Magnetic Fields of Weak-Line T Tauri Stars

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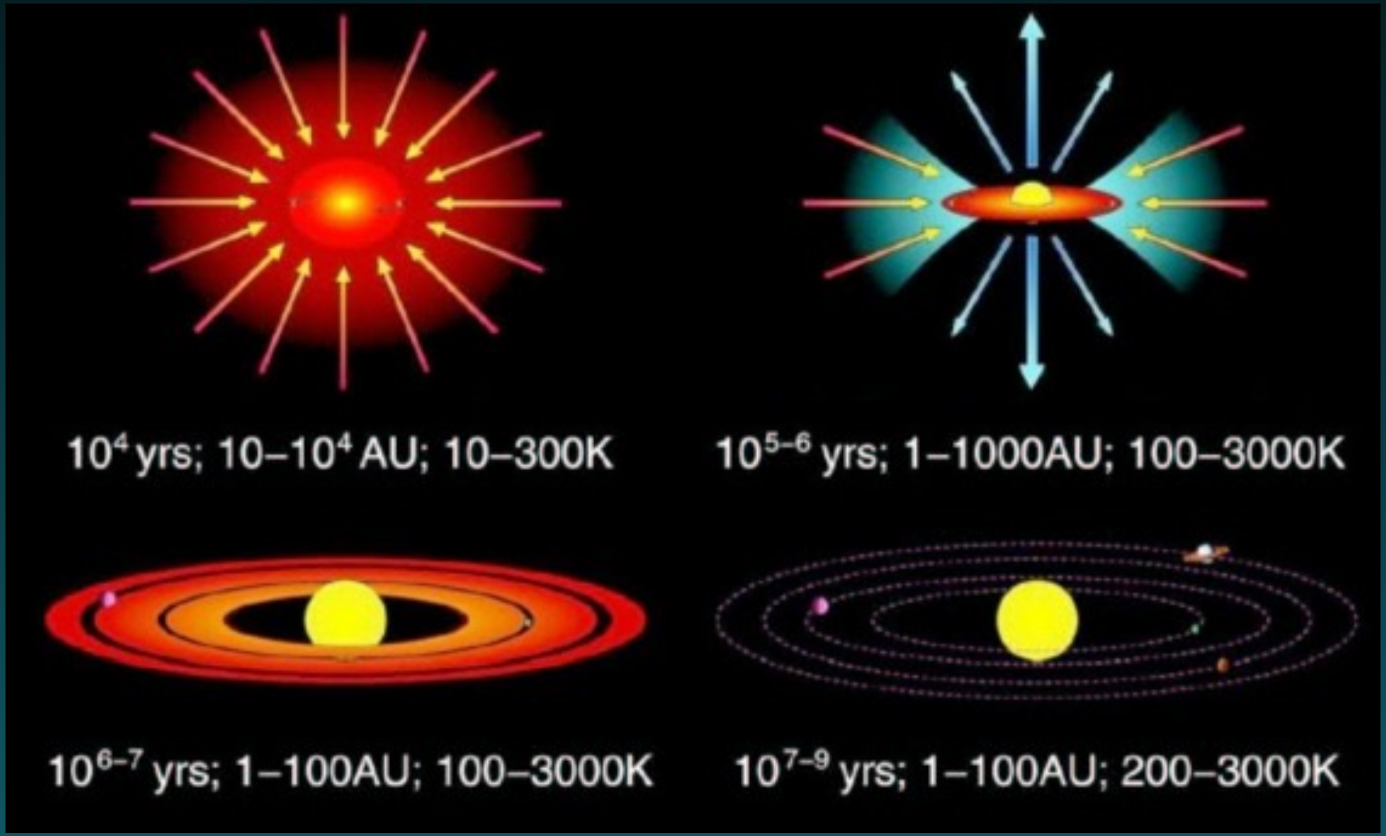
Early stellar evolution

- 1-10 Myr low-mass PMS stars
  - Emerged from dust cocoons
  - Contracting towards MS

- Classical T-Tauri stars (cTTSs)
  - surrounded by massive (presumably planet-forming) accretion disc

- Weak-line T-Tauri stars (wTTSs)
  - Disc mostly dissipated

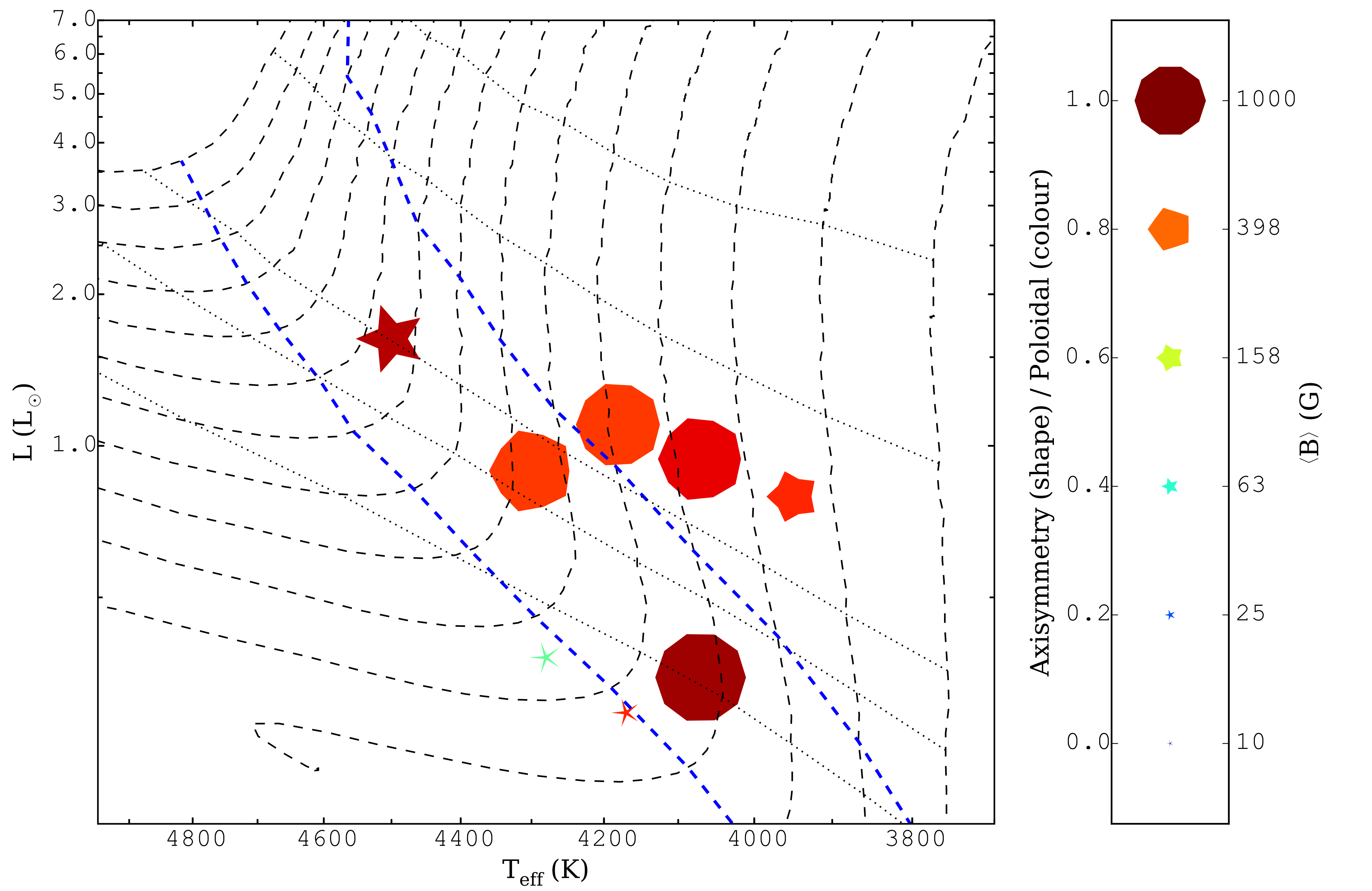


Shu et al. 1987

- Magnetic fields have largest impact during early stellar evolution
  - Accretion, outflow, angular momentum evolution

Magnetic fields of cTTSs

- Large-scale fields of cTTSs strongly depend on internal structure
  - Mostly convective - Stronger field - dipolar/higher mode with simple topology
  - Mostly radiative - Weaker field - more complex topology
  - MaPP project, Gregory et al. 2012



Evolutionary tracks:
1.9 - 0.5 M⊙

Isochrones:
0.5, 1, 3, 5, 10 Myr

Blue lines:
0% and 50% radiative core (radius)

Models from Siess 2000

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- **Ma**gnetic **T**opologies of **Y**oung **S**tars & the **S**urvival of close-in massive **E**xoplanets
- ESPaDOnS@CFHT, Narval@TBL, HARPS@ESO-3.6m
- ~35 targets (wTTSs and cTTSs), > 15 spectra each
- **Are large-scale fields of wTTSs similar to those of cTTSs?**
- **Is disc migration the main process for producing hot Jupiters?**
  - Are magnetospheric gaps key to their survival?
- **Variability of magnetospheric gaps & winds due to non-stationary dynamos in cTTSs**

