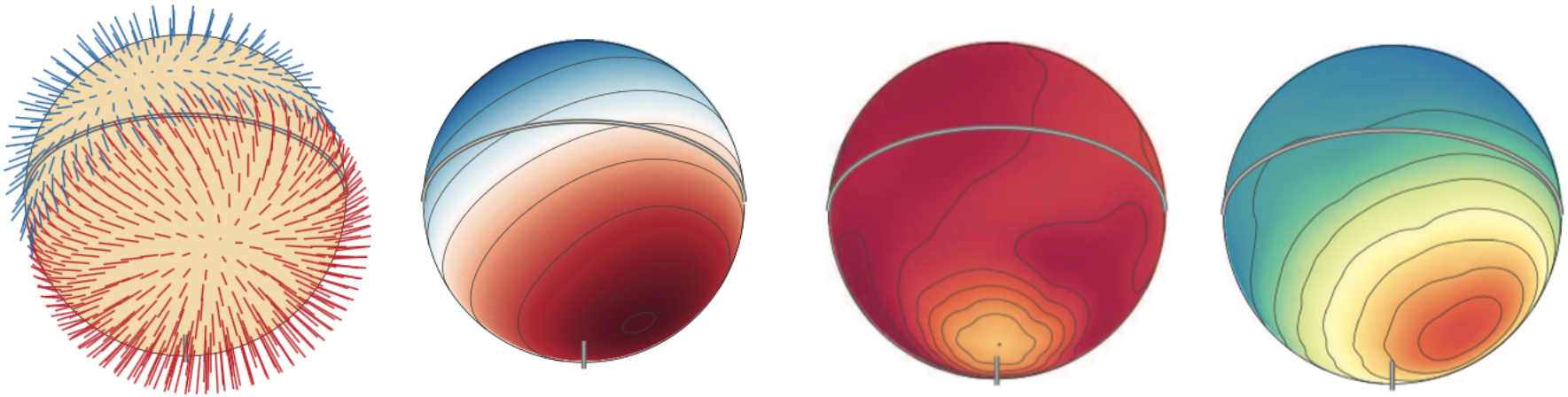
Magnetic Properties of Ap Stars: A Complete Volume-Limited Picture



(Rusomarov et al. 2014)

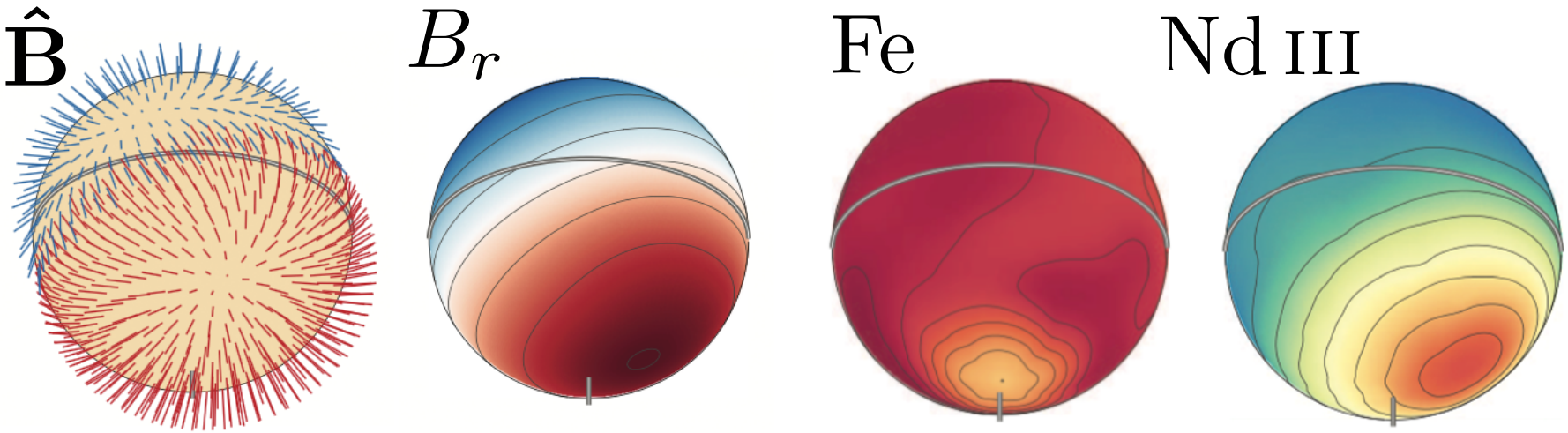
James Sikora[1,2],

Gregg Wade[2], Jennifer Power[1,2]

[1]Dept. of Physics, Queen's University, Kingston, ON

[2]Dept. Of Physics, Royal Military College of Canada, Kingston, ON

Ap Stars



(Rusomarov et al. 2014)

- Magnetic class of intermediate-mass CP stars
- Primarily **dipole** fields

Origin:
1. **Fossil fields?**
2. **Stellar mergers?**
3. **???**

Ap Stars

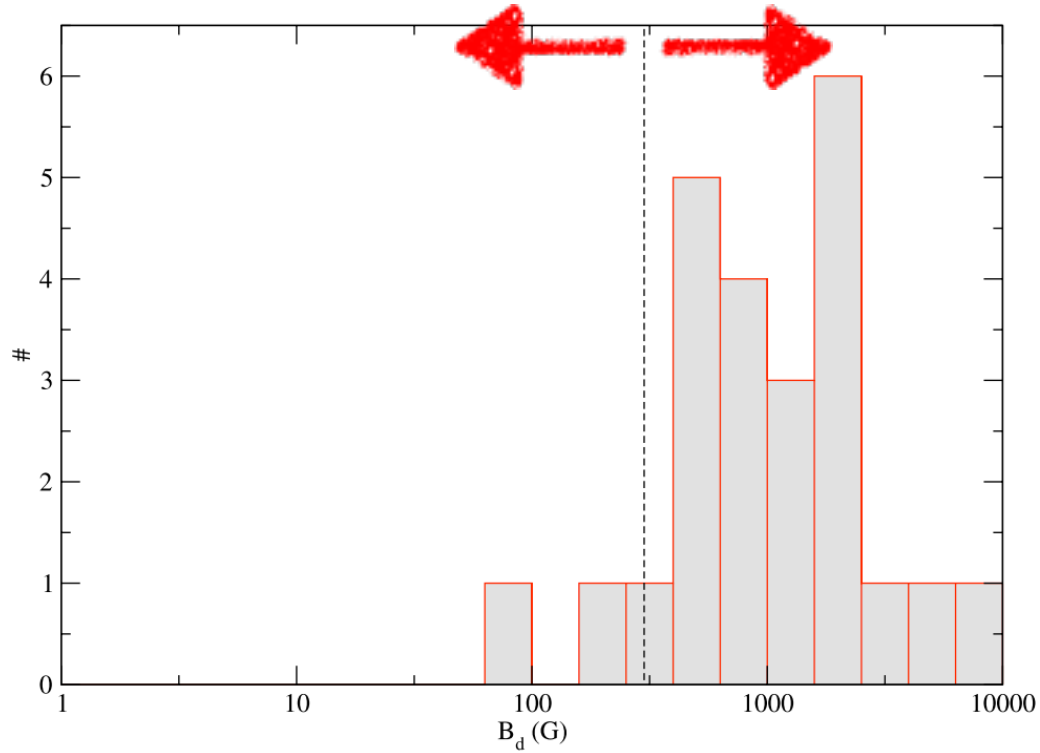
Magnetic dichotomy: There may exist a critical B_p below which fields decay

Ultra-weak fields

($B_z < 1$ G)

e.g. Vega
(Lignières et al. 2009)

e.g. Ursae Majoris
(Blazère et al. 2015)



(Aurière et al. 2007)

