Abundances, radiative acceleration, stratification of elements in stars

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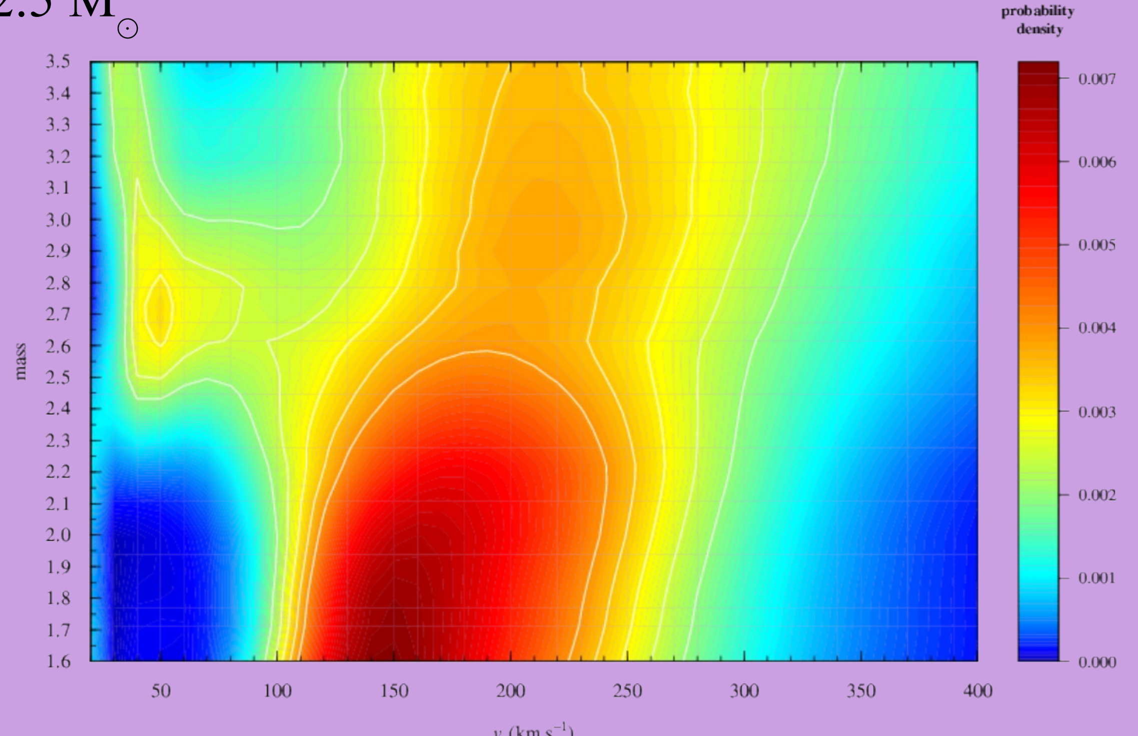
Context:
B8-A1 type stars with low *v* sin *i*

- Distribution of equatorial velocities for intermediate mass stars
  - Known binary or chemically peculiar (CP) stars are discarded from the sample
  - Bimodality around 2.5 $M_\odot$



Zorec & Royer (2012)

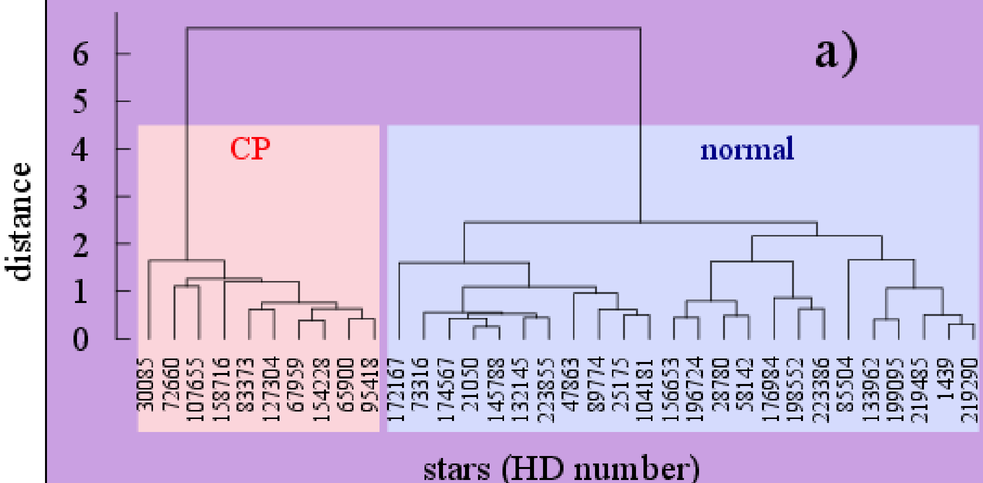
Observational programme – part A
Data

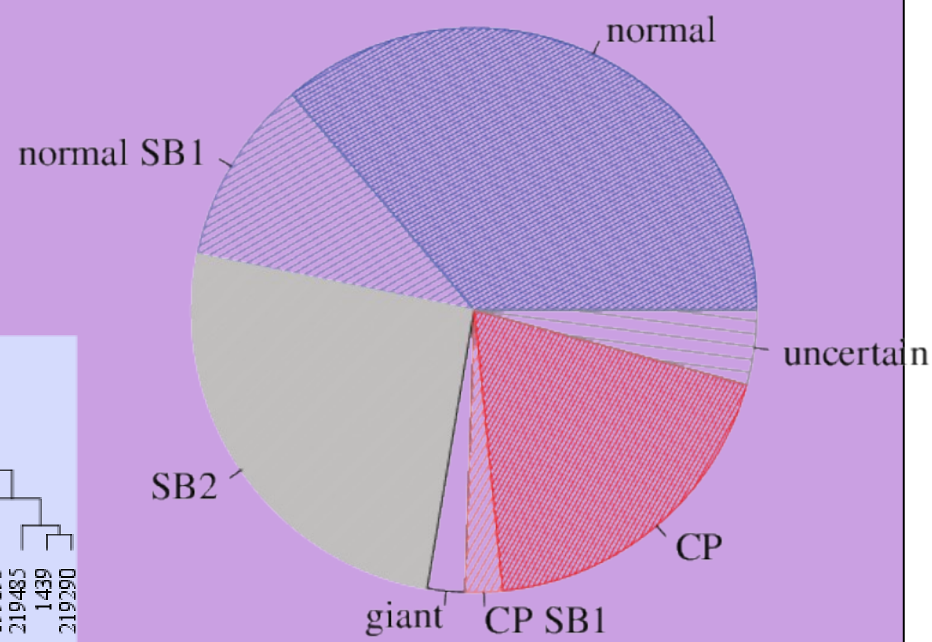
- What composes the low rotational velocity mode around 2.5 $M_\odot$?
  - Undetected binary or CP stars ?
  - Intrinsic slowly rotating normal stars or pole-on fast rotators ?

