Magnetism, rotation and accretion in Herbig Ae/Be stars

Evelyne Alecian, Gregg Wade, Claude Catala
Royal Military College of Canada
LESIA – Observatoire de Paris

The Ap/Bp stars

- 5 – 10% intermediate mass stars (A/B stars)
- Large-scale organised magnetic field
- Strengths ranging from 300 G to 30 kG
    - ➔ Favoured hypothesis : fossil field origin
    - ➔ Some of PMS intermediate mass stars should be magnetic
- Slow rotator
    - ➔ 1st hypothesis : Magnetic braking during the PMS phase ? (Stepien 2000, Stepien & Landstreet 2002)
    - ➔ 2nd hypothesis : The magnetic field cannot survive in fast rotators (see Lignères 1996)

Magnetospheric accretion during the PMS evolution ?

- **Observational clues of circumstellar disk** : emission lines, UV continuum excess, NIR excess, millimeter & submillimeter excess (eg. Mannings & Sargent 1997, 2000)
- **Direct evidence of circumstellar disk** : interferometric data at millimeter, submillimeter and NIR (Eisner et al. 2003, Nata et al. 2000)
- **Disk properties similar to those of T Tauri stars** (eg. Nata et al. 2001)
- Origin of emission lines in T Tauri stars : **magnetospheric accretion** (Konigl 1991, Muzerolle et al. 1998, 2001)
- **Magnetospheric accretion model successfully applied to Herbig Ae/Be stars** (Muzerolle et al. 2004)

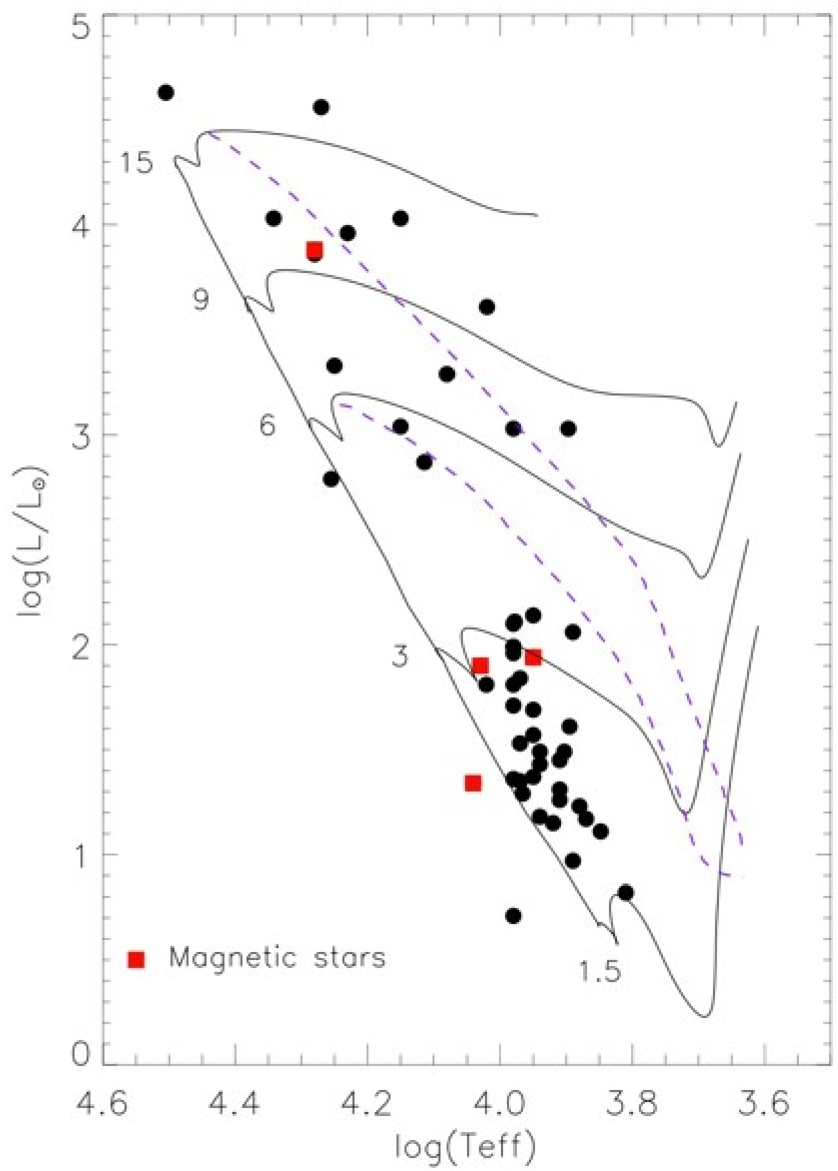
➔ We need to investigate the magnetic field in the PMS intermediate mass stars = the Herbig Ae/Be stars

