Star-disc interaction : do planets care ?

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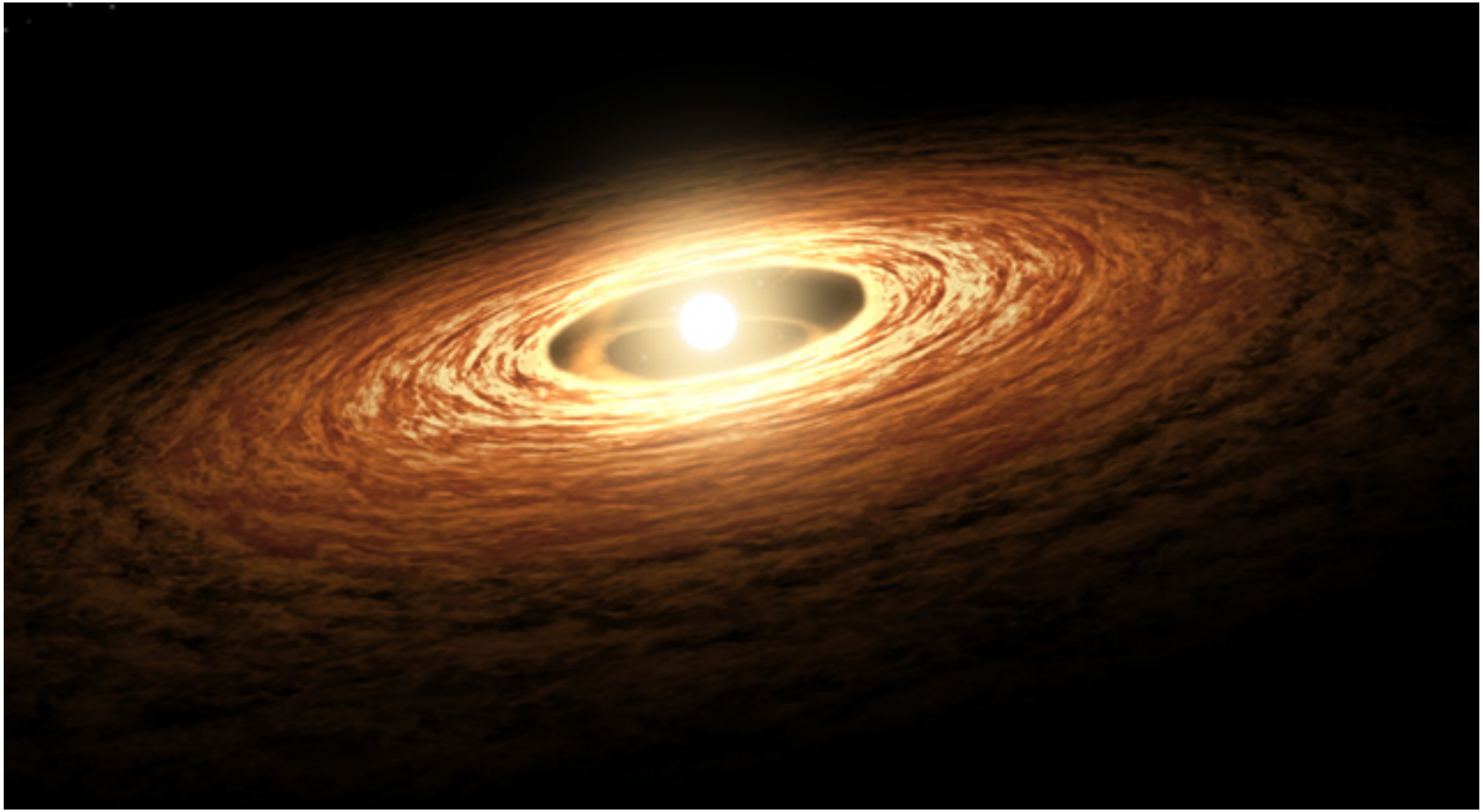
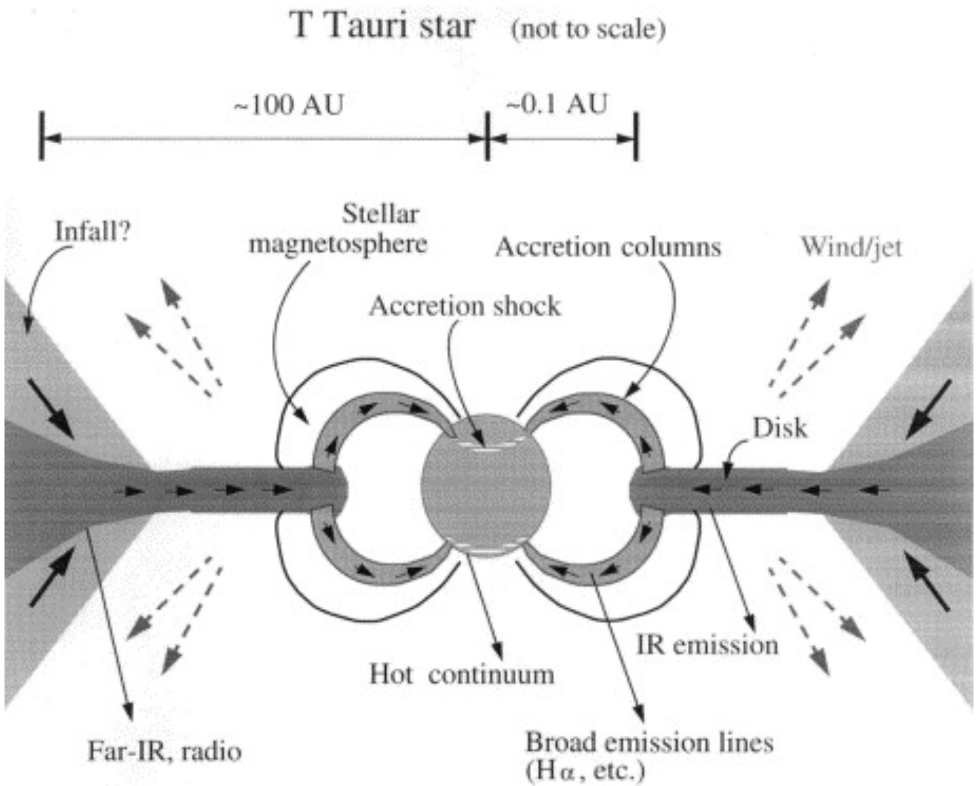
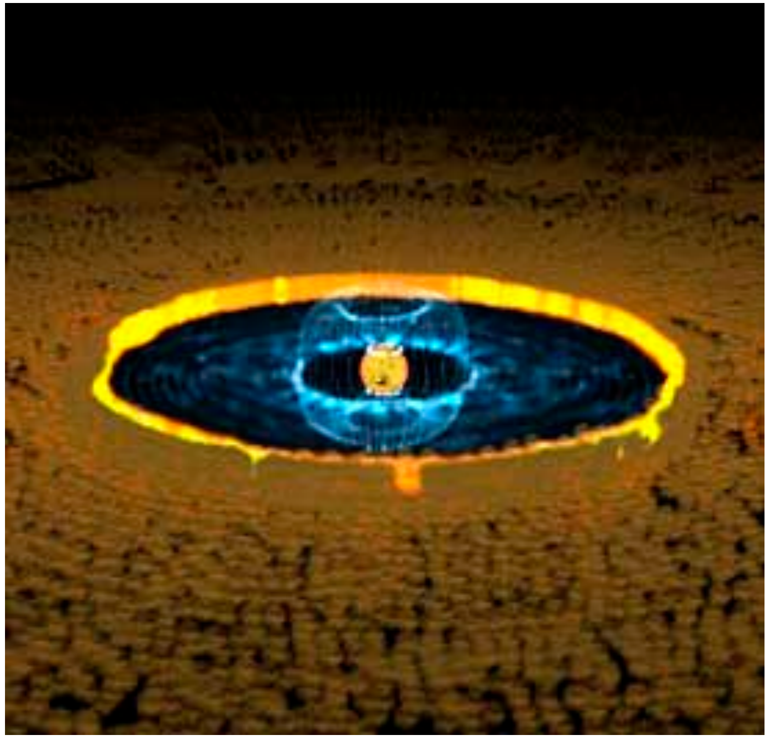
If you think T Tauri disks look like this :