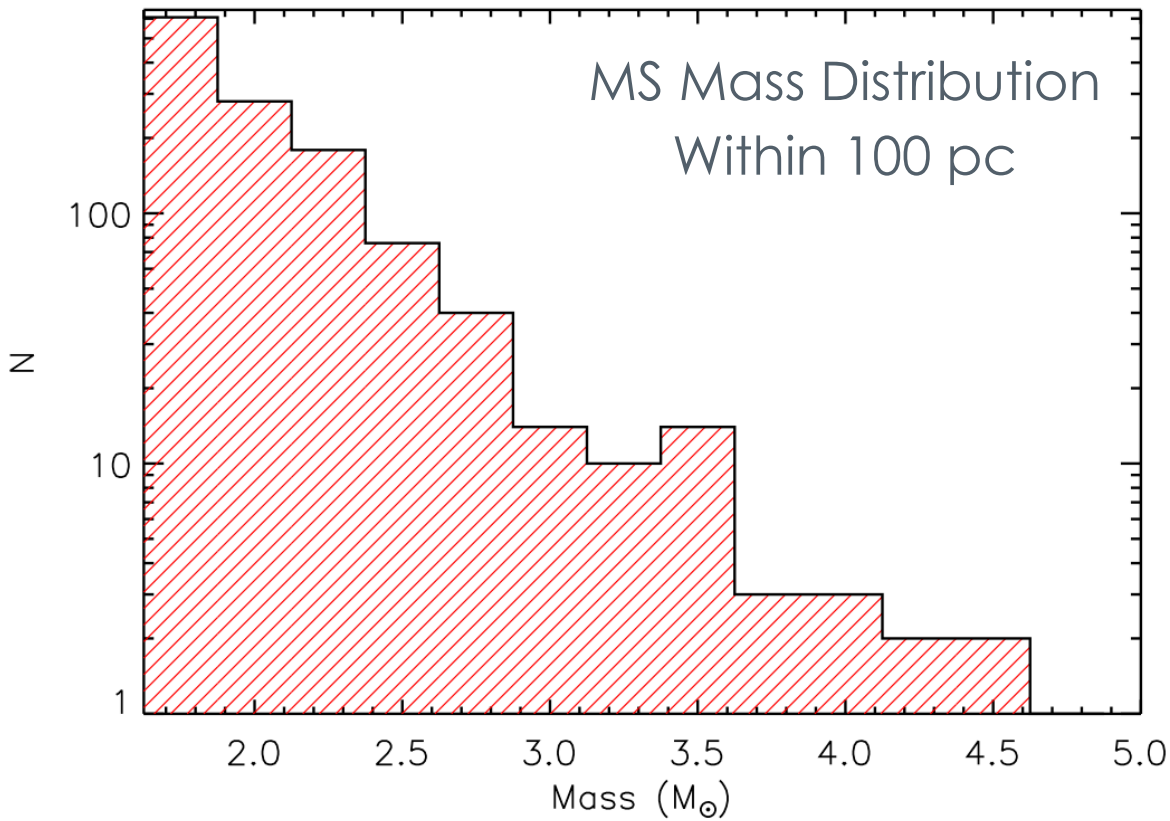
Ap Stars

1. Why study Ap stars?

2. Why do we need a **volume-limited** survey?

Ap Stars

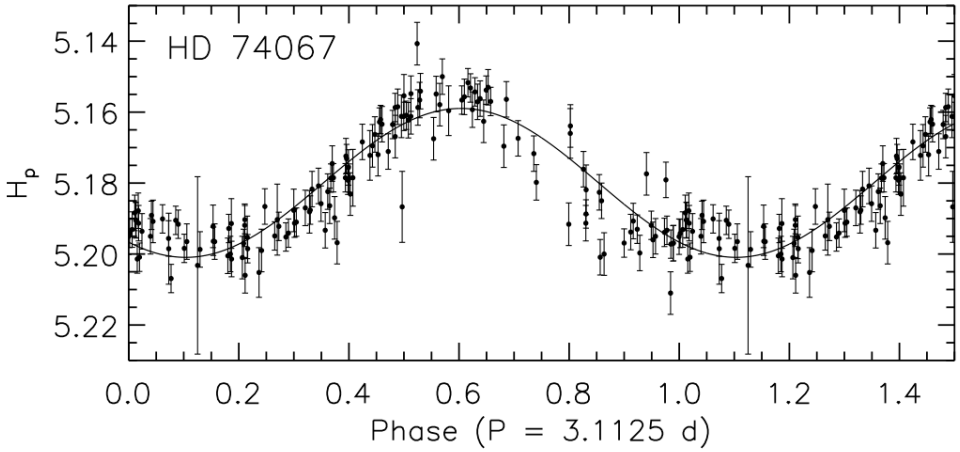
~10% of hot stars are magnetic



The Sample

Catalogue of Ap, HgMn, and Am Stars (Renson & Manfroid 2009)

Candidate Ap/Bp Stars



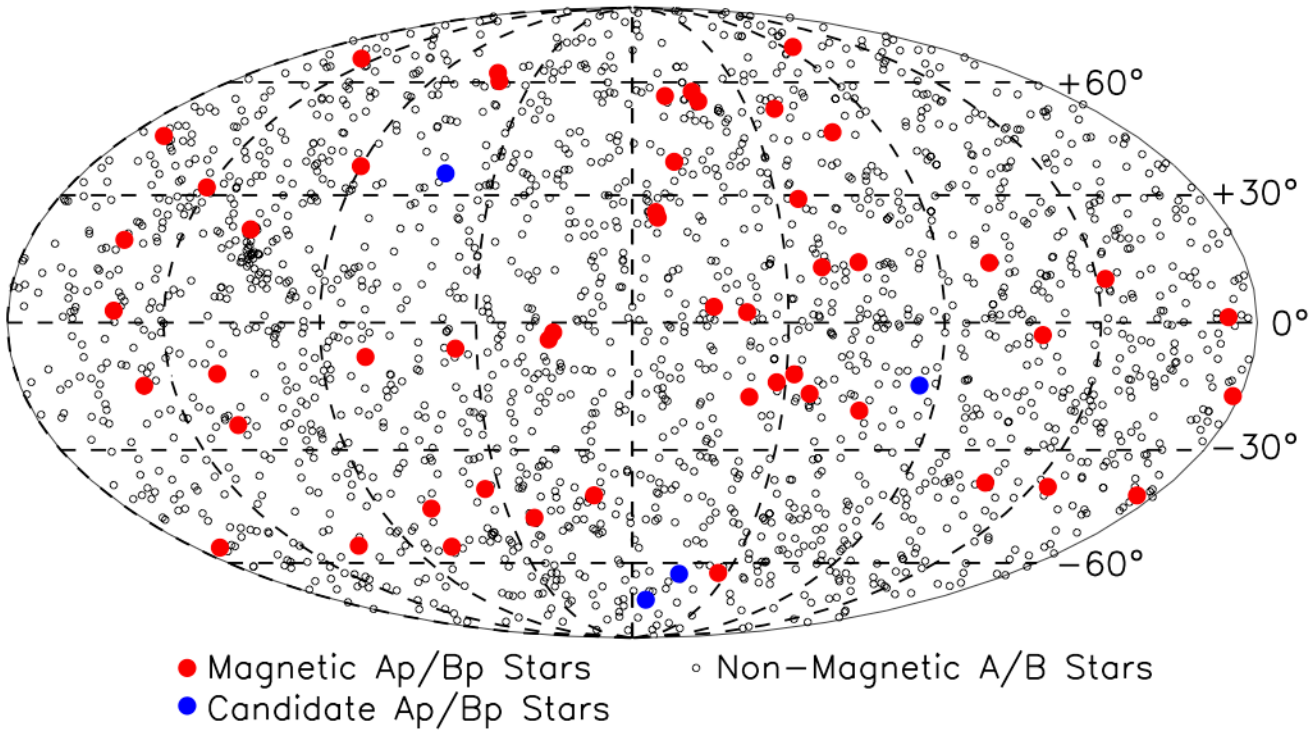
1. Detected magnetic fields
2. Photometric variability
3. Photometric peculiarity index

Bona fide magnetic Ap/Bp star

The Sample

Hipparcos catalogue within 100 pc:

- ~19,000 stars
- ~2,000 MS A/B stars within 100 pc



The Sample

# of Known Ap/Bp Stars (d ≤ 100 pc)	**51**
# of New ESPaDOnS Spectra Obtained	**94**
# of Stars Observed	**38**
# of Stars w/o High-Res. Spectropolarimetry (prior to this survey)	**25**

Target B_z Uncertainty: ≤ 25 G

Fundamental Parameters

T_{eff} Calibrations:

Strömgren *uvbyβ*

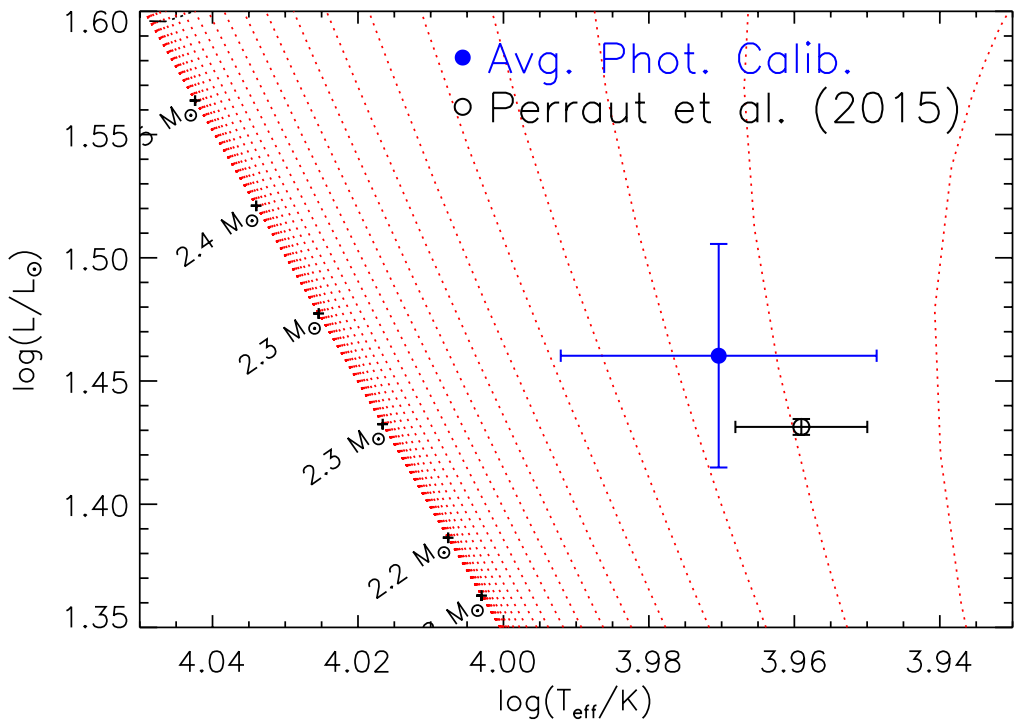
- (Balona 1994, Stepien 1994)

Geneva

- (Hauck & North 1993)

Johnson *UBV*

- (Grey 2005)



BC Calibrations:

- (Landstreet et al. 2007)