The Herbig Ae/Be stars

- Intermediate-mass PMS stars
    - ➔ Progenitors of the main sequence A/B stars
- IR emission
- Association with nebulae
- Characteristics associated with magnetic activity :
    - resonance lines as N V and O VI, X-ray emission :
      → chromospheres or coronae (Bouret et al. 1997, Roberge et al. 2001, Hamaguchi et al. 2005)
    - magnetospheric accretion
    - rotational modulation of resonance lines :
      → wind structured by magnetic field (Praderie et al. 1986, Catala et al. 1989, 1991, 1999)

Our sample

- Catalogues : Vieira et al . (2003) and Thé et al. (1994)
- 55 Herbig Ae/Be stars
- 1.5 – 15 Msun
- Aim : to study the magnetic field, the rotation and the interaction with circumstellar surroundings



Observations and Reductions

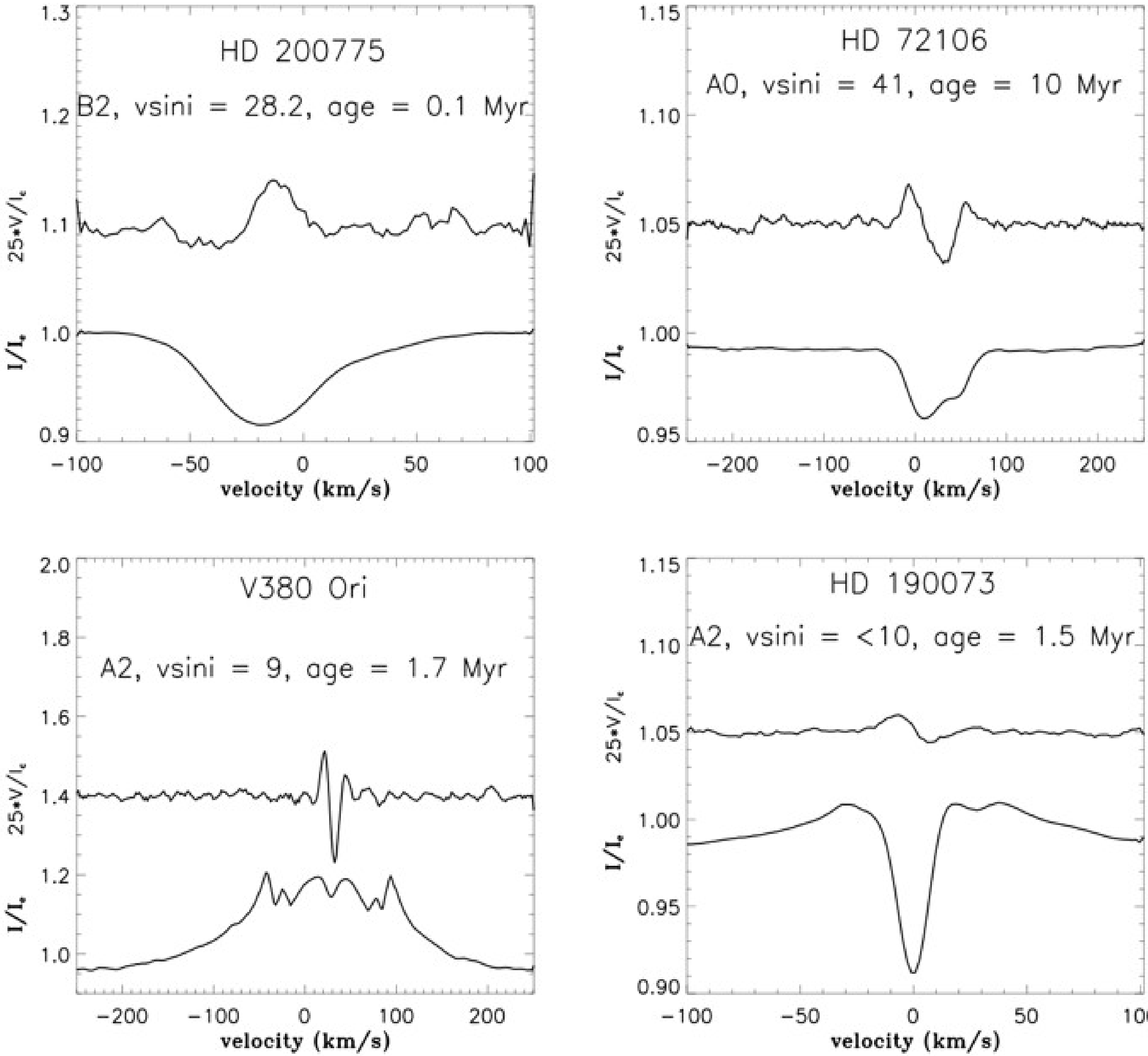
- High-resolution spectropolarimeter ESPaDOnS at CFHT
- In polarimetric mode : R = 65000
- Data : intensity I and circular polarisation V spectra
- Reduction : Libre-Esprit package
  (Donati et al. 1997, 2007)
- Least Squares Deconvolution method (Donati et al., 1997)

