Magnetism in the Herbig Ae/Be stars

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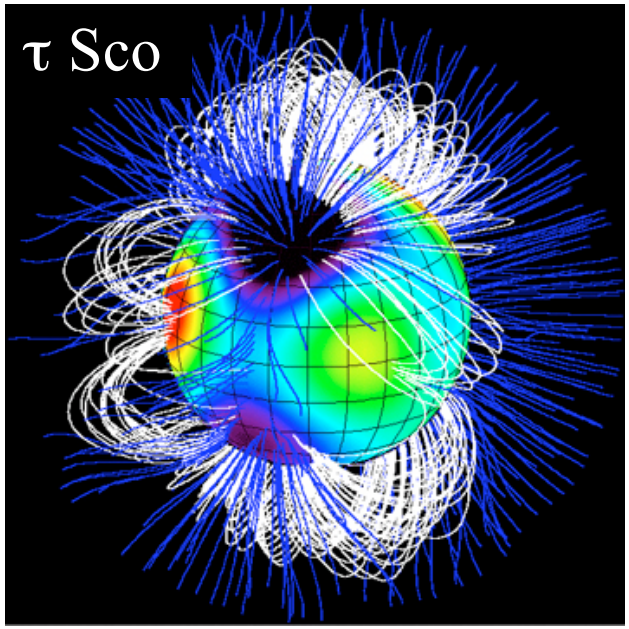
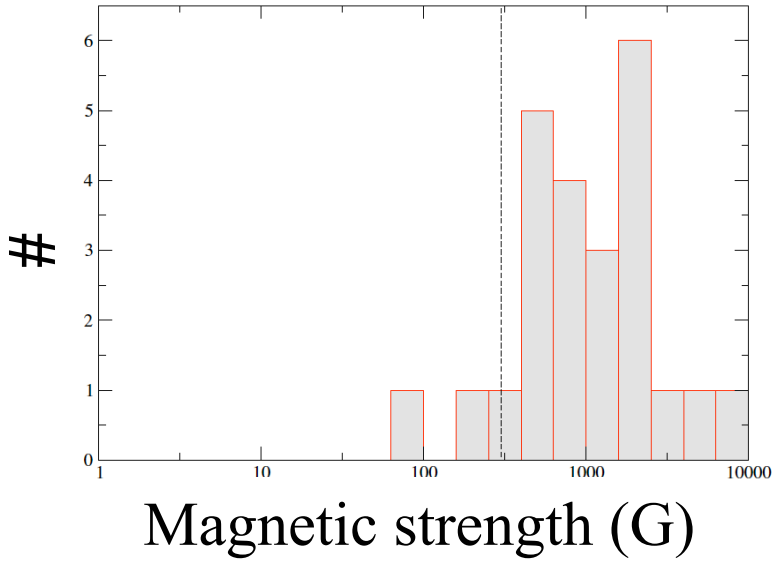
The chemically peculiar stars

- Ap/Bp : ~5% of A/B stars
- Abundances anomalies compared to normal A/B stars
- **Ap/Bp: Magnetic stars** : 300G to 30kG, large scale organised magnetic field : mostly dipole+quadrupole, stable over thens of years



Donati et al. (2006)

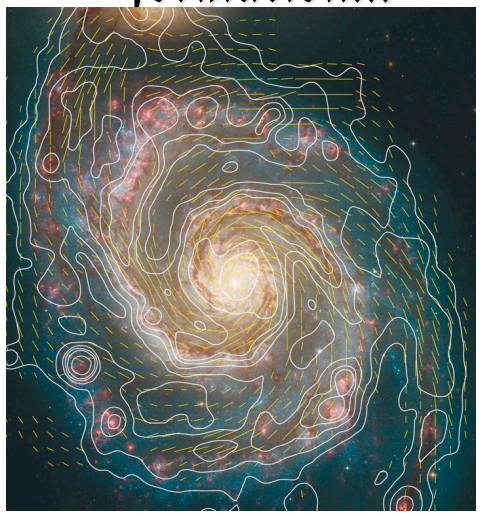


Aurière et al. (2007)

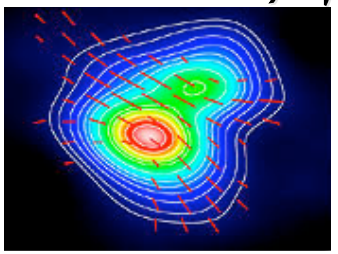
Pb: Origin of the Ap/Pb stars magnetic fields

- **The fossil field theory**

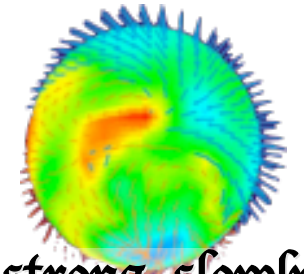
Galactic magnetic flux is swept up during star formation...