or even like that :

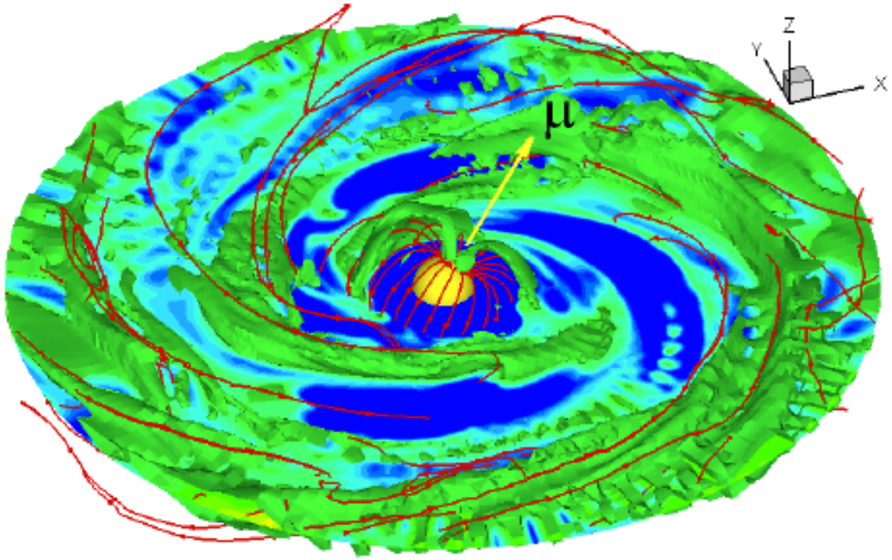


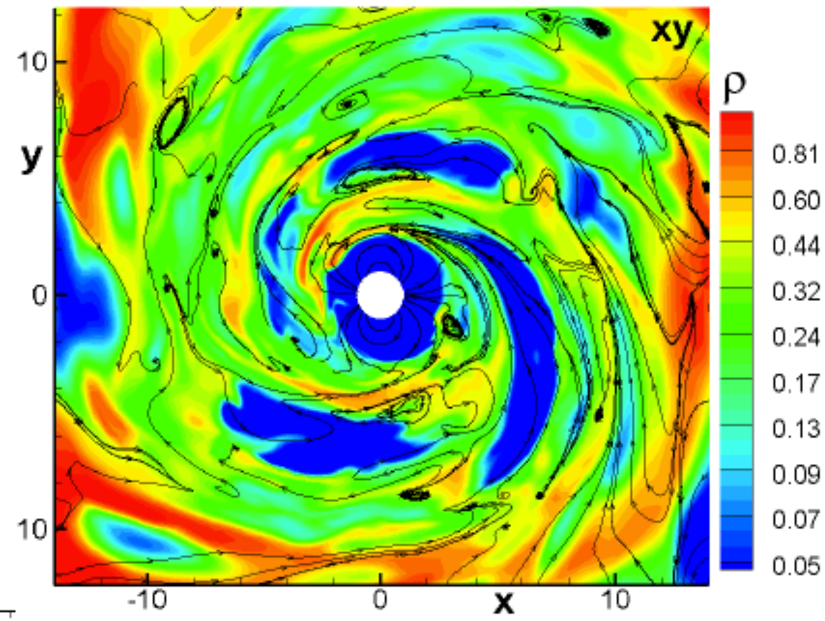


Because…

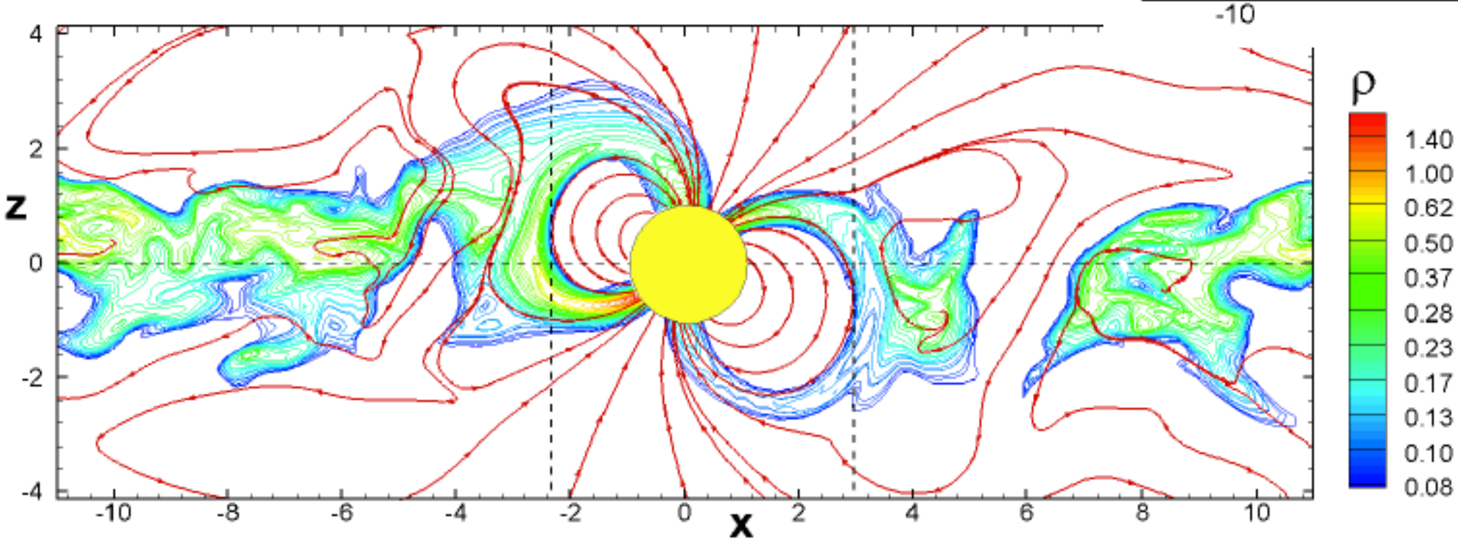
YOU ARE GOING TO BE DISAPPOINTED !