- Collect high quality spectroscopic data for 47 A0-A1 stars : vsini<75 km/s
  - ELODIE and SOPHIE observations
    - Detect spectroscopic binary stars (SB2 and SB1)
    - Derive chemical abundances and classify normal vs CP stars

Observational programme – part A
Results (1)

- Abundance determinations for 14 chemical species (C, O, Mg, Si, Ca, Sc, Ti, Cr, Fe, Ni, Sr, Y, Zr, Ba)
- Classification

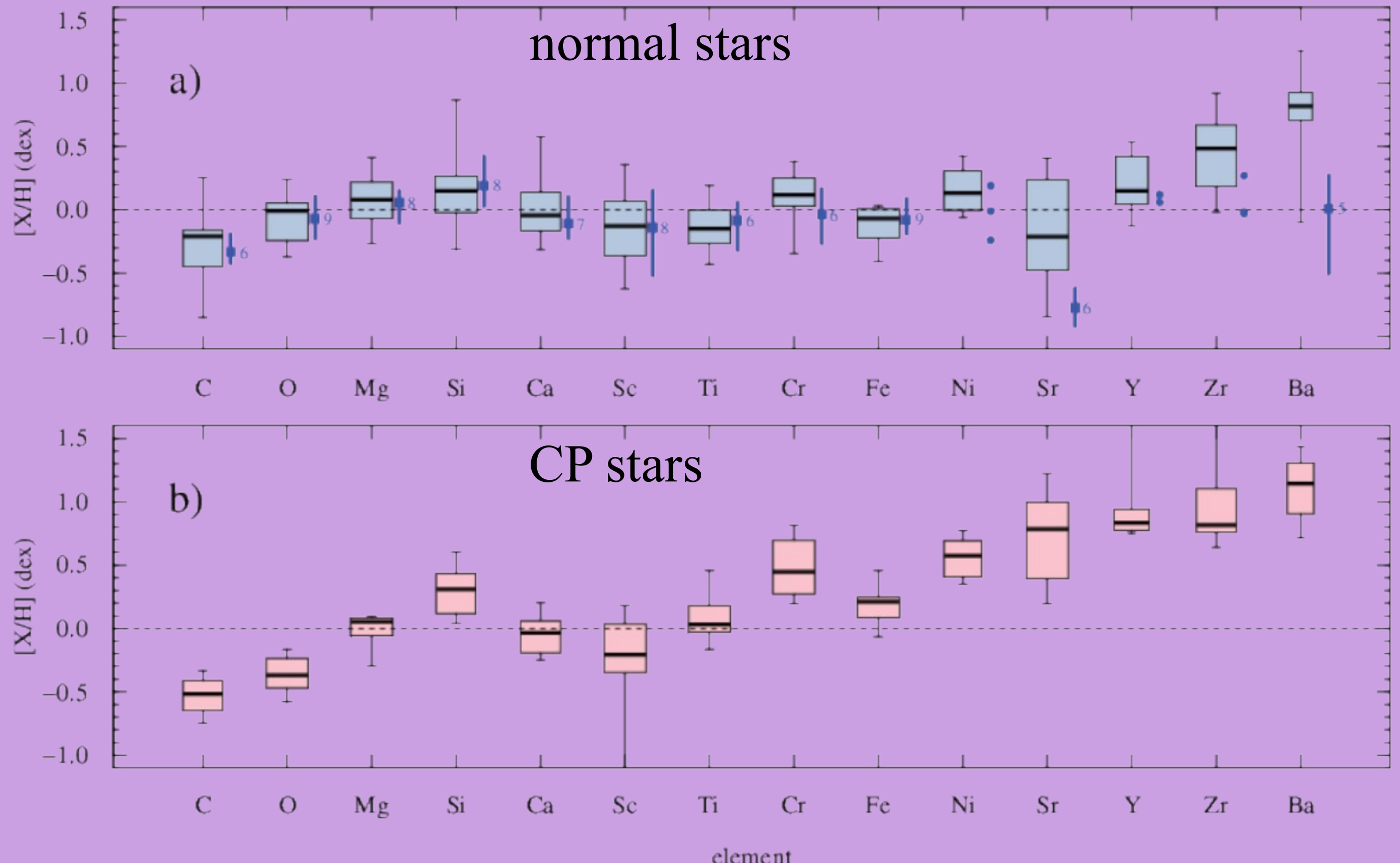




Royer et al. (2014)

Observational programme – part A
Results (2)