... concentrated in the protostar...



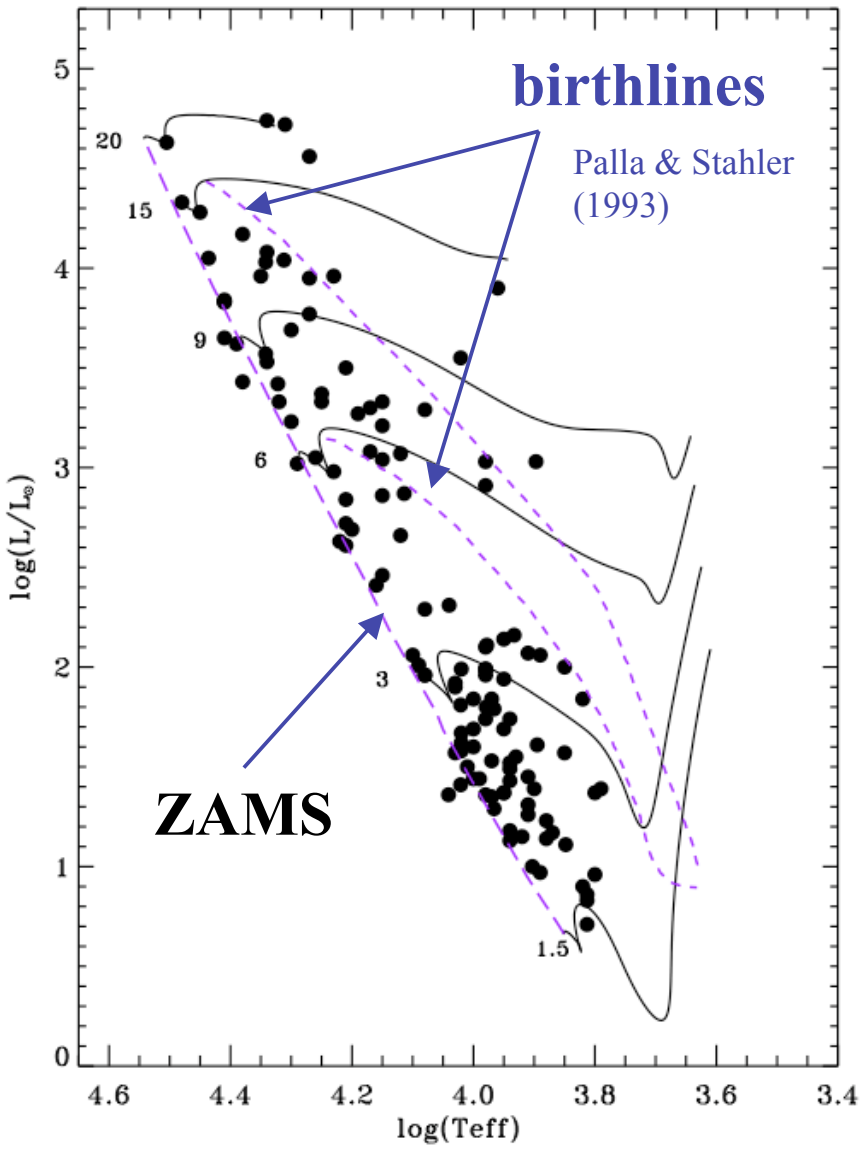
PMS ?



... producing a strong, slowly decaying stellar magnetic field...