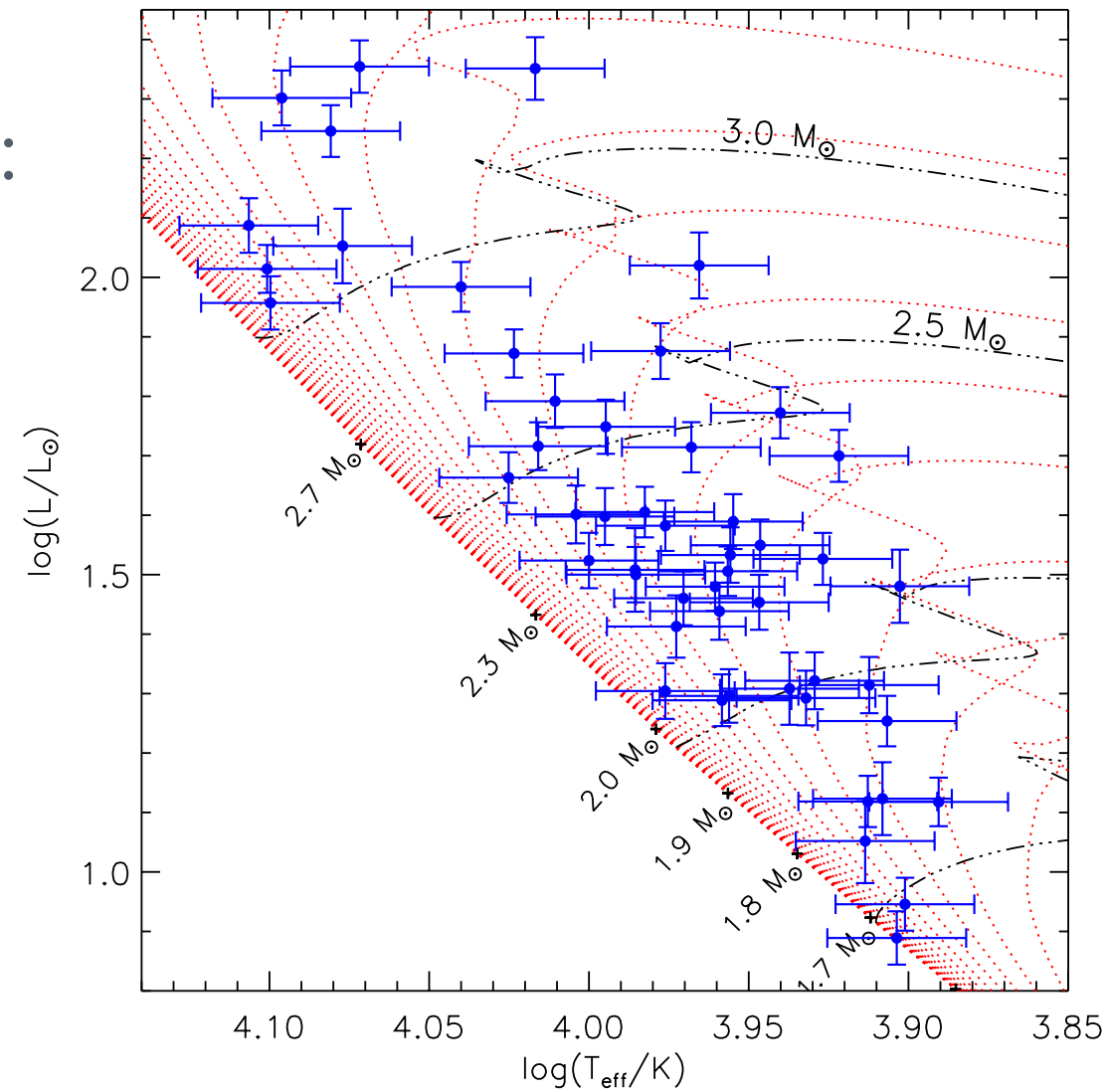
Fundamental Parameters

Evolutionary Models:

Non-rotating, Solar Metallicity

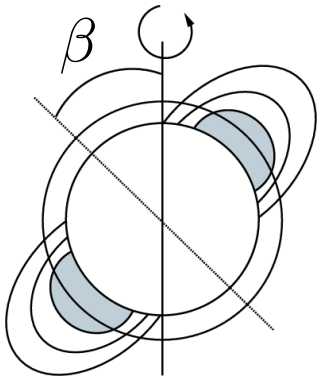
- (Ekström et al. 2012)

$$M,\ R_p,\ \tau_{\mathrm{age}}$$

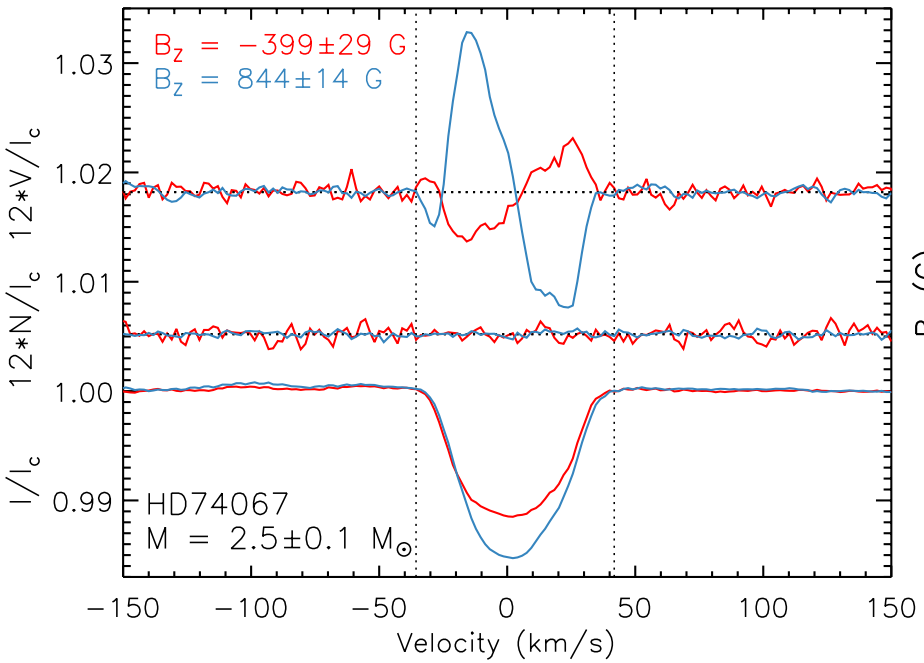


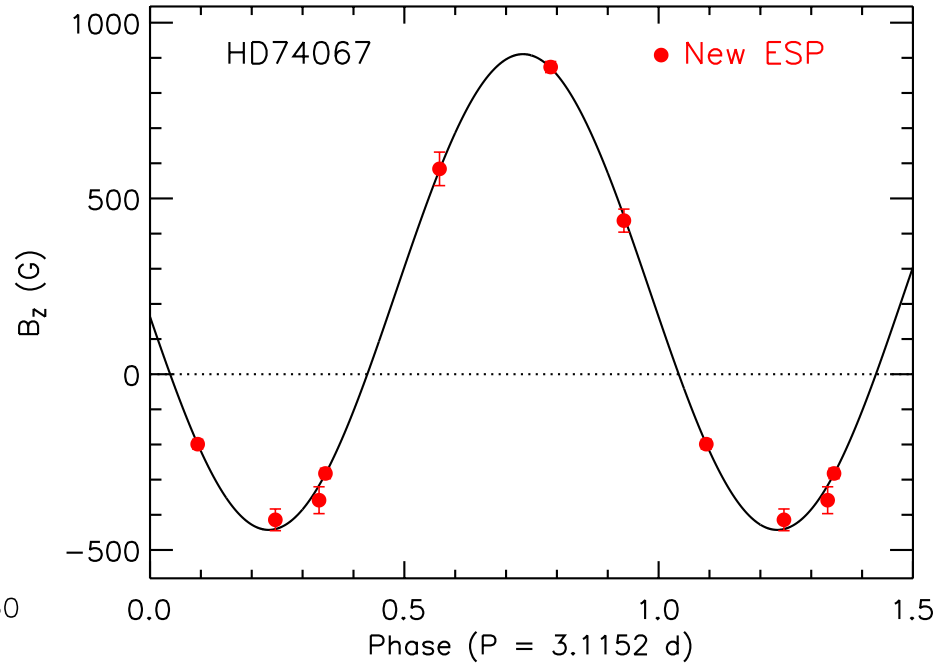
Magnetic Analysis

- Oblique Rotator Model (Stibbs 1950)



Rauw et al. (2010)

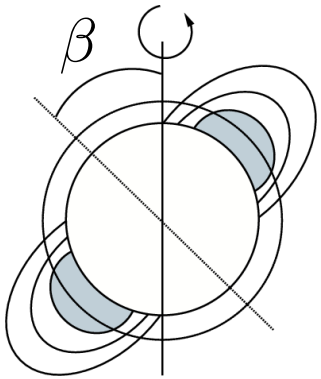




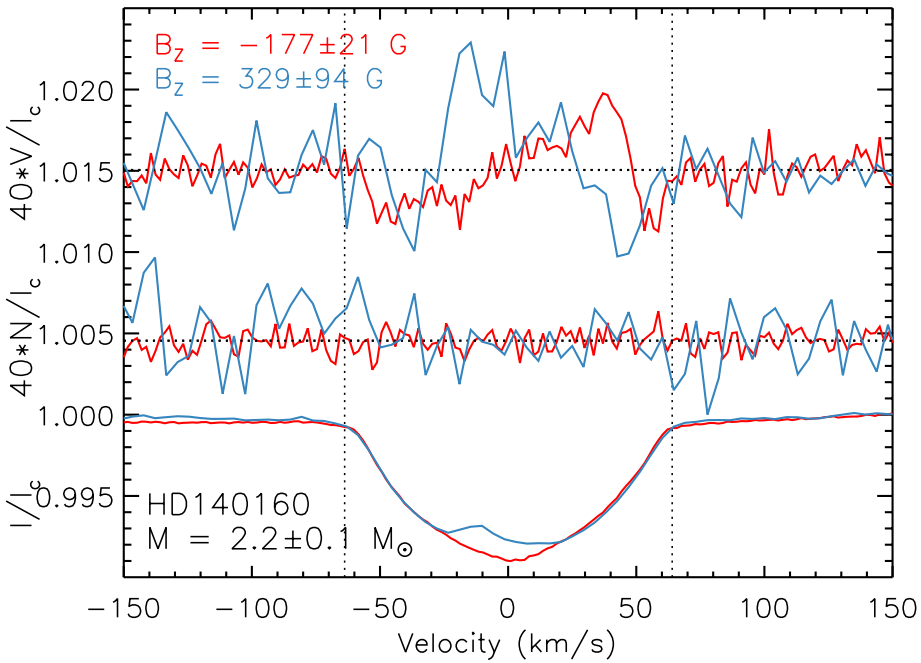
$$i = 58^{+26}_{-12}\,^{\circ} \qquad \beta = 61^{+10}_{-44}\,^{\circ} \qquad B_p = 3.1^{+0.2}_{-0.1}\,\mathrm{kG}$$

