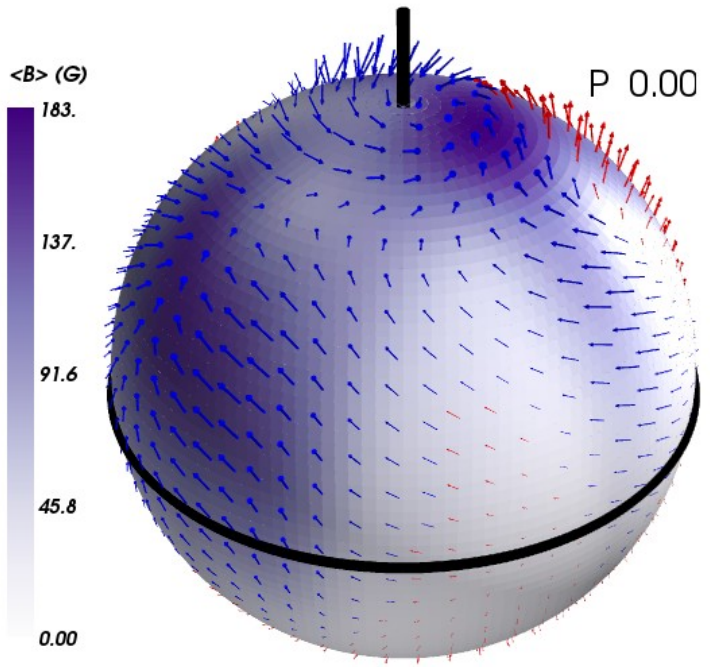
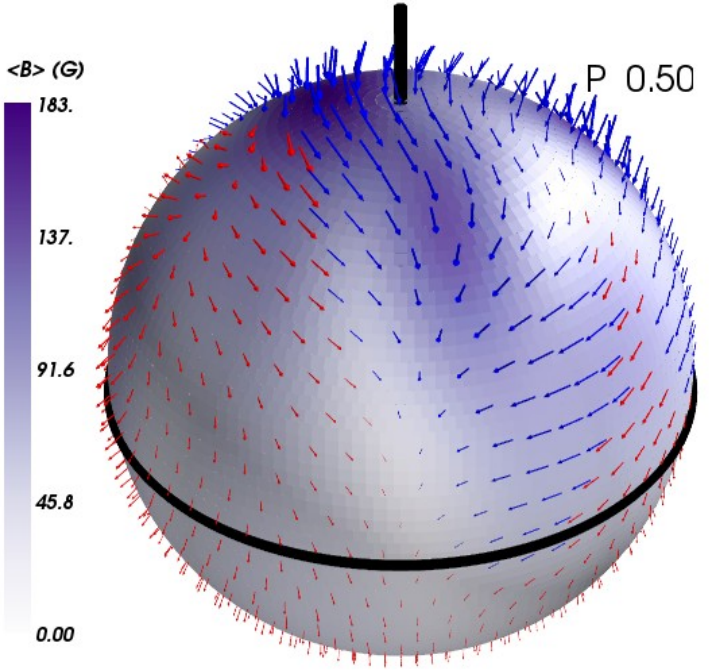
The evolution of surface magnetic fields in young solar-type stars





C. P. Folsom (IPAG),
P. Petit (IRAP), J. Bouvier (IPAG), J. Morin (Montpellier), A. Lèbre (Montpellier)

TOwards Understanding the sPIn Evolution of Stars

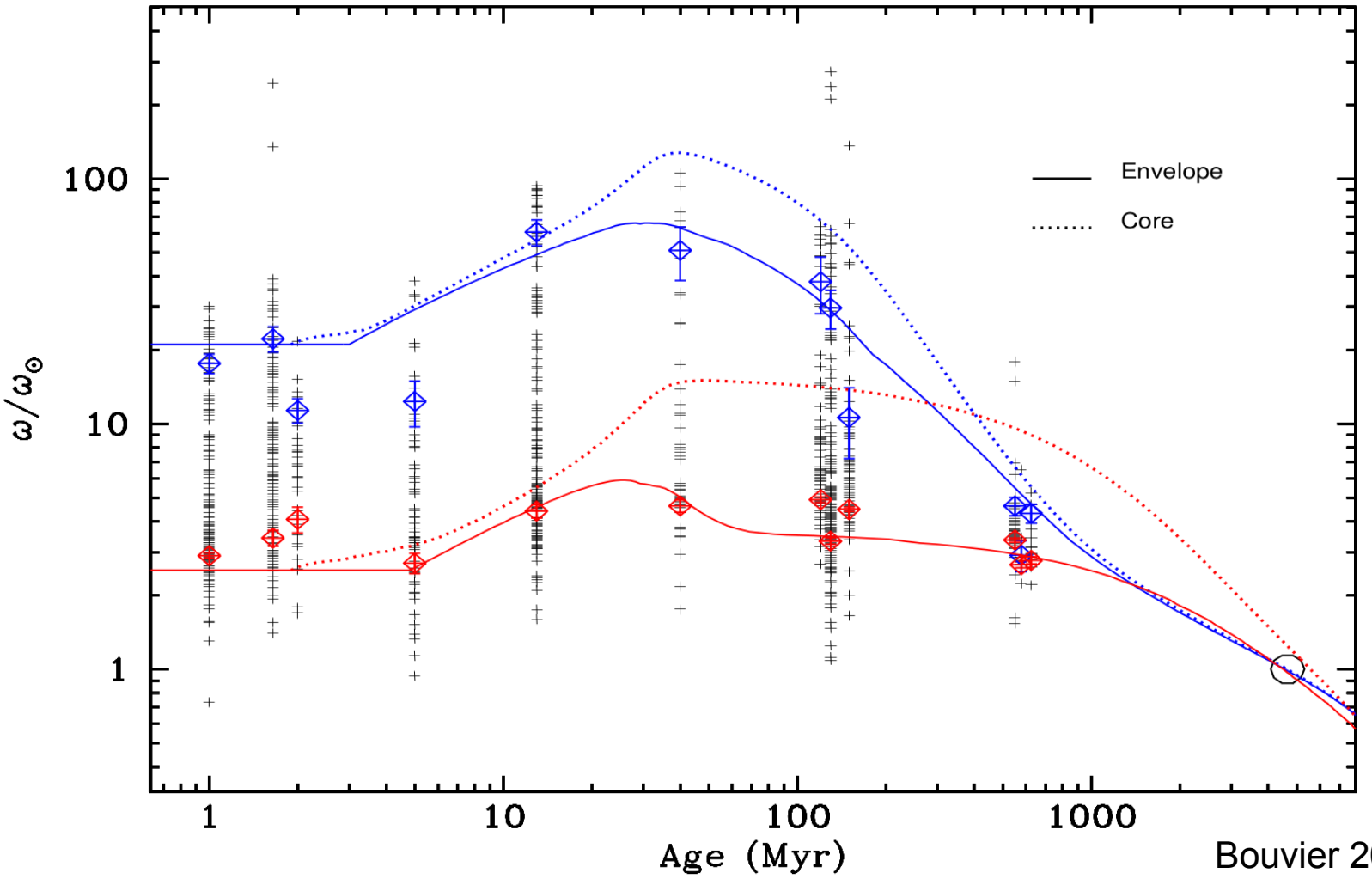
IPAG

UNIVERSITÉ Grenoble Alpes

cnrs dépasser les frontières

Motivation

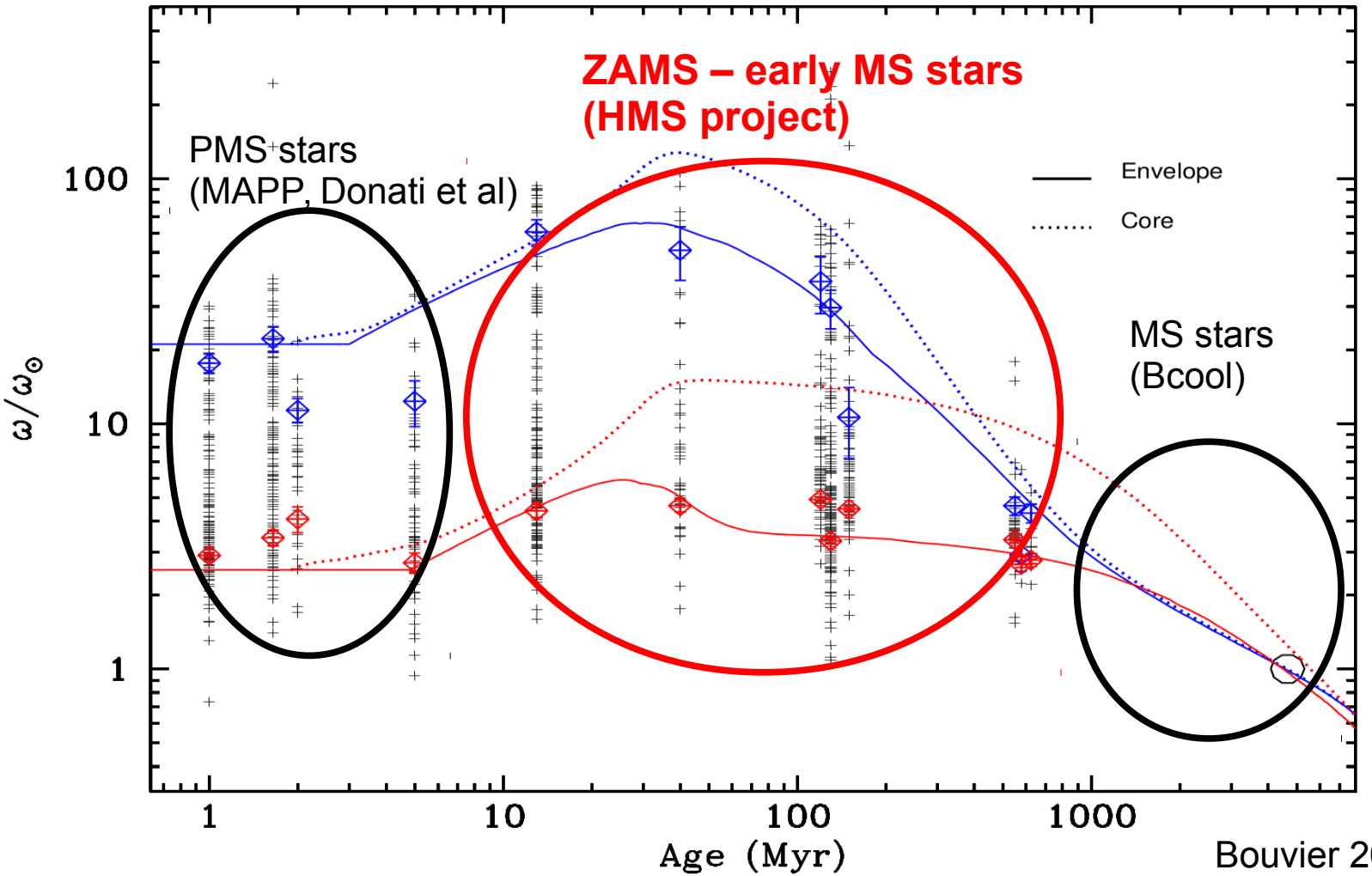
- Important evolution in rotation rates & differential rotation



Bouvier 2008
Gallet & Bouvier 2013
Gallet & Bouvier 2015

Motivation

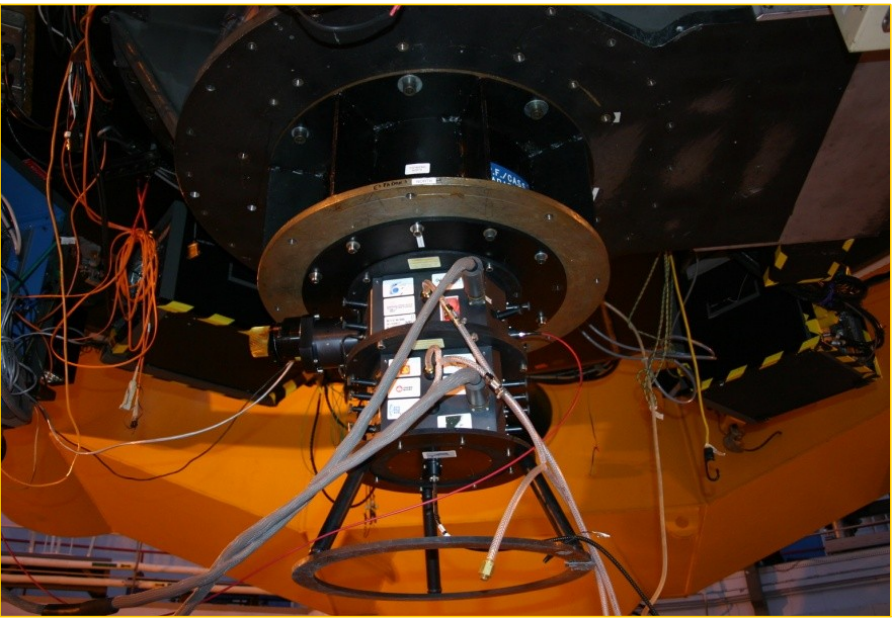
- Important evolution in rotation rates & differential rotation