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- **Are magnetic topologies of cTTSs similar to initial conditions of wTTSs?**
  - Or significantly different?
  - e.g. accretion or star/disc coupling torques modifying dynamo processes and large-scale field topology

- wTTSs no longer accreting - role of accretion, impact of its interruption

- What kind of magnetosphere do young Sun-like stars have when they contract and spin-up towards the MS?
  - Consistently explain rotational history of low-mass stars once on MS
  - Magnetic braking main cause of spin down

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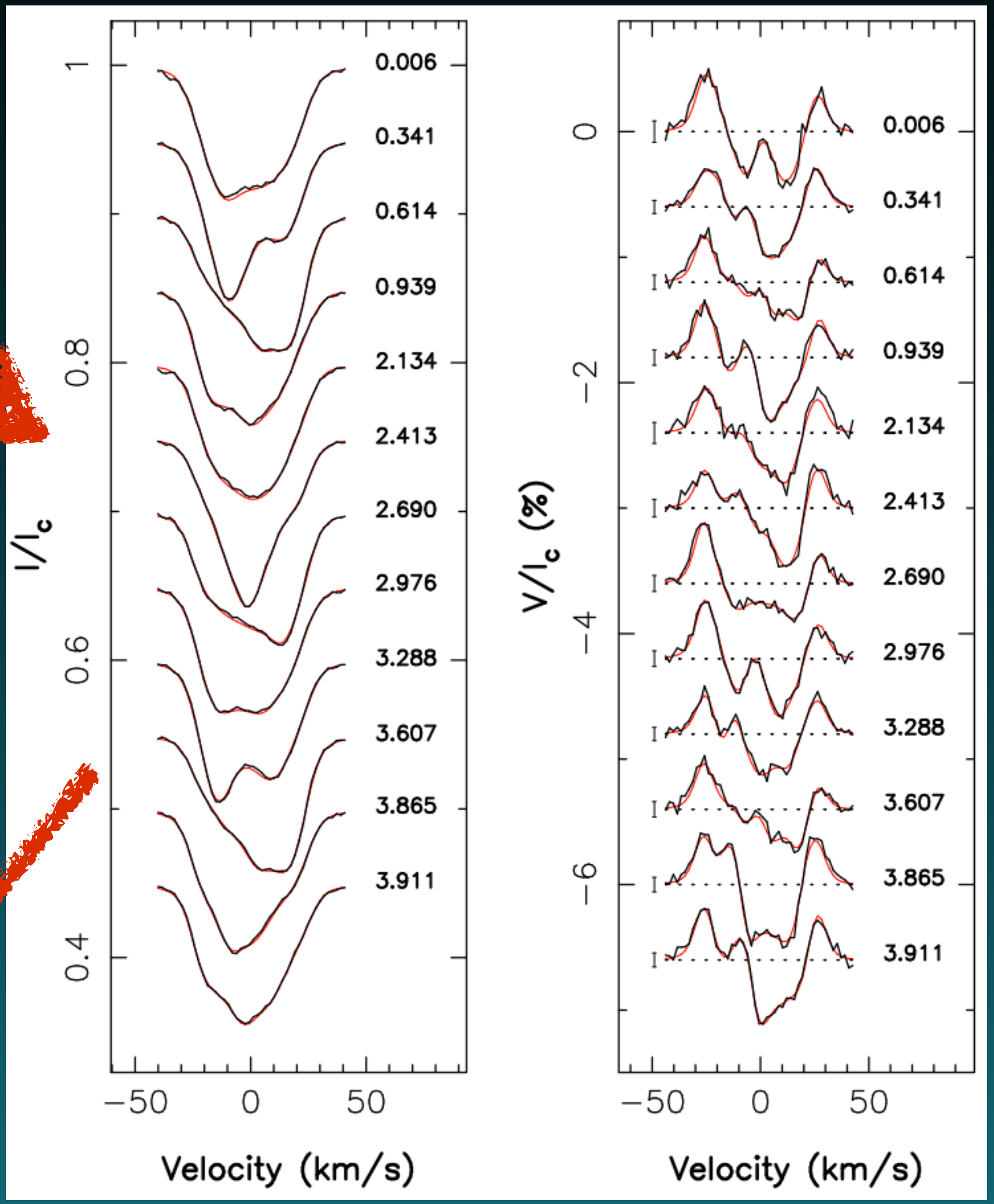
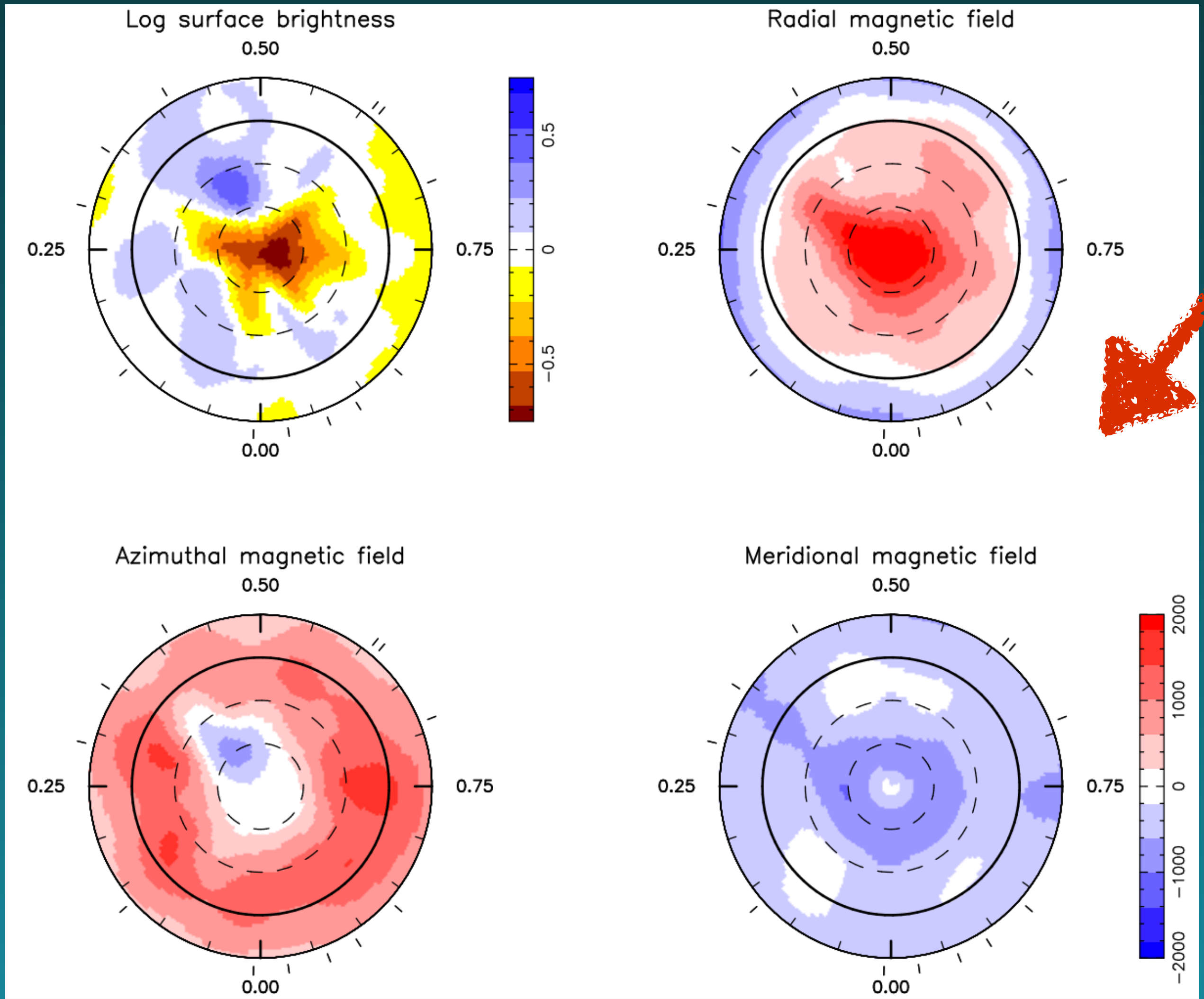
- Zeeman Doppler Imaging (ZDI)
- Invert a time series of Stokes I & V spectra (LSD profiles)
- wTTSs - Stokes I & V fit simultaneously
- Map magnetic fields and spots/plages