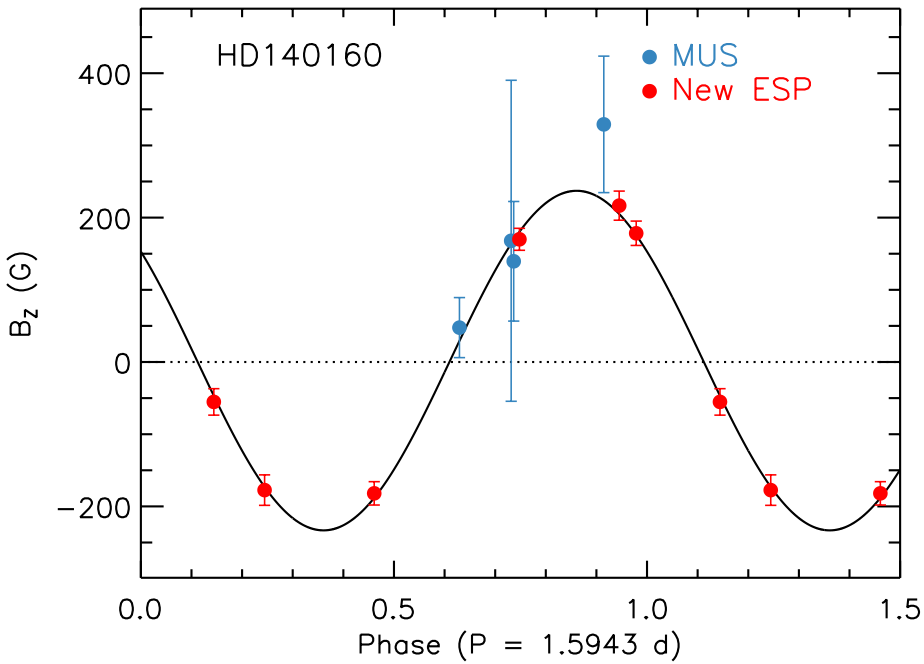
Magnetic Analysis

- Oblique Rotator Model (Stibbs 1950)



Rauw et al. (2010)

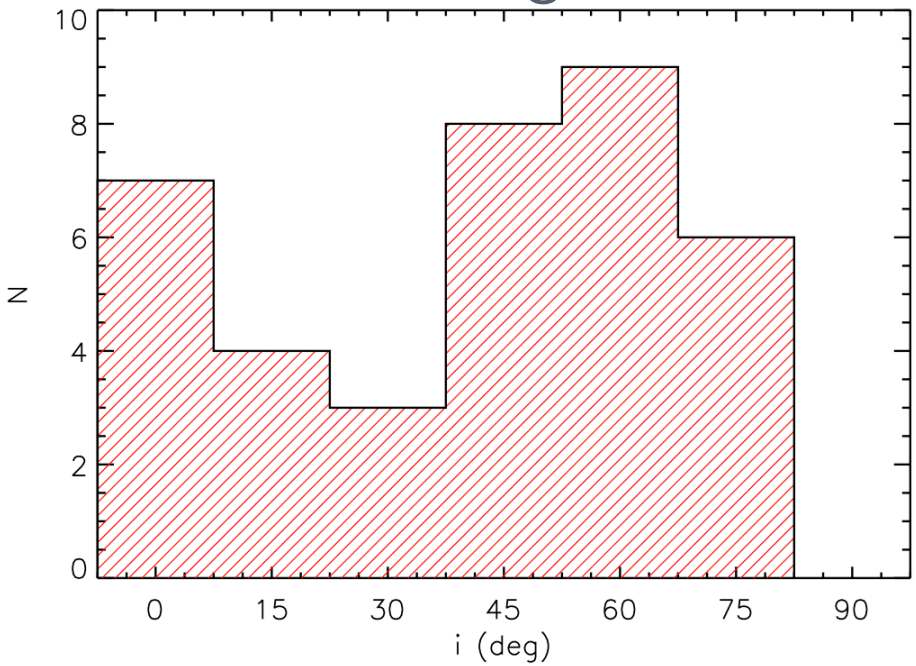




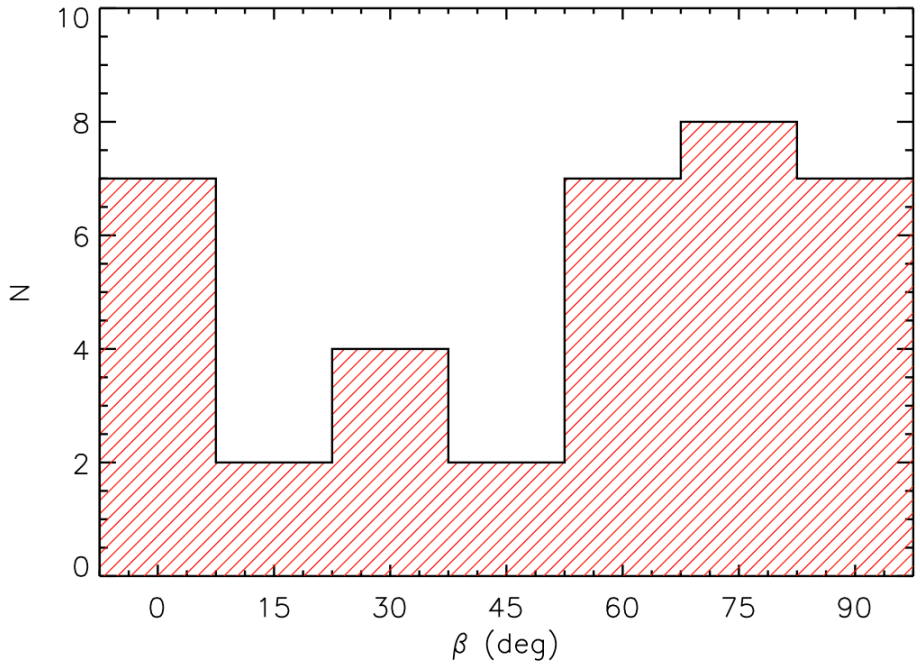
$$i = 56^{+19}_{-10}\,^{\circ} \qquad \beta \geq 72^{\circ} \qquad B_p = 1.0^{+0.3}_{-0.2}\,\mathrm{kG}$$

Magnetic Analysis

Inclination Angle



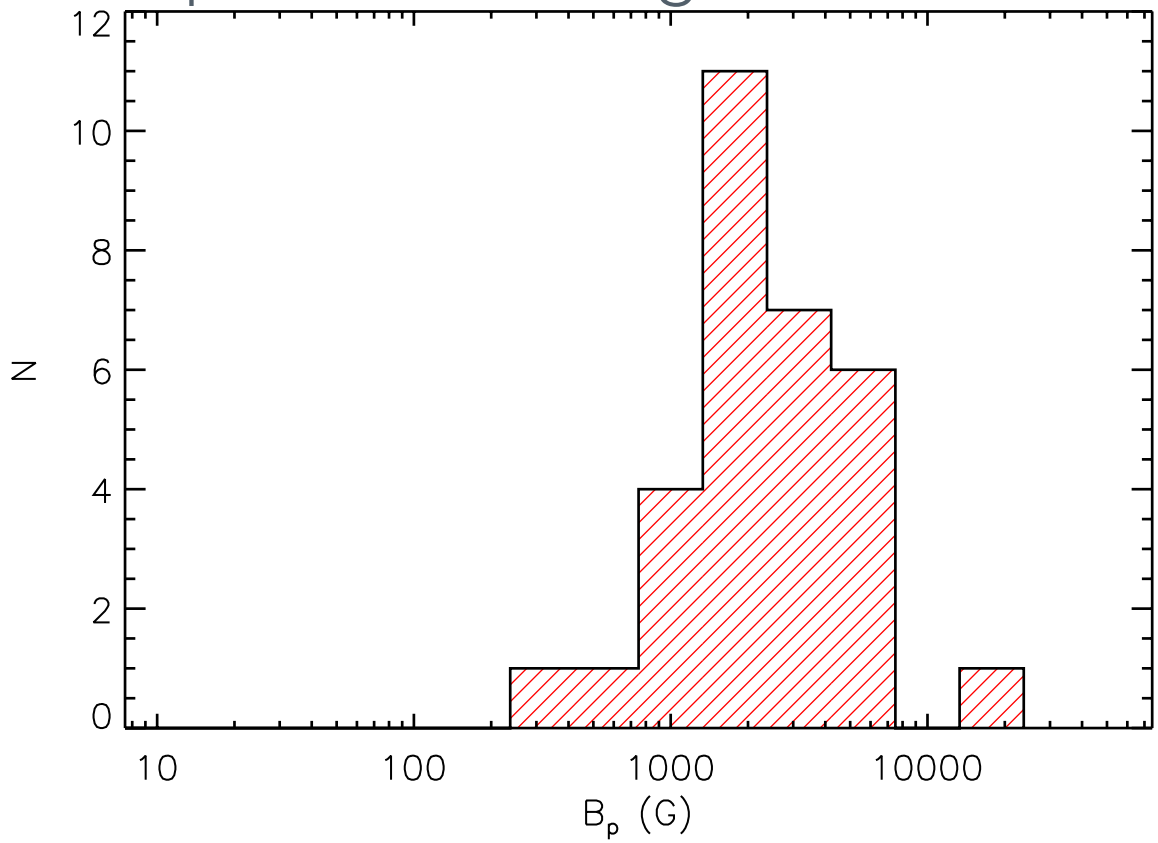
Obliquity Angle



Preliminary results!

