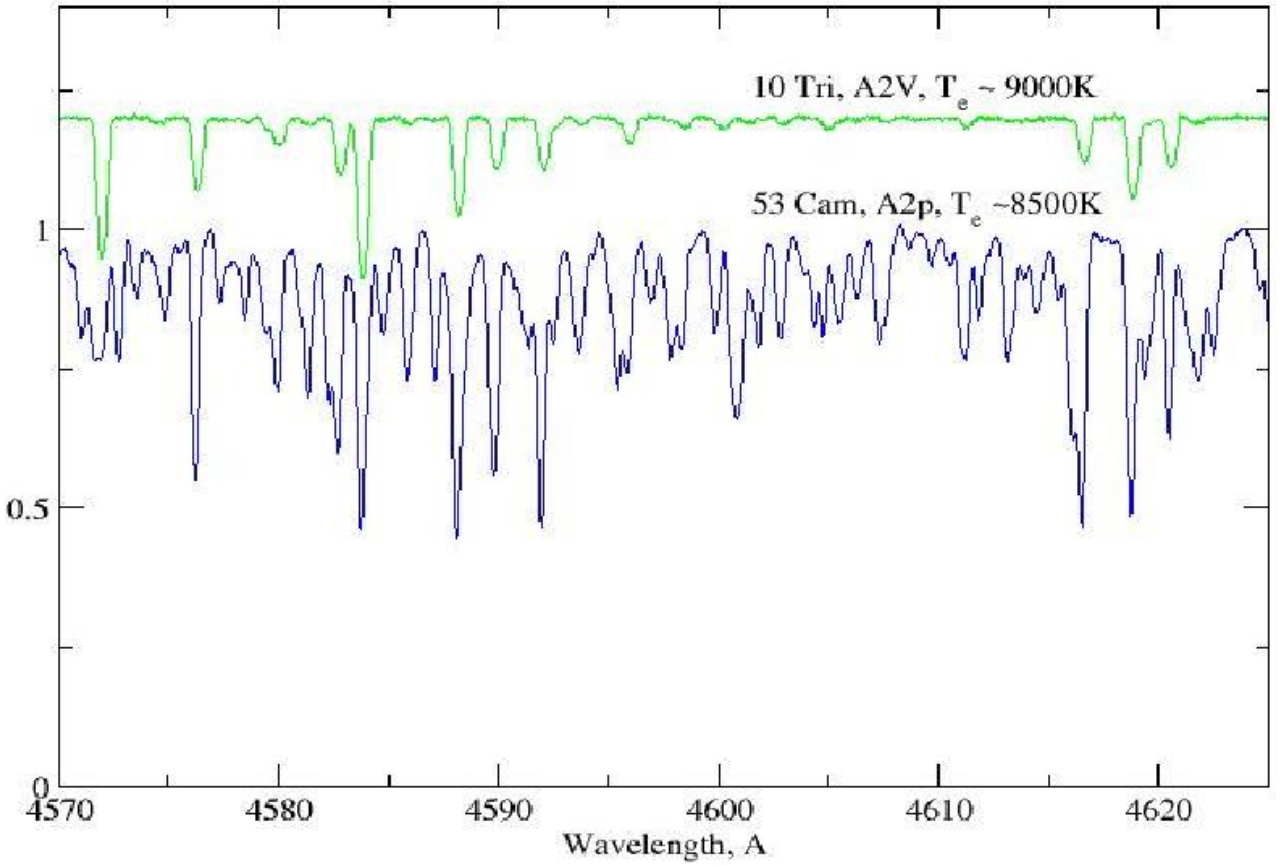
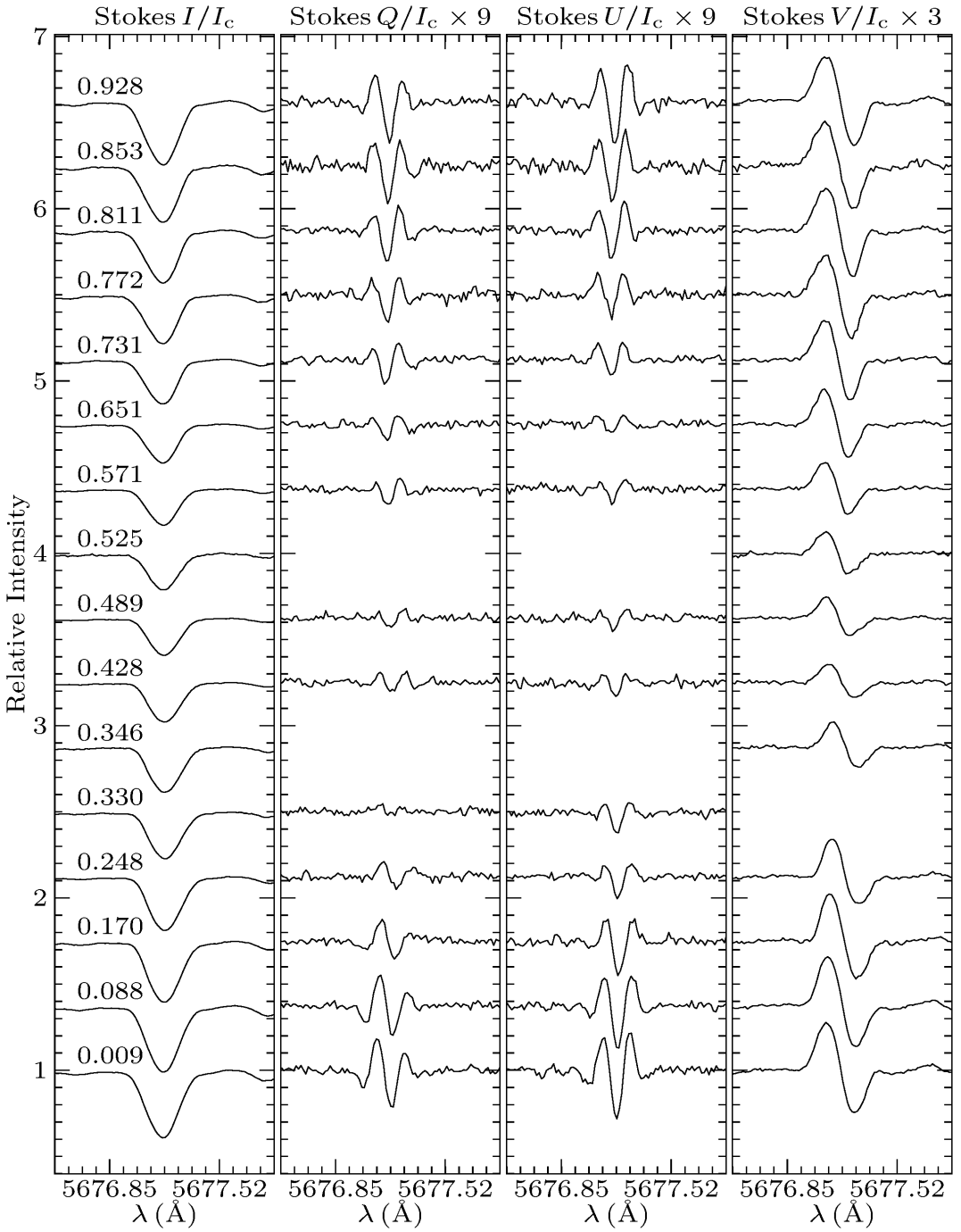
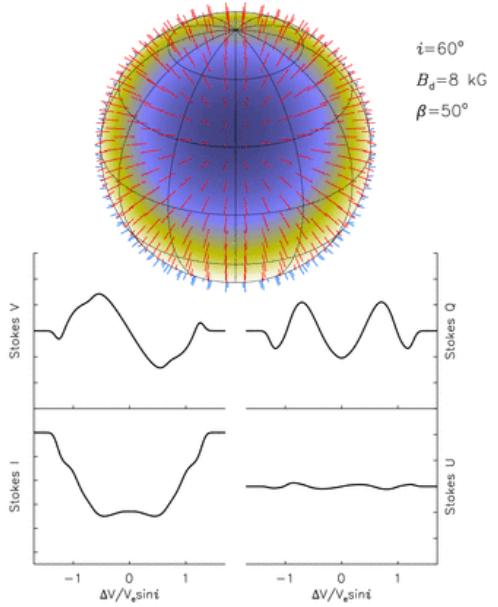