LkCa 4
~0.9 M⊙ ~2 Myr
vsini ~ 28 km/s P_{rot} = 3.37 d
Donati et al. 2014

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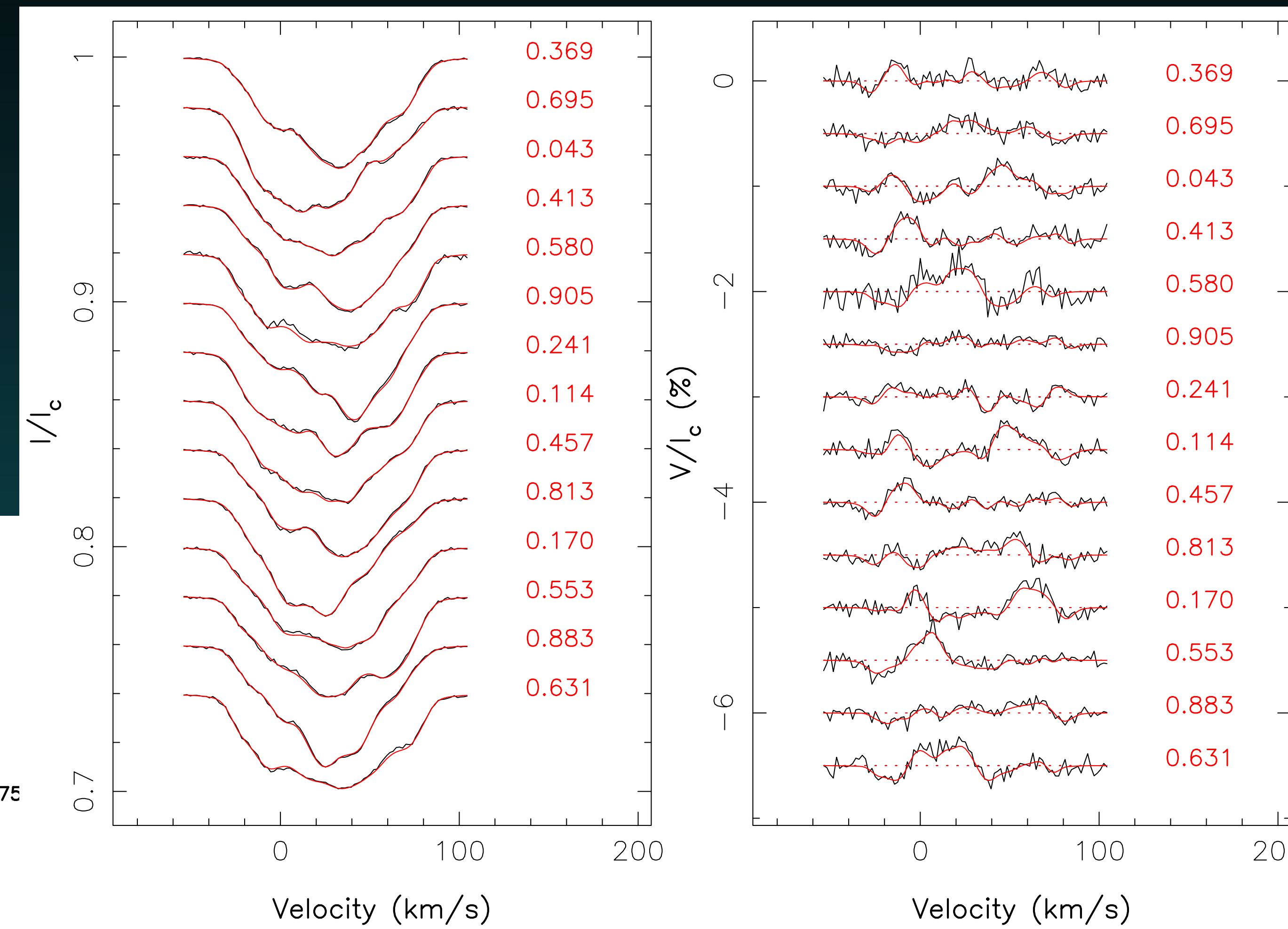
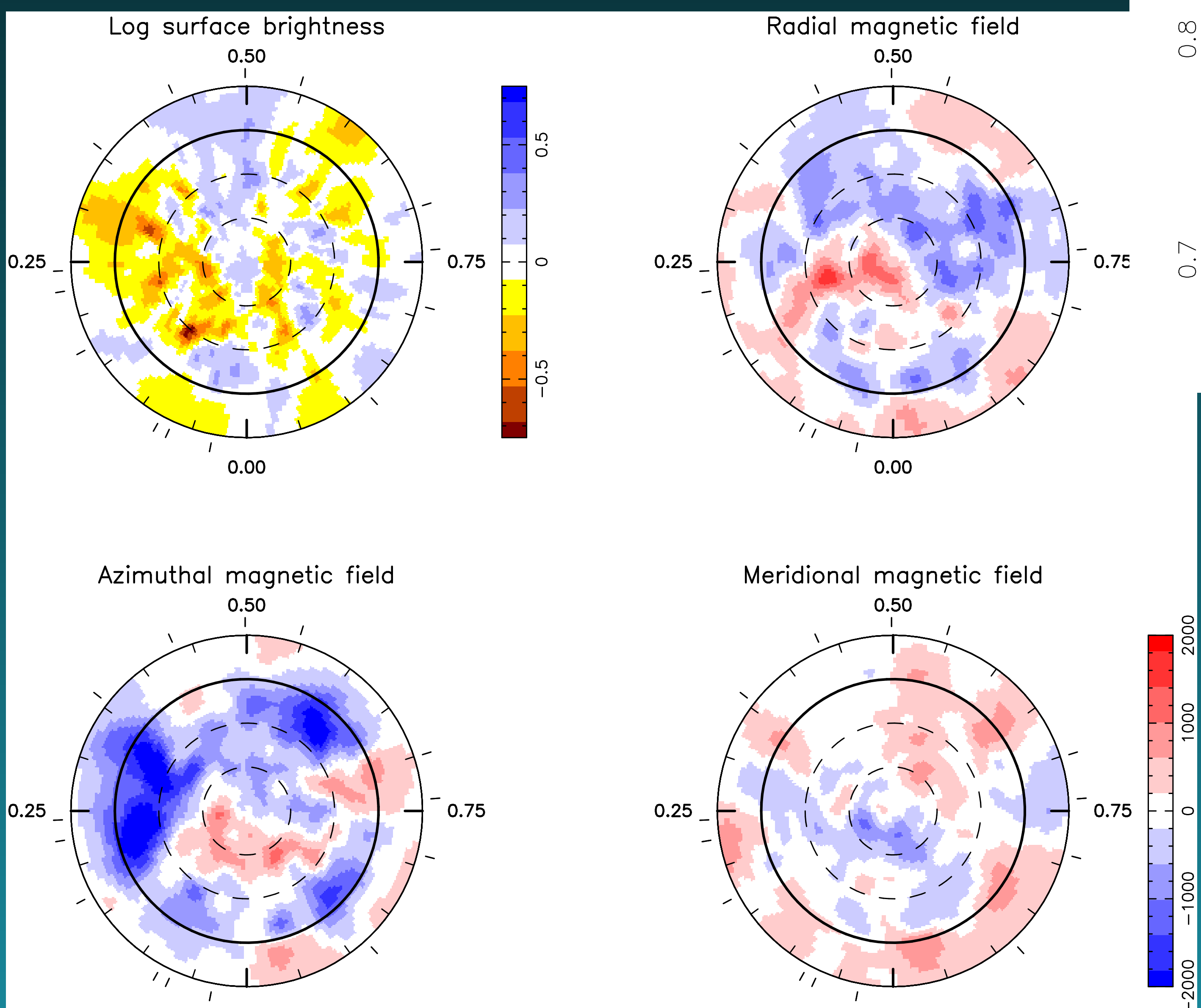
Par 2244 (wTTs)
~1.8 M☉
~1.1 Myr
vsini ~ 57 km/s
P_{rot} = 2.8 d





Complex field
Average unsigned flux ~ 0.9 kG
60% Poloidal (Mostly non-axisymmetric)
40% Toroidal (Mostly axisymmetric)