Magnetic Analysis

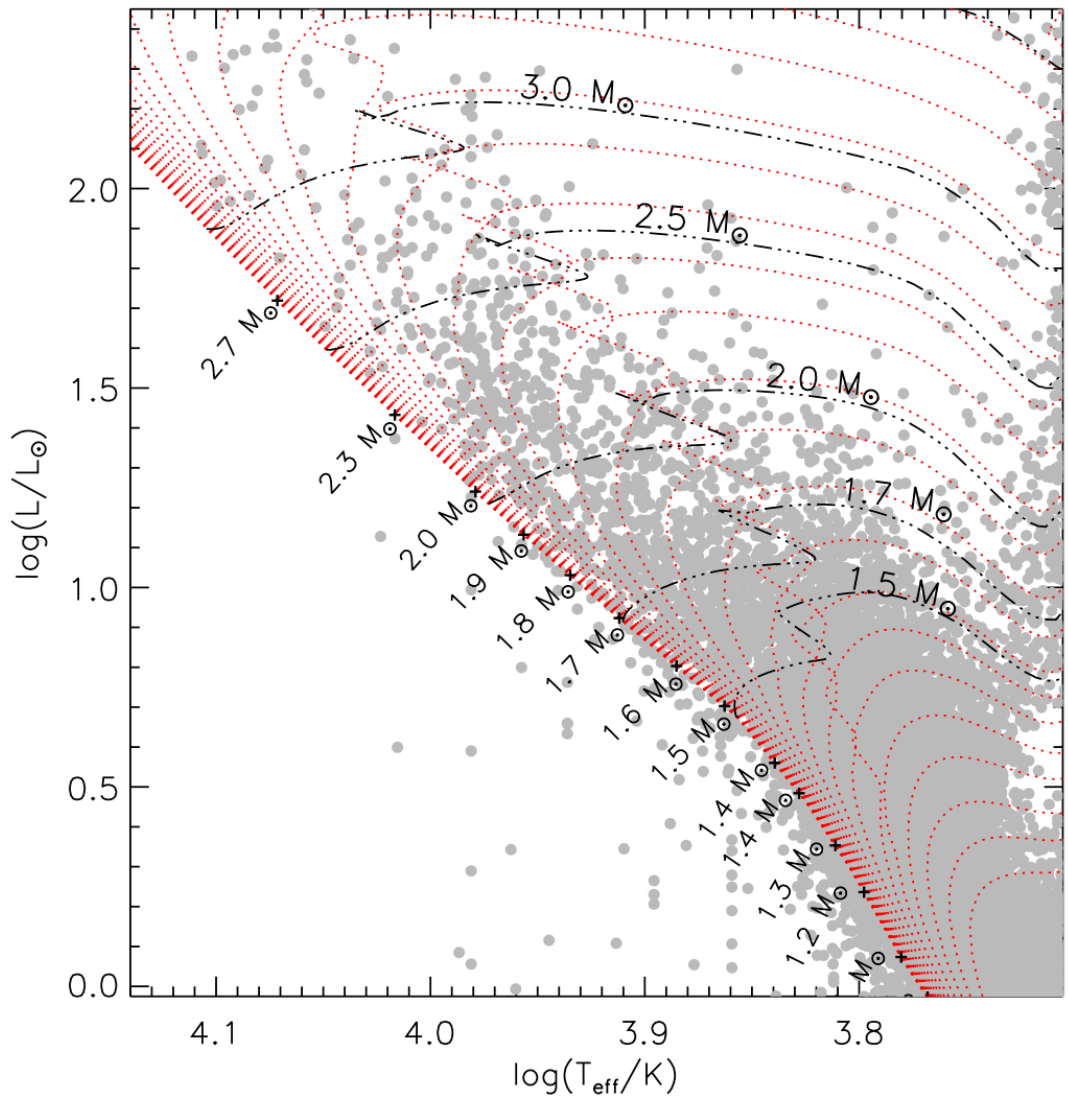
Dipole Field Strength



... also very preliminary!