Line profile variability



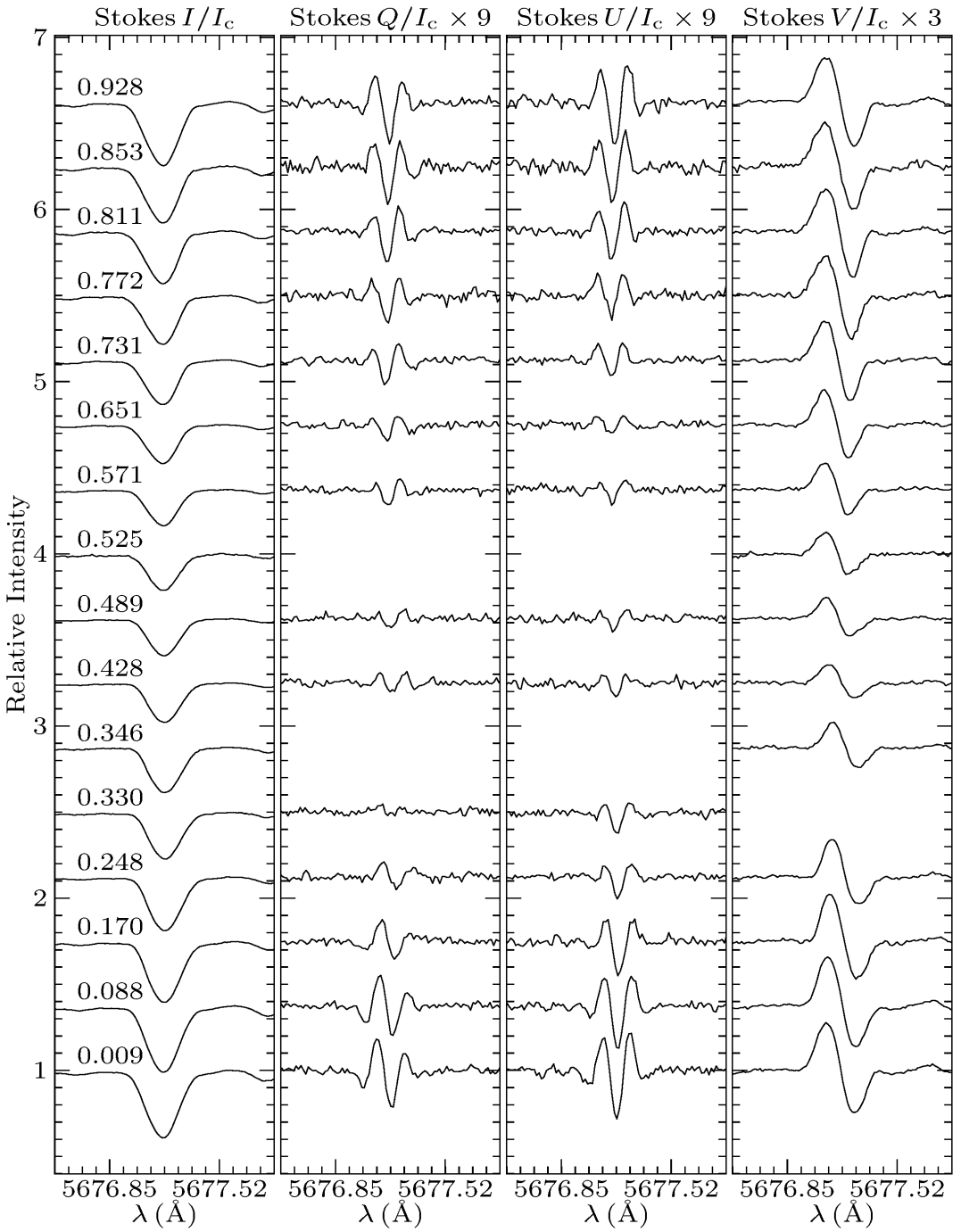
HD 24712 (NdIII 5677.18); Rusomarov et al. (2013)



Intensity and polarization in spectral lines changes due to stellar rotation

- Doppler effect
- Zeeman effect
- geometrical projection

Magnetic (Zeeman) Doppler Imaging



HD 24712 (NdIII 5677.18); Rusomarov et al. (2013)

Given the line profile time series find 2-D maps of abundace distribution and magnetic field at the surface of the star

<u>High maintenance method!</u>

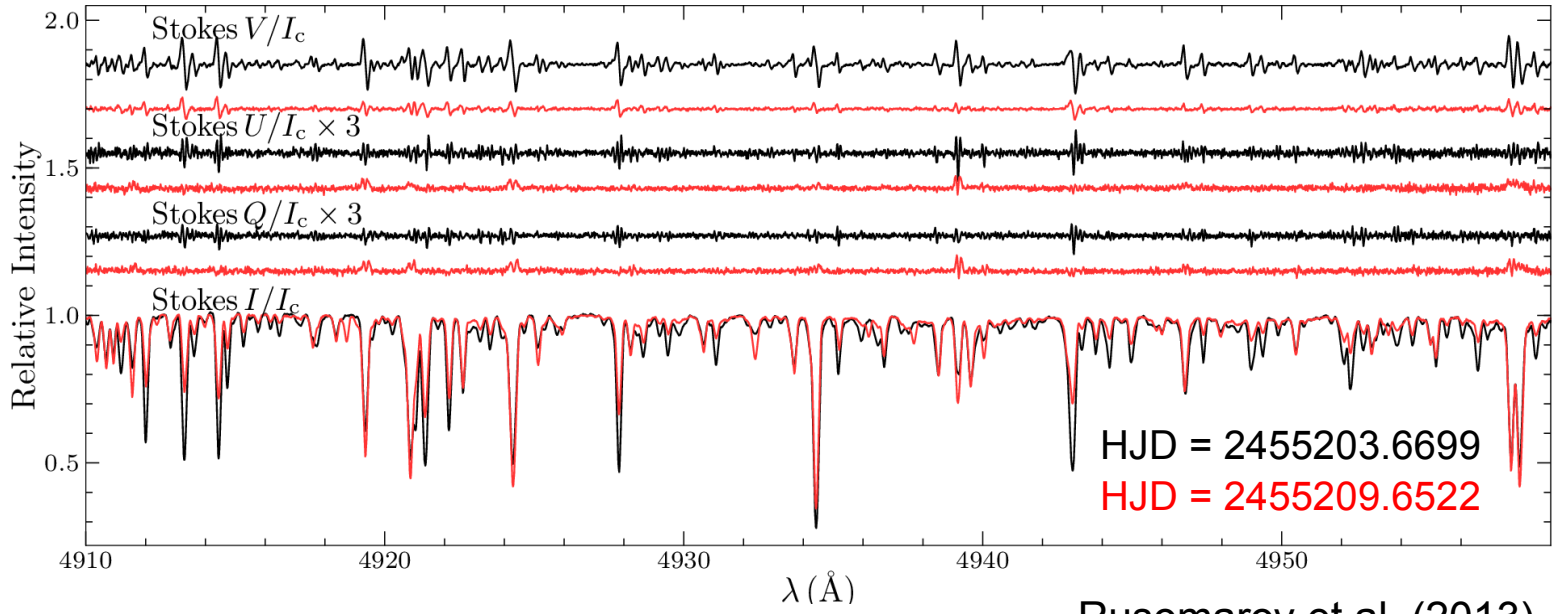
- High spectral resolution
- Spectra with high SNR
- Good phase coverage
- Requires previous knowledge about the object (vsini, inclination)
- Polarimetric measurements in all four Stokes parameters
- Computationally expensive