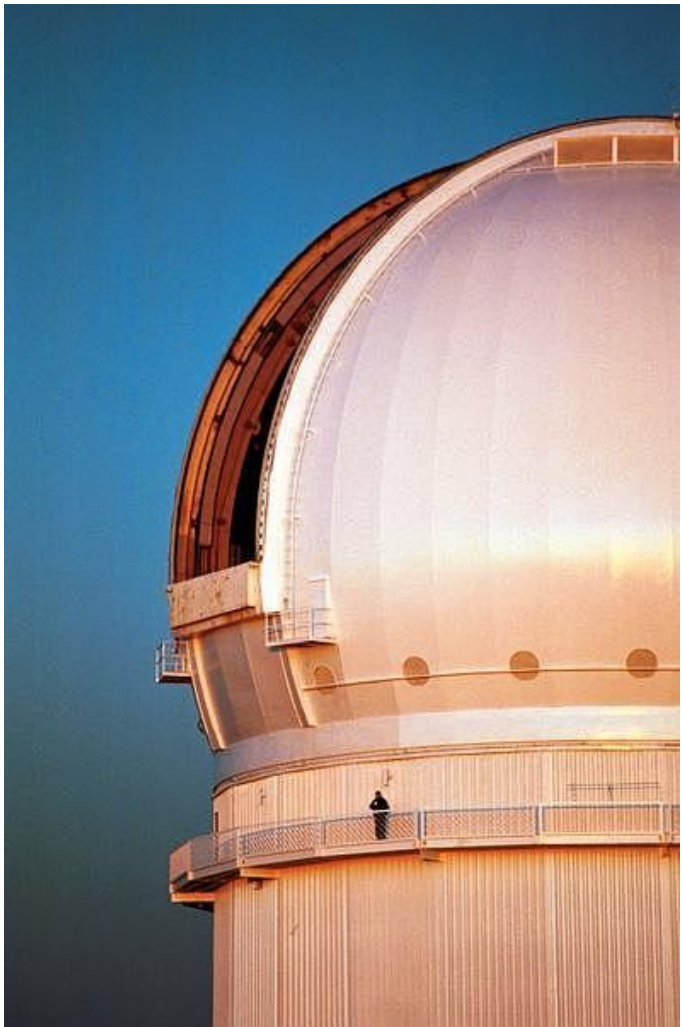
Bouvier 2008
Gallet & Bouvier 2013
Gallet & Bouvier 2015

Observations

- High resolution spectropolarimetry
- CFHT + ESPaDOnS
- TBL + Narval
- ESO 3.6m + HARPSpol
- R = 65000, covering 3700-10500 Å

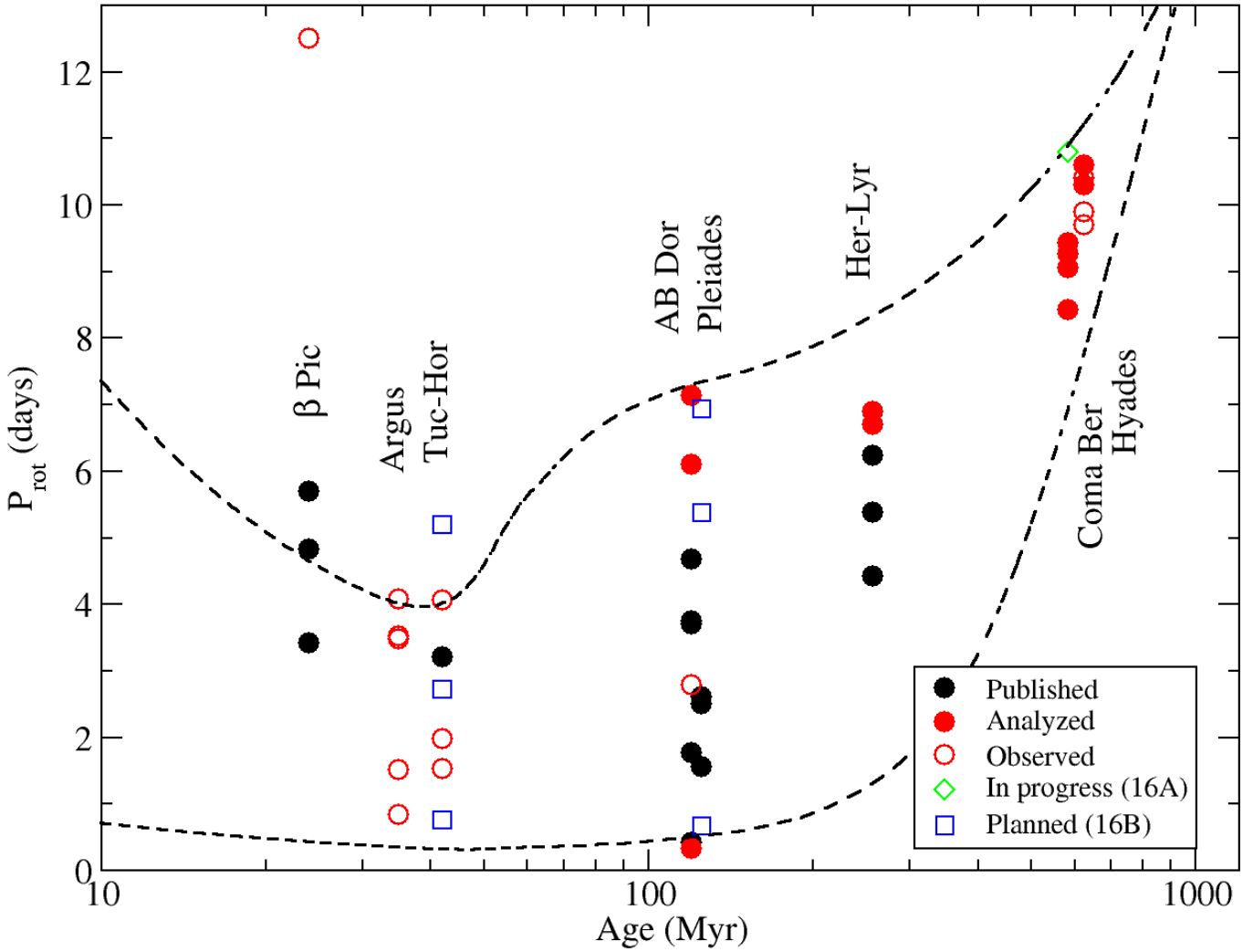


(Ongoing Large Program at CFHT
PI: P. Petit)



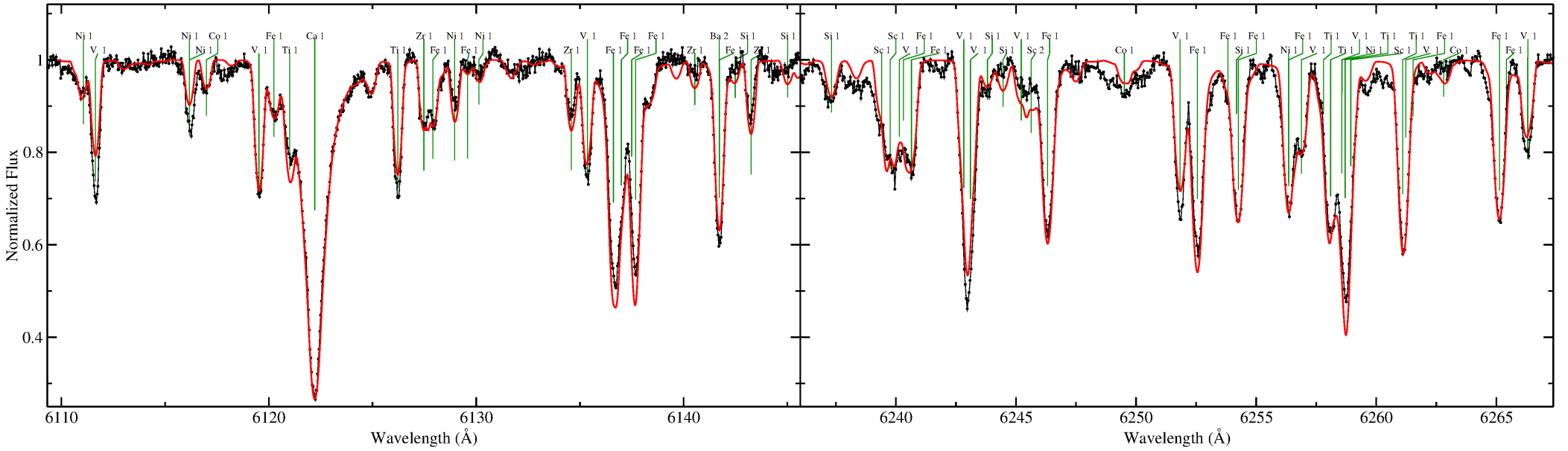
Observations

- Currently 39 observed / 46 total targets
- CFHT LP (2015A – 2016B): 215.8 hrs over 4 semesters



Analysis: Atmospheric Parameters

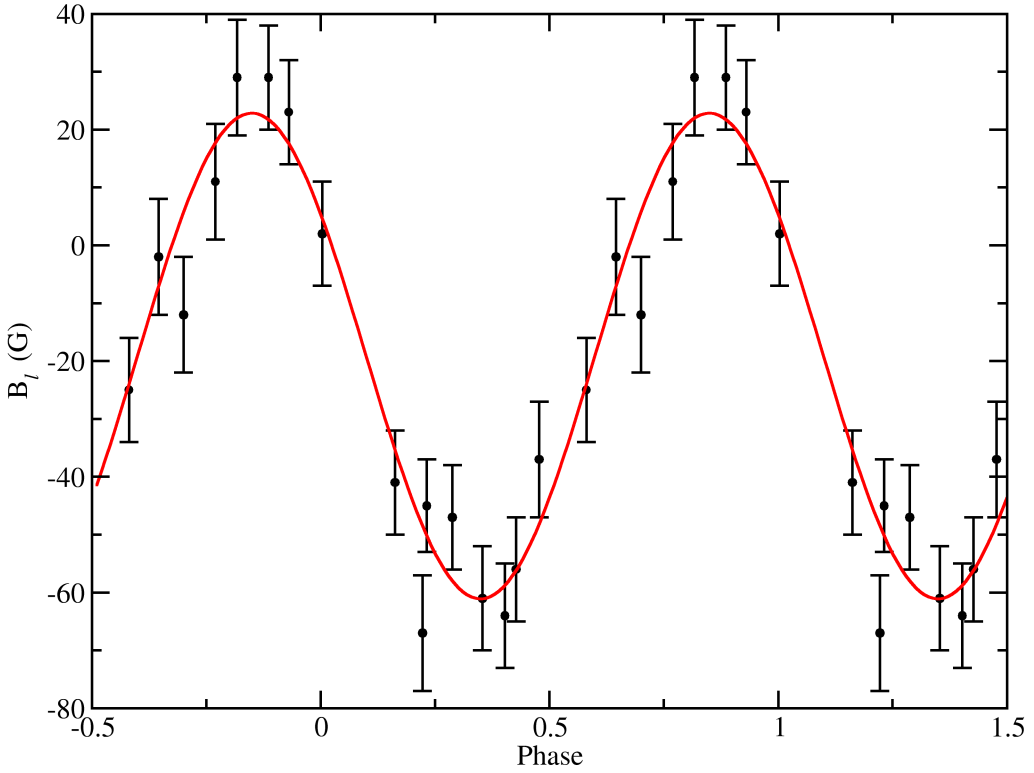
- Spectroscopic fitting
  - $T_{\rm eff}$, log$g$, $v$sin$i$, microturbulence, V_r
  - Li abundances, metallicity
- Synthetic spectra
  - Fit observations by χ^2
- Analysis by A. Lèbre