Hill et al. 2017

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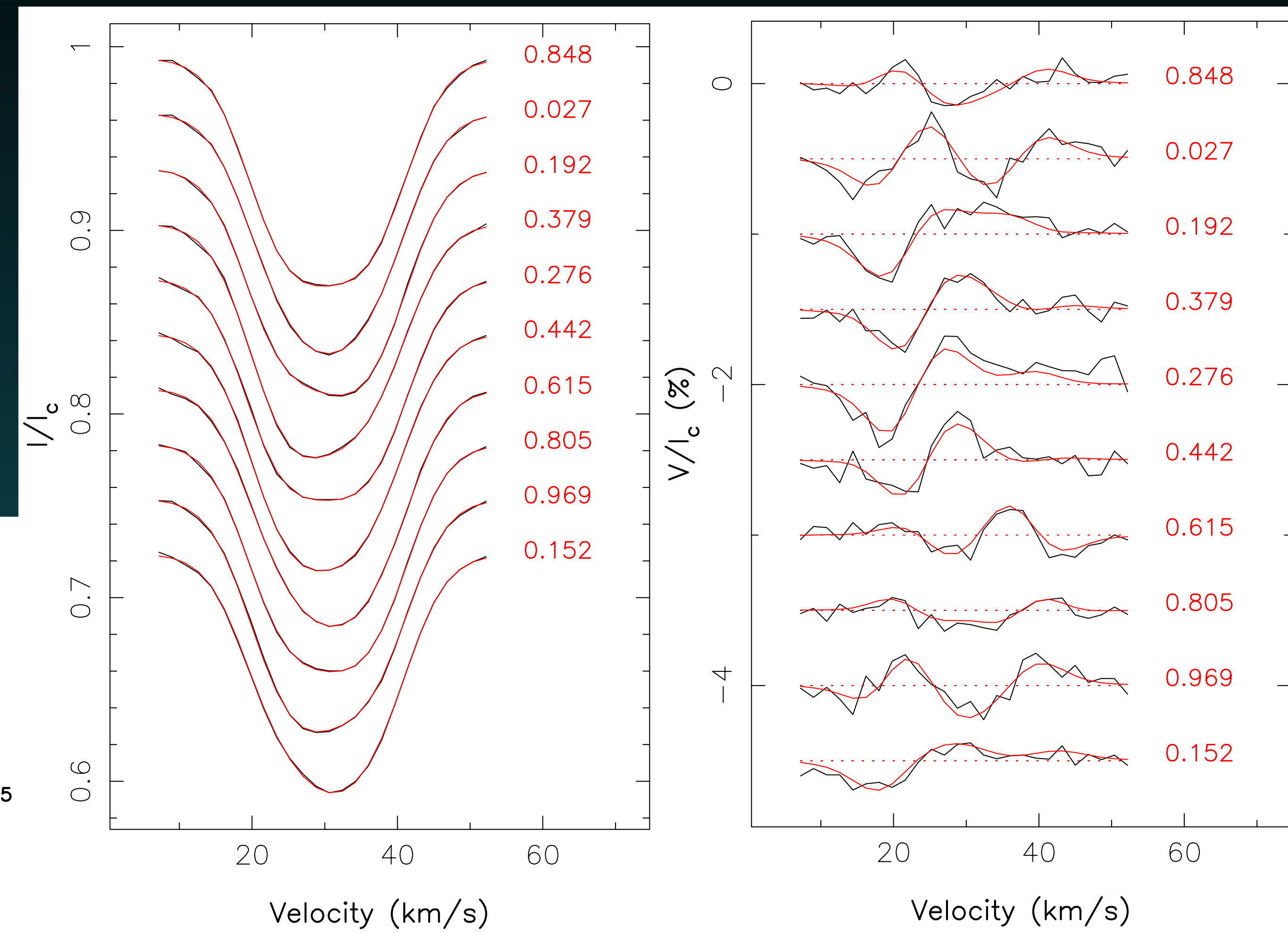
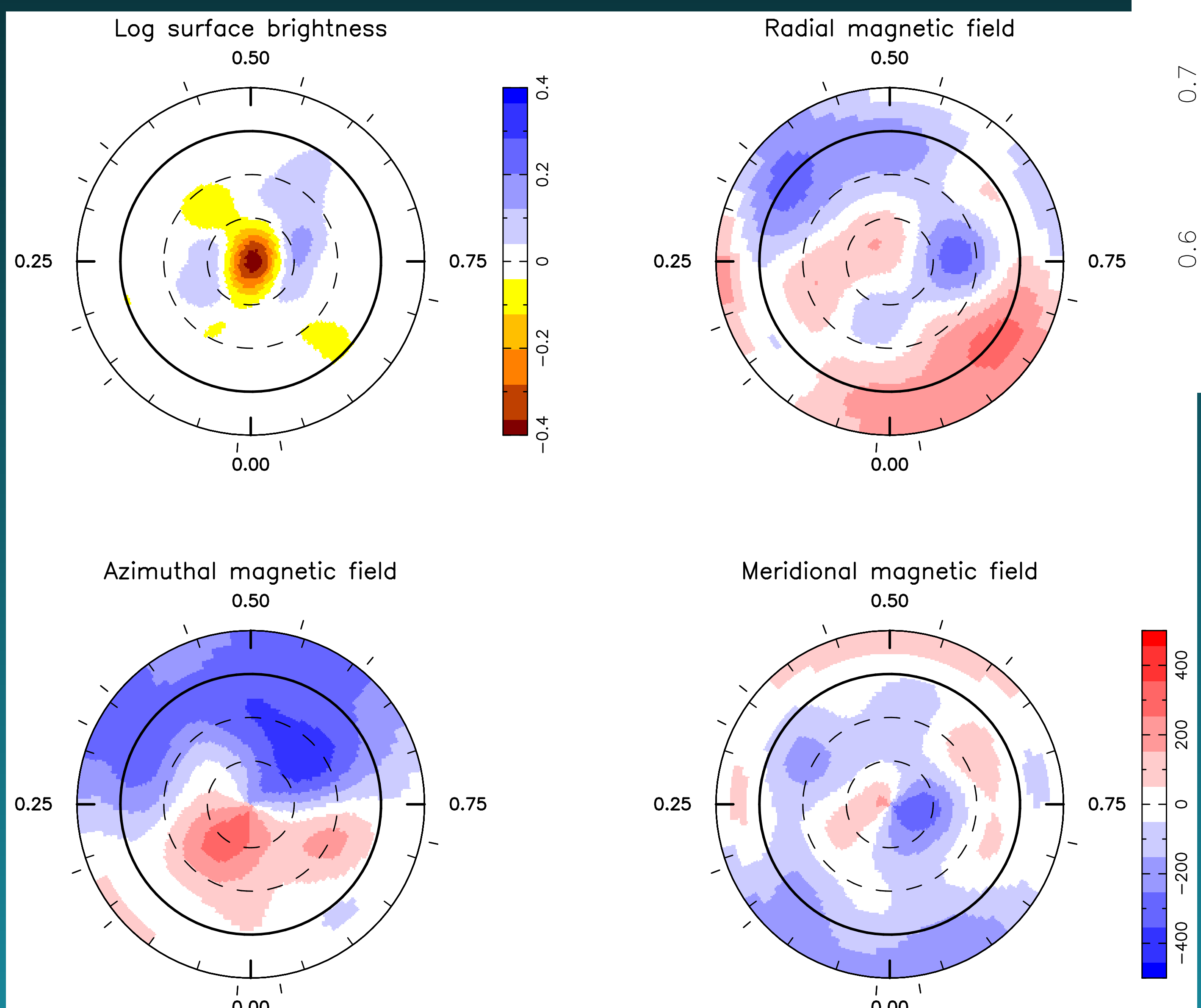
Par 1379 (wTTs)
~1.6 M⊙
~1.8 Myr
vsini ~ 14 km/s
P_{rot} = 5.6 d





Average unsigned flux ~ 0.3 kG
80% Poloidal (Mostly non-axisymmetric)
20% Toroidal (Mostly axisymmetric)