<u>Advantages:</u>

- **Self-consistent** and **simultaneous** mapping of magnetic field vector and abundance distributions
- Highest resolution method in astronomy

Observations

Prot≈12.458d



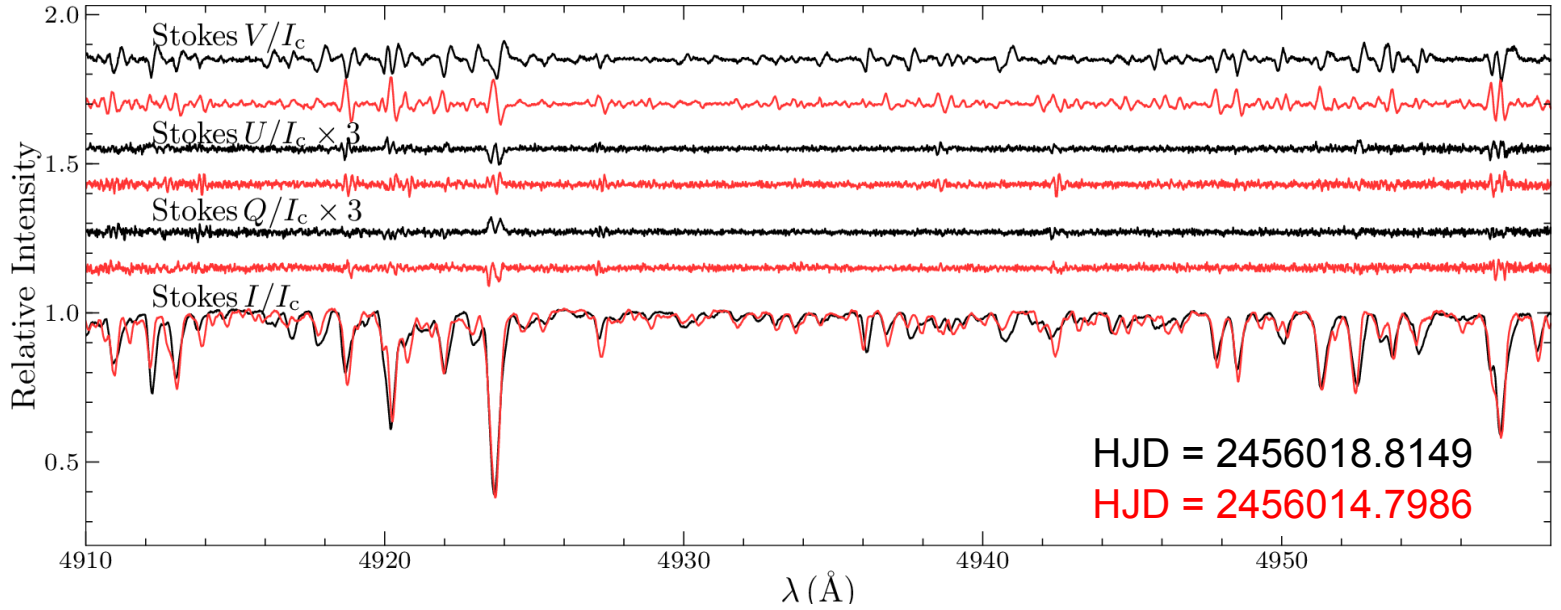
HD24712 (HR1217)

- observed 2010 – 2011
- HARPSpol, ESO 3.6m
- full phase coverage
- S/N 300 – 600
- resolution $\lambda/\Delta\lambda > 10^5$

Prototypical roAp star!

Rusomarov et al. (2013)