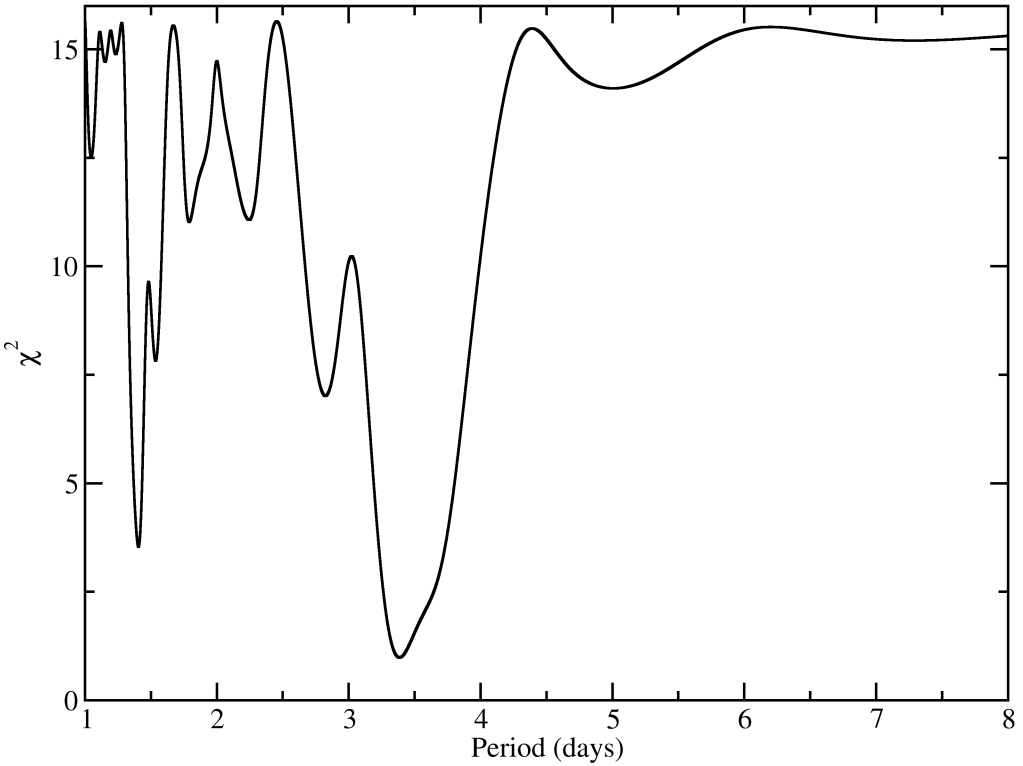


Analysis: Rotation Periods

- Estimates from photometric periods
- Verify (and refine) spectroscopically:
  - B_l, V_r, LSD, ZDI