Observations indicate they are more like this (in the -simplest- dipolar case):

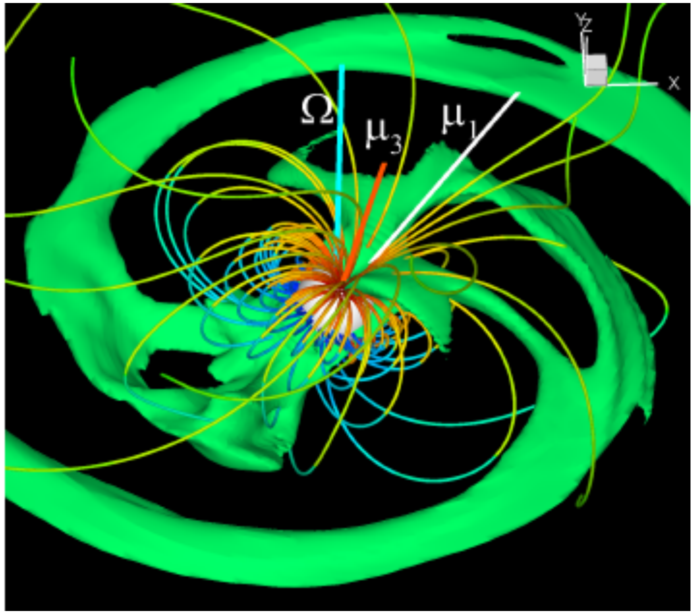




Romanova et al. 2012



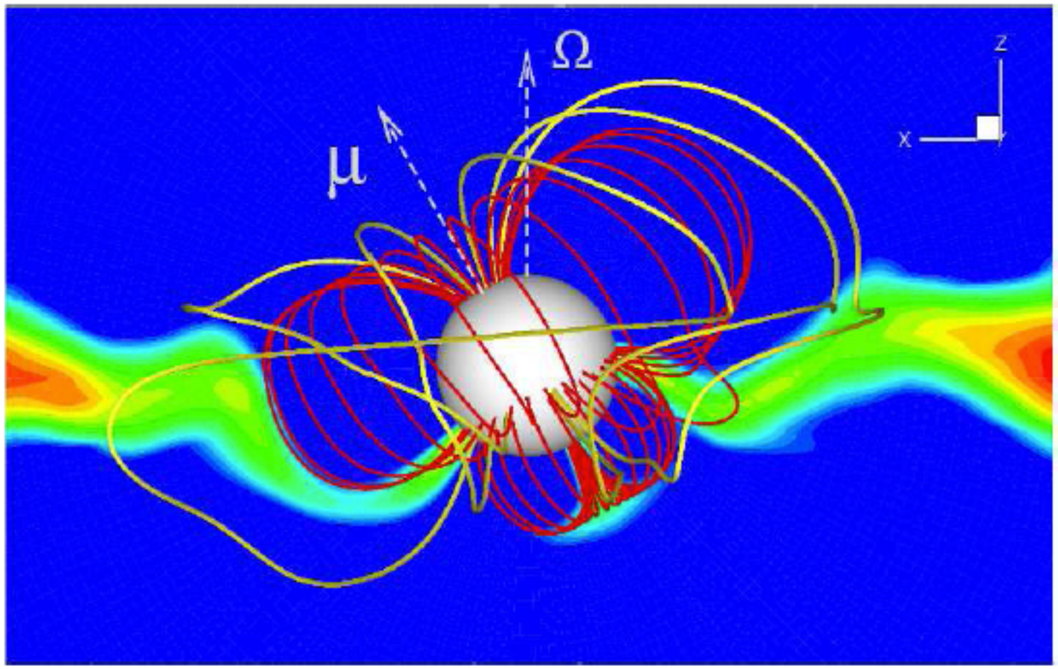
Or even worse (in most cases?) :