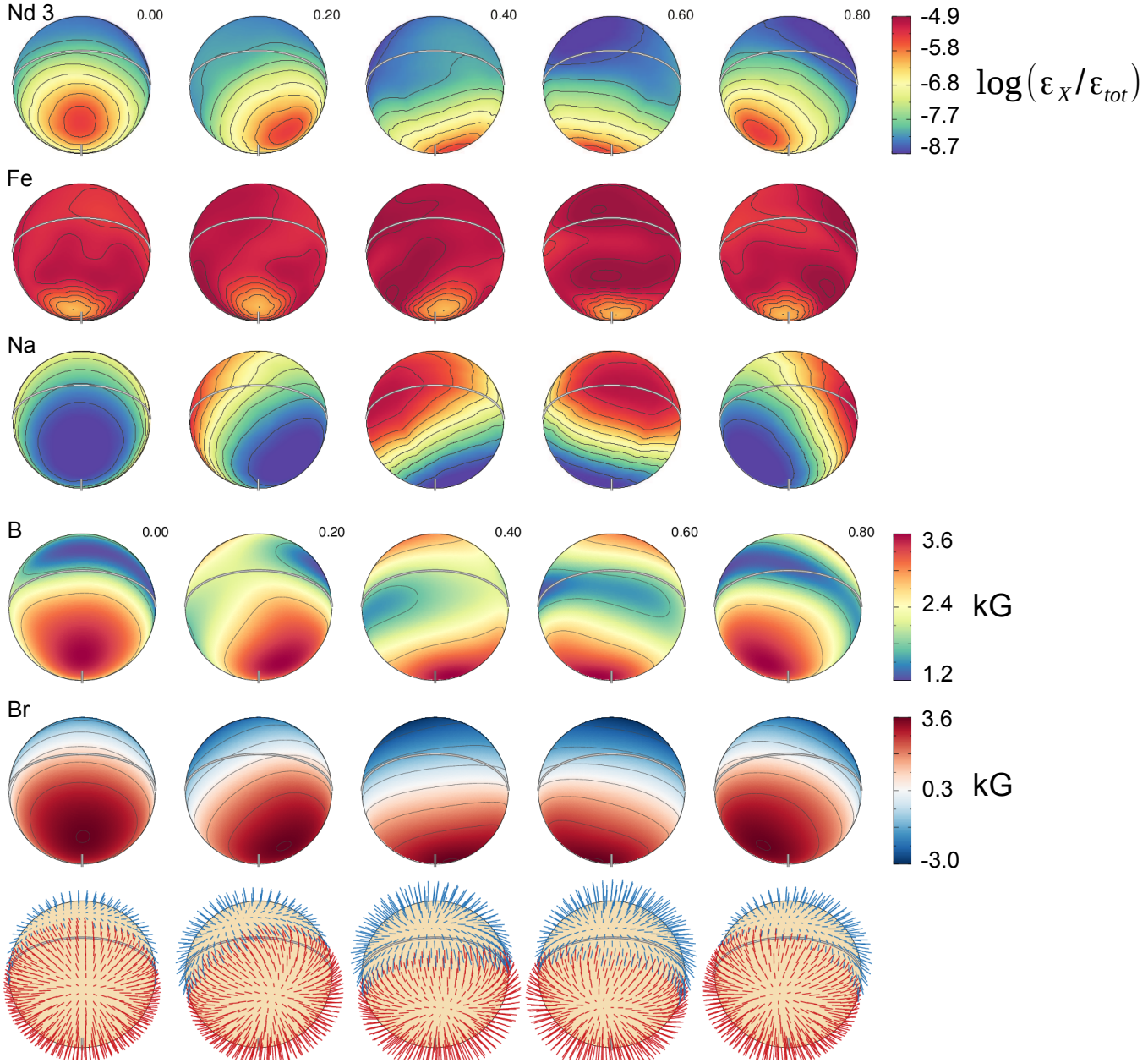
P≈9.296d



HD125248

- observed 2012 – 2013
- HARPSpol, ESO 3.6m
- full phase coverage
- S/N 200 – 300
- resolution $\lambda/\Delta\lambda > 10^5$

MDI study of HD24712



Rusomarov et al. 2014, (in preparation)