  → Increase the S/N ratio

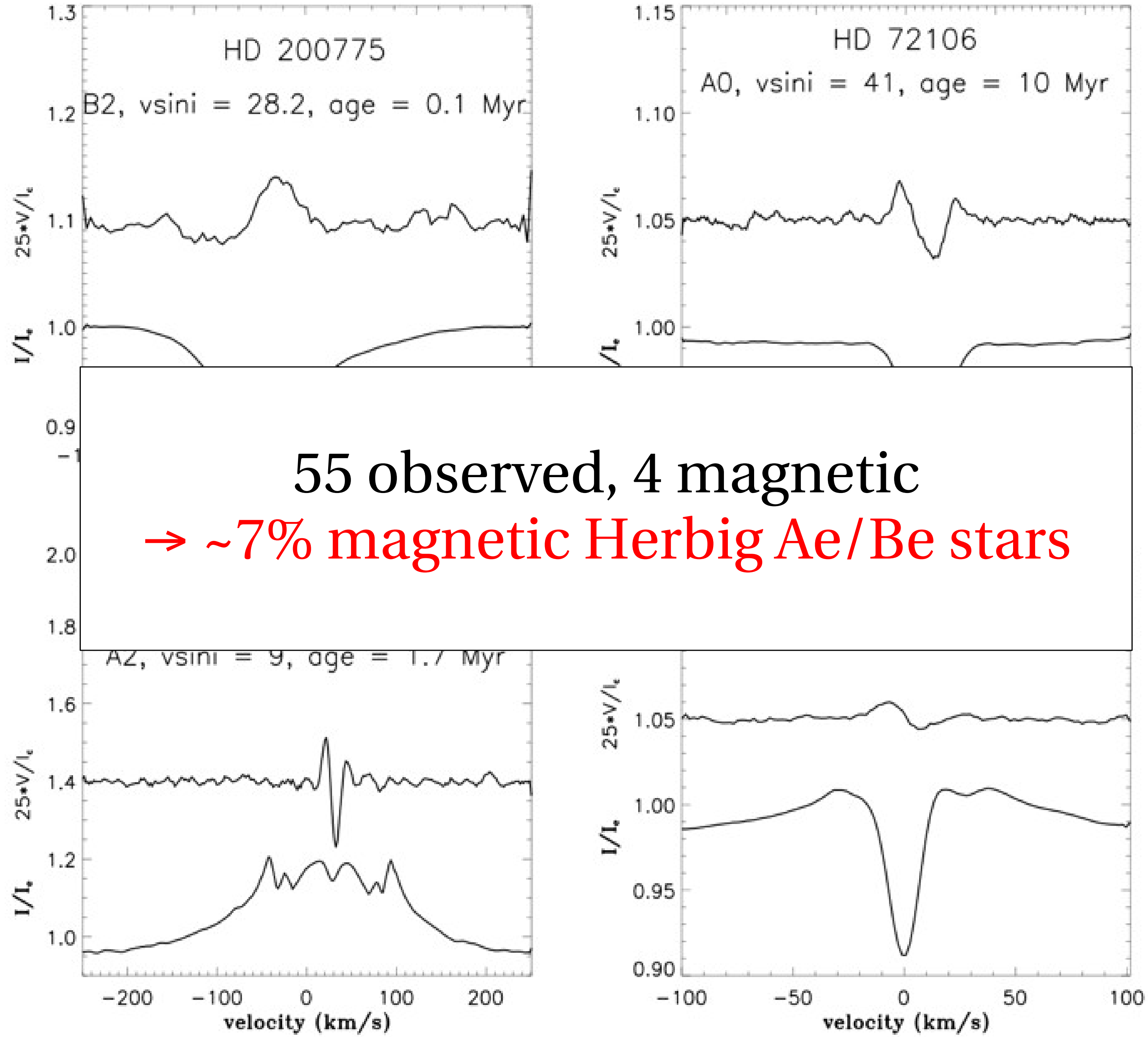
  → Mean Stokes I and V profiles

We have detected 4 new magnetic fields !

Results


HD 200775
B2, vsini = 28.2, age = 0.1 Myr
HD 72106
A0, vsini = 41, age = 10 Myr
V380 Ori
A2, vsini = 9, age = 1.7 Myr
HD 190073
