The dipper population of Taurus seen with *K2*

Noemi Roggero[1], J. Bouvier[1], L.M. Rebull[2], A.M. Cody[3]

[1] Univ. Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France
[2] Infrared Science Archive (IRSA), IPAC, 1200 E. California Blvd., California Institute of Technology, Pasadena, CA 91125, USA
[3] SETI Institute, 189 N Bernardo Ave. Suite 200, Mountain View, CA 94043 USA

1. Dippers and the inner disk

At the inner disk rim (~ 0.02 AU, i.e. a few stellar radii) of a T Tauri star, accretion processes still occur and are controlled by the stellar magnetic field. In the scenario of magnetospheric accretion (Fig. 2), dust is lifted above the disk plane and is accreted onto the star. For a certain inclination of the system, this material can occult the star and cause dips in its light curve. The flux dips in an otherwise flat light curve might obscure the star up to 1 mag and are irregular in shape and depth, although their occurrence can be periodic [1].

The observations were run on the now retired *Kepler* satellite. Among light curves of ~800 stars in the field, ~180 are most probably Taurus members. Each star is observed for around 80 d, with a cadence of 30 min. Among them, 34 are classified as dippers.

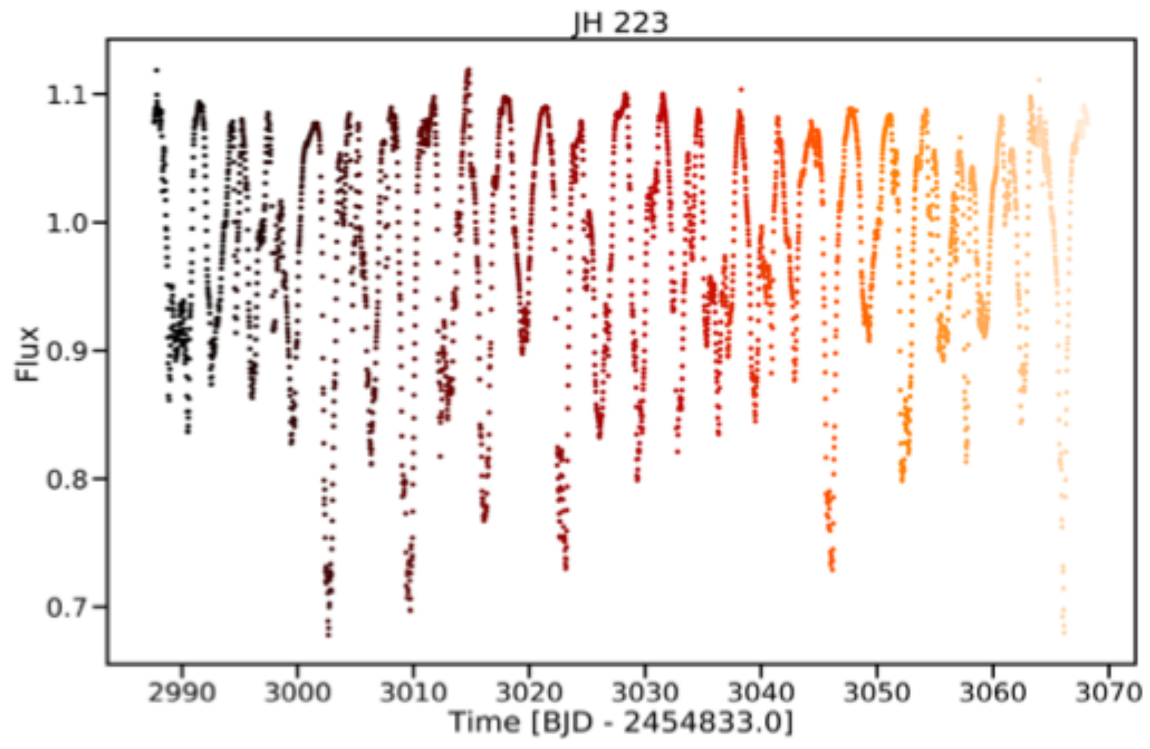

Fig. 1: Dipper light curve of JH 223

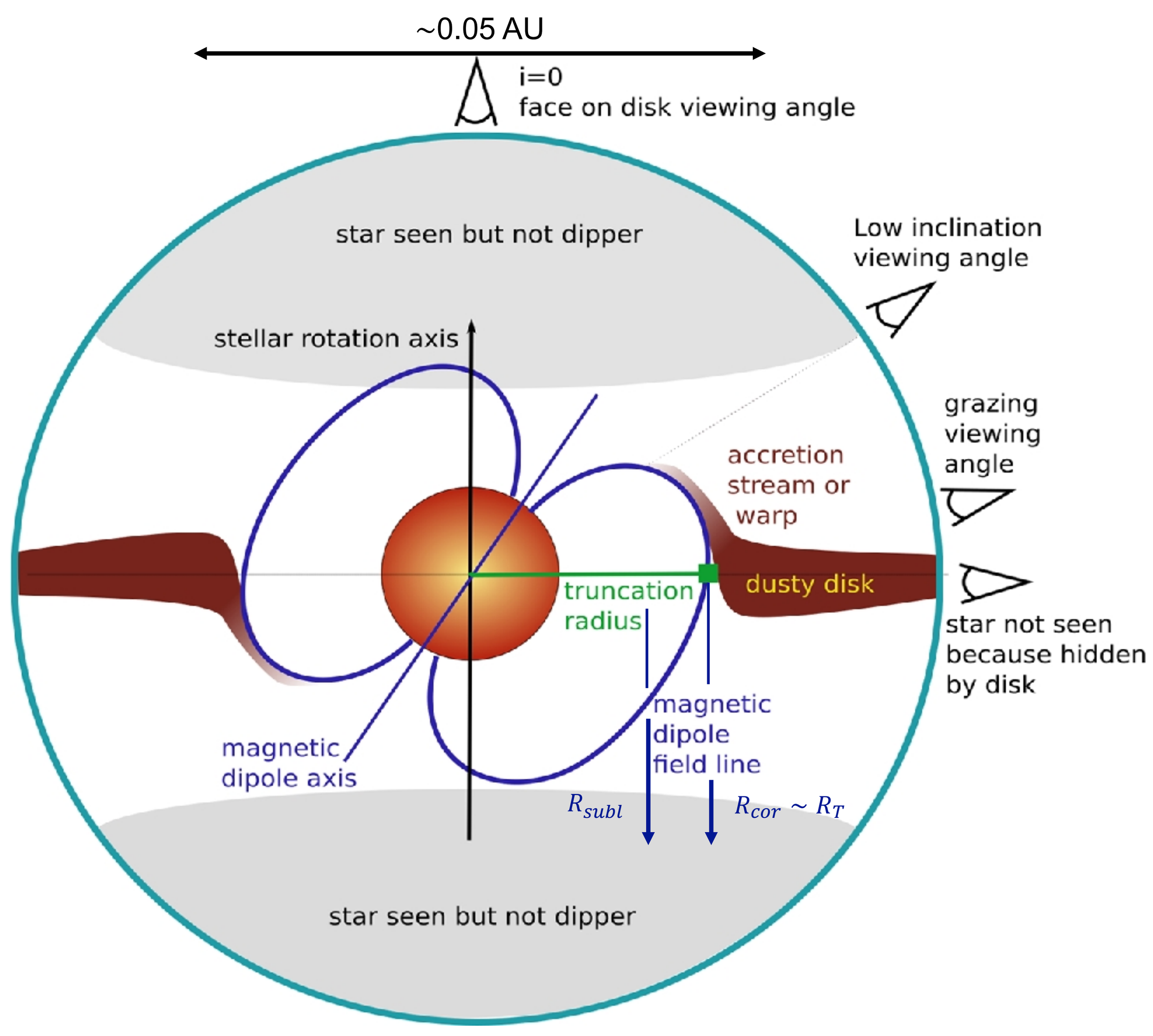

Fig. 2: The inner disk according to the magnetospheric accretion mode, adapted from [2]

2. Stellar properties

The stellar parameters are derived computing the stars' luminosity, converting spectral types to temperatures [3], and from evolutionary tracks [4]. From these, it is possible to compute at which distance the disk material corotates with the star and what is its temperature.