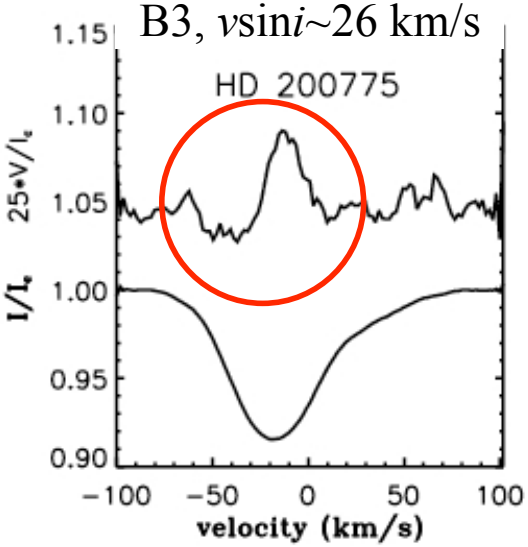
The Herbig Ae/Be stars

- Definition (Herbig 1960):
  - A and B stars with emission lines
  - IR excess
  - Association with nebulae
- Characteristics associated with magnetic activity:
  - resonance lines (N V, O VI), X-ray emission: → hot chromospheres or coronae (e.g. Bouret et al. 1997)
  - magnetospheric accretion (e.g. Mannings & Sargent 1997)
  - rotational modulation of resonance lines: → wind structured by magnetic field (e.g. Catala et al. 1989, 1999)
- Spectropolarimetric observations:
  - HAeBes in the Galactic field and in young clusters
  - ESPaDOnS (CFHT), Narval (TBL)