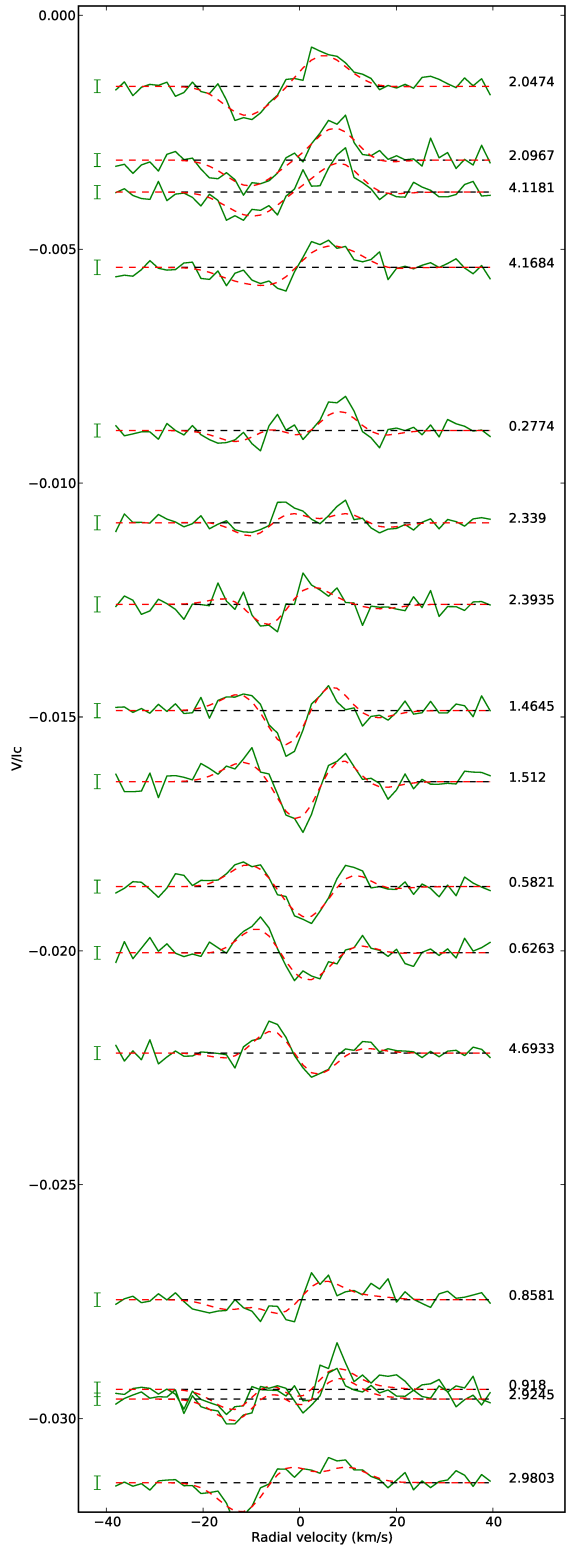
TYC 6349-200-1: B_l

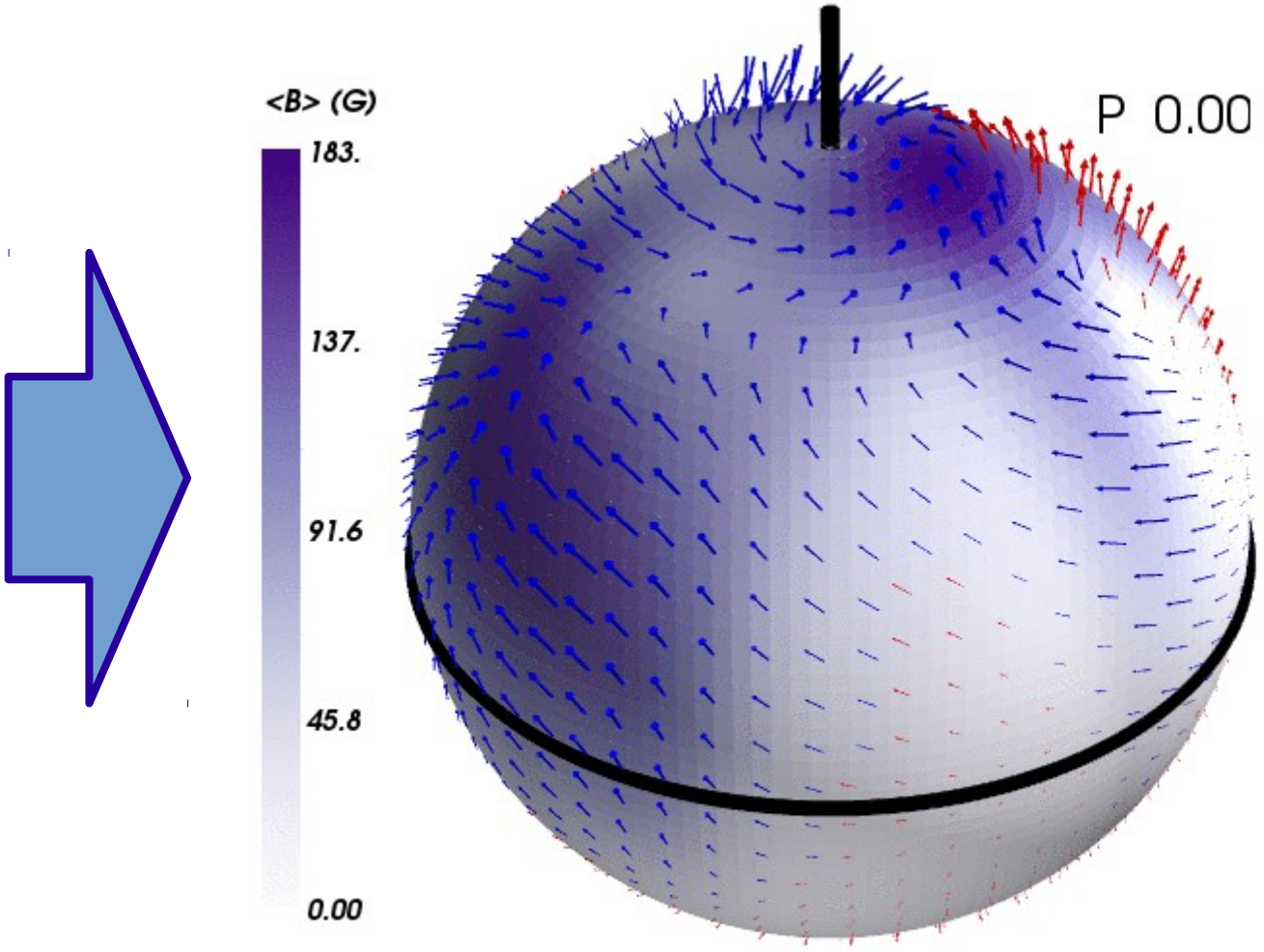


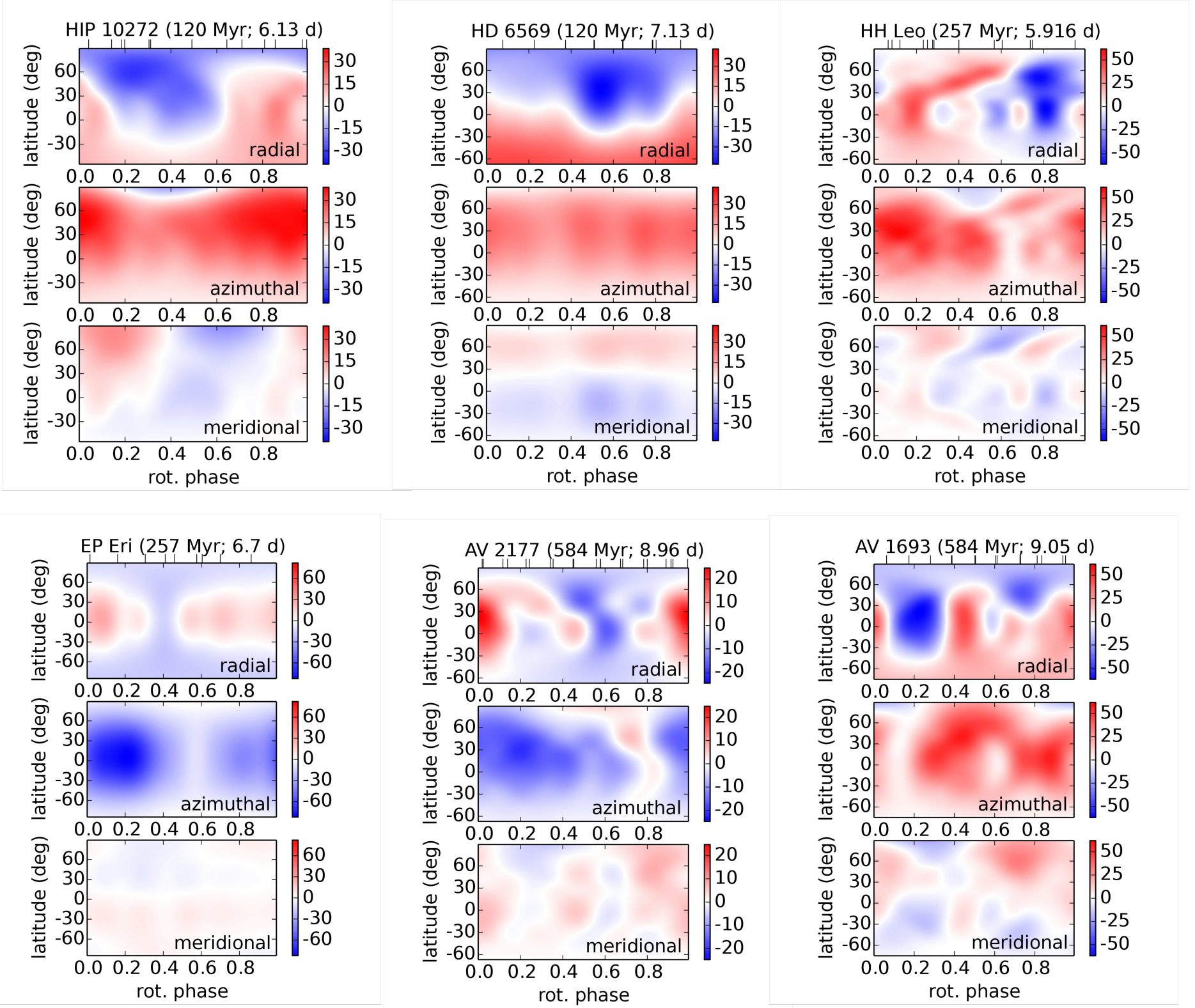


Analysis: ZDI

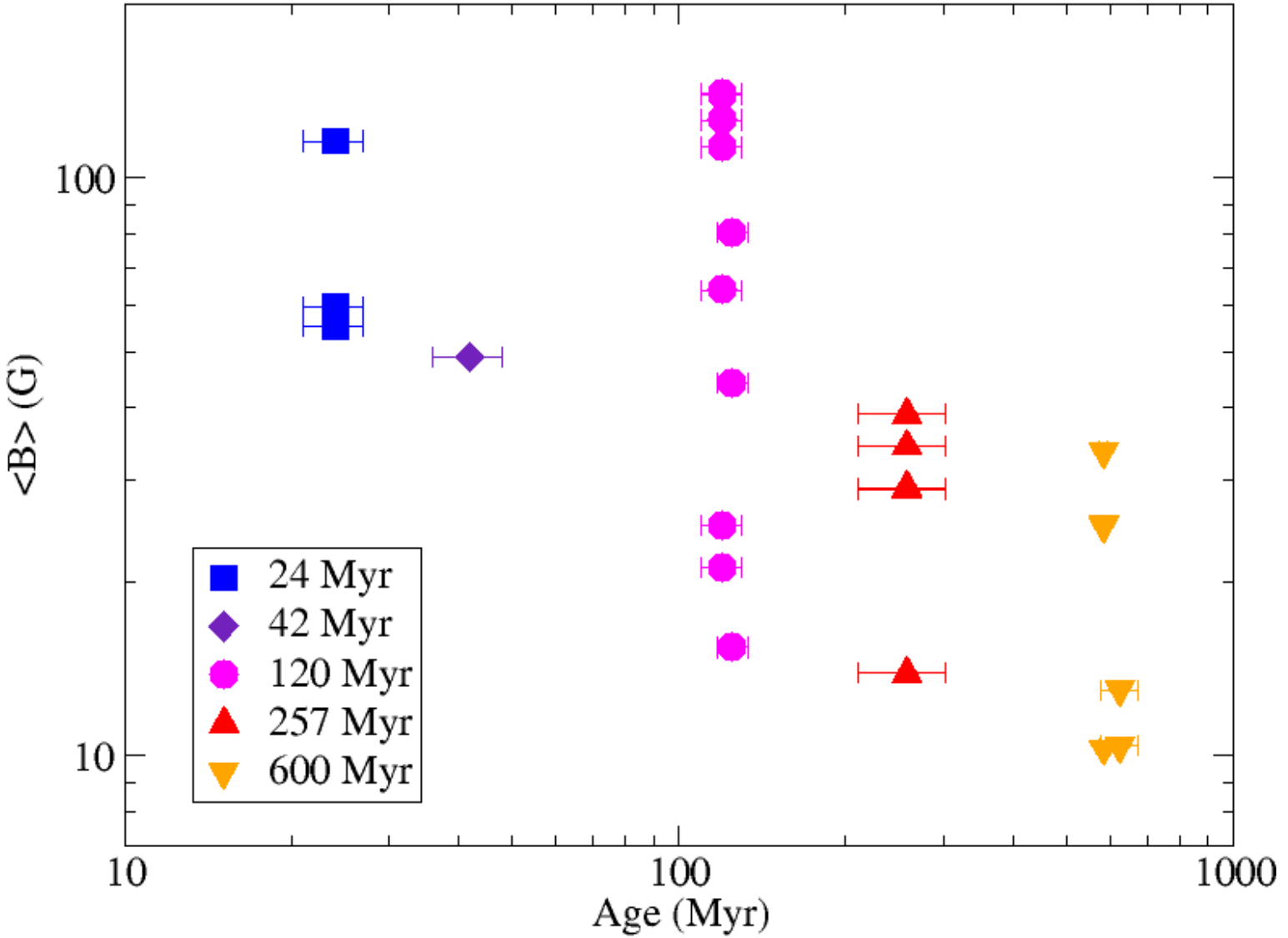
- Reconstruct magnetic strength & geometry
- Input: period, *v*sin*i*, *i*, V_r, (LSD mask)






HIP 10272 (120 Myr; 6.13 d)
HD 6569 (120 Myr; 7.13 d)
HH Leo (257 Myr; 5.916 d)
EP Eri (257 Myr; 6.7 d)
AV 2177 (584 Myr; 8.96 d)
AV 1693 (584 Myr; 9.05 d)
latitude (deg)
rot. phase
radial
azimuthal
meridional

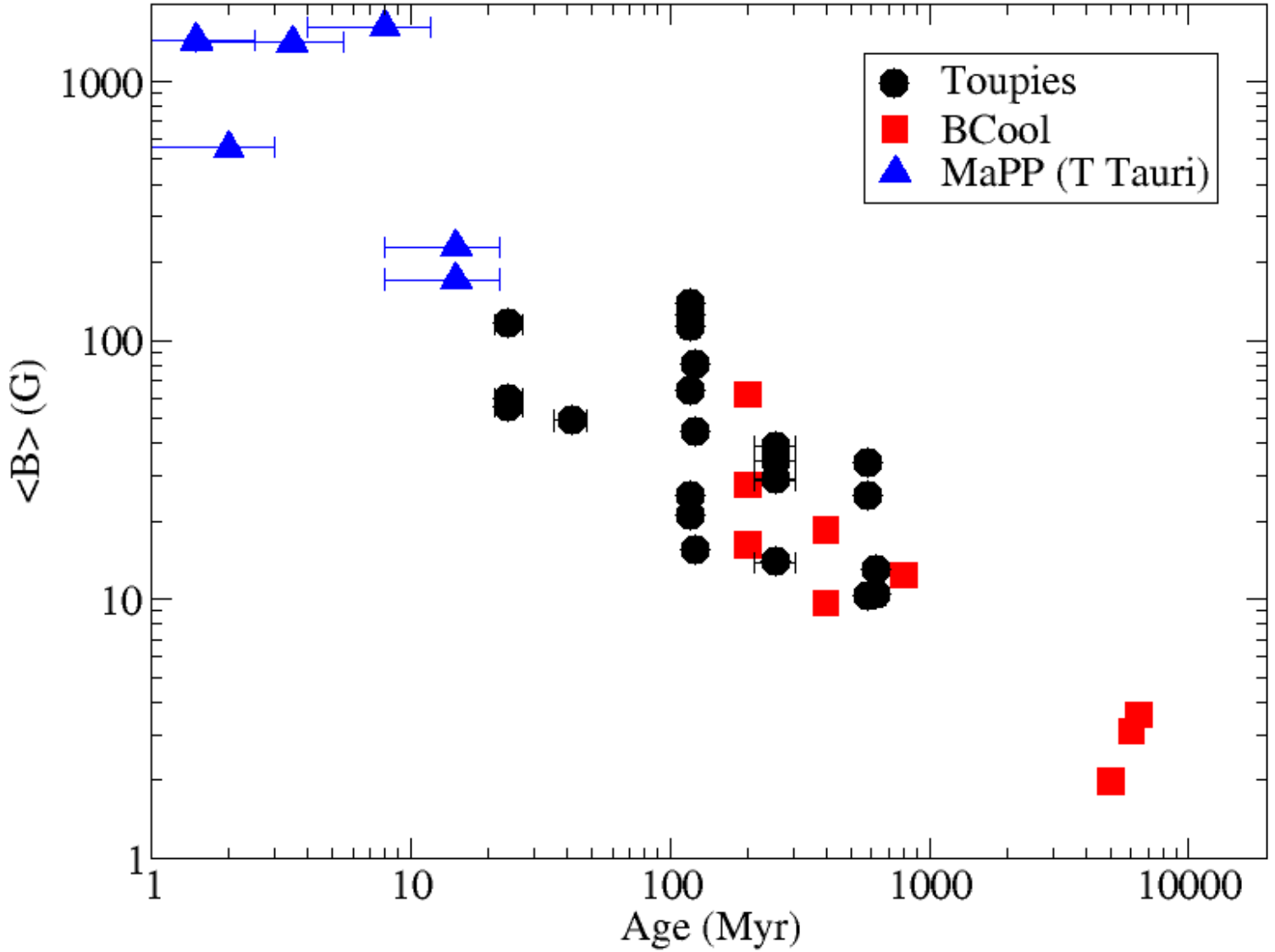
Results: Trends



Mass range: 1.0 – 0.7 M_{sun}

(see also Vidotto et al. 2014)

Results: Trends



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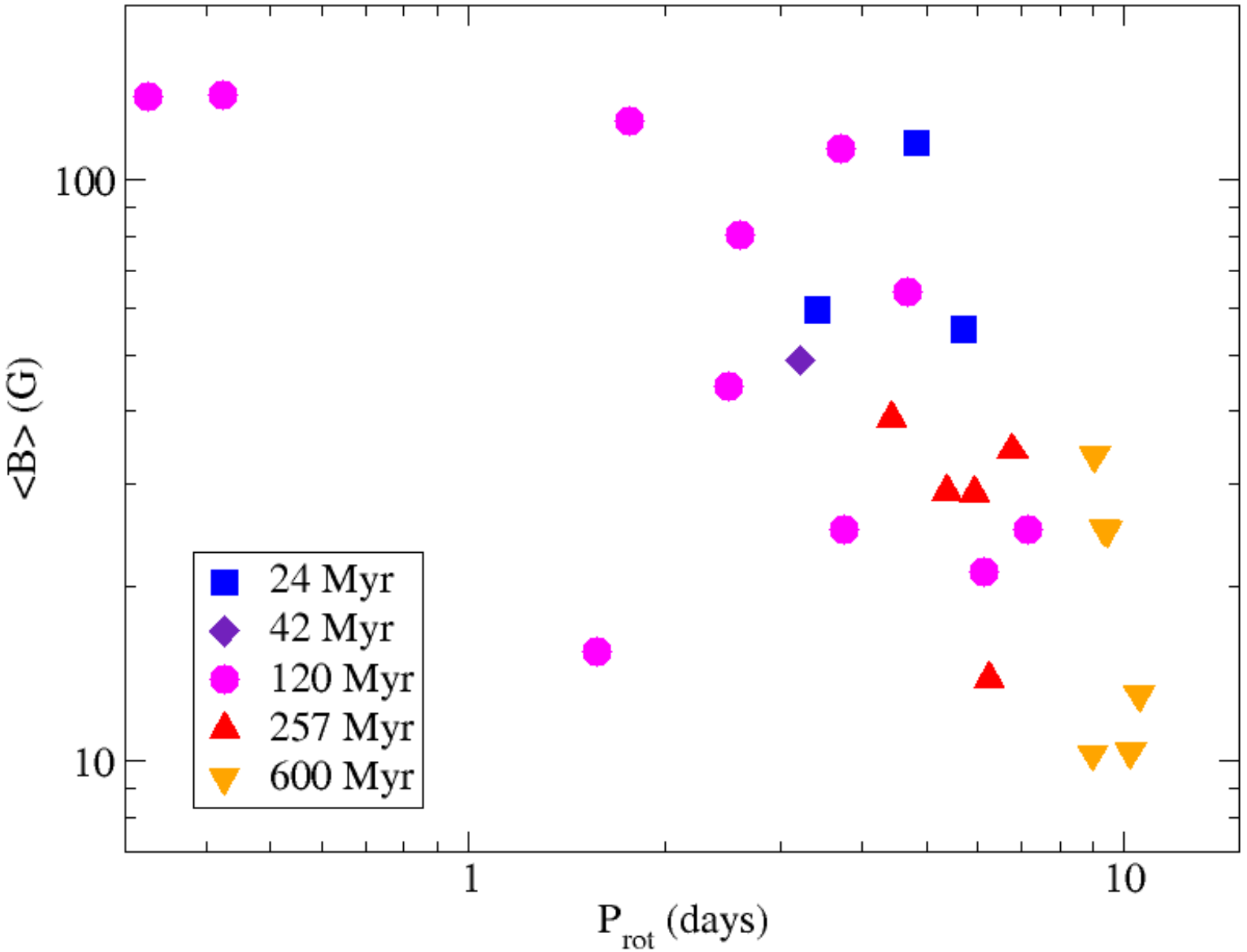
Results: Trends