Romanova et al. 2010

Dipole + octupole field

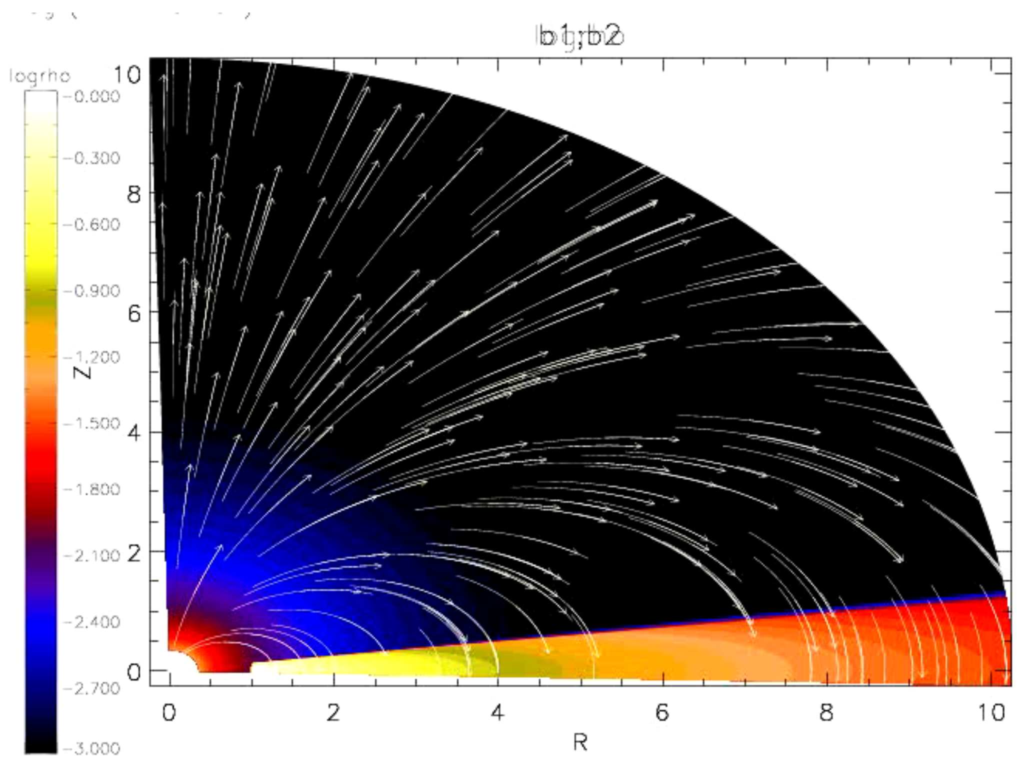
Long et al. 2007



And they keep changing…

- All these complicated inner disk structures are strongly time variable on a timescale of weeks to years…

Bessolaz et al. 2008



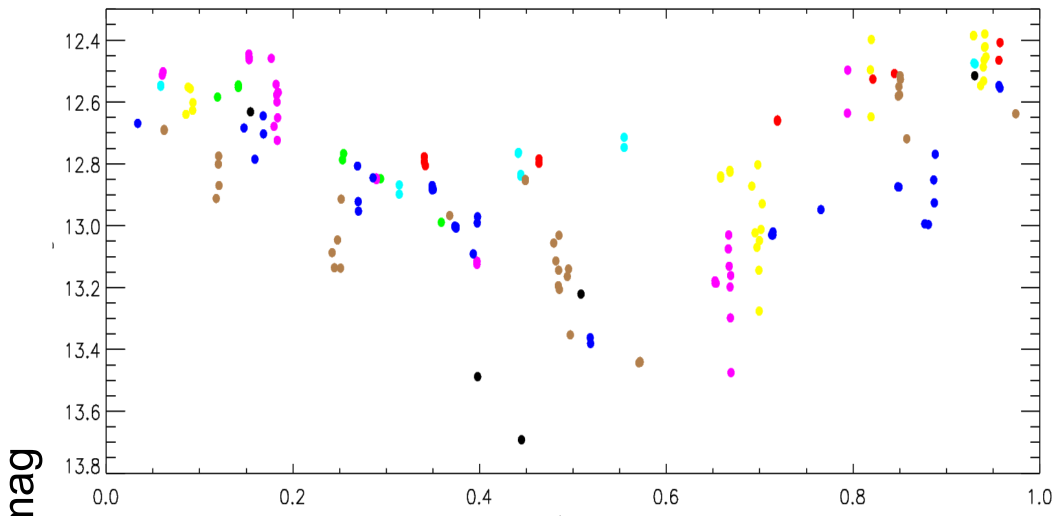
We can’t probe these inner regions (≤0.1 AU) with interferometry, so…

HOW DO WE KNOW ?

By observing CTTS systems' variability on a timescale of weeks to months

AA TAU : THE PROTOTYPE

AA Tau: synoptic studies with simultaneous spectroscopy and photometry (Bouvier et al. 1999, 2003, 2007)

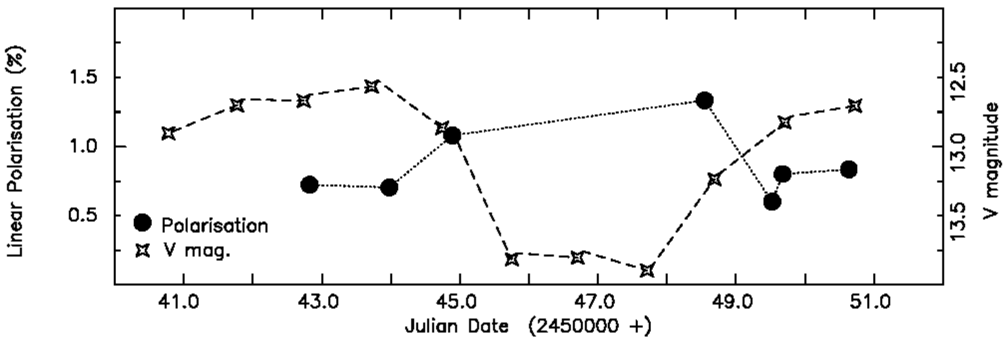


Bouvier et al. (2007)