- Abundance pattern

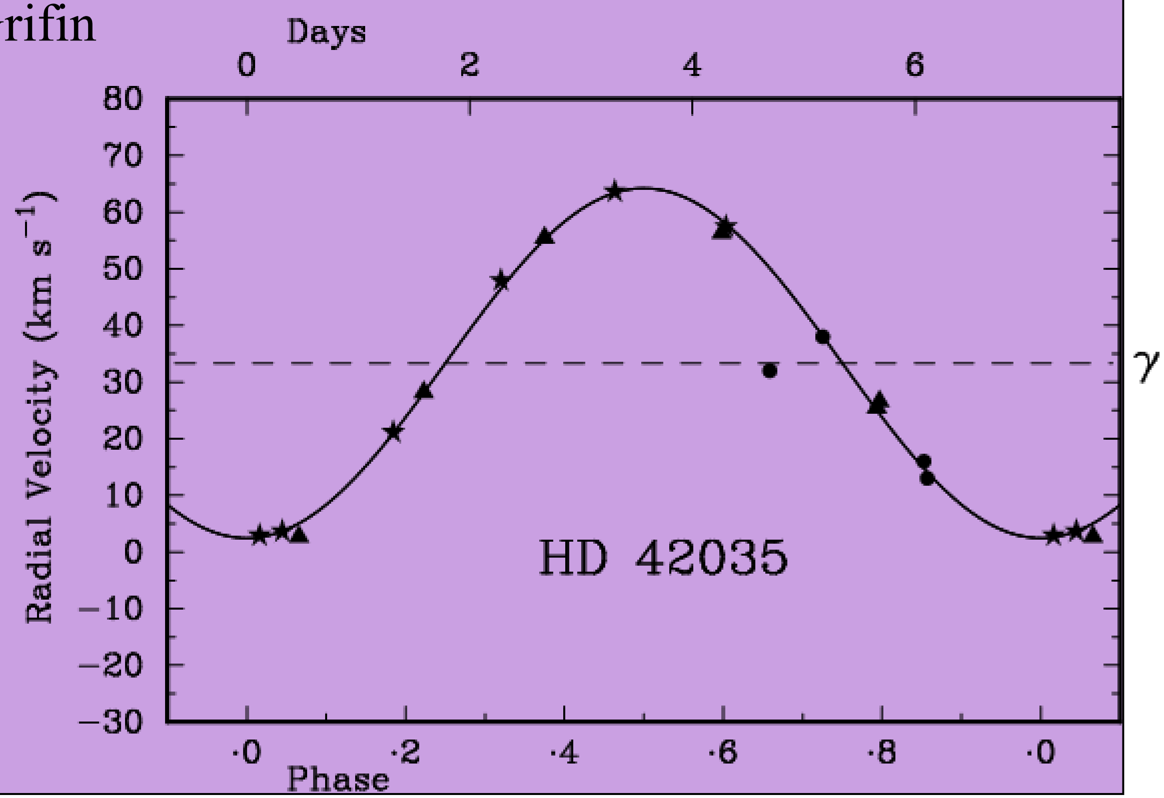


Observational programme part B

- In parallel, data are collected for a B8-B9-type stars sample
  - Same selection : a priori normal targets, vsini<75 km/s
  - SOPHIE spectrograph, started in 2014, on going
    - 40 targets observed, 30 have normal abundances ...

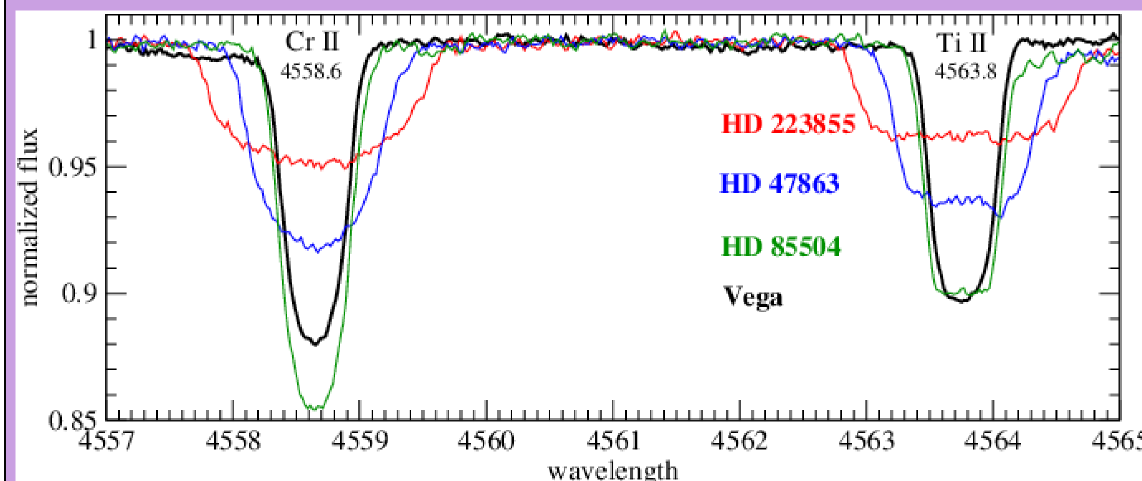
Binary stars

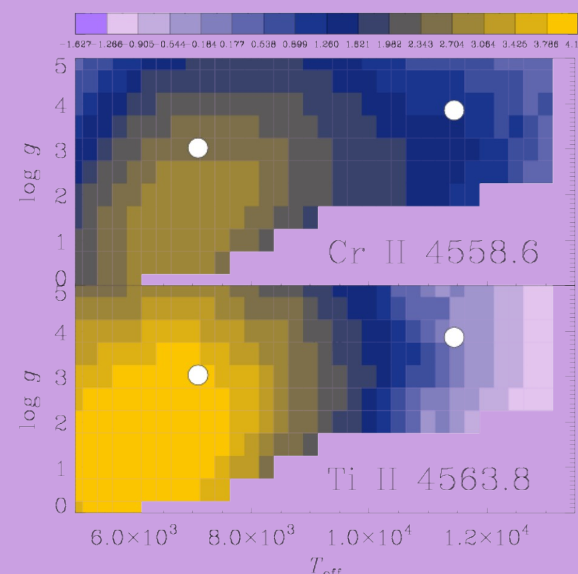
- Focus on HD 42035
- SB2 with a sharp component component (vsini = 3.7 km/s) and a much shallower one
  - Collaboration with E. Grifin
  - RV follow-up