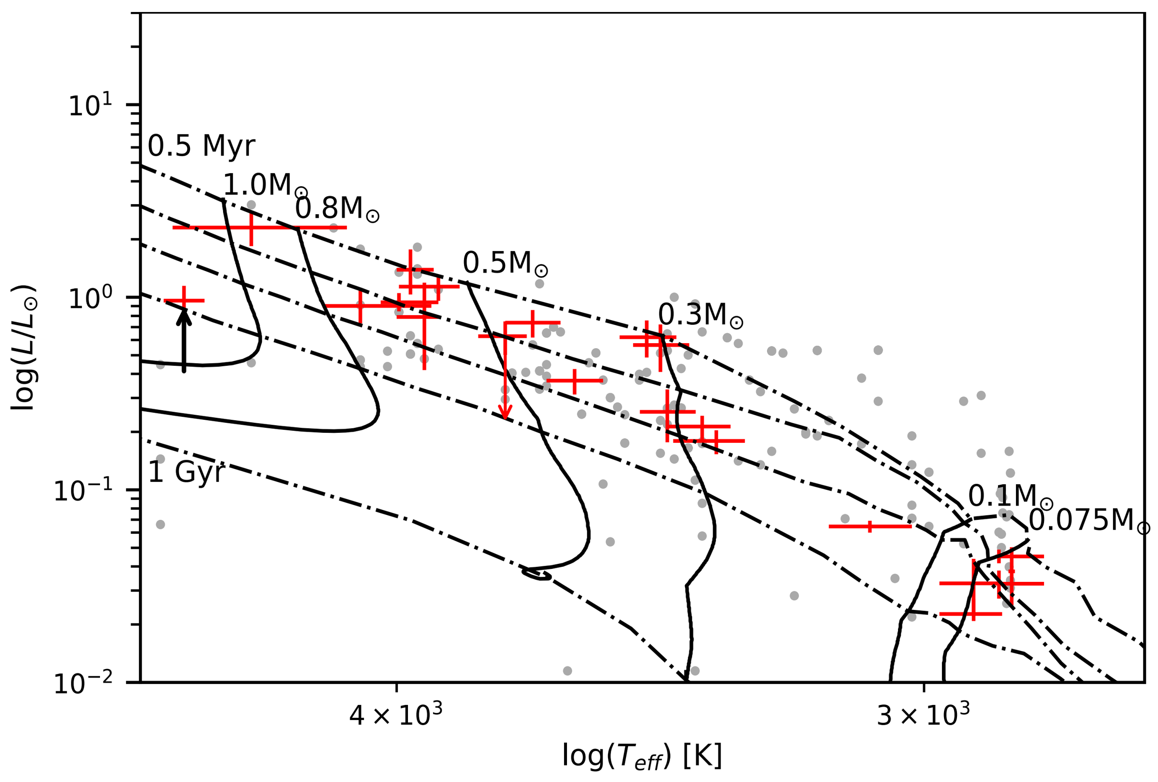

Fig. 3: Hertzsprung-Russell diagram of the sample [5]. Solid lines: evolutionary tracks for given masses [4]. Dashed lines: Isochrones

Properties

	From	To
Spectral types	M6	K4
Masses	$0.075\ M_\odot$	$\sim 1\ M_\odot$
Radii	$0.6\ R_\odot$	$2.5\ R_\odot$
Periods	2 d	10 d
Corotation radii	$2\ R_*$	$8\ R_*$
Temperatures at corotation	800 K	1600 K
Inclinations	$\sim 30°$	$\sim 80°$

3. Discussion

- Spectral types, periods and corotation radii are typical of dippers, as found in other regions
- If dust causes eclipses ⇒

  $T_{cor} < T_{subl}$ of dust (1400-1600K)
- Inclination angles are rather moderate in Taurus. Two objects have stellar inclinations too low to be compatible with warps
- Stellar inclinations are, in general, higher than outer disk inclinations