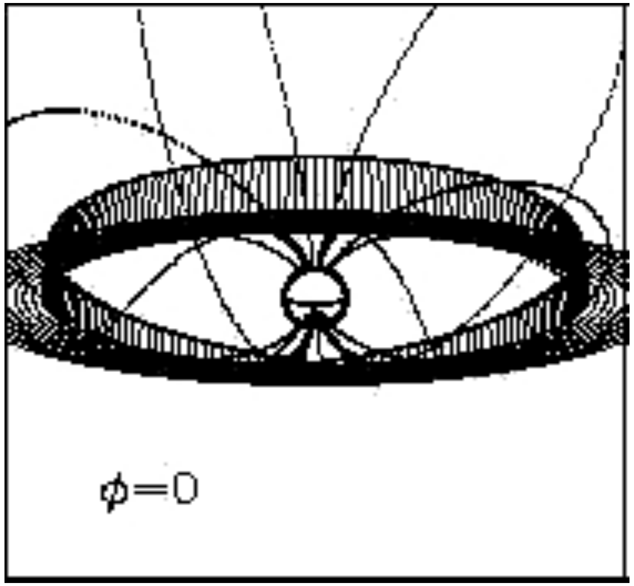
Light curve shows periodical (~ 8.2 days) eclipses of the photosphere that occur without much color variation.

The linear polarization increases as the system fades.

Periodical occultation of the photosphere by an optically thick, magnetically-warped inner disk region

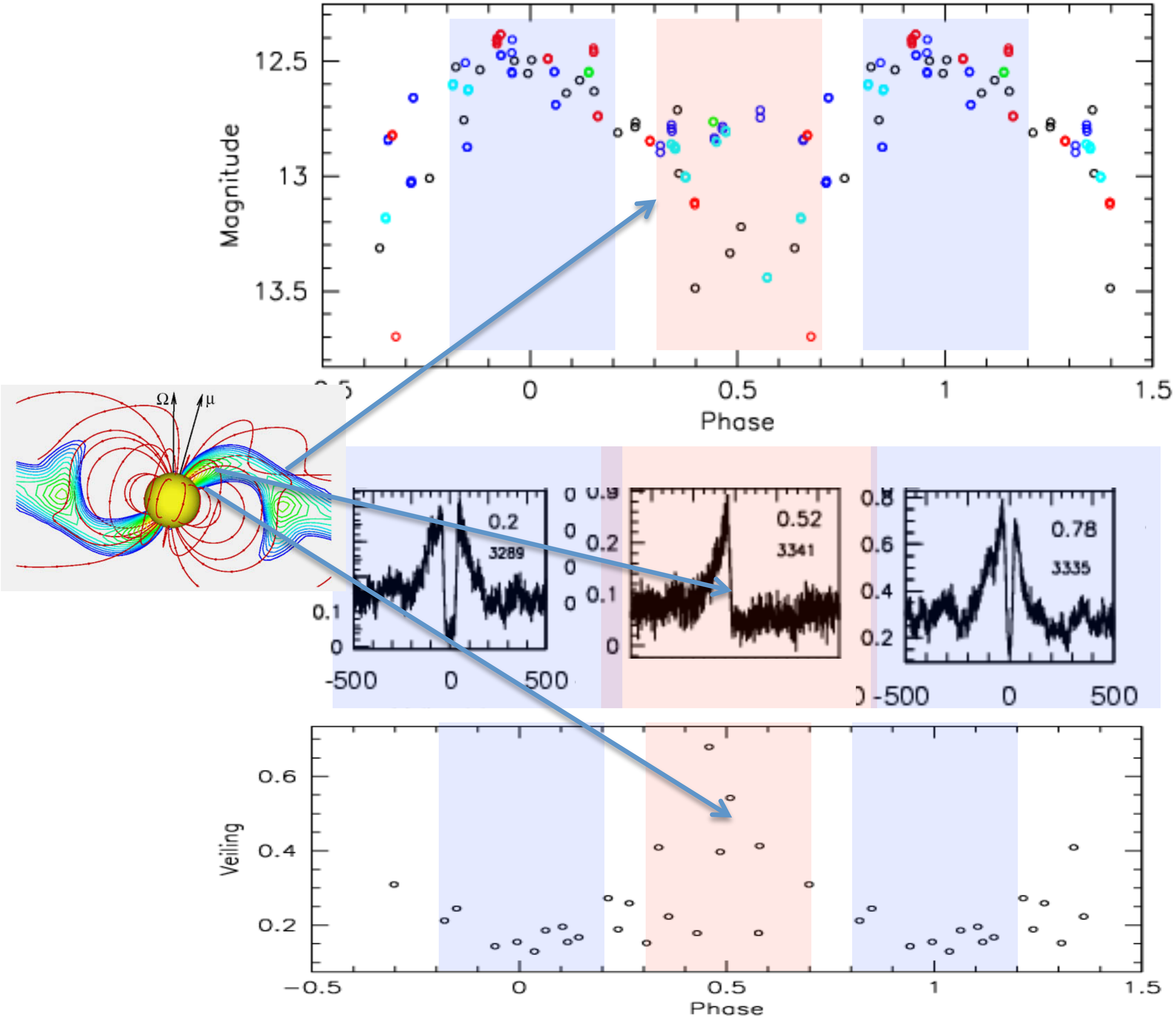


Ménard et al. (2003)



Inclined magnetosphere (Bouvier et al. 2007)

Disk warp, accretion column, accretion shock : all spatially associated



Periodical eclipses

(inner disk warp)

P=8.22d

Balmer lines

(accretion funnel)

Veiling

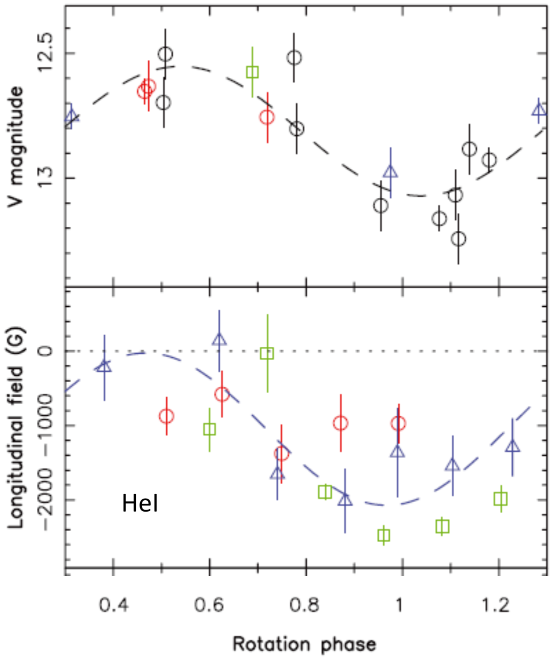
(accretion shock)