HR Diagram Within 100 pc

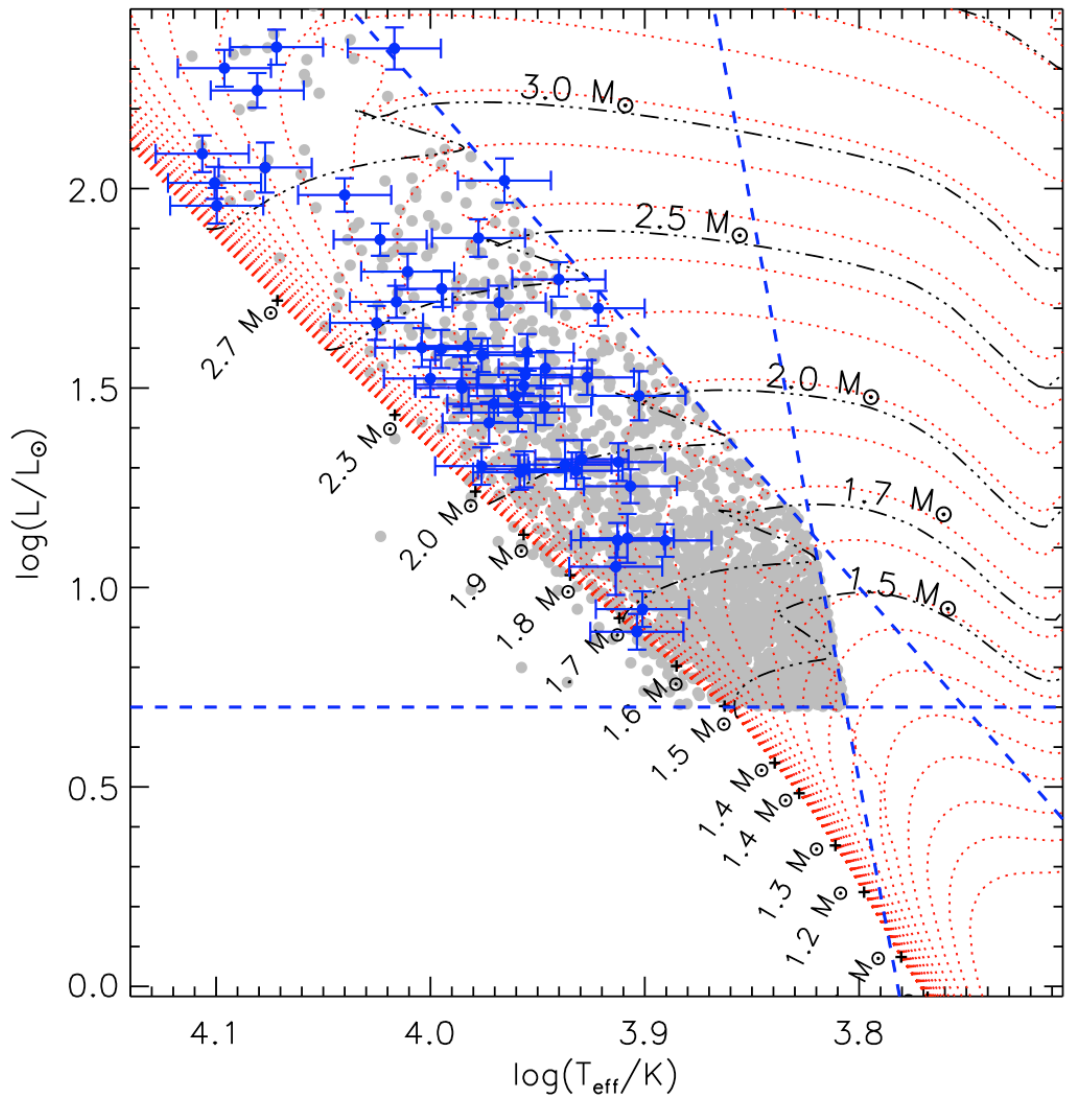
1. Calculate T_{eff}, L photometrically



HR Diagram Within 100 pc

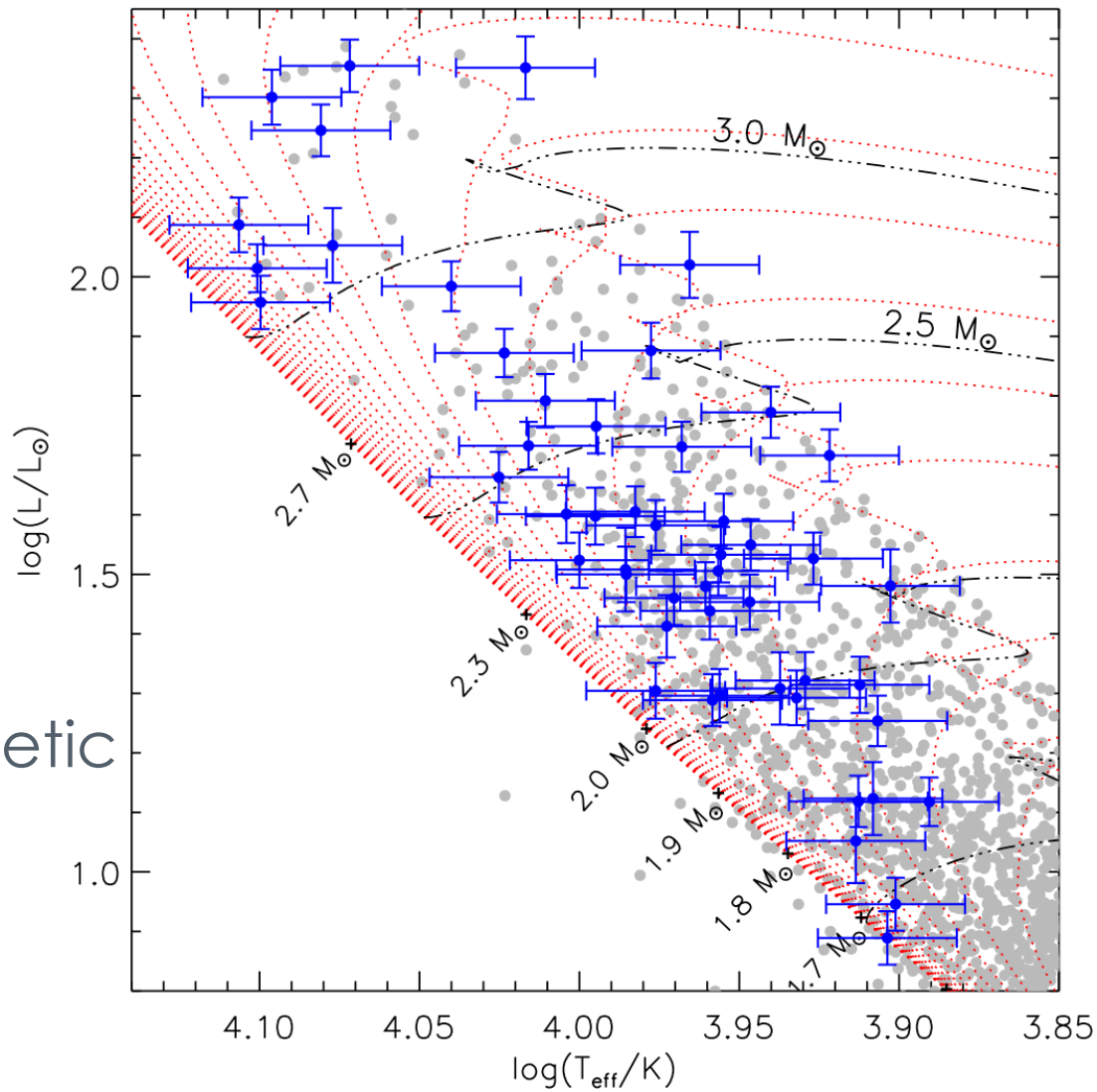
1. Calculate T_{eff}, L photometrically

2. Remove evolved stars



HR Diagram Within 100 pc

1. Calculate T_{eff}, L photometrically
2. Remove evolved stars
3. Compare the magnetic and non-magnetic samples



HR Diagram Within 100 pc

Spectroscopic Binaries:

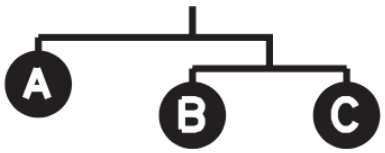
Alpha Pisc.

(BRITE Survey, Neiner & Lèbre 2014)

Resolved multi-star systems:

(VAST Survey, De Rosa et al. 2014)

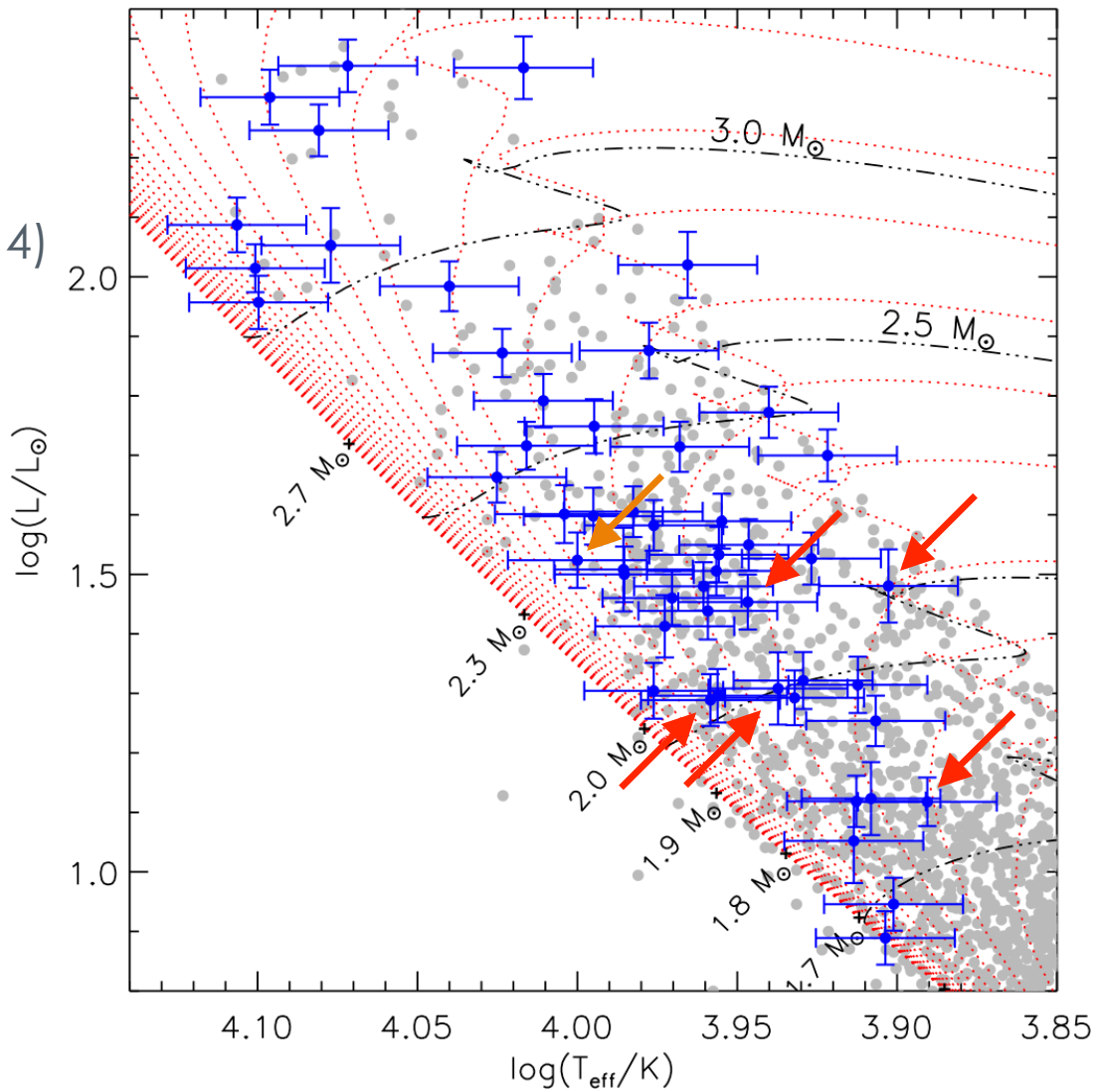
e.g.) HIP 82321



$\log P_{B-C} = 4.31$

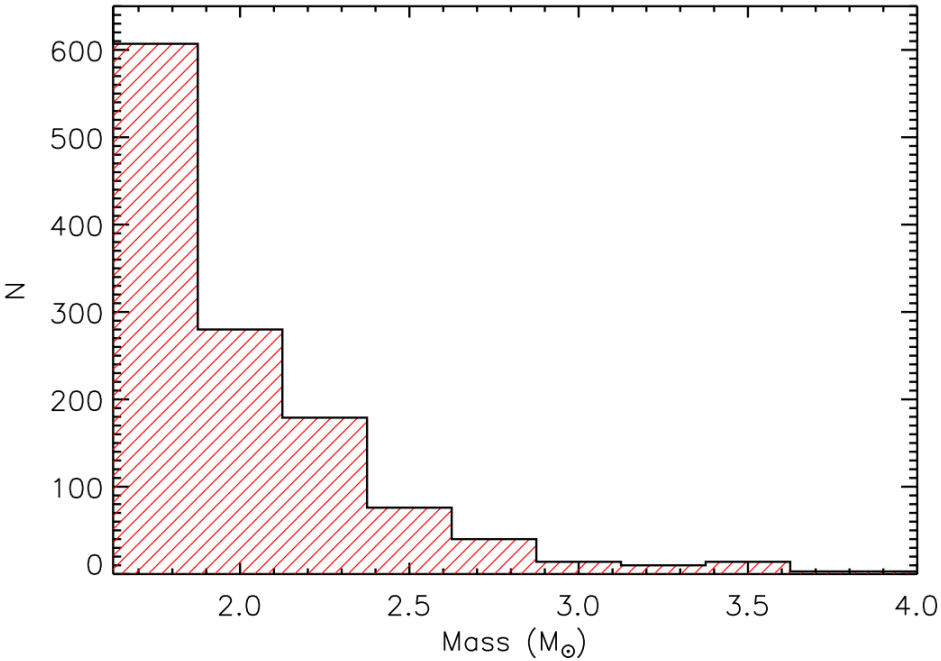
$\log P_{A-BC} = 5.35$

(De Rosa et al. 2014)