Normal single stars
Rotation rate

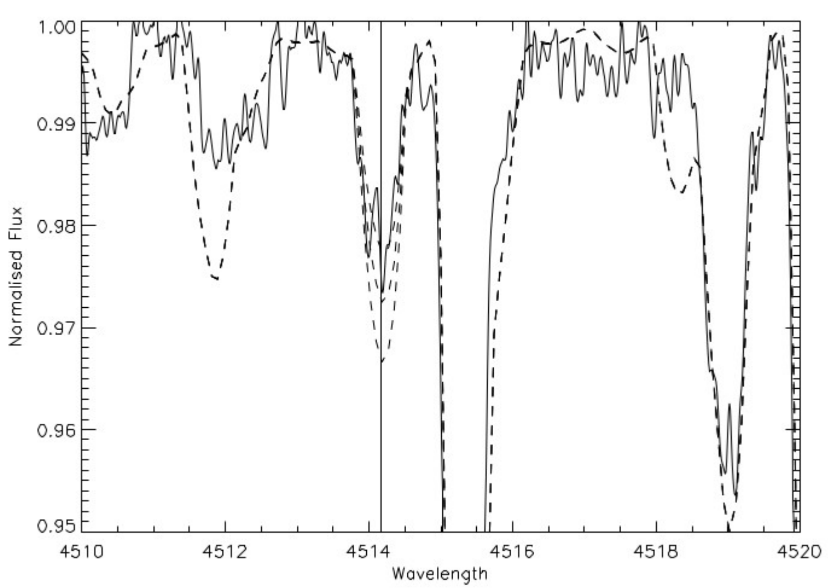
- Look for signatures of <u>gravity darkening</u> to disentangle **intrinsic slow rotation** from **inclination effect**
- Collaboration with Y. Frémat





Chemically peculiar stars

- Detection of new CP stars :
  - 4 new HgMn stars: HD 18104, HD 30085, HD 32867, and HD 53588 (*Monier et al. 2015*)
  - Focus on HD 30085 (*Monier et al. In prep.*)



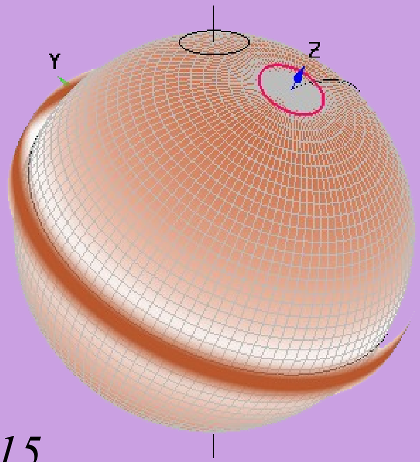
- He, Mg, Sc, Ni underabundant
- Ti, Cr, Mn, Y, Zr, Ba, Pt, Hg overabundant (Pt II 4514.17 Å line)
- No detected variation of line profiles (for now)

Distribution des abondances dans les atmosphères magnétiques – *G. Alecian & M. Stift*

Modélisation théorique et numérique incluant la diffusion microscopique

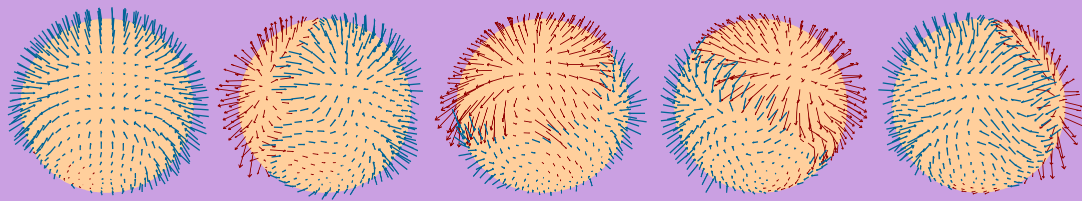
- Les travaux commencés l'an dernier on été poursuivis.
- Sur le thème soutenu par l'AFE, en 2015: 1 article publié, 1 soumis et 1 en préparation

- Pour 2016, il est prévu de passer de la 2D vers la 3D avec un champ non-dipolaire ou un dipôle décentré afin de permettre une modélisation plus réaliste. Une étape future serait la modélisation pour un champ quelconque.

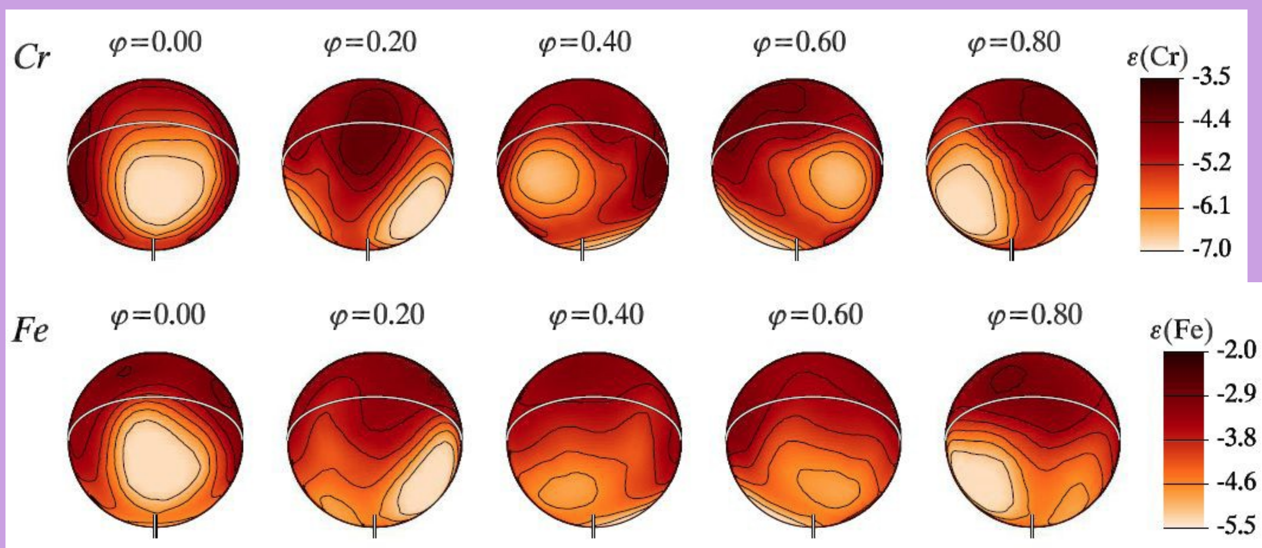


Alecian & Stift 2010, 2012, 2015
Modèles numériques dipolaires (ici le Fe)