Hill et al. 2017

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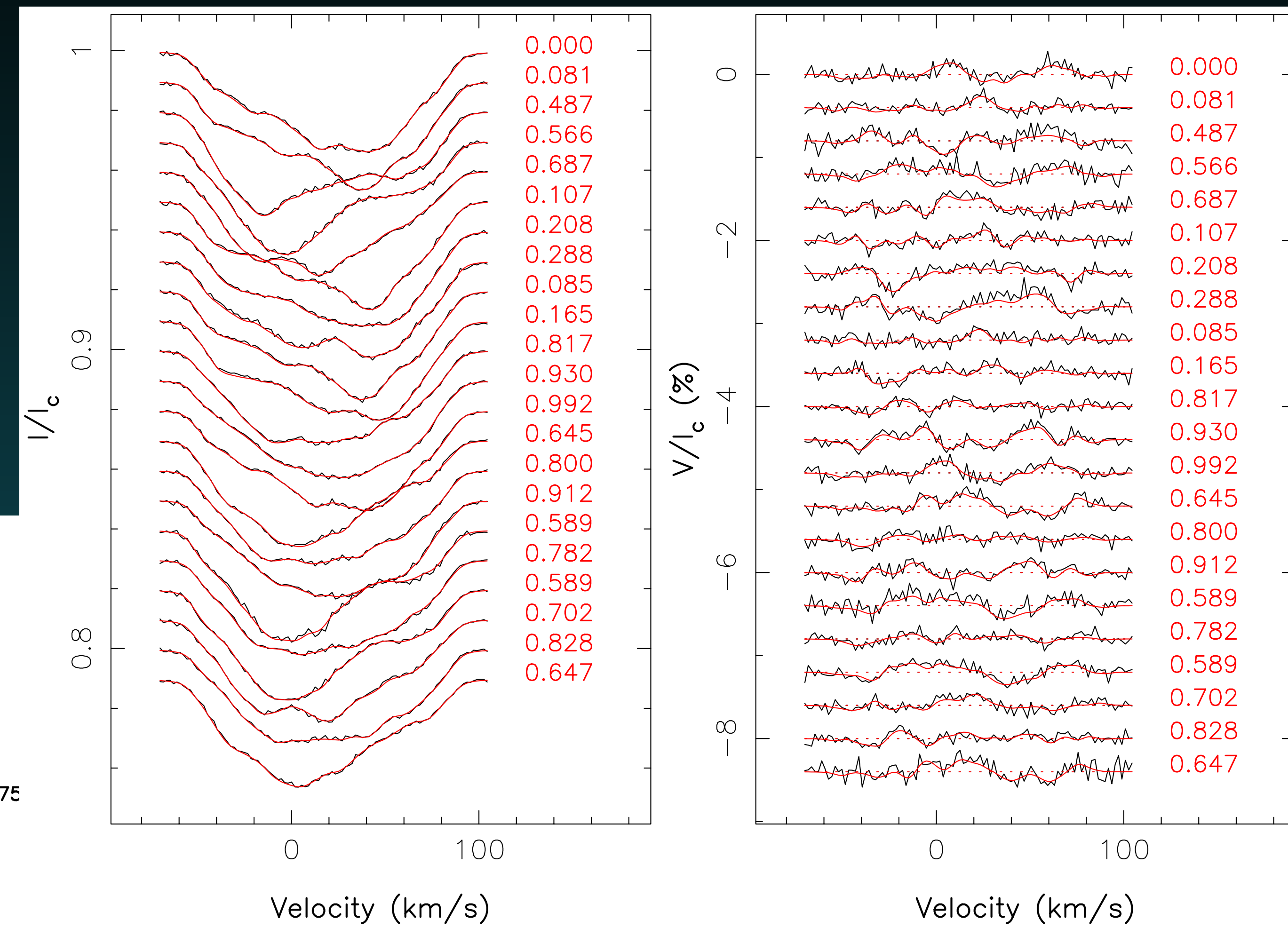
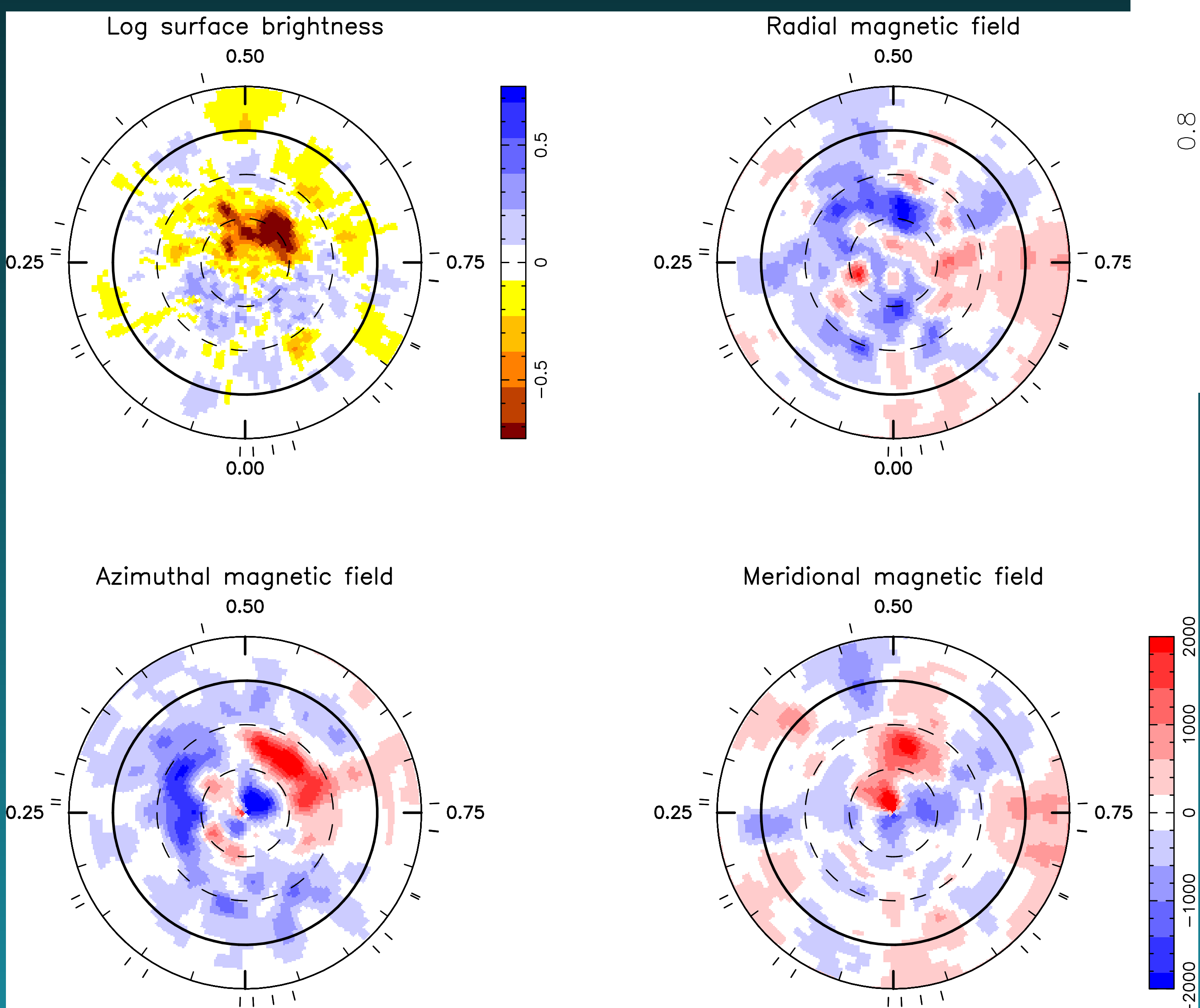
TWA 6 (wTTs)
~ 0.7 M⊙
~ 10 Myr
vsini ~ 73 km/s
P_{rot} = 0.54 d





Average unsigned flux ~ 0.8 kG
50% Poloidal, 50% Toroidal
Mostly axisymmetric
Energy mostly in $\ell > 3$ modes

Hill et al. in prep

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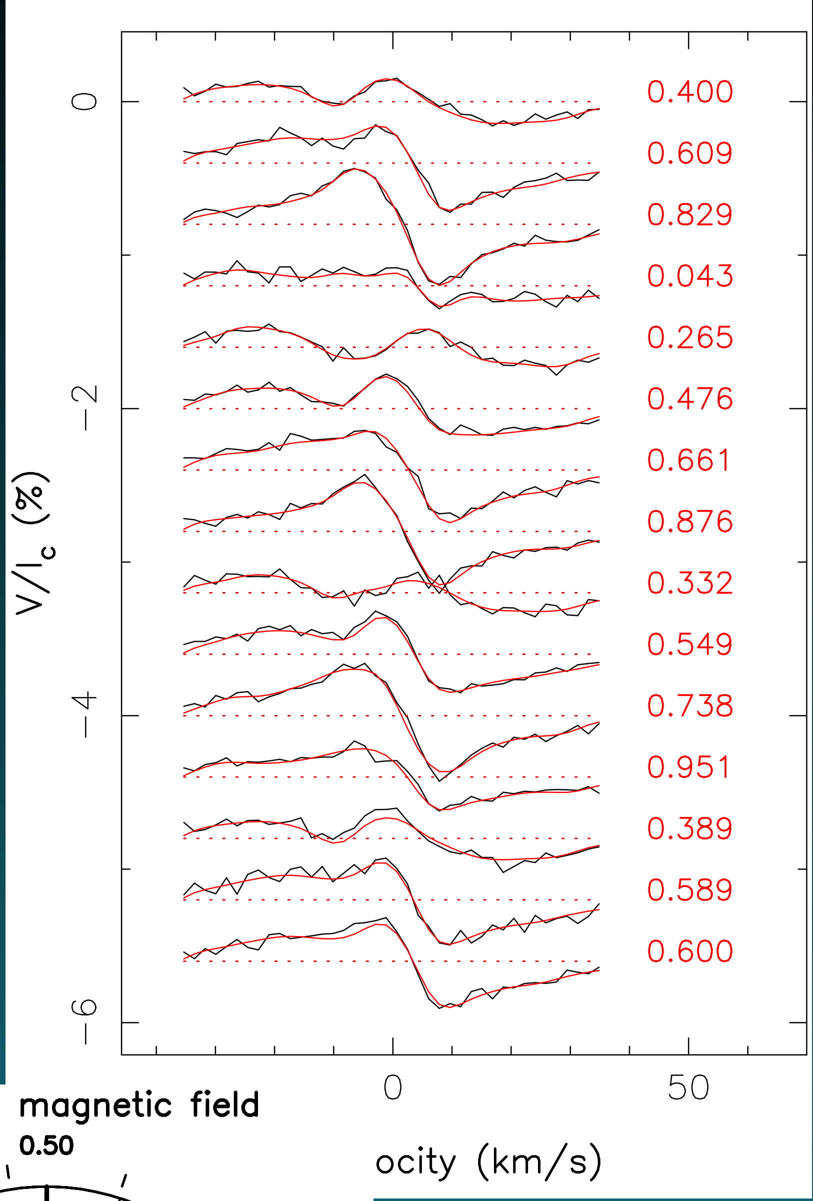
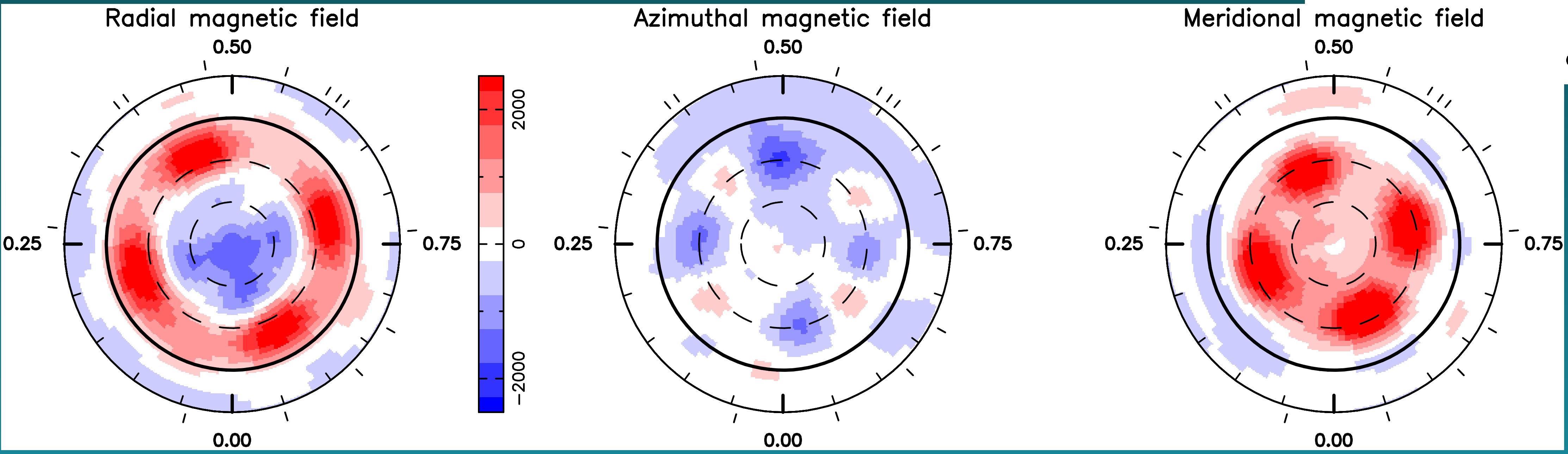
TWA 8A (wTTs)
~ 0.5 M☉
~ 10? Myr
vsini ~ 6 km/s
P_{rot} = 4.66 d