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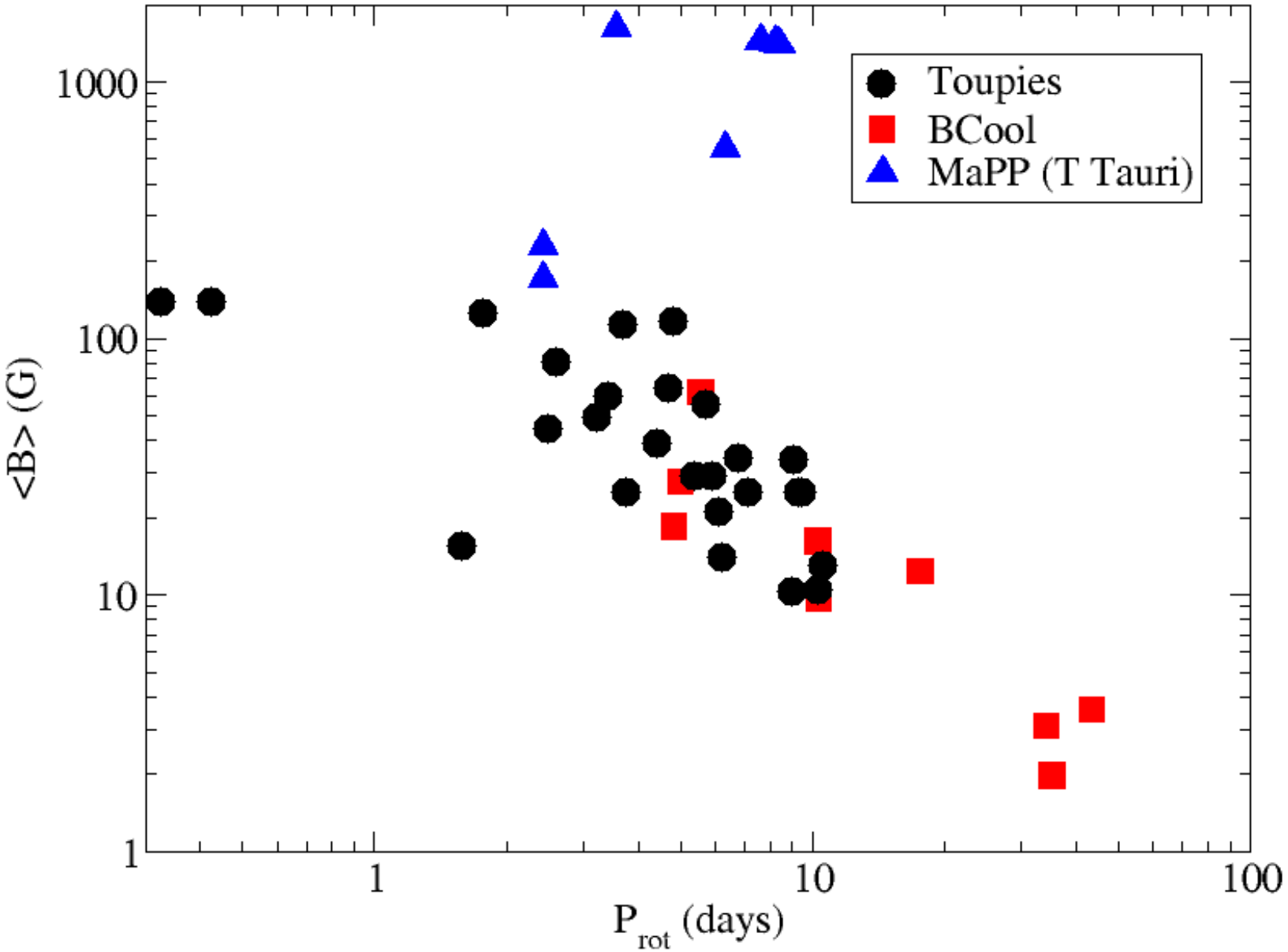

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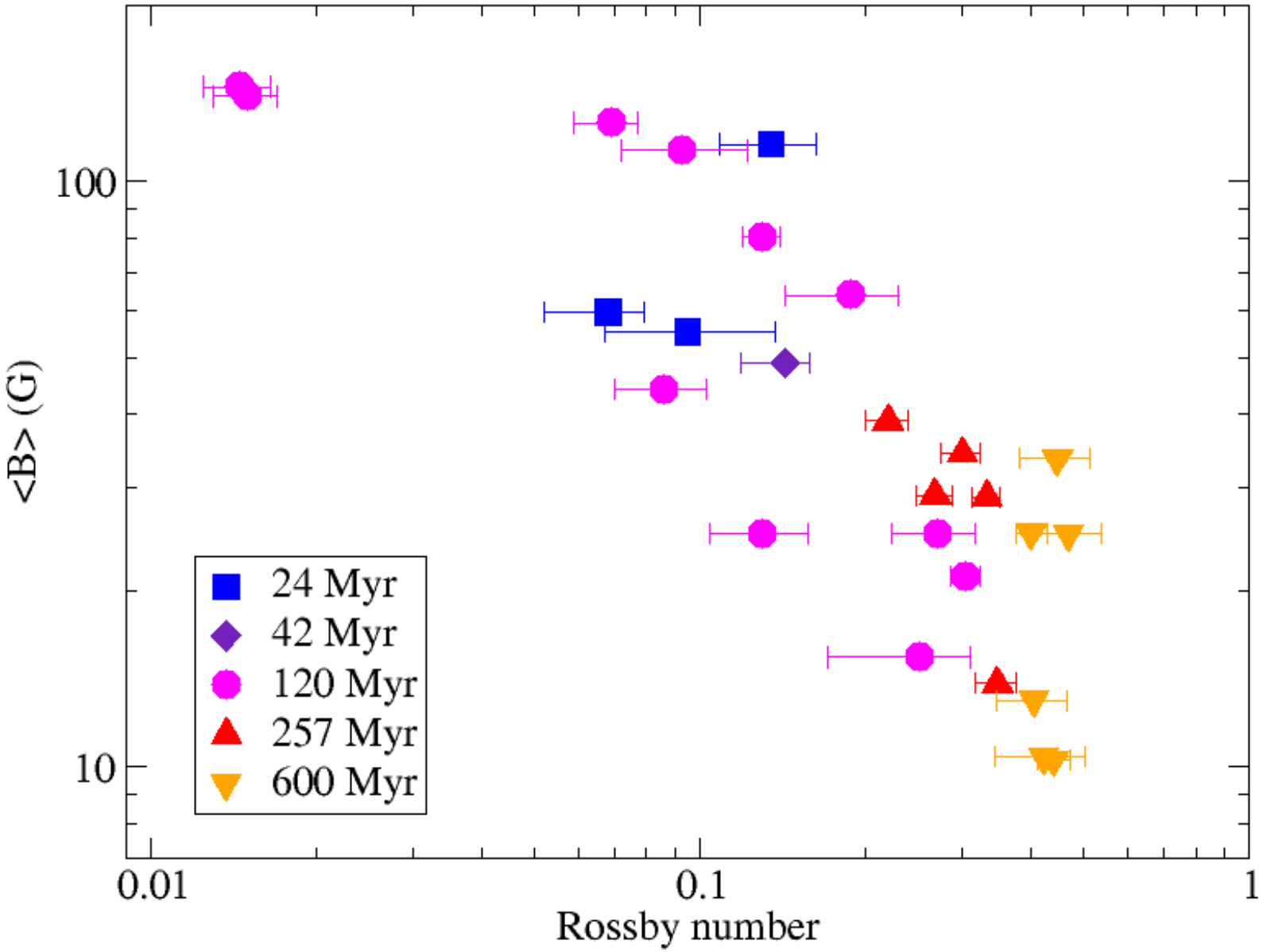
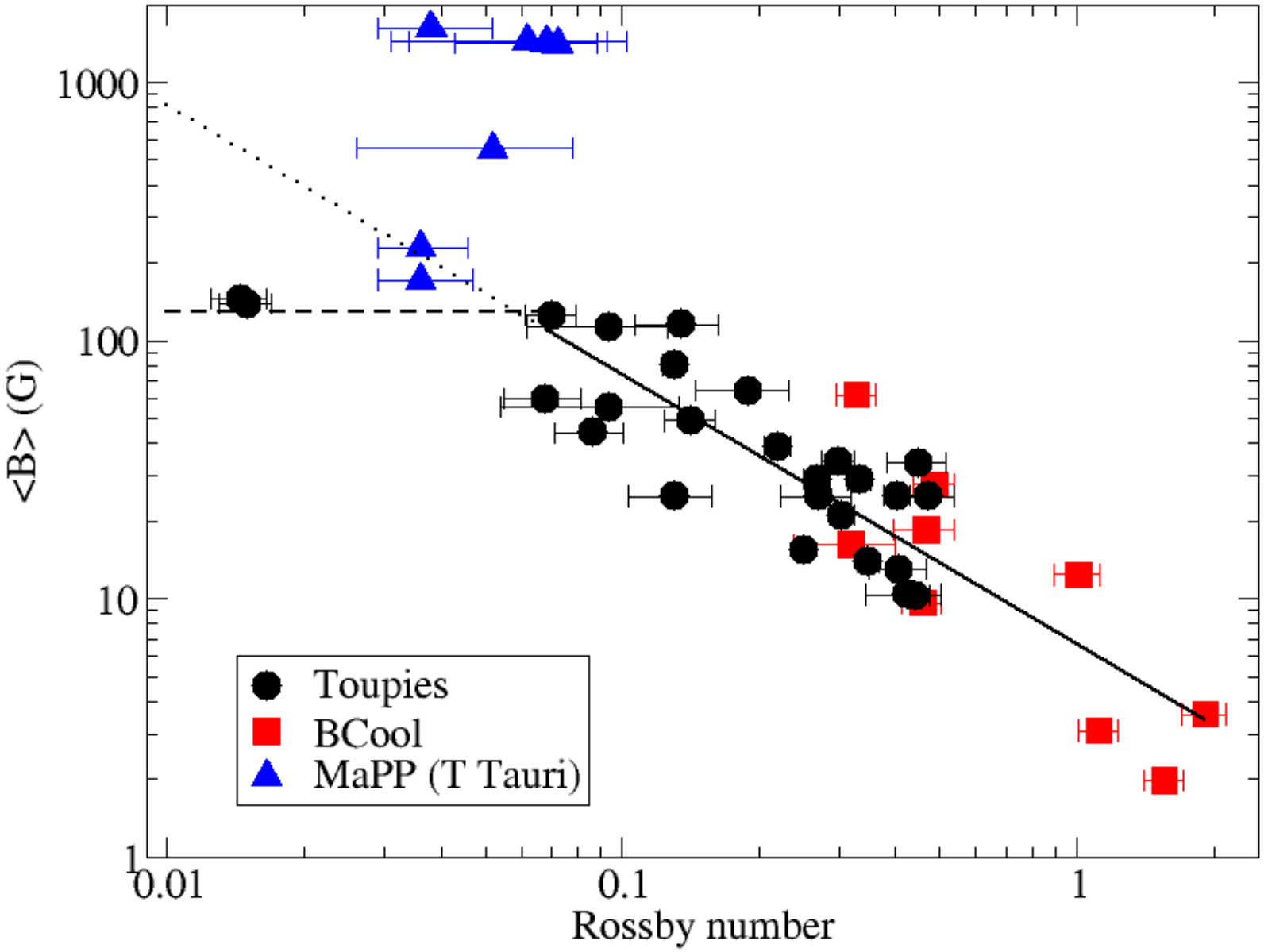