Rappel: une atmosphère magnétique ApBp dans un cas observé: α^2 CVn



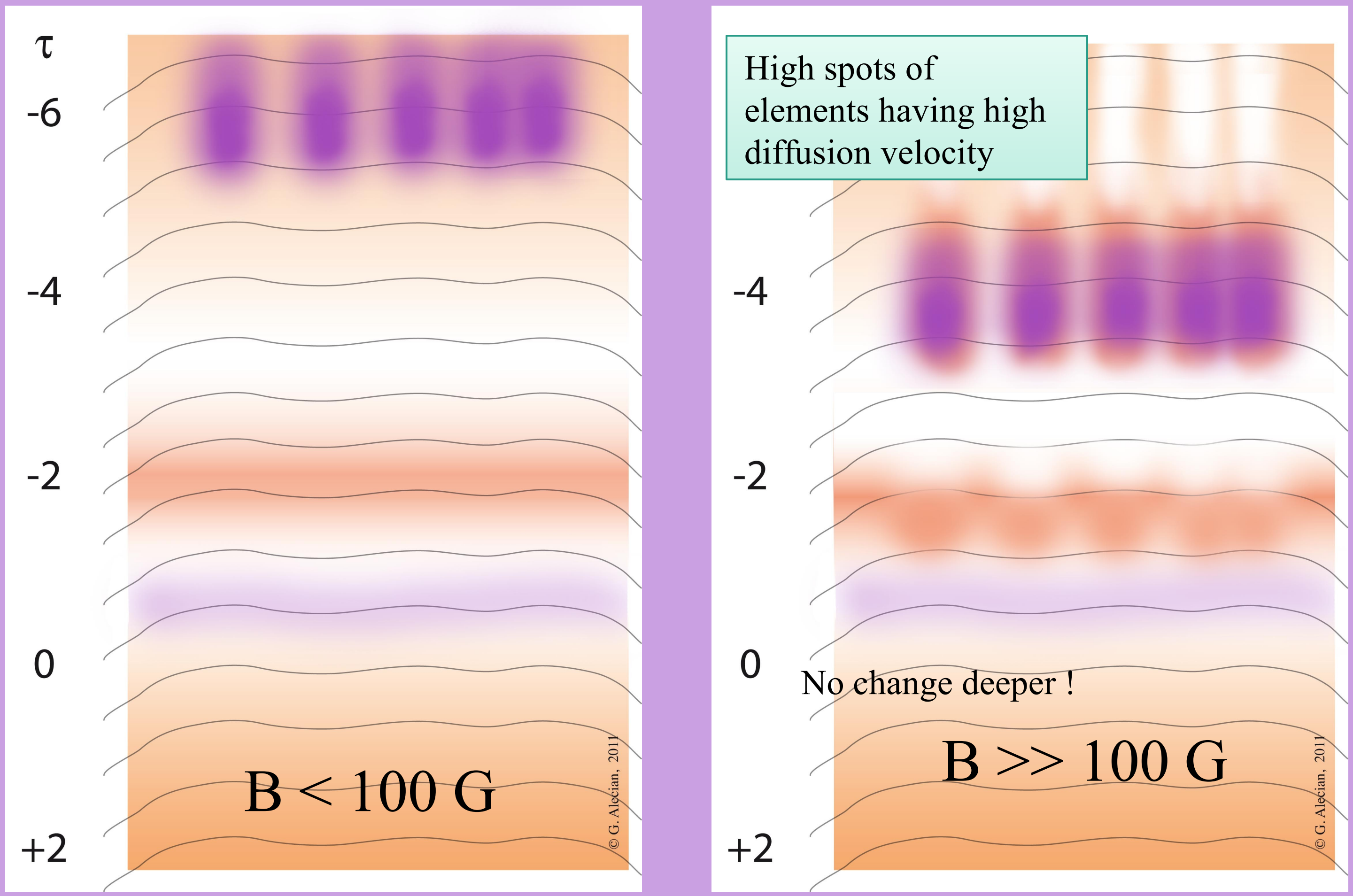
B



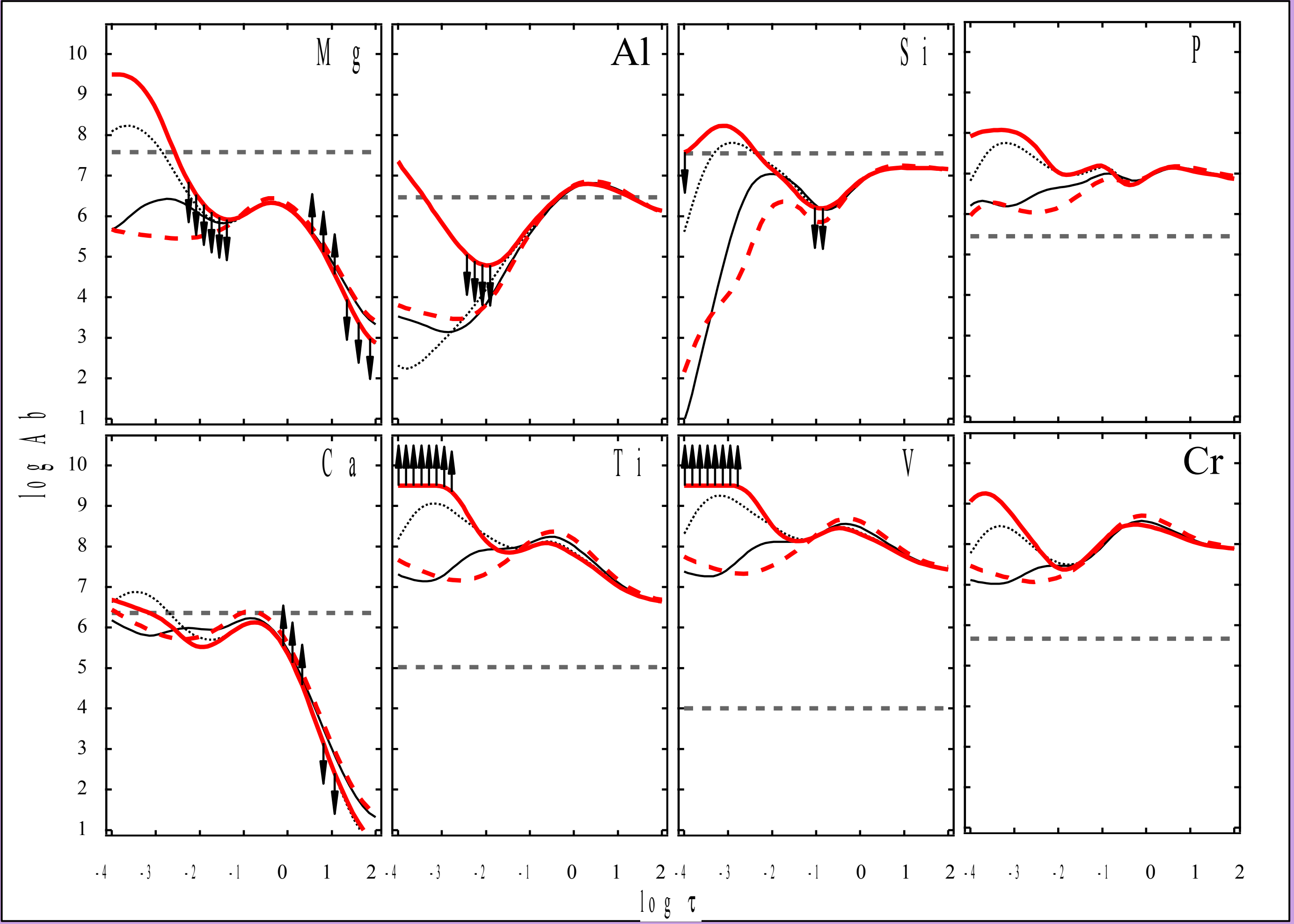
concentration

α^2 CVn, Silvester et al. 2014