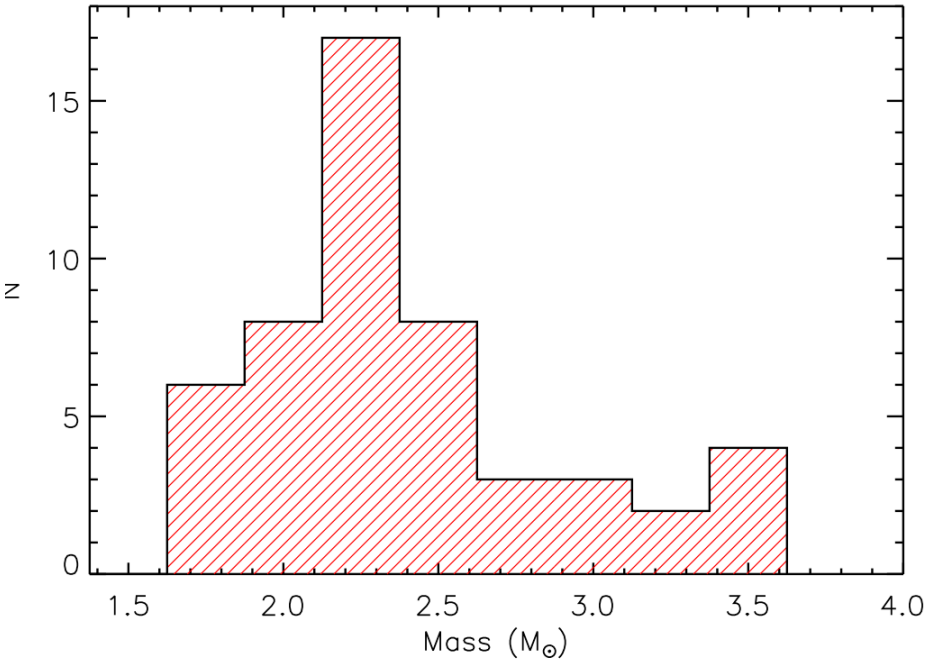


Comparing the Populations

Non-Magnetic MS A/B Stars

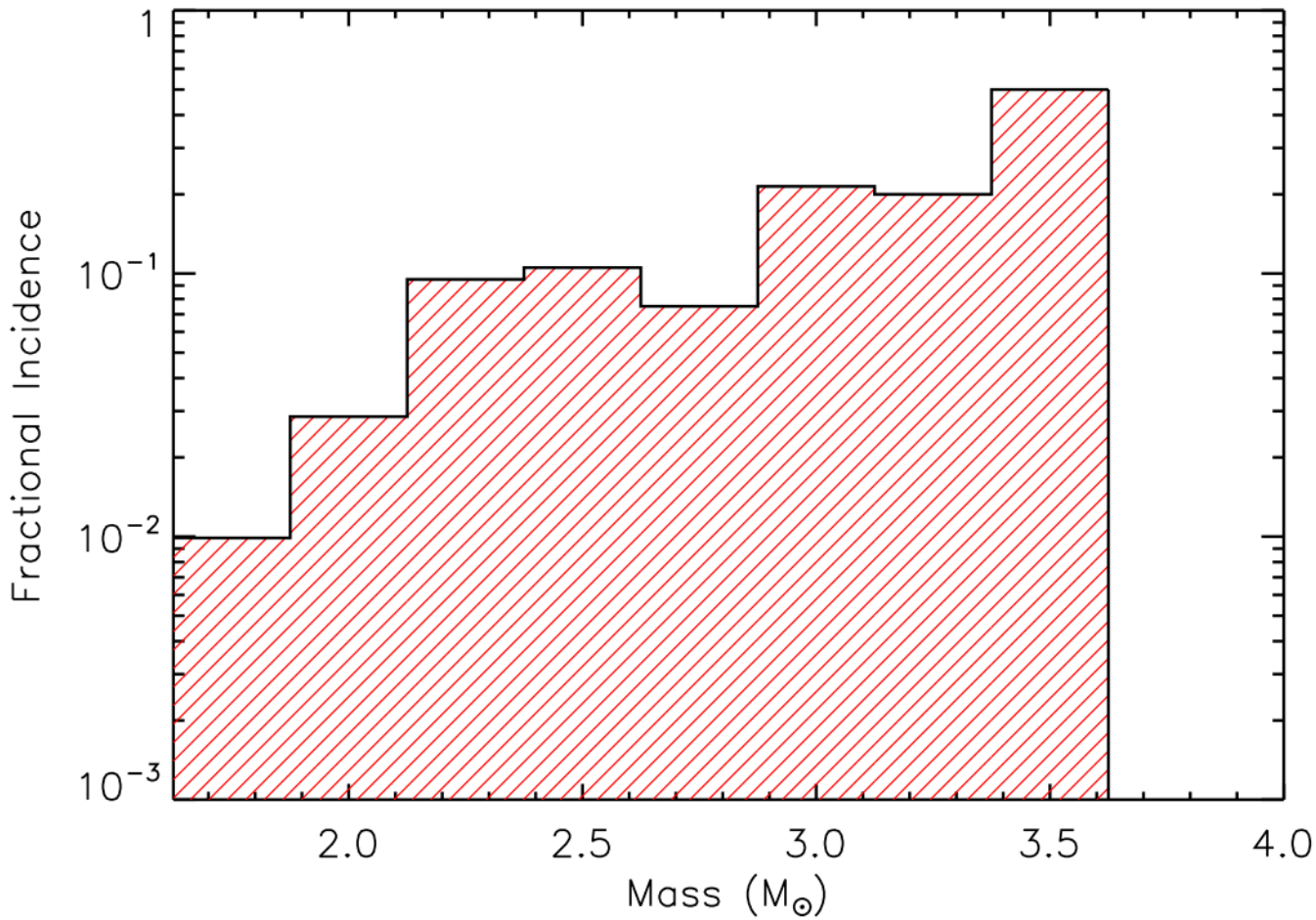


Magnetic Ap/Bp Stars



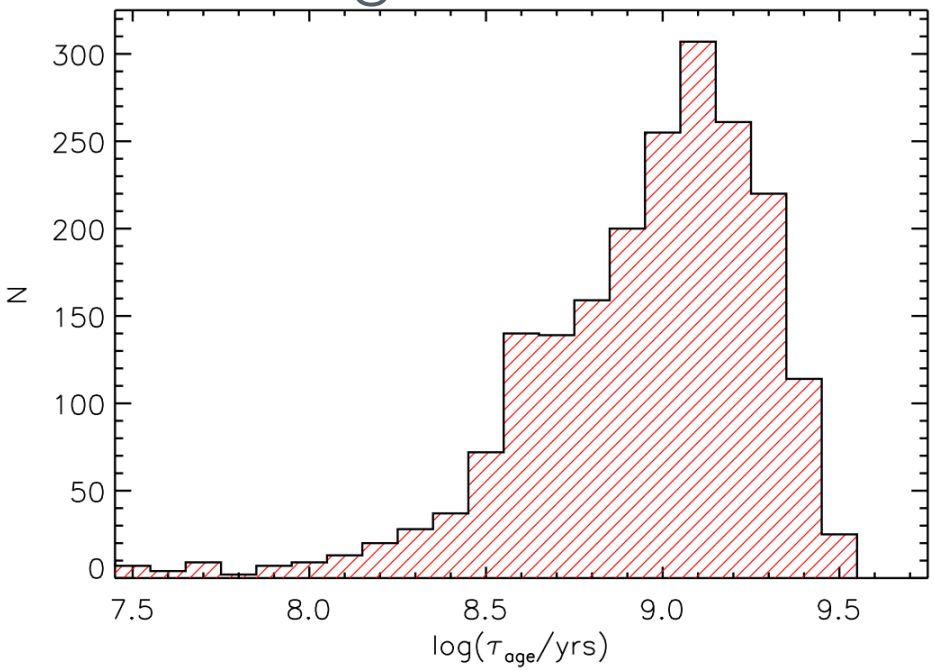
Comparing the Populations

Fractional Incidence of Mag. Fields With Mass

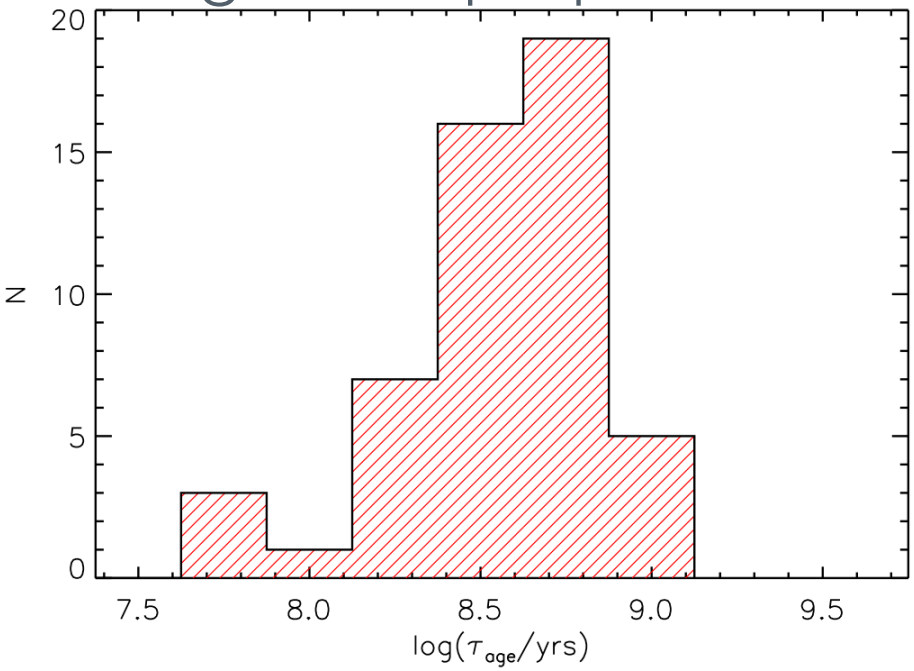


Comparing the Populations

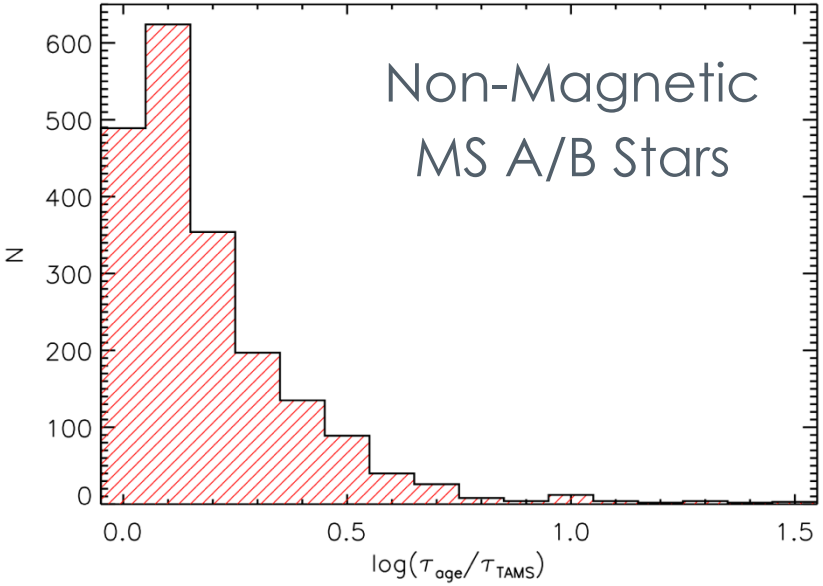
Non-Magnetic MS A/B Stars

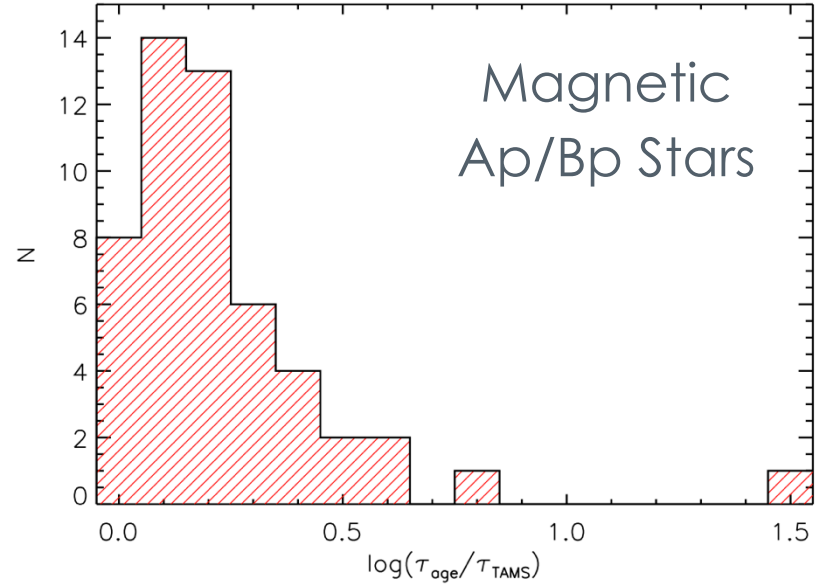


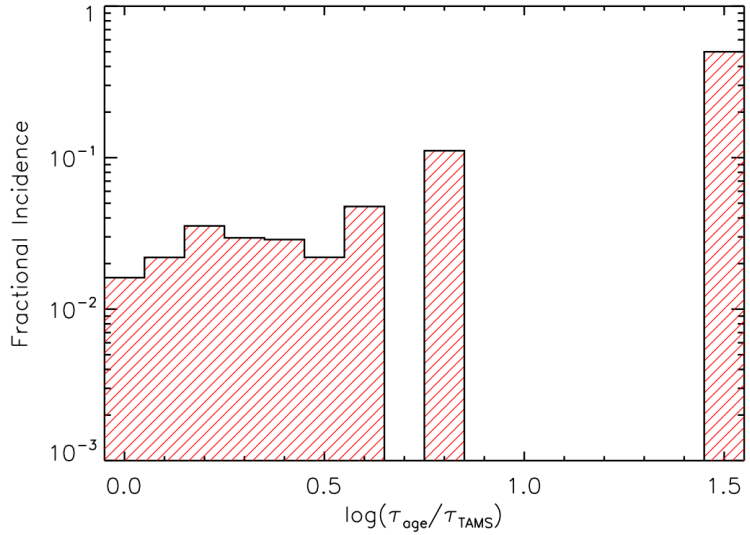
Magnetic Ap/Bp Stars



Comparing the Populations







Summary/Future Work