Rossby Number = P_{rot} / τ_c (τ_c from Amard et al. in prep)

Results: Trends



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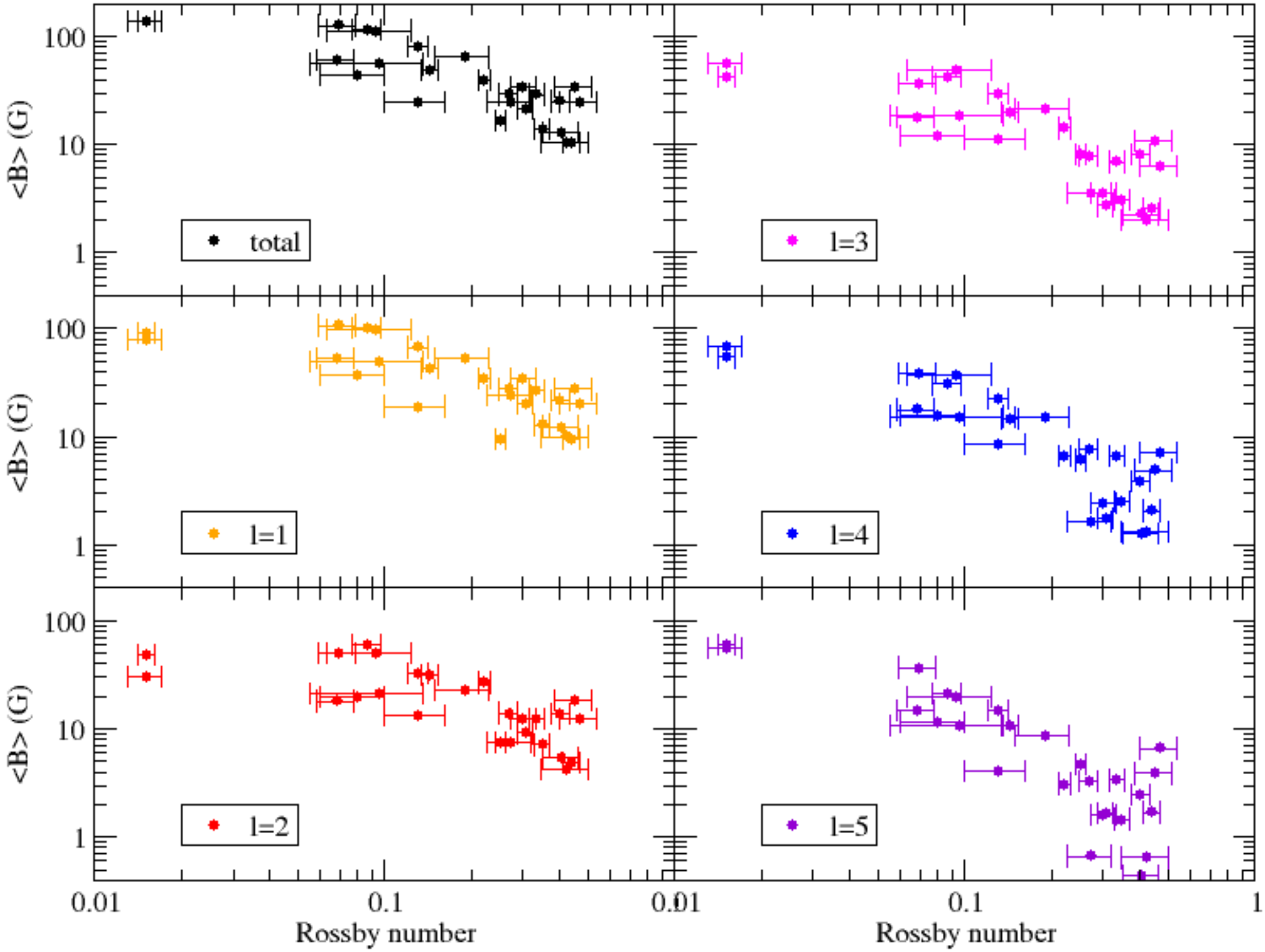
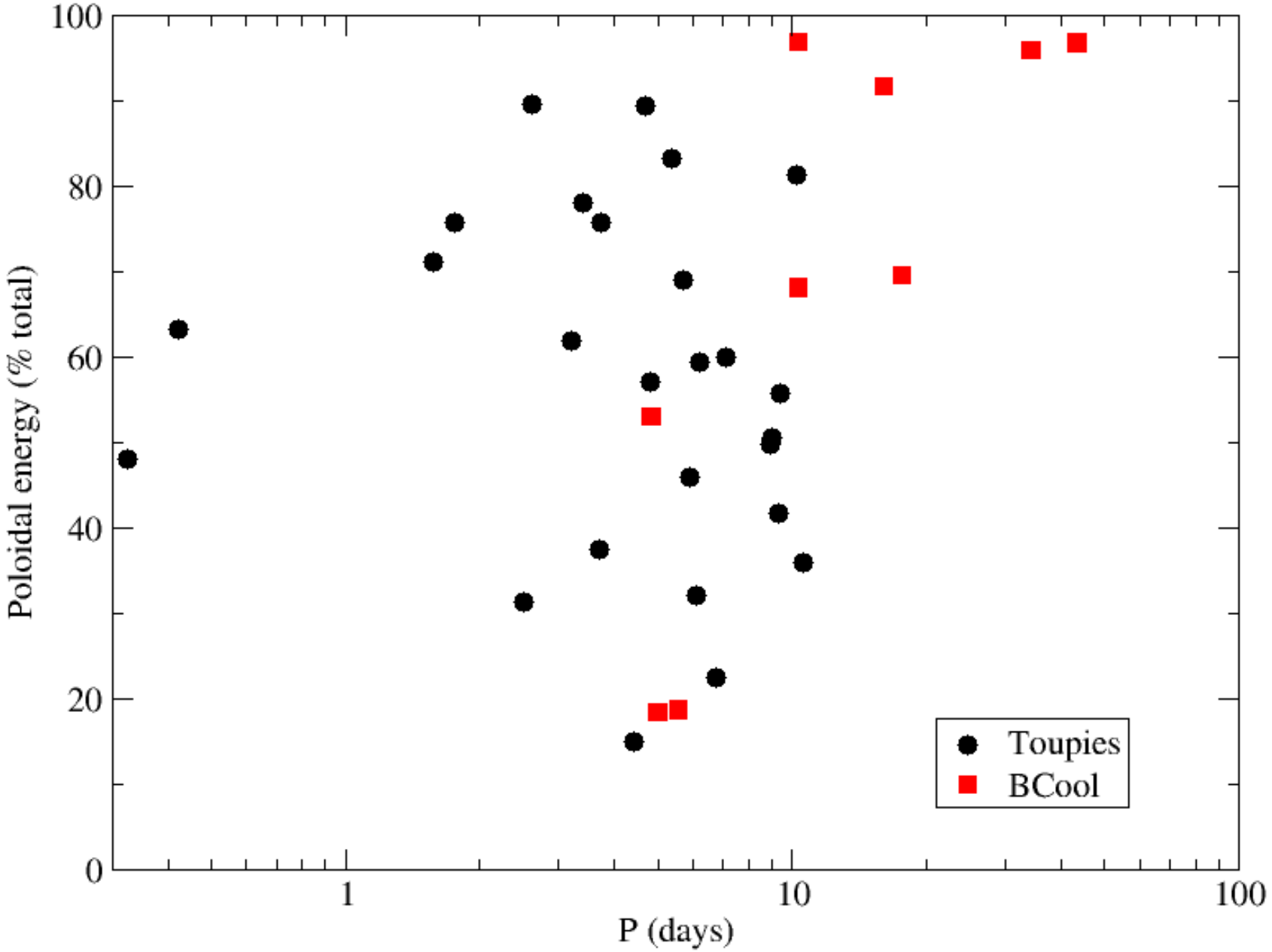
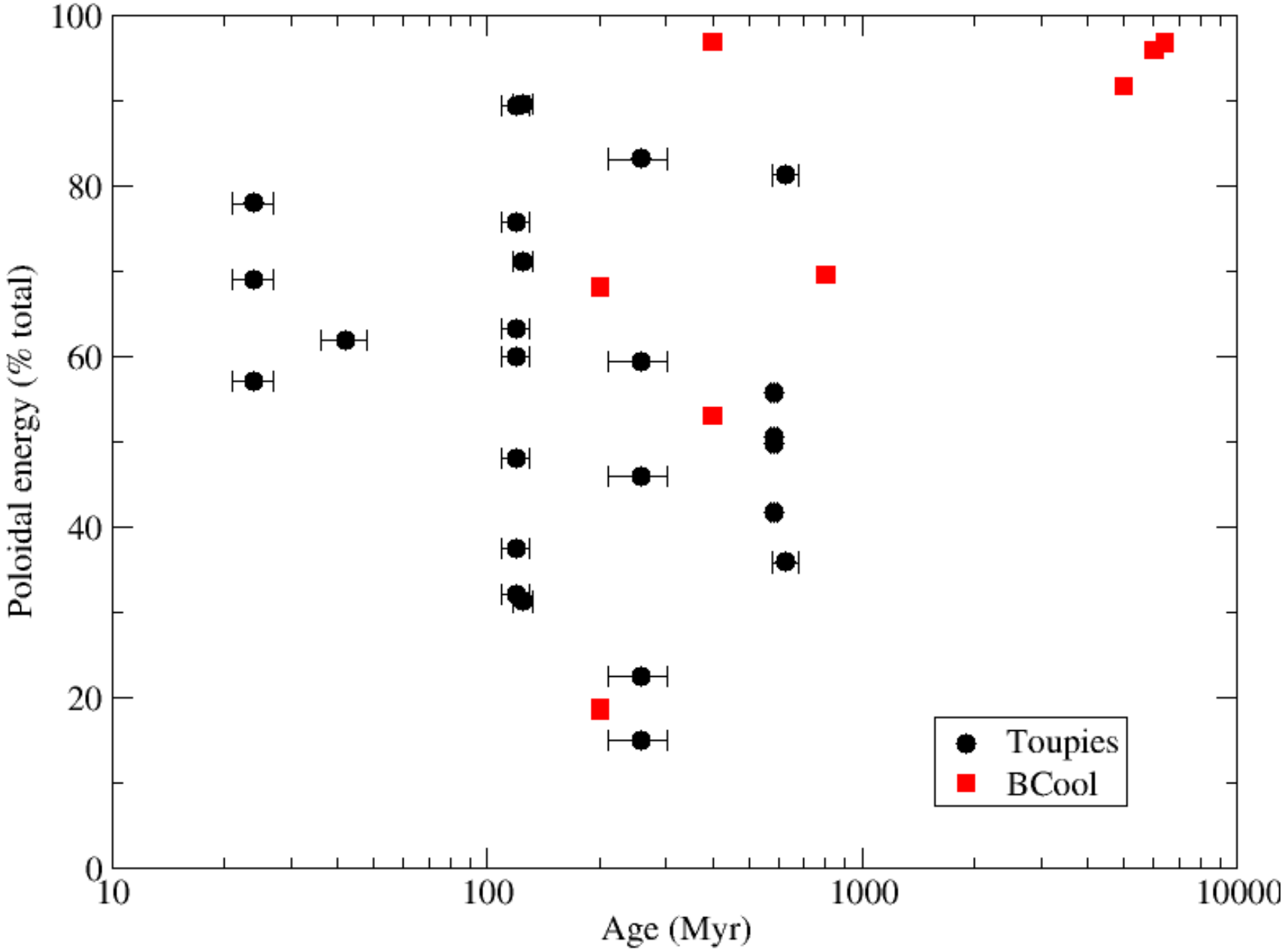