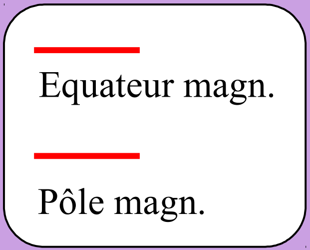
Rappel: le modèle théorique



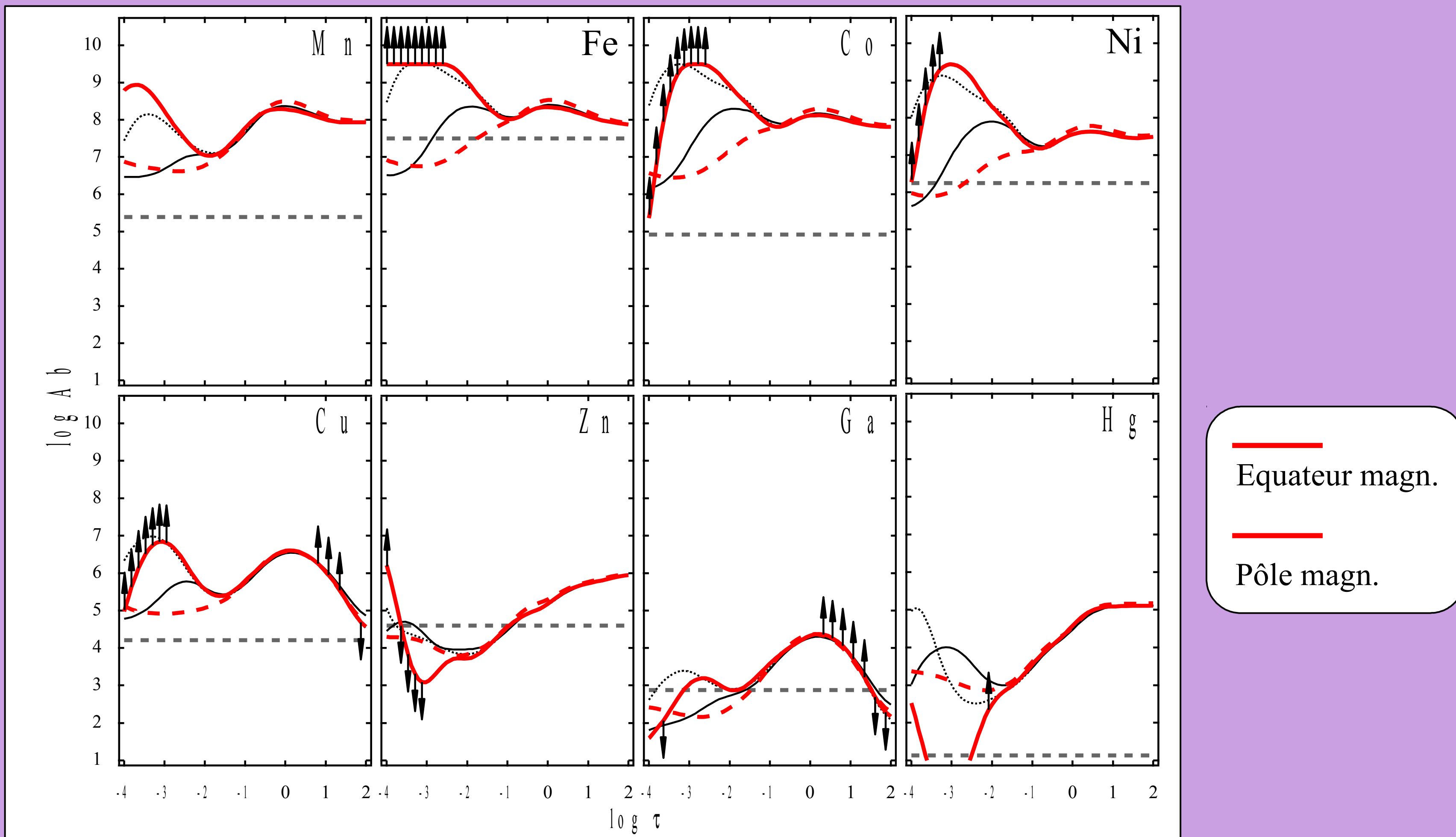
Stratifications d’équilibre théoriques 1D
(Alecian 2015, MNRAS, 454, 3143)