4. Are slow rotators obscured by larger warps?

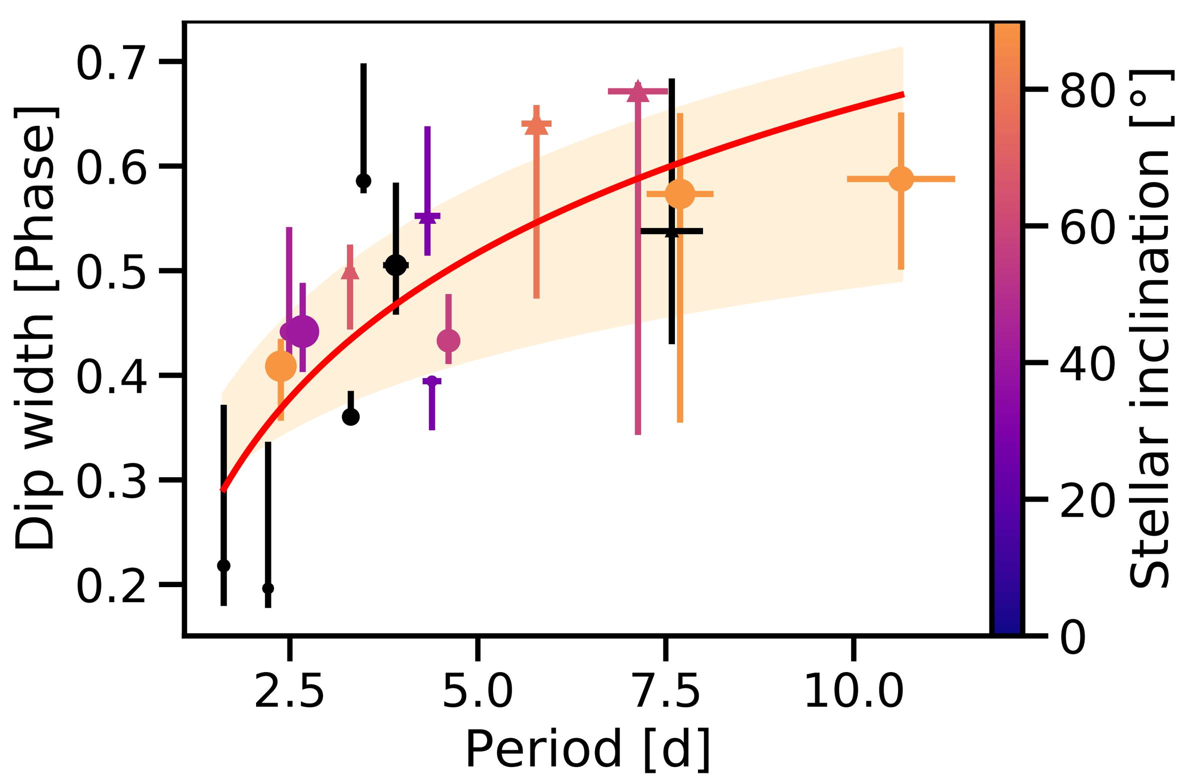

Fig. 4: Dip width as a function of period, i_* (color), dip amplitude (size), dip morphology (triangle = multi-peaked). [5]

A dip width can be defined as FWHM of an averaged, folded light curve. This is directly related to the azimuthal extension of the occulting structure. For Taurus, this is correlated with the period, implying that the structures occulting slow rotators must be larger.

5. A rather complex dip structure

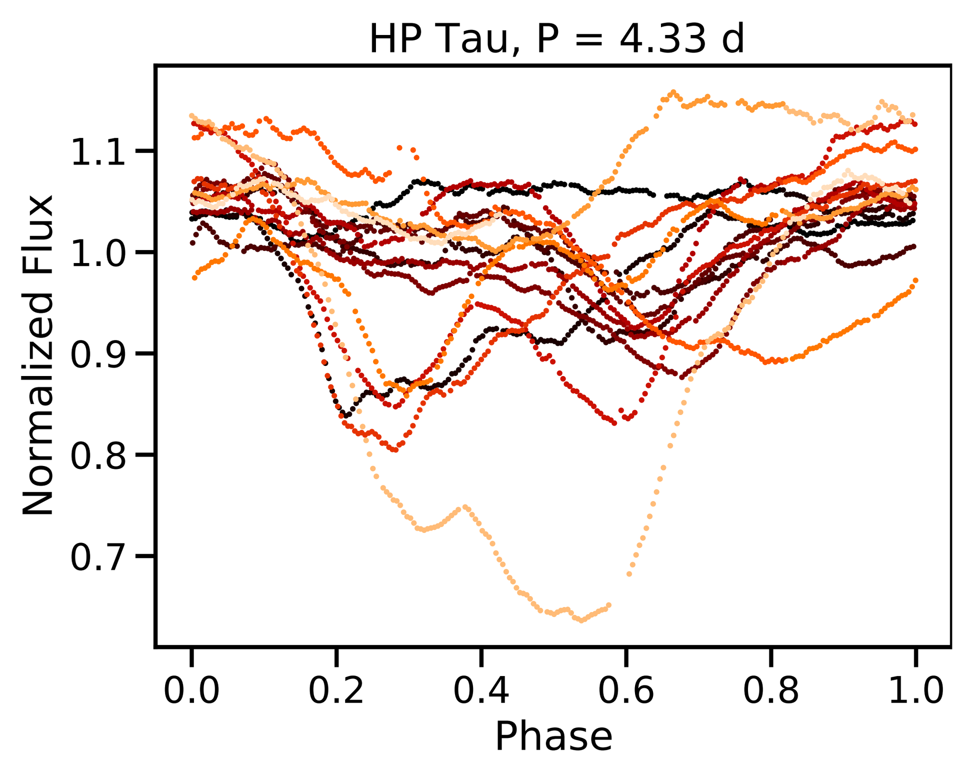

Fig. 5: Light curve of HP Tau folded in phase.

Many of the dipper light curves present multi-peaked dips, whose shapes seem to vary independently from one cycle to the other. Either we see a complex structure evolving over time, or several of them at the same time.

6. Open Questions

- Is the period of the dips really related to the rotation period of the star?
- What are the dust properties (grain size, opacity)?
- How strong is the magnetic field? What is the accretion regime?

References

[1] Cody, A. M., Stauffer, J., Baglin, A., et al. 2014, AJ, 147, 82
[2] Bodman, E. H. L., Quillen, A. C., Ansdell, M., et al. 2017, MNRAS, 470, 202
[3] Pecaut, M. J. & Mamajek, E. E. 2013, ApJS, 208, 9
[4] Baraffe, I., Homeier, D., Allard, F., & Chabrier, G. 2015, A&A, 577, A42
[5] Roggero, N., Bouvier, J., Rebull, L.M., Cody, A.M. (submitted to A&A)

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 742095; *SPIDI*: Star-Planets-Inner Disk-Interactions). www.spidi-eu.org