AA Tau spectro-polarimetry

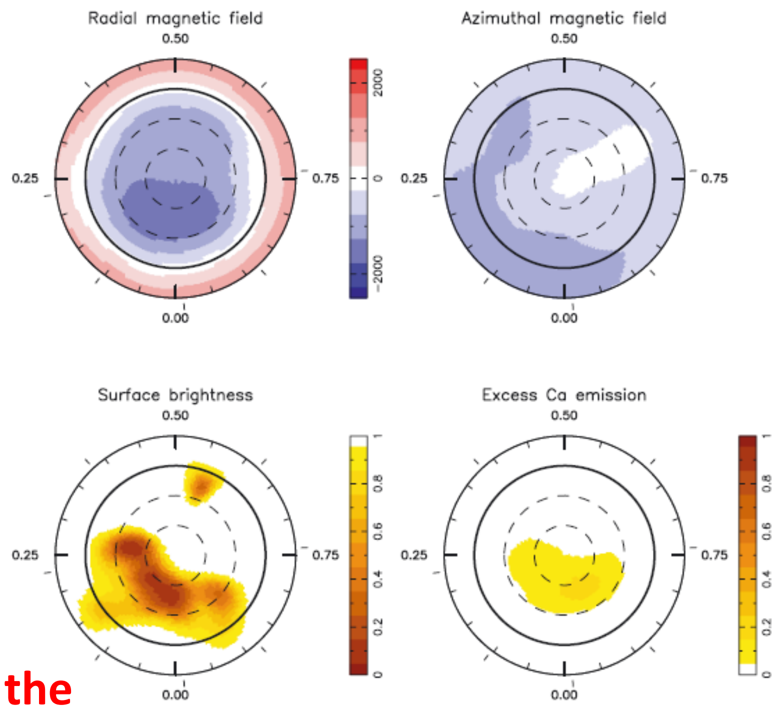
2-3kG dipole, tilted at ~20 deg onto the rotation axis

AA Tau : M~0.7Mo, log(Macc) = -9.2

Donati et al. 2010



Magnetospheric accretion and spin-down of AA Tau 1357

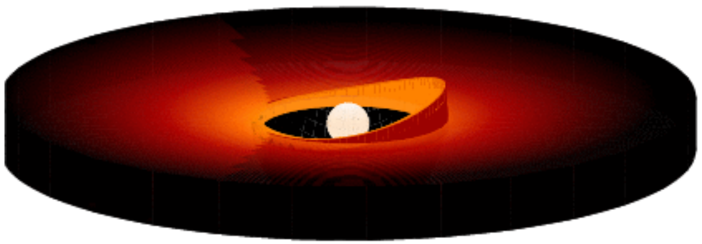


The magnetic pole is located at about the same azimuth as the disk warp that produces the eclipse

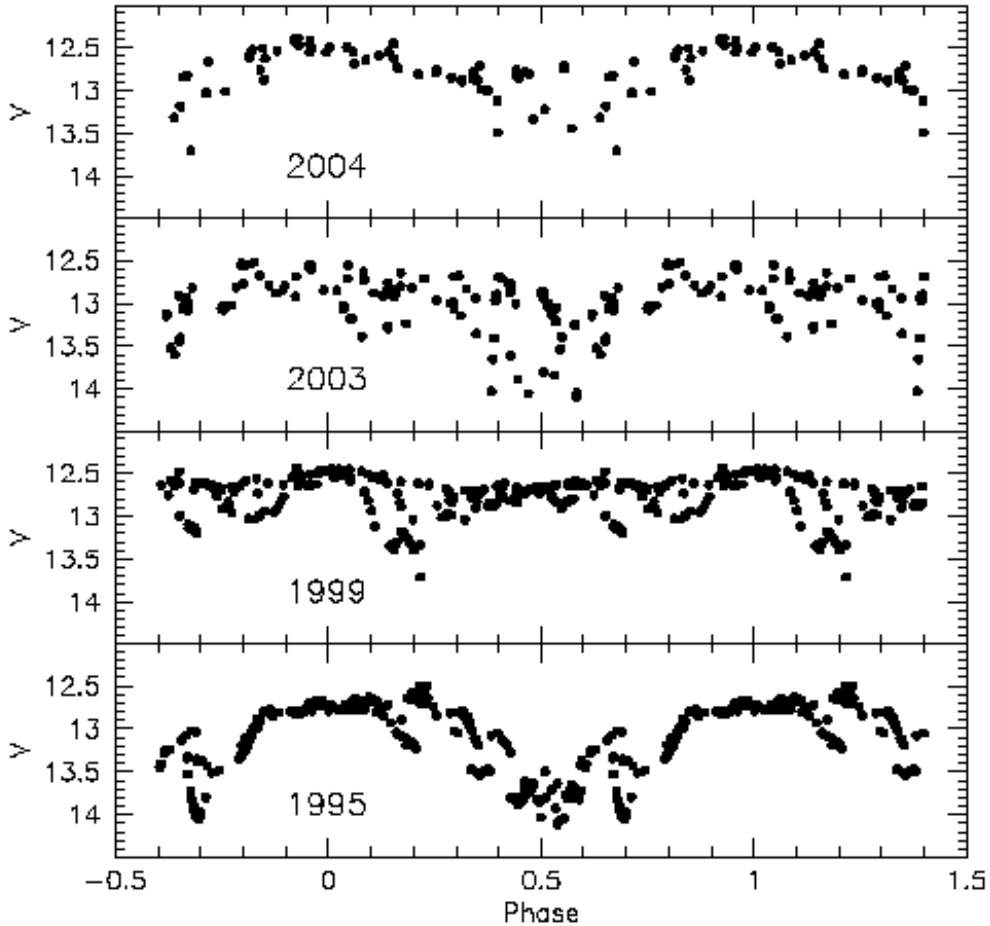
Both a cold (magnetic) spot and a hot (accretion) spot are found close to the magnetic pole

Short term (weeks) variability supports the idea of **"magnetospheric accretion cycles"** on a timescale of a few rotation periods in accreting T Tauri stars.