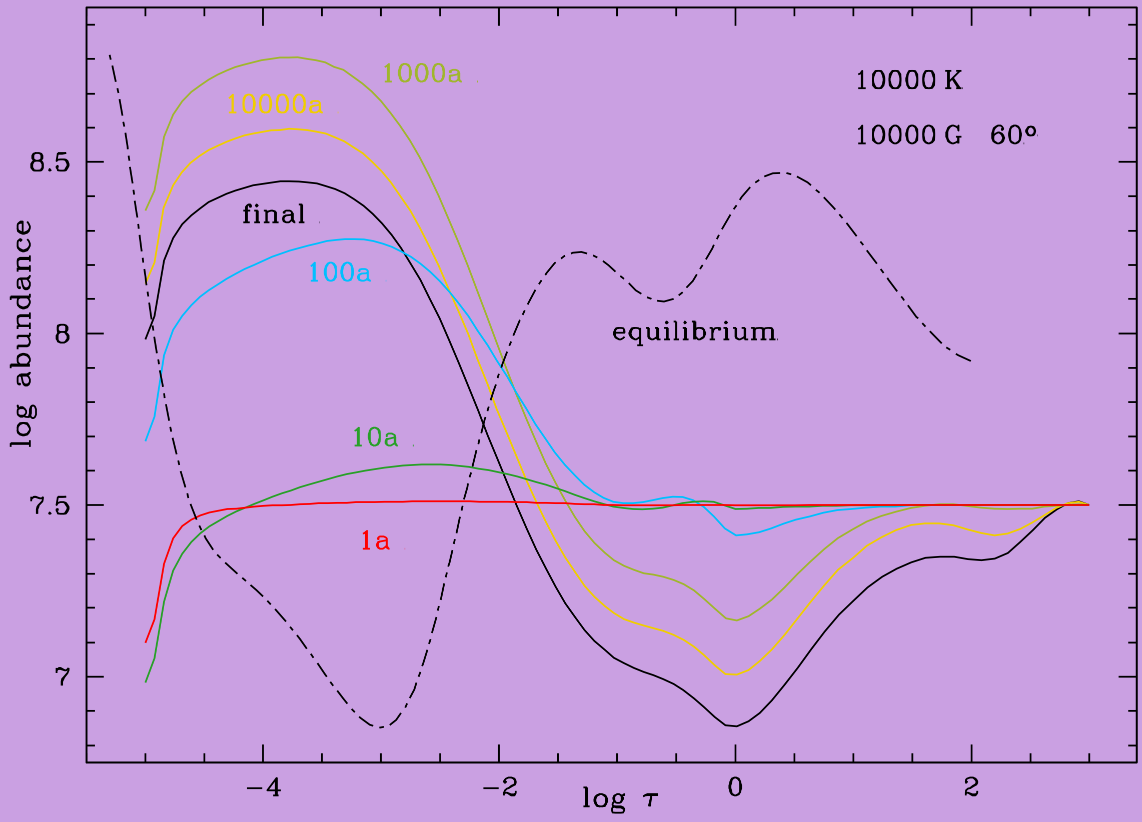
20 kG au pôle magnétique



Stratifications d'équilibre 1D théorique
(Alecian 2015, MNRAS, 454, 3143) - Suite

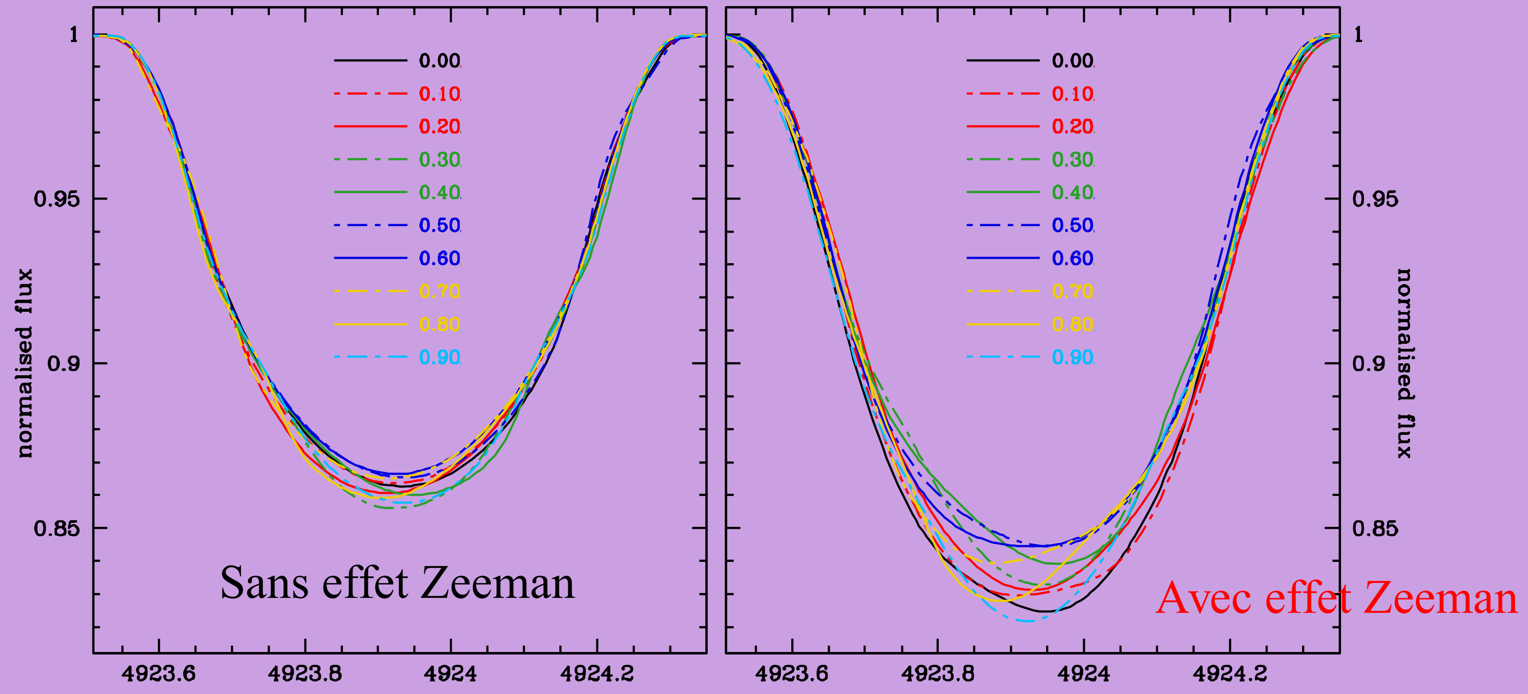


Time-dependent atomic diffusion in magnetic ApBp stars
(Stift & Alecian, 2015, MNRAS soumis)



Comparaison avec la solution d'équilibre

Time-dependent atomic diffusion in magnetic ApBp stars (Stift & Alecian, 2015, MNRAS soumis) - SUITE



Variation du profile d'une raie (Fe II) au cours de la rotation, dans un modèle stratifié pour un dipôle centré. On voit à droite l'intensification Zeeman due à la rotation d'un anneau équatorial.