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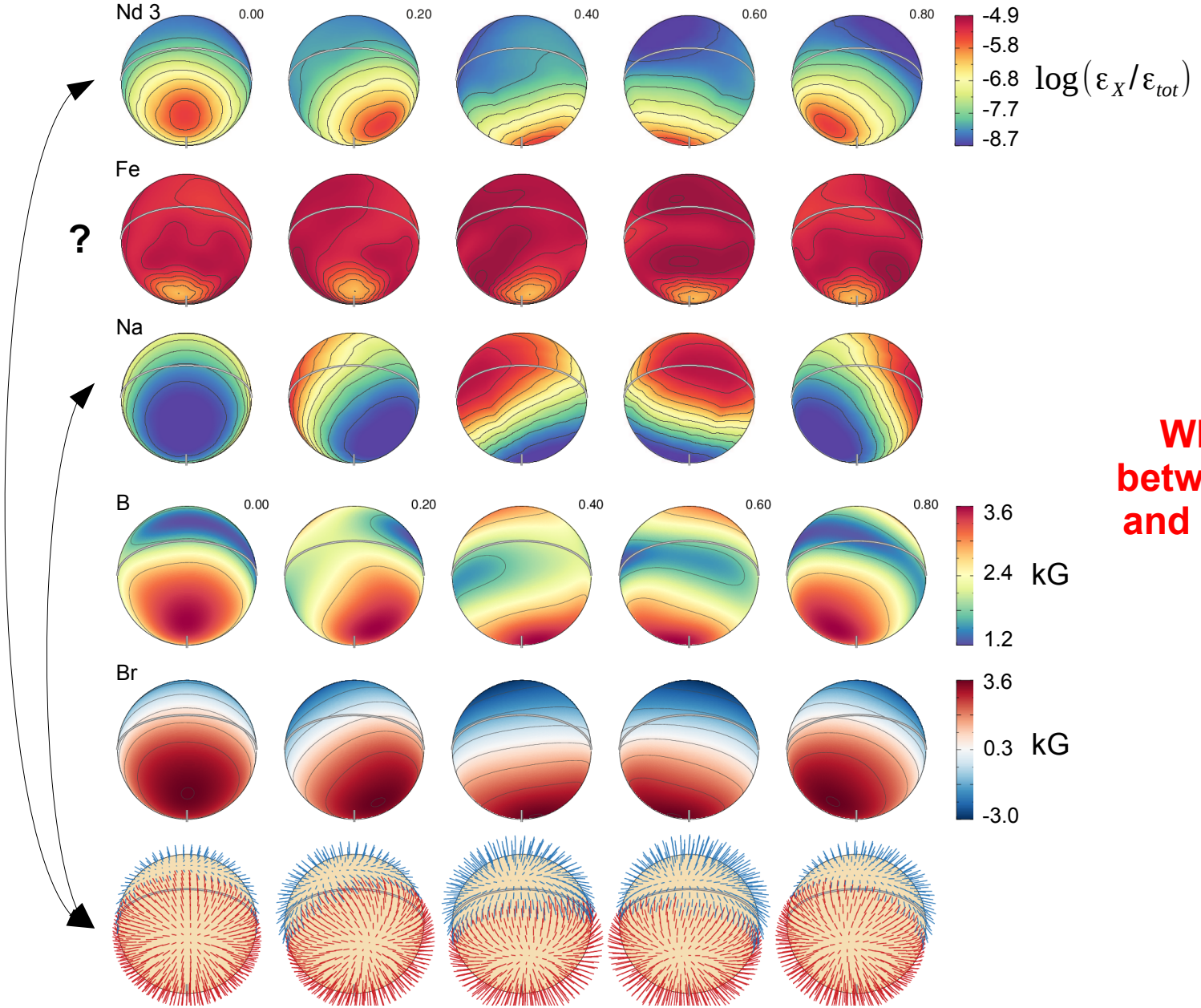


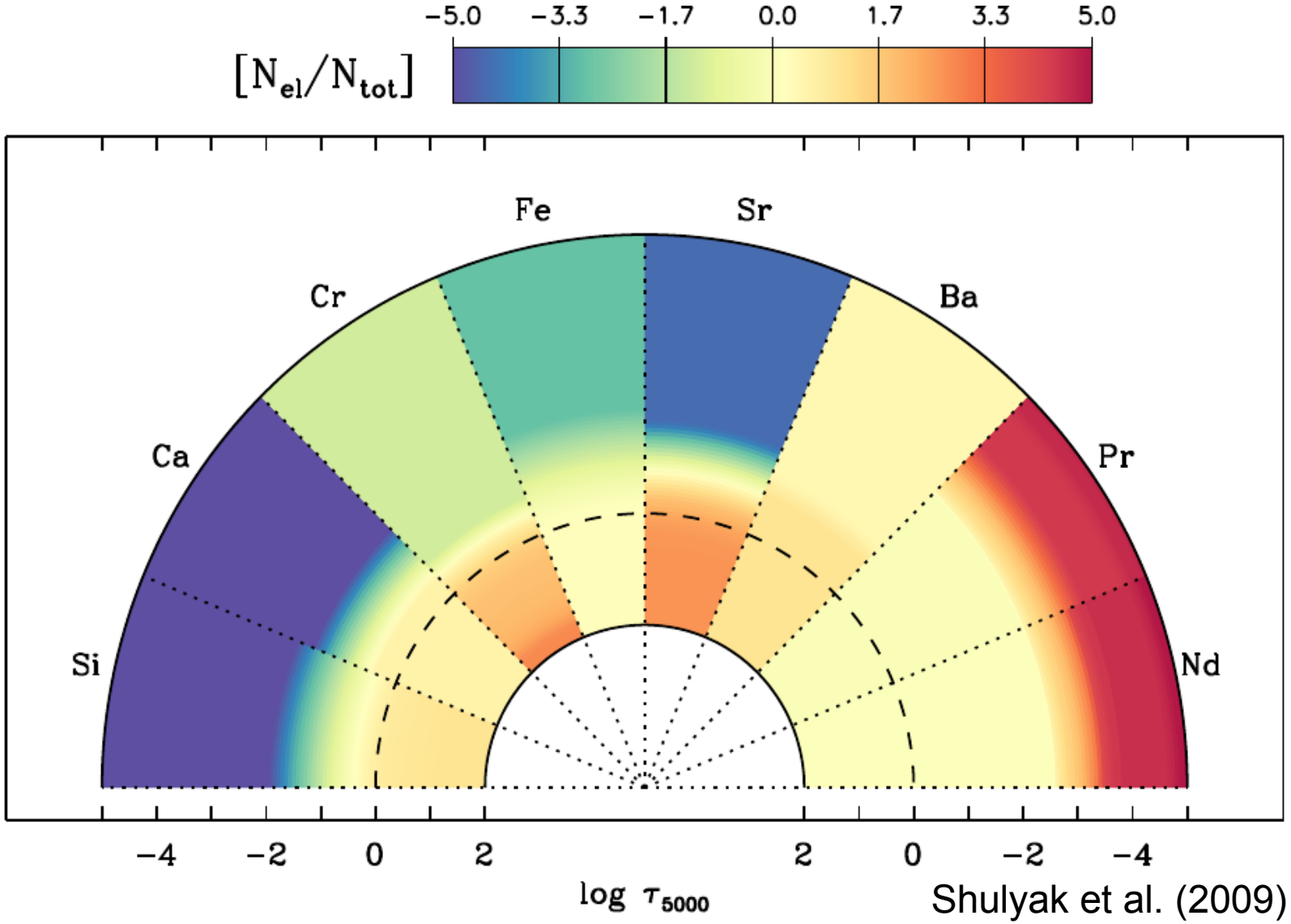
What is the relation between chemical spots and the magnetic field?