- Newly obtained ESPaDOnS observations have increased volume-limited sample of **precisely characterized** Ap stars from **59% to ≥ 80%**
- No detections from 20 candidate CP2 Ap stars:

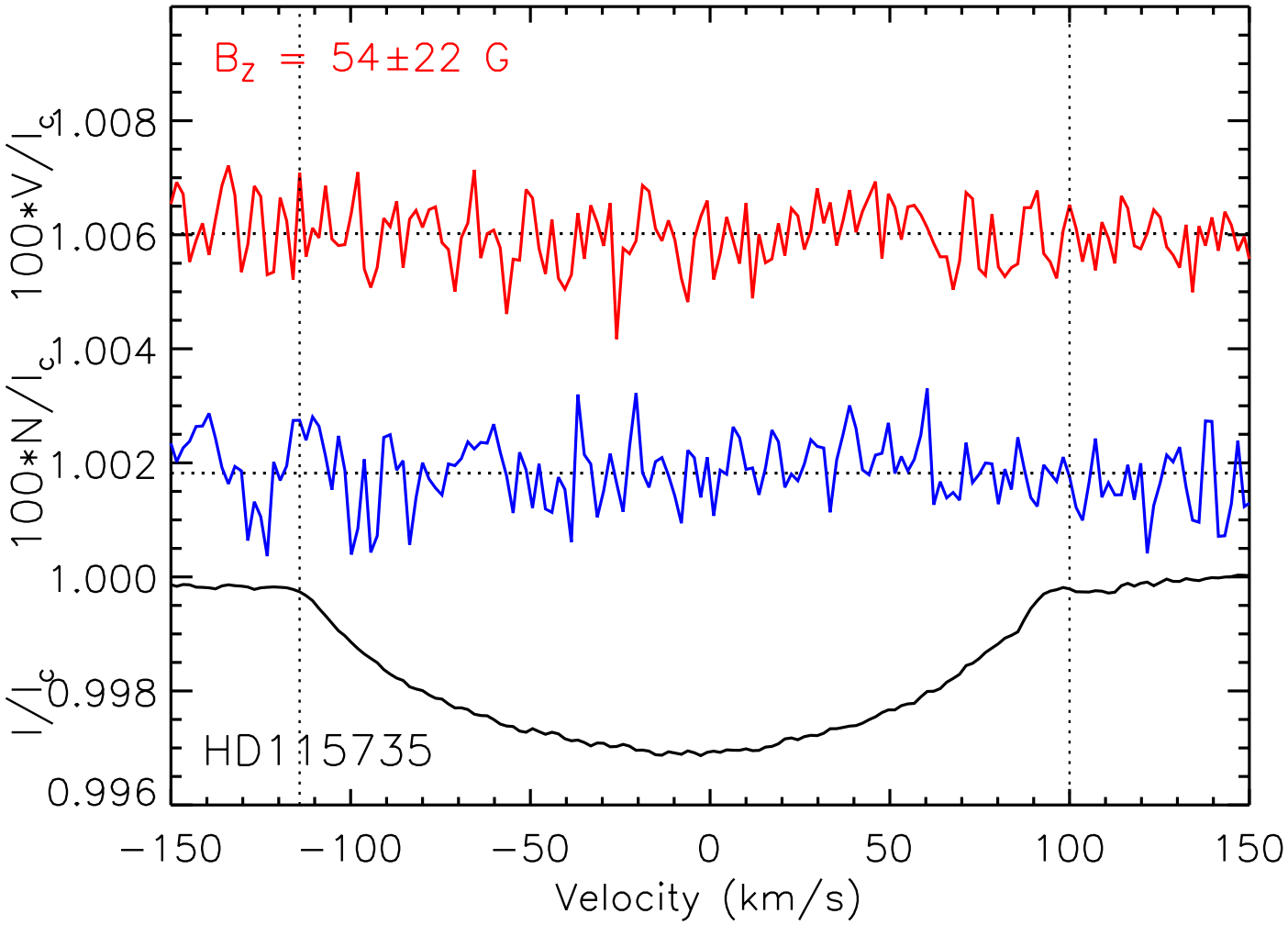
$$0.3 \leq \sigma_{\langle B_z \rangle} \leq 26\,\mathrm{G} \qquad \mathrm{median}(\sigma_{\langle B_z \rangle}) = 9\,\mathrm{G}$$

- **Future Work:** Spectral line modelling taking into account Zeeman broadening and binarity:
  - T_{eff}
  - log(g)
  - vsin*i*
  - Chemical Abundances

RMC CMR

Queen's UNIVERSITY

The Sample


B_z = 54±22 G
100*V/I$_c$
100*N/I$_c$
I/I$_c$
1.008
1.006
1.004
1.002
1.000
0.998
0.996
HD115735
−150
−100
−50
0
50
100
150
Velocity (km/s)