total
l=1
l=2
l=3
l=4
l=5
<B> (G)
100
10
1
0.01
0.1
1
Rossby number

Geometry



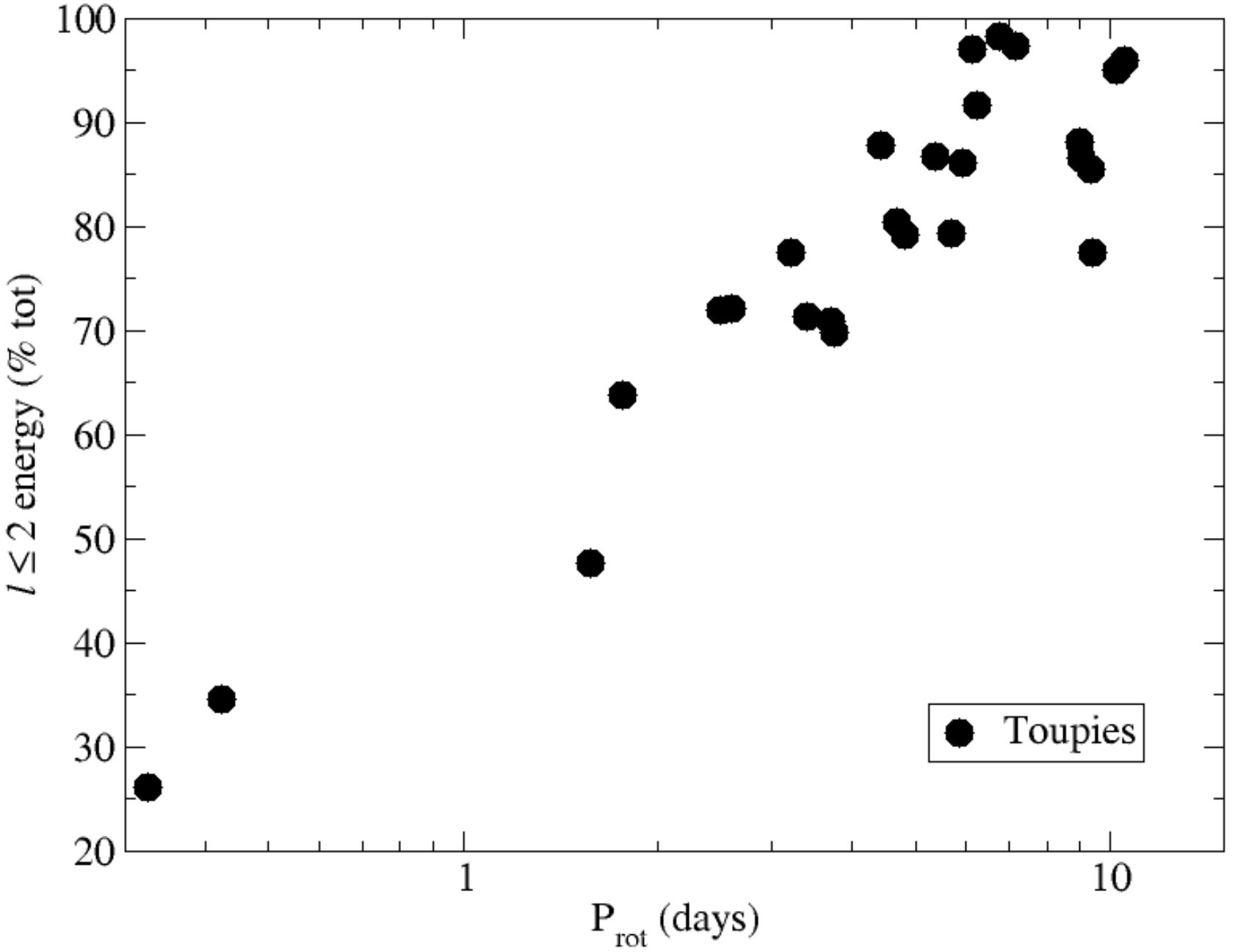
See also: Petit et al. (2008), See et al. (in prep.), Petit et al. (in prep: BCool)

Geometry

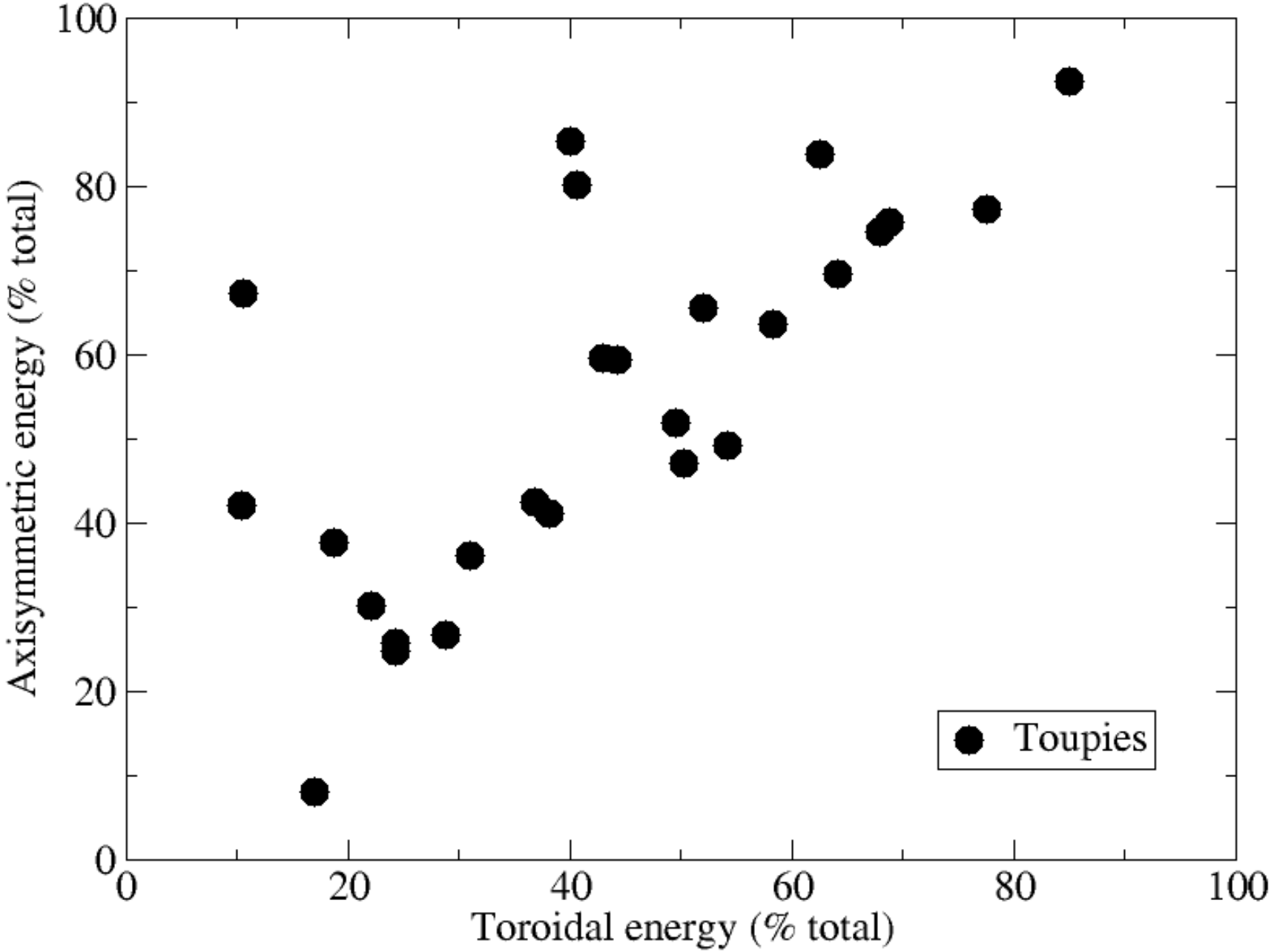


See also: Petit et al. (2008), See et al. (in prep.), Petit et al. (in prep: BCool)

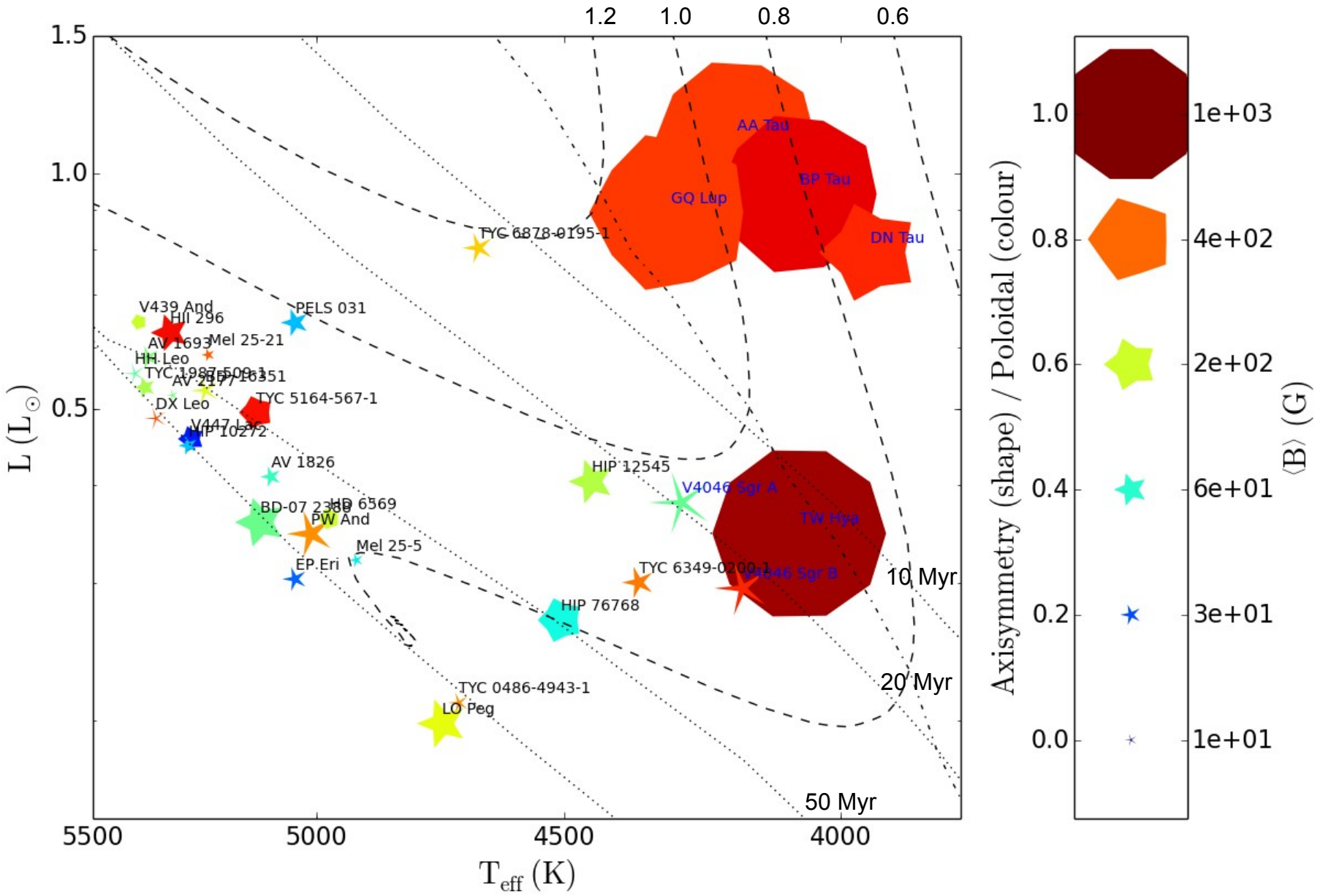
Geometry


100
90
80
70
60
50
40
30
20
1
10
$l \leq 2$ energy (% tot)
P_{rot} (days)
Toupies