Rusomarov et al. 2014, (in preparation)

Stratification of chemical elements

From high resolution spectra we can also study <u>vertical stratification</u> of chemical elements in the atmosphere of the star.

1. From anomalies of line profiles and line strengths.

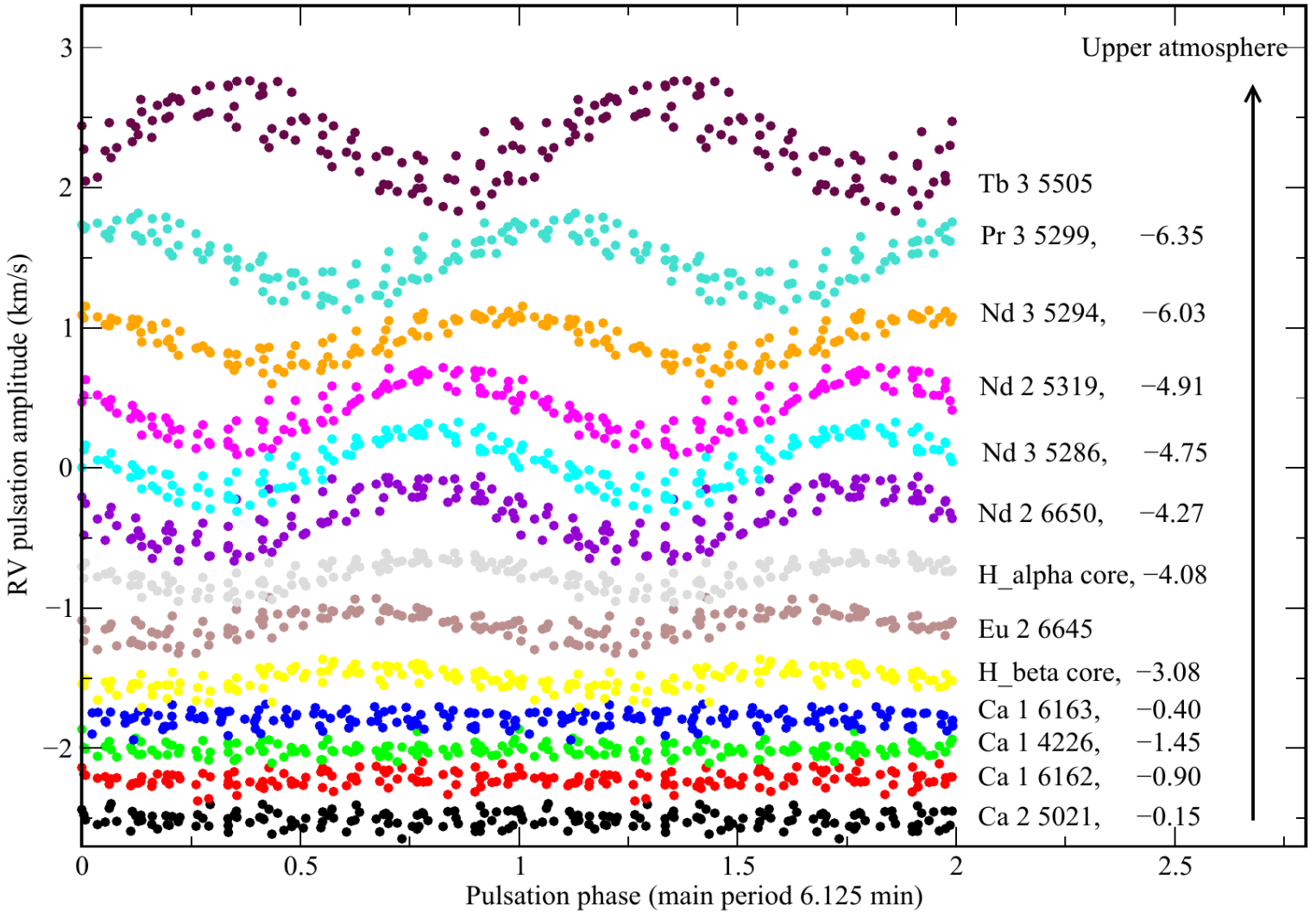


Shulyak et al. (2009)