Average unsigned flux ~ 10 kG
90% Poloidal (mostly axisymmetric)
10% Toroidal (mostly non-axisymmetric
Energy mostly in $\ell = 2$

Hill et al. in prep





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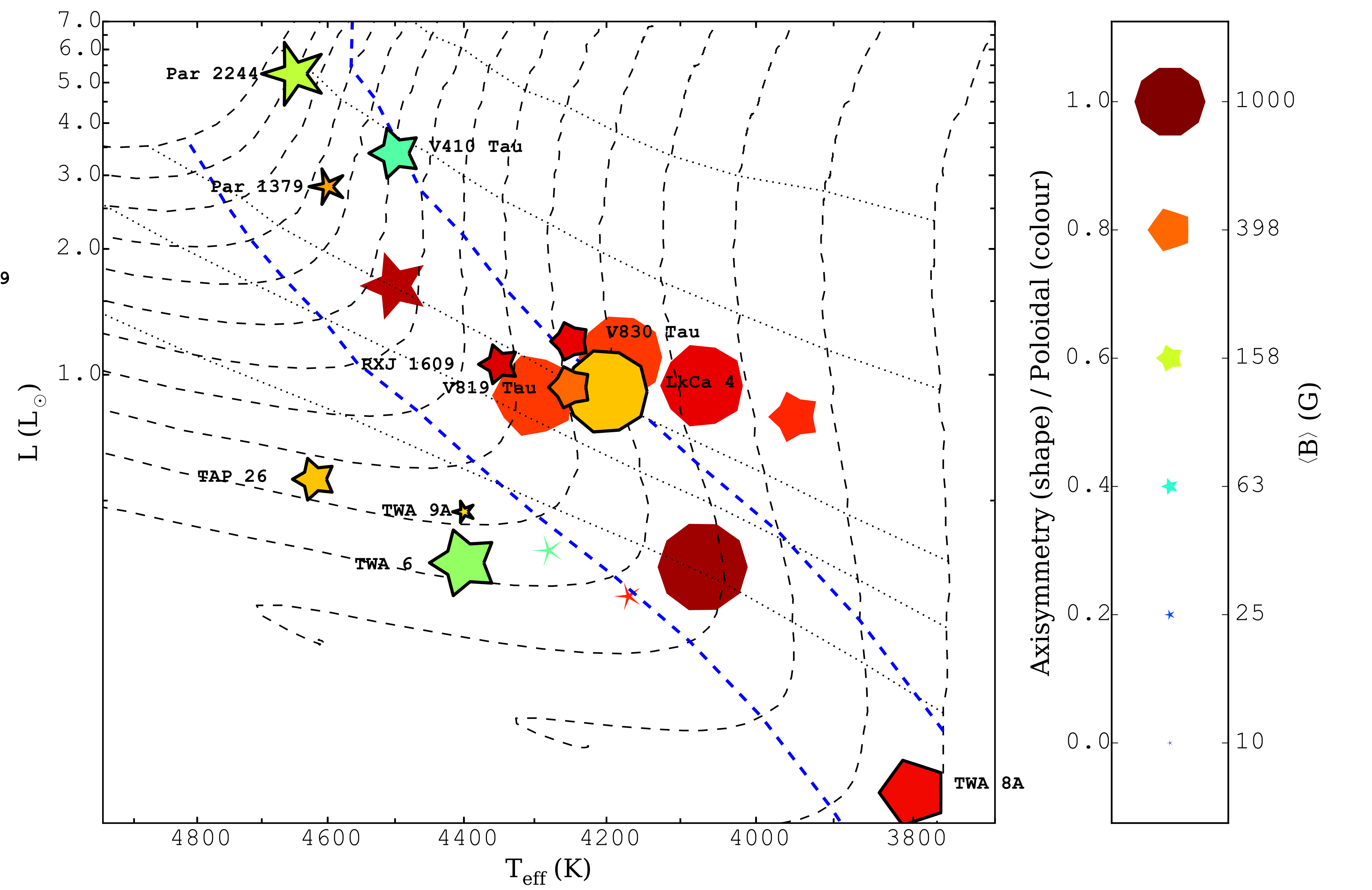
- So far, wTTSs show:
  - Wider range of field topologies compared to cTTSs
  - Large scale fields can be more toroidal and non-axisymmetric than cTTSs
  - May have significant toroidal component after disc dissipation
  - Evolution of fields may impact planet formation…