A2, vsini = <10, age = 1.5 Myr
25*V/Ic
I/Ic
velocity (km/s)

Results

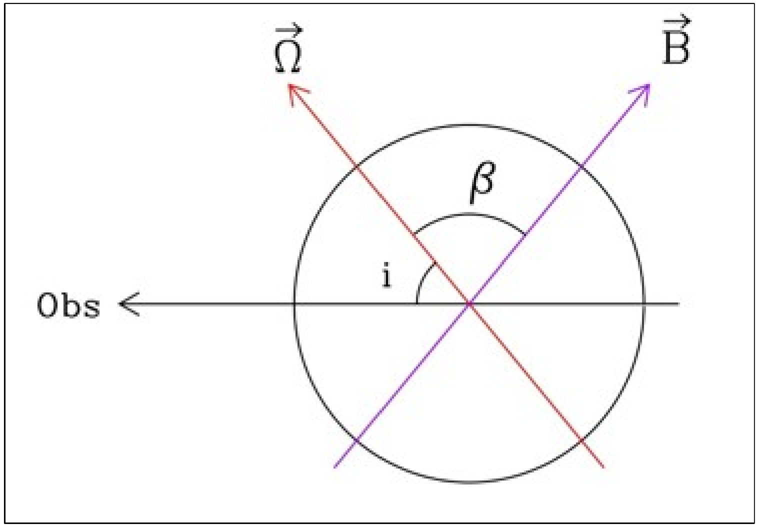


55 observed, 4 magnetic

→ ~7% magnetic Herbig Ae/Be stars

Magnetic Topology

- Method :
  - Model : oblique rotator
  - Fit temporal variations of the Stokes V profiles