Stratification of chemical elements

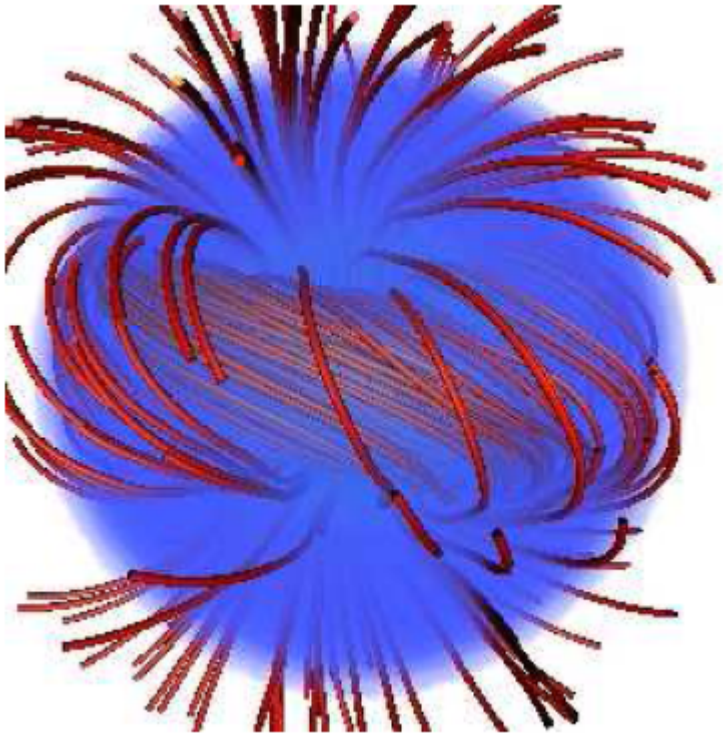
From high resolution spectra we can also study <u>vertical stratification</u> of chemical elements in the atmosphere of the star.

2. From spectroscopic pulsational behavior of roAp stars (HD24712)

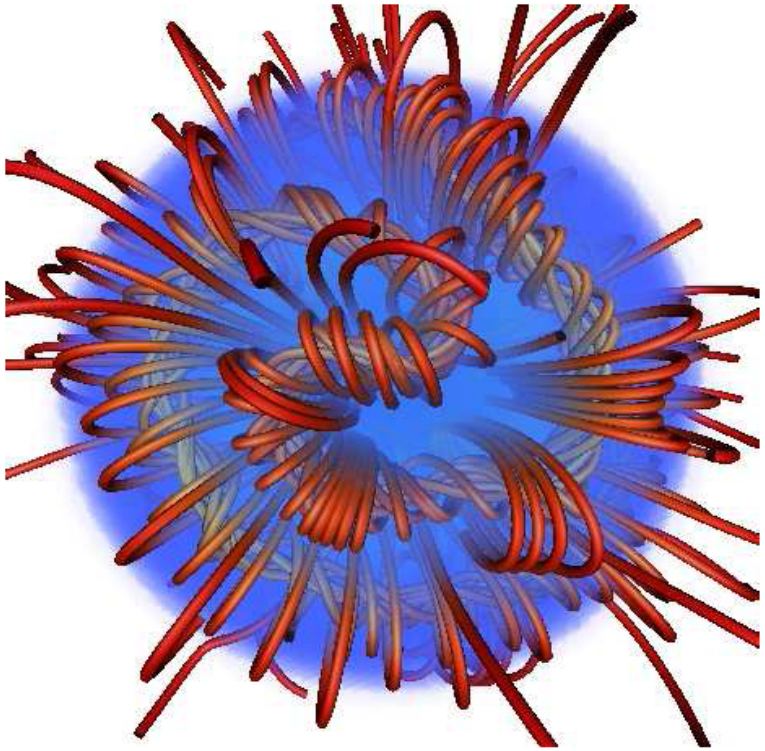


Ryabchikova et al. (2007)

The origin and stability of magnetic fields in Ap/Bp stars



Axisymmetric equilibrium



Non-axisymmetric equilibrium

(Braithwaite 2008 & 2009)

Current problems

1. The origin and evolution of fossil magnetic fields (Braithwaite et al., 2006)

MDI studies of other Ap/Bp stars in four Stokes parameters

Current problems

1. The origin and evolution of fossil magnetic fields (Braithwaite et al., 2006)

↓

MDI studies of other Ap/Bp stars in four Stokes parameters

2. Radiative diffusion in strong magnetic field (Alecian & Stift, 2010)

What is the relation between:
- chemical spots and magnetic field
- between horizontal and vertical structure

↓

Simultaneous study of 3-D magnetic and chemical structures using high quality four Stokes parameters

Future plans

HD 24712

- Analysis of 3D structure of chemical spots and magnetic field
- Submit latest paper
- ...

Other Ap stars

- Obtain detailed maps of the magnetic field and horizontal and vertical abundance structures.

Thank you for attention!