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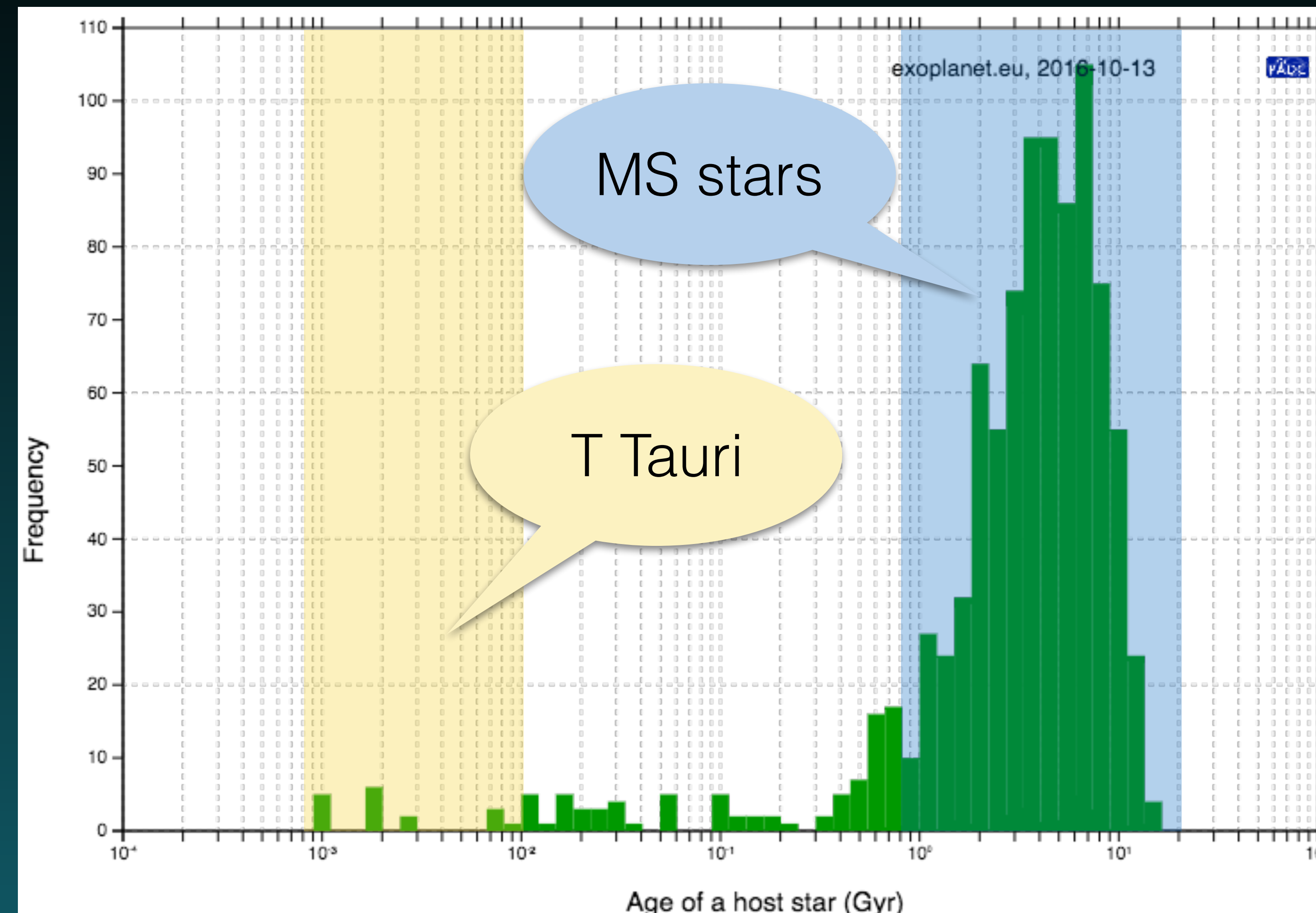
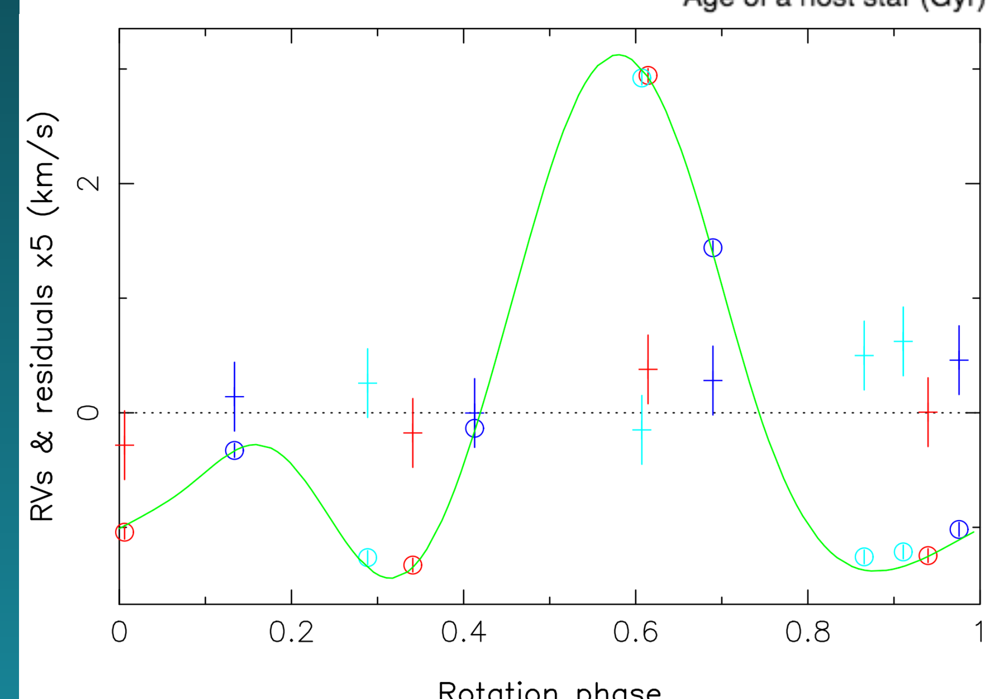
- Disc migration main process for producing hJs?
  - Are magnetospheric gaps & winds key factors for their survival?

- If so, can expect to find at least as many hJs in TTSs as are in mature stars
  - Significantly more if we account for those absorbed by protostar over contraction phase.

- Model RV variability (spots)
  - Filter from RV curves
  - Key to understanding the formation / migration of hJs





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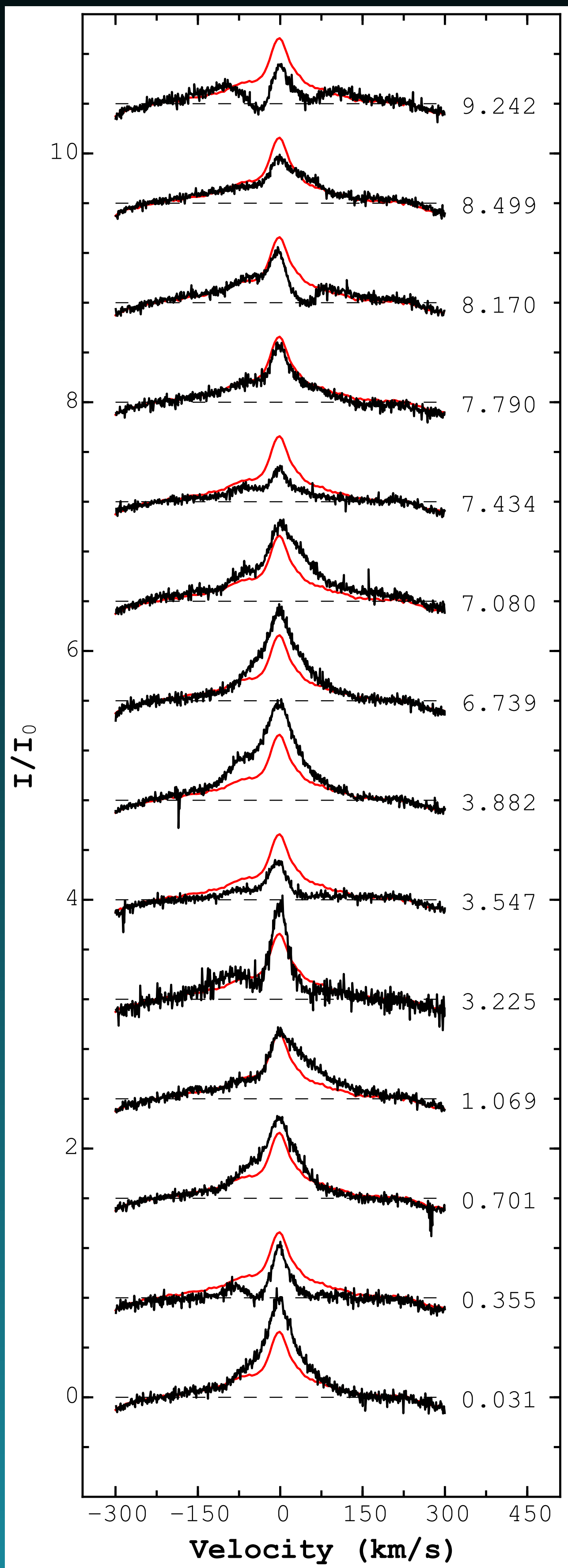