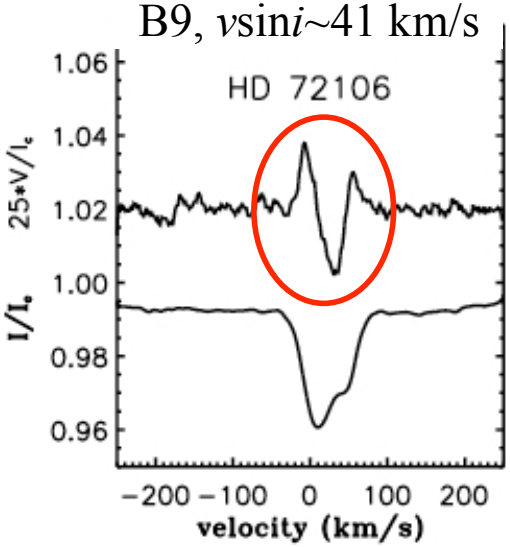


Discovery of magnetic fields

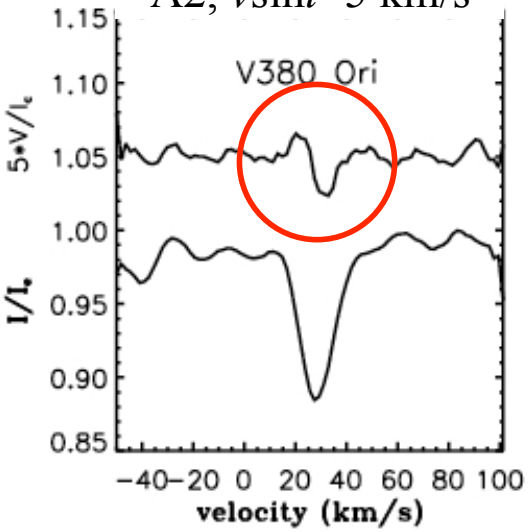
B3, *v*sin*i*~26 km/s



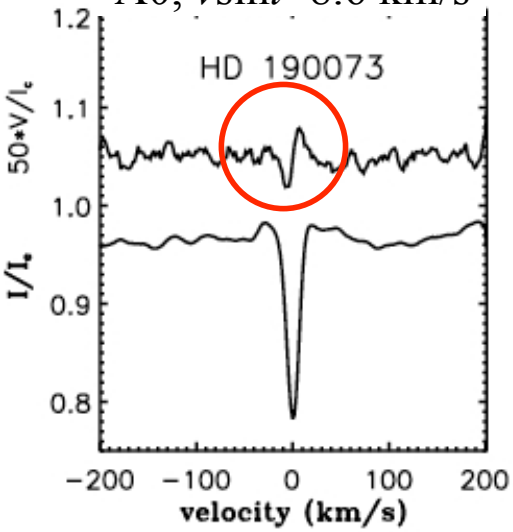
B9, *v*sin*i*~41 km/s



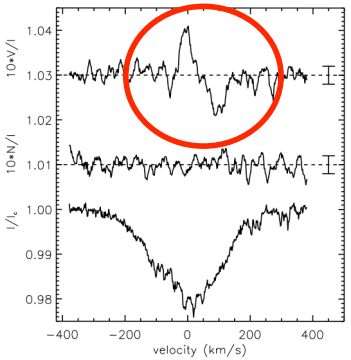
A2, *v*sin*i*~5 km/s



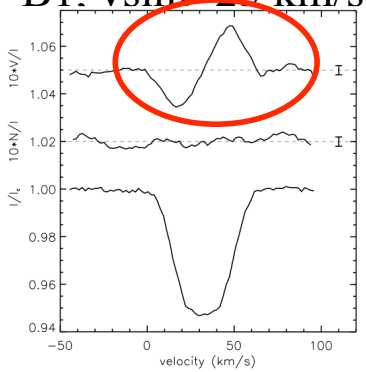
A0, *v*sin*i*~8.6 km/s



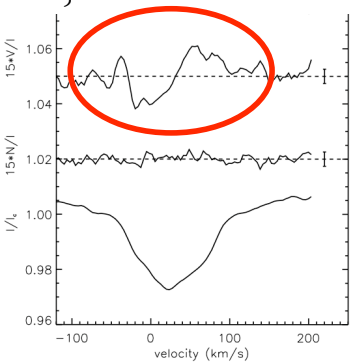
NGC 6611 601
B1.5, vsini~180 km/s



NGC 2244 201
B1, vsini~25 km/s



NGC 2264 83
B3, vsini~65 km/s



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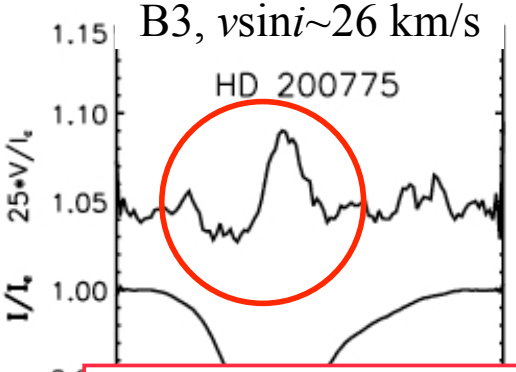

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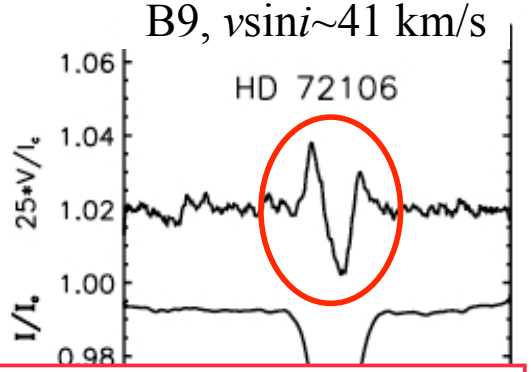

128 observed, 7 magnetic

→ ~5% magnetic Herbig Ae/Be stars

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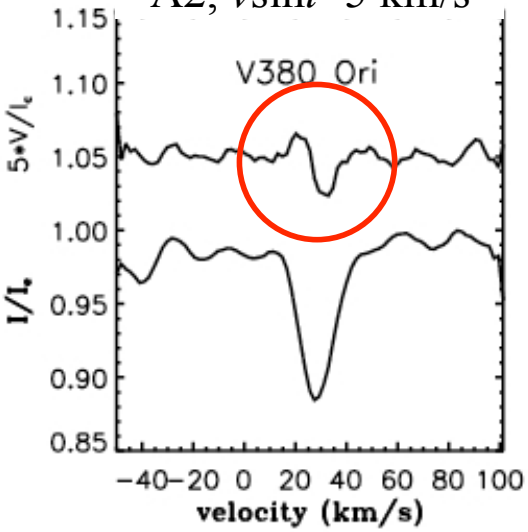

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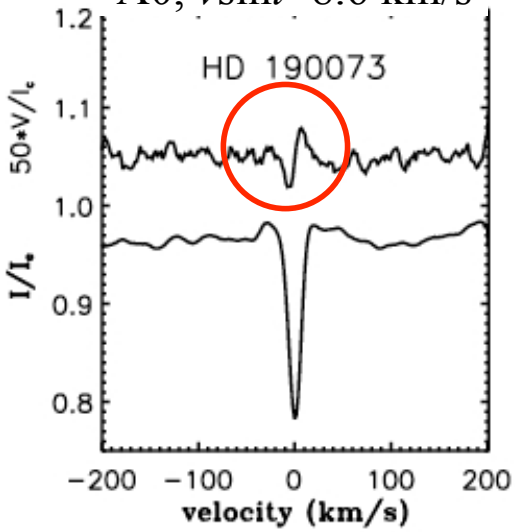