Magnetic configurations of the star-disk interaction can also vary on a much longer timescale (~a few years).

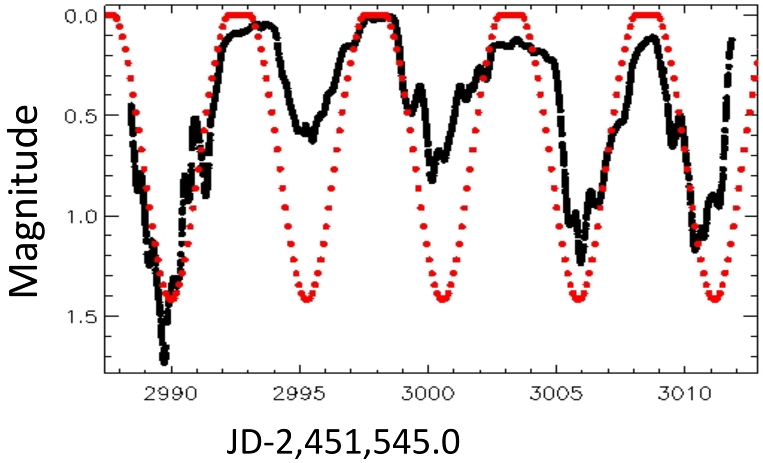


AA Tau's eclipses



Occultation model applied to V354 Mon (an AA Tau-type system)

Fixed model parameters



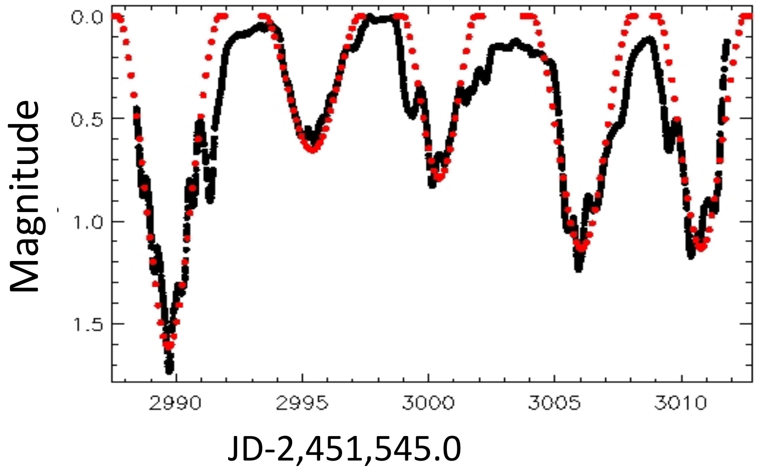
$h_{max} = 0.3\ r_c$

Azimuthal extension: 360°

Same parameters obtained in AA Tau fit (Bouvier et al. 1999)

Disk models (Duchêne et al. 2010): ~ 0.05 – 0.1 r_c

Varying h_{max} and extension



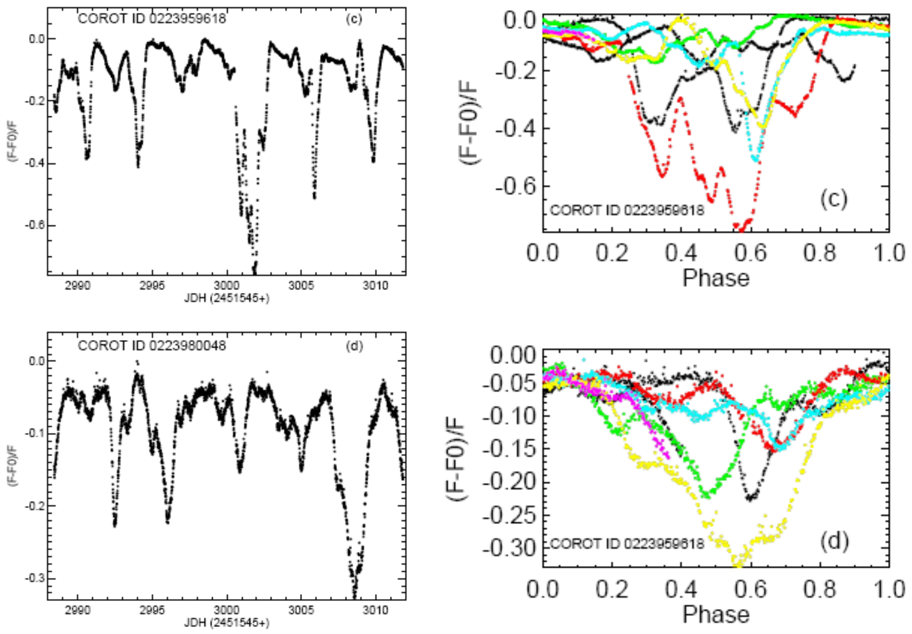
h_{max} (r_c)	azim. ext. (°)
0.31	320
0.23	320
0.25	240
0.28	320
0.28	280

Fonseca et al., in prep.

NO, it is the rule rather than the exception

IS AA TAU UNIQUE ?

Occultations by inner disk warps are relatively common

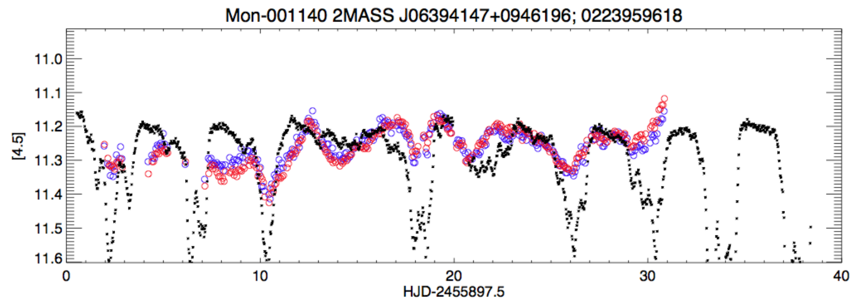


(Corot, NGC 2264)

About 40% of systems with a thick inner disk exhibit AA Tau-like optical light curves

Suggests h/R ~ 0.3 at the inner disk edge !