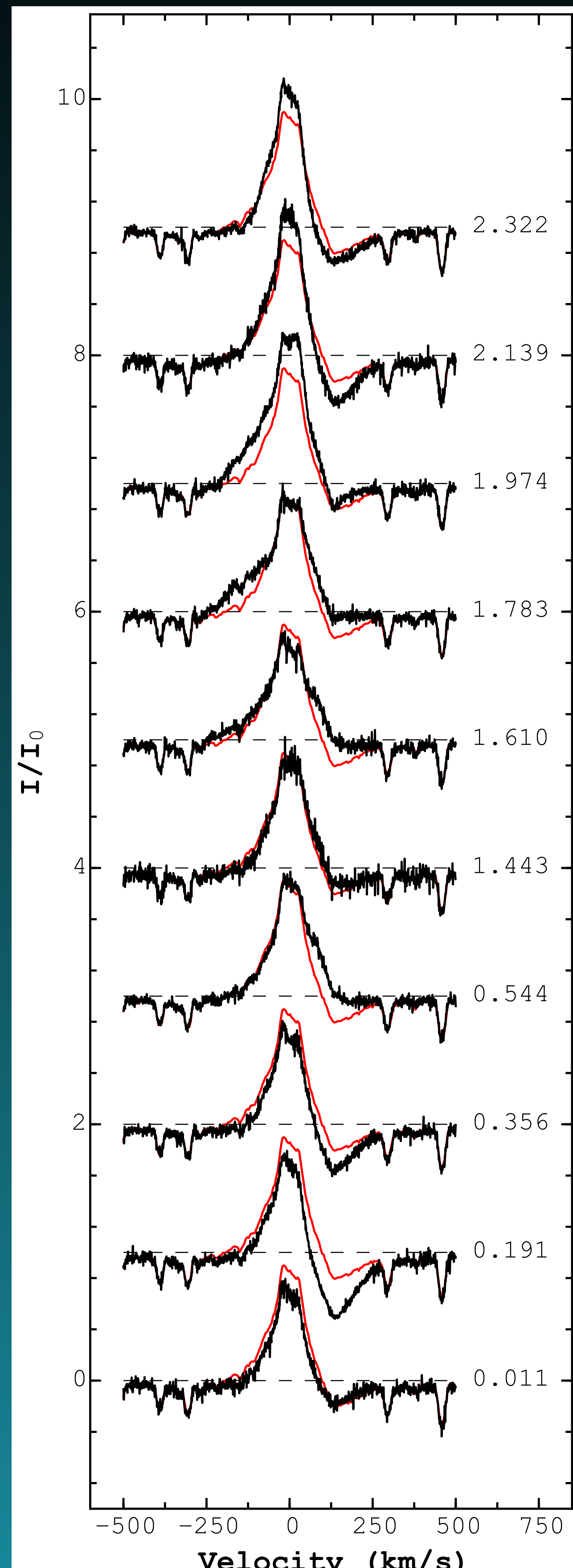

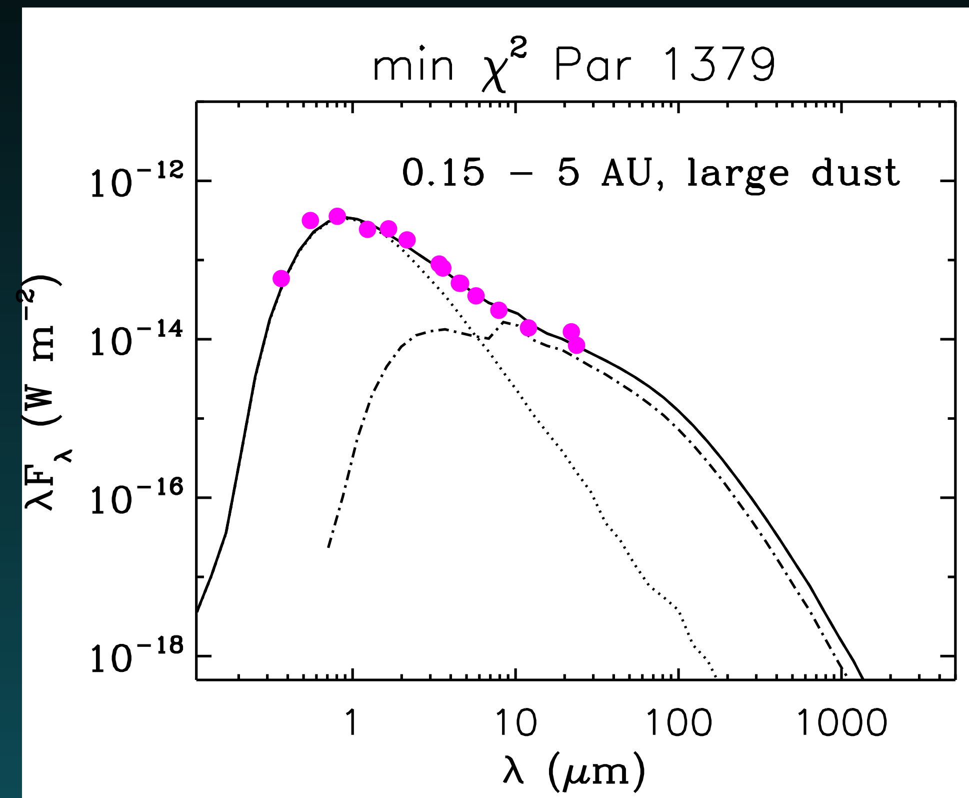

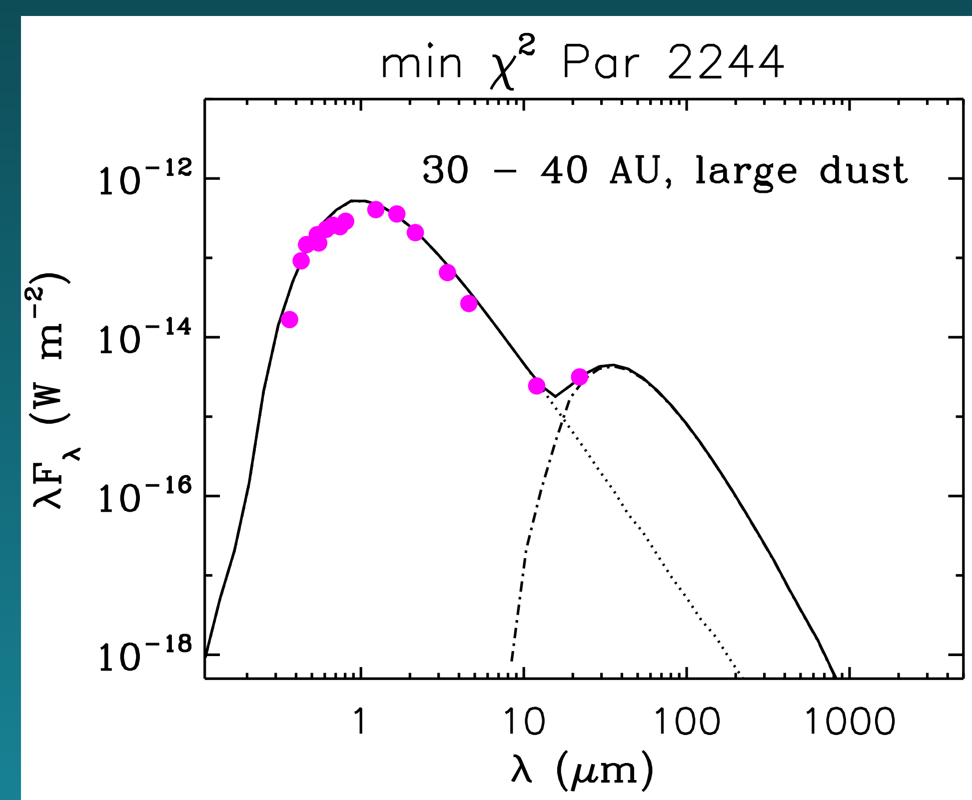

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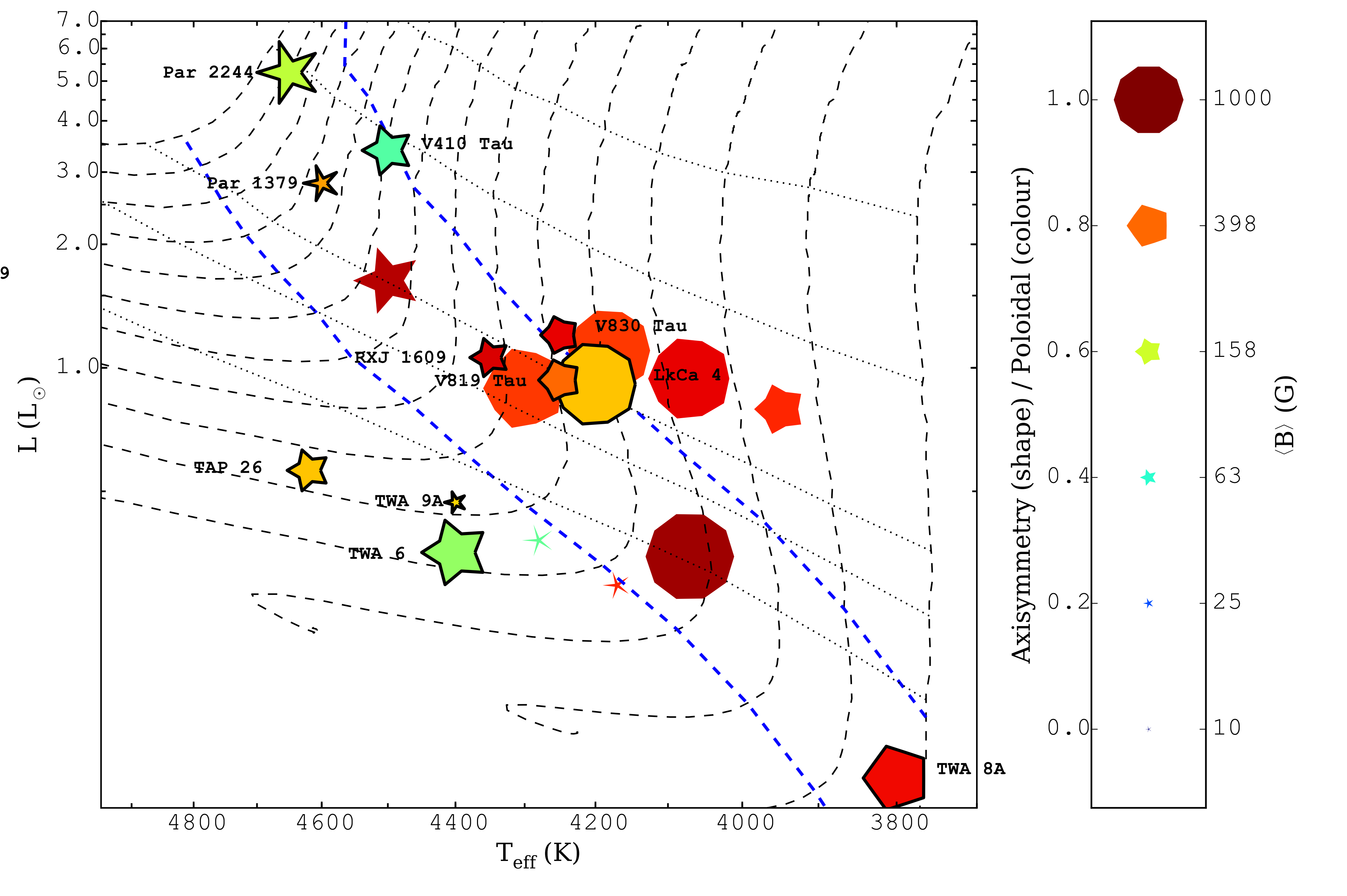

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