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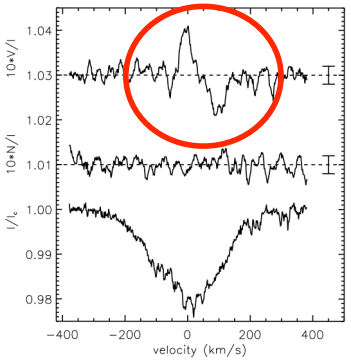

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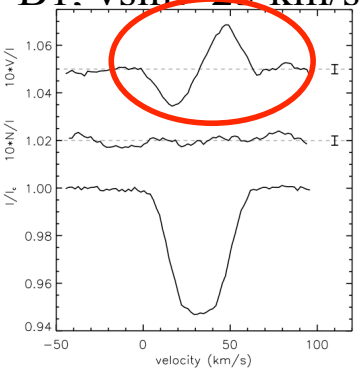

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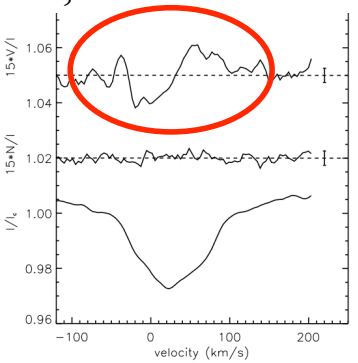