Tests of inversion methods *(Stift & Alecian)*
(En cours)

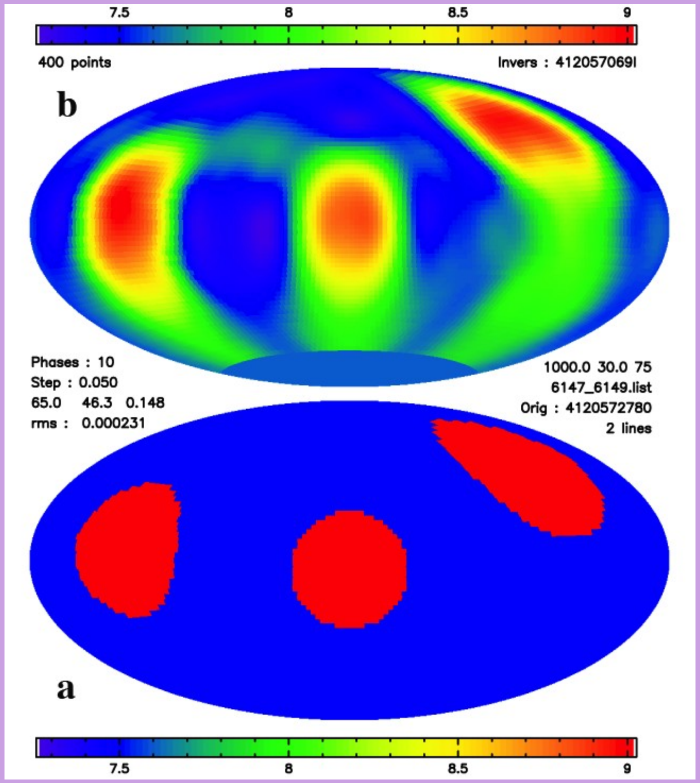
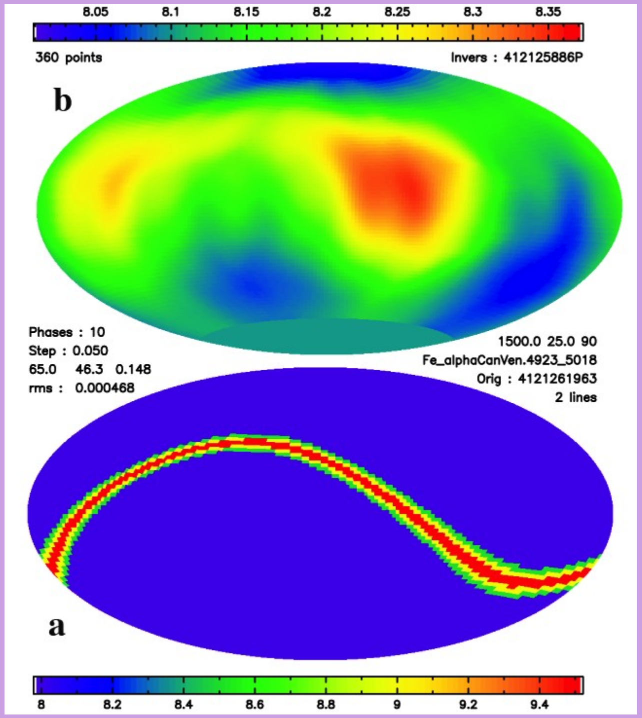


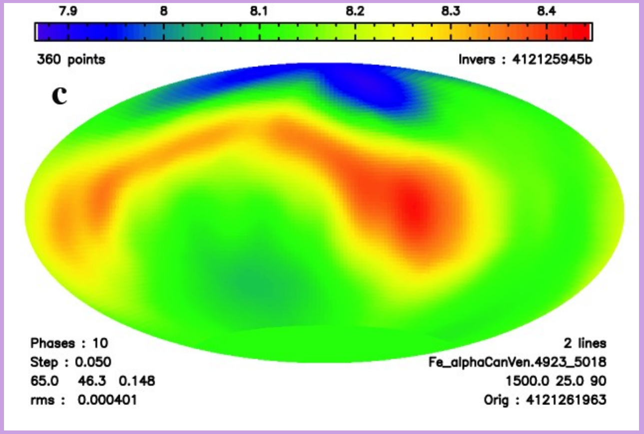
Figure 4. Equal-area Hammer projection of a 3-spot ZDM test case. The bottom part **(a)** of the plot shows the adopted spot distribution and contrast, the upper part **(b)** the result of the ZDM inversion. The spectral lines used are the two Fe lines at $\lambda\,6147.74$ and $\lambda\,6149.26$ at 10 equidistant rotational phases; the spectral resolution is 50 mÅ, giving an overall 400 "observational" points to be used in the inversion. The inclination i of the rotational axis is $65\,^\circ$, the magnetic field originating from a tilted eccentric dipole is characterised by an obliquity of $46.3\,^\circ$ and by a displacement from the centre of 0.148 (in units of radius). The rotational velocity is $30\,\mathrm{km\,s^{-1}}$. All stellar and magnetic field parameters are assumed to be exactly known for ZDM. The residual rms error of the fit to the line profiles points is $2.3\,10^{-4}$. Note: Hammer projections show the whole stellar surface from $-90\,^\circ$ to $+90\,^\circ$; the part invisible to the observer is clearly marked in the upper panel.

Cas simple (2 raies du Fe)

Tests of inversion methods *(Stift & Alecian)*



Inversion avec *Stokes I* seul



Inversion avec les 4 vecteurs de *Stokes*