as in See et al. 2015



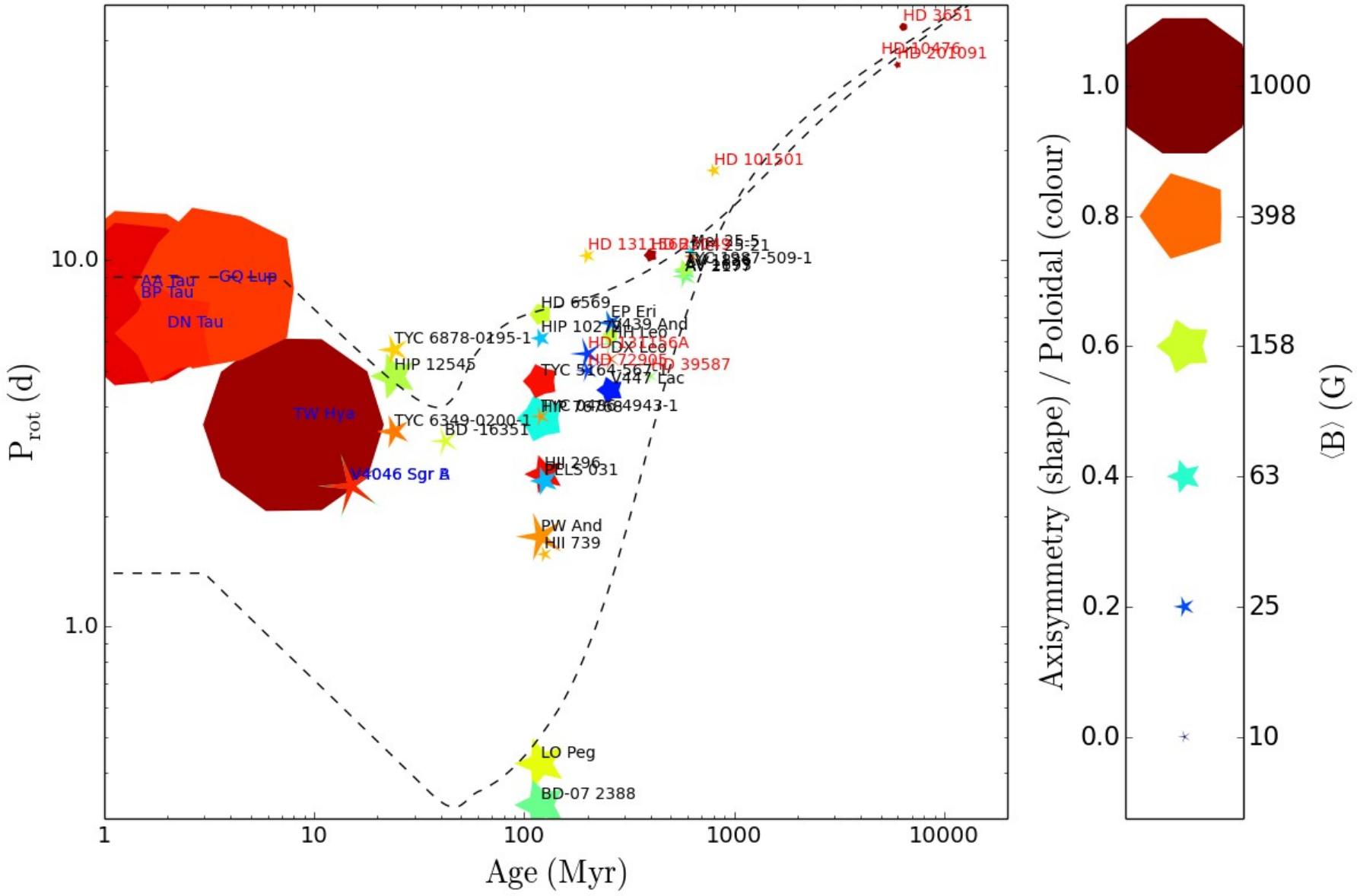
Results: Trends



Data: HMS (black) & MAPP (blue; Donati et al.)

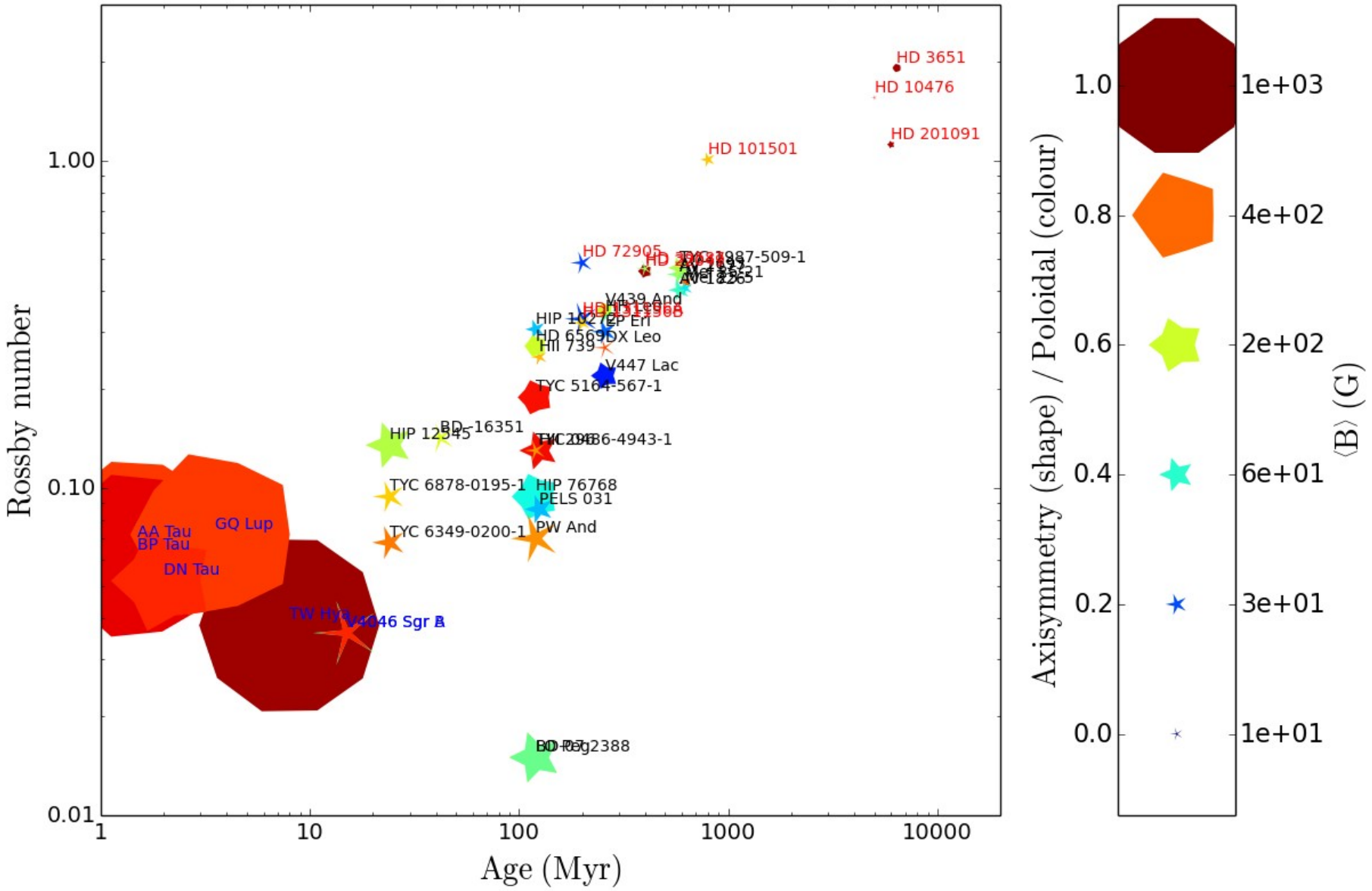
Evolutionary tracks: Amard et al. (in prep)

Results: Trends



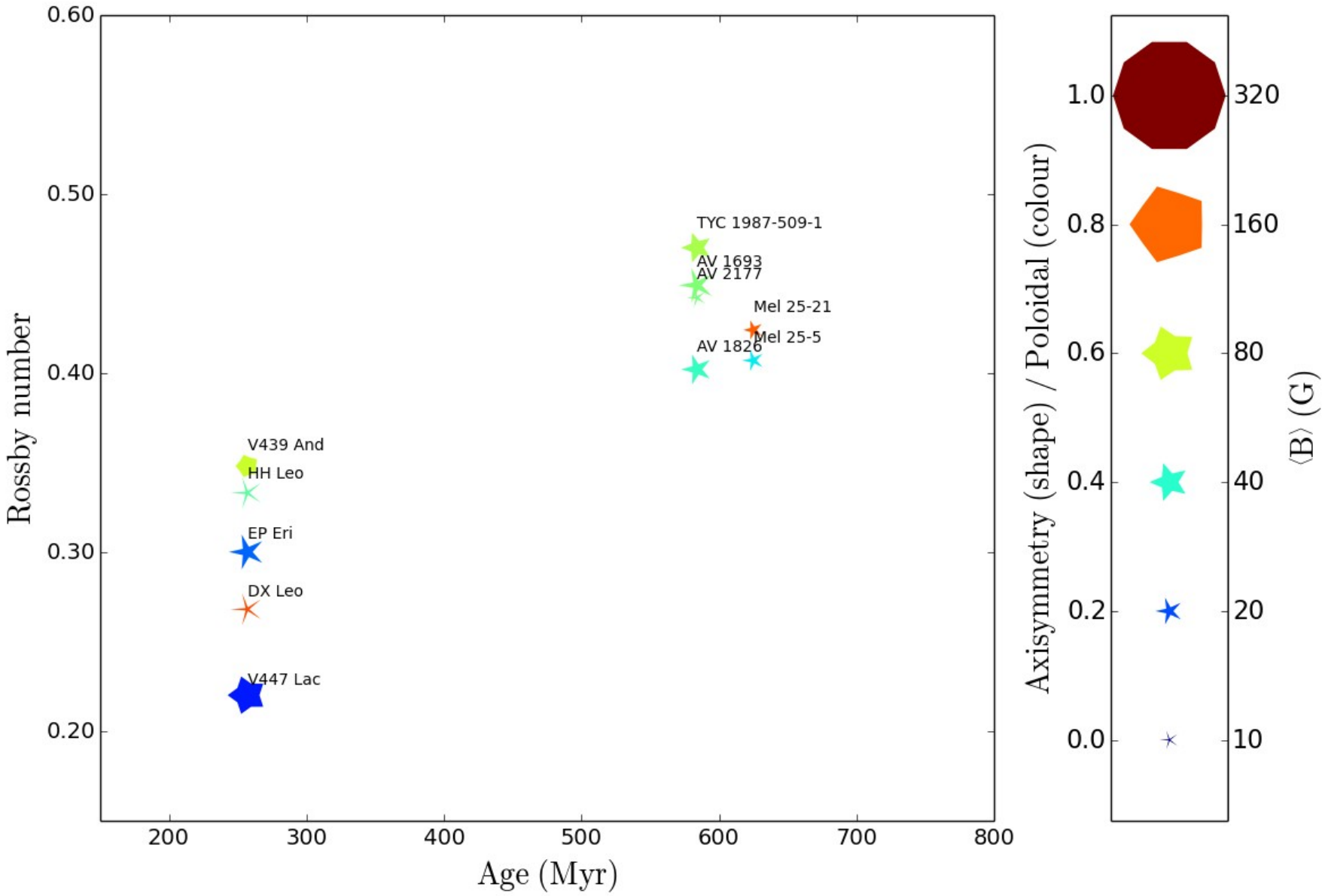
Data: HMS (black), MAPP (blue; Donati et al.) & BCool (red)

Results: Trends



Data: HMS (black), MAPP (blue; Donati et al.) & BCool (red)

Results: Trends



Data: HMS (black)

Conclusions

- Evolution towards weaker less organized fields with age
  - PMS evolution due to structural properties
  - ZAMS & MS evolution due to rotation
- Good correlation between <B> and Rossby number
  - except for T Tauri stars
  - hint of saturation below R_o of 0.1
- ZAMS: large dispersion
  - dynamo saturation?
  - radial differential rotation?

- Currently extending sample
  - ongoing Large Program at CFHT (PI Pascal Petit)