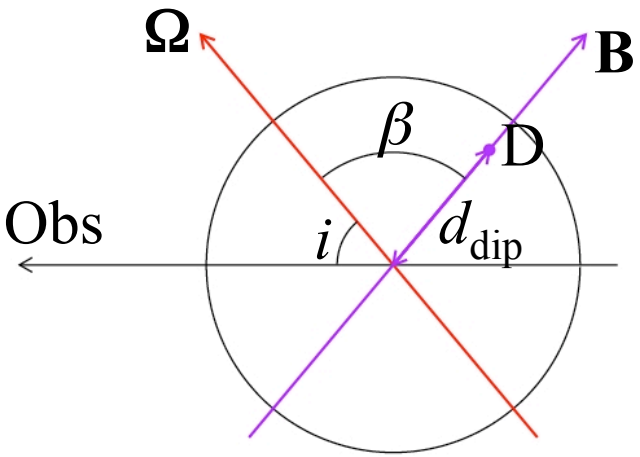
HAeBes - Magnetism

- 5% of magnetic HAeBe stars
- B caracterisation → Oblic Rotator Model

$$V = -Cg\lambda^2 B_\ell \frac{dI}{d\lambda}$$

- B_l varies with the rotation

  → Stokes V varies with the rotation



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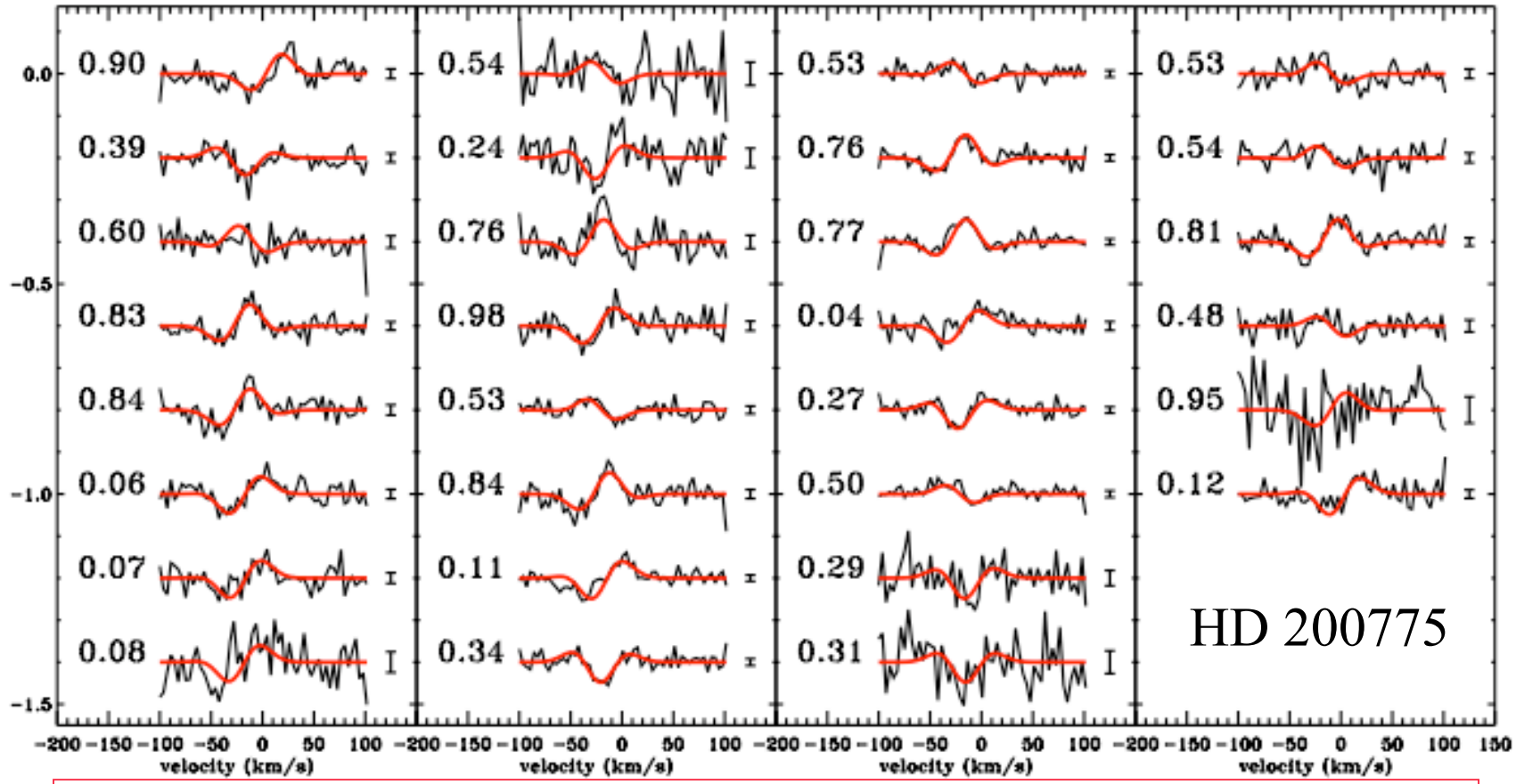

$P = 4.3281$ j, $i = 60°$, $\beta = 125°$, $B_d = 1000$ G, $d_{dip} = 0.05$

Alecian et al. 2008, MNRAS 385, 391

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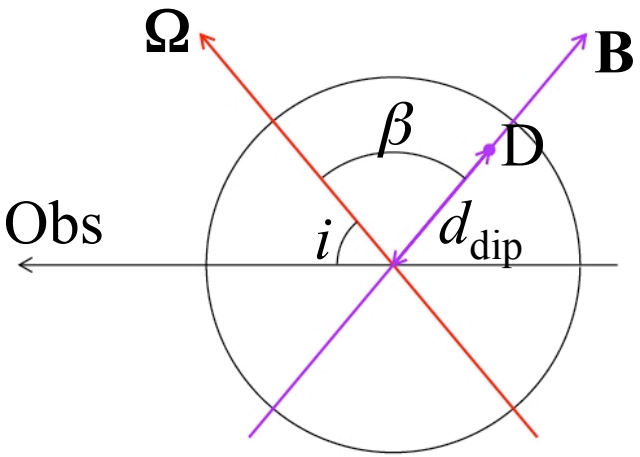

- B_l varies with the rotation

  → Stokes V varies with the rotation

- Magnetic fields mainly dipolar with strength from 300 G to 2.1 kG

  Catala, Alecian et al. 2007; Alecian et al. 2008; Folsom et al. 2008; Alecian et al. soumis

→ Arguments in favour of the fossil field hypothesis

Conclusion and open issue

- The magnetic fields of the intermediate mass stars are very likely fossile

- Magnetic detections :
  - 9 HAeBe stars : HD 190073, V380 Ori, HD 200775, HD 72106, NGC 6611 601, NGC 2244 201, NGC 2264 83, HD 104237, HD 101412
  - X-rays emissions : V380 Ori, HD 104237, HD 200775, NGC 2264 83
  - Non X-rays emissions : NGC 2244 201
- Best magnetic candidates **undetected** :
  - AB Aur, HD 163296 : line rotational modulation, highly ionised species, X-rays emission

    ⇒ A strong magnetic field is not at the origin of these characteristics

⇒ **X-rays emissions are not a proxy for magnetic fields in the Herbig Ae/Be stars**

What is the origin of the X-rays in the Herbig Ae/Be stars ?