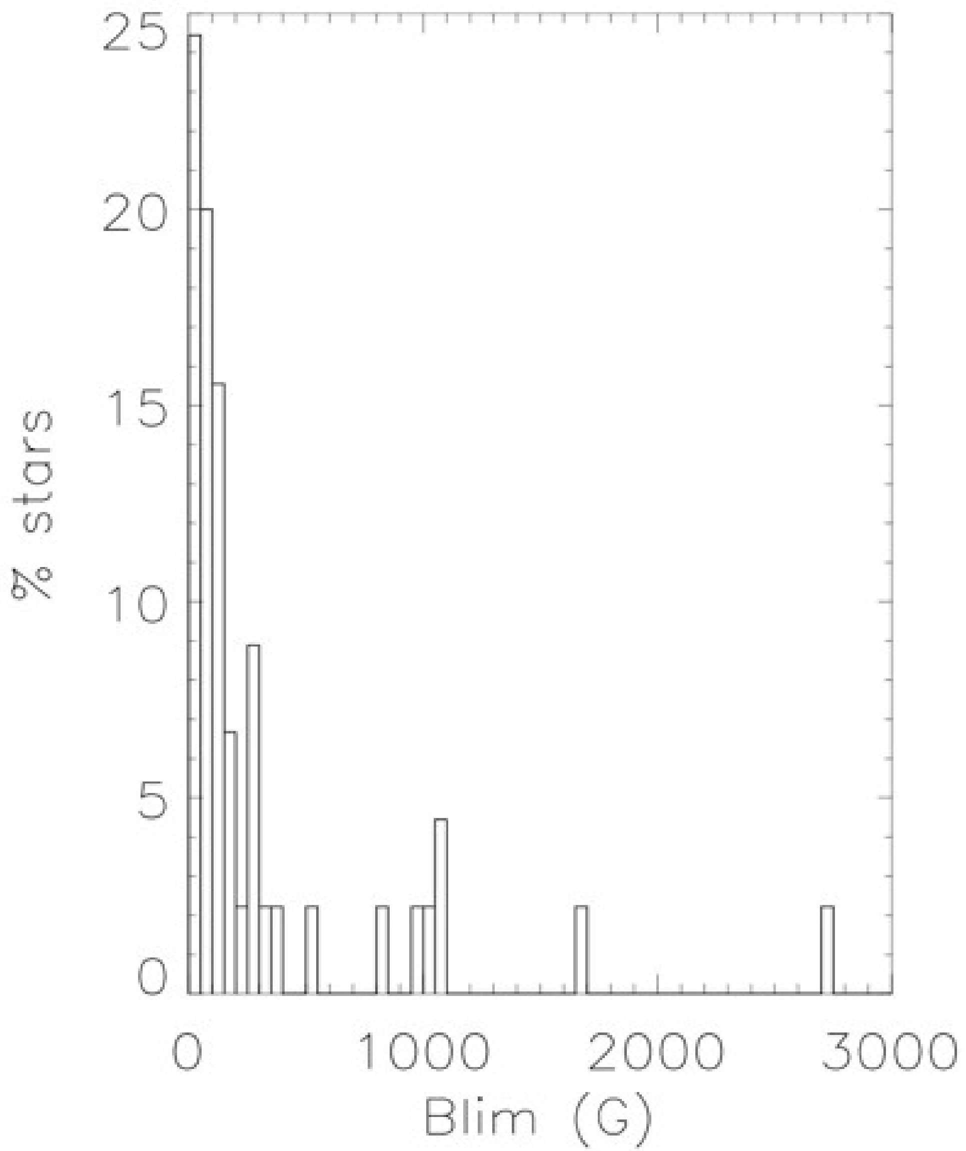


- Results :
  - HD 200775, V380 Ori and HD 72106:
    - ➔ a decentered and centered dipole models
    - ➔ β= 76°, 90° , and [20°,60°] (Alecian et al. 2007, to be submitted) (Folsom et al. 2007, in prep.)
  - HD 190073 :
    - ➔ dipole magnetic field (Catala et al. 2007, A&A 462, 293)

Magnetic intensity

- Magnetic stars : from 100 G to 1 kG
- Undetected stars
  - Determination of the uncertainties
  - ~25% have σ< 50 G
  - If they are magnetic, B<100 G

Wade, Alecian et al. (2007), in prep.



Magnetospheric accretion models

Magnetic stars

Surface Polar intensity required for the models of :

Königl (1991) and Shu et al. (1994) : from 60G to 4kG

→ 1 star on 4

Cameron & Campbell (1993) : from 10 G to 500G

→ 4 stars on 4

see also Johns-Krull et al. (1999)

Undetected stars

Stars well constrained : if they host a magnetic field, it is not enough strong to lead to magnetospheric accretion

➔ Magnetospheric accretion do not occur in all Herbig stars

Conclusions

- Magnetic field : 7% of Herbig stars, large-scale organised between 100G and 1kG
  - ➔ consistent with the fossil field hypothesis
- Rotation : 2 magnetic stars are very slow rotators : less than 10 km/s with an age around 1.5 Myr
  - ➔ a braking mechanism exists very early in the PMS evolution : magnetic braking ?
- Magnetospheric accretion :
  - ➔ should concern all PMS stars of intermediate mass
  - ➔ some of Herbig Ae/Be stars do not have a magnetic field strong enough to have magnetospheric accrection, whereas some others have it