Also seen in the IR (Spitzer), though less frequent

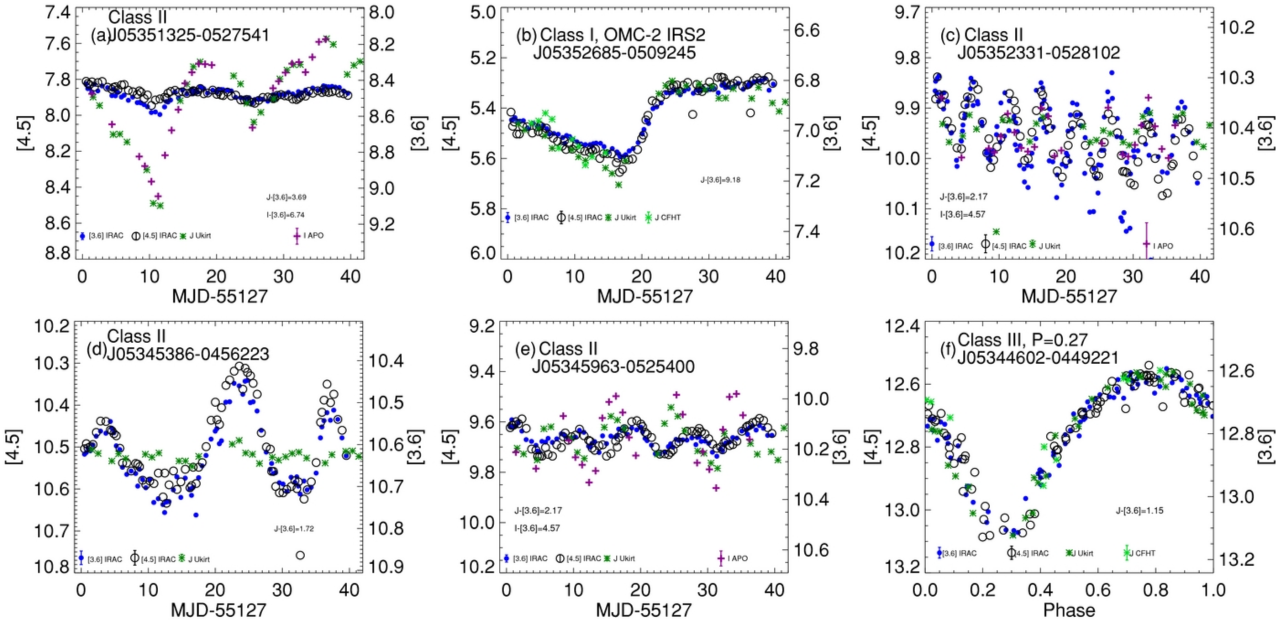


Rapid (~rotation cycle) and significant variations of the occulting material : **the star-disk interaction is a highly dynamical process**

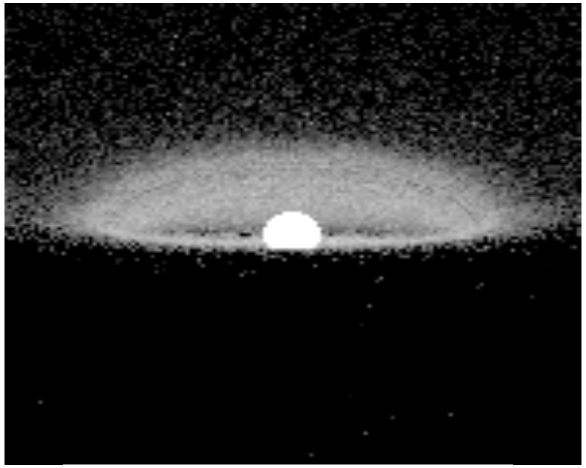
Morales-Calderon et al. 2011

Alencar et al. 2010

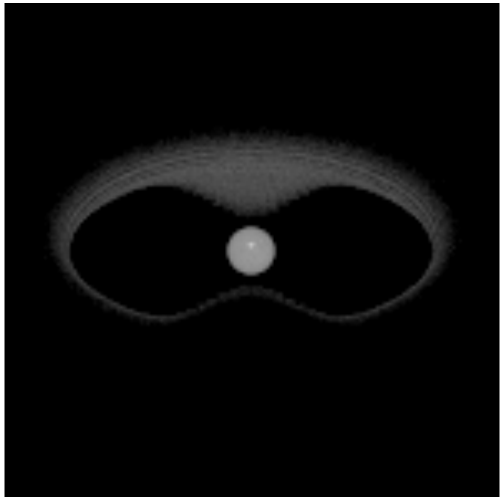
A gallery of opt/IR variability (Corot/Spitzer)



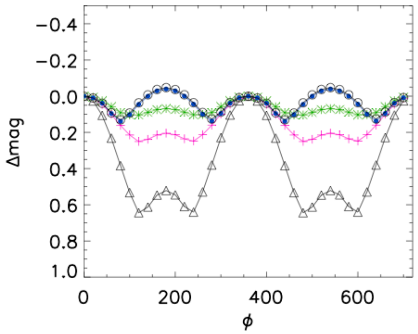
CSI 2264 : Coordinated Investigation of NGC 2264

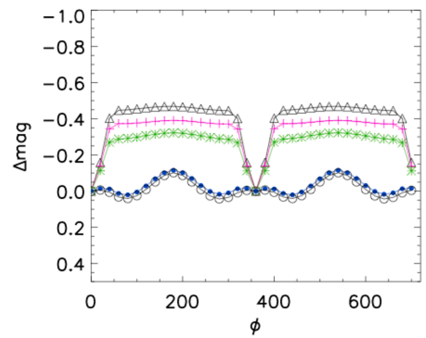


Cody, Stauffer, et al., in prep.



And preliminary models…





Kesseli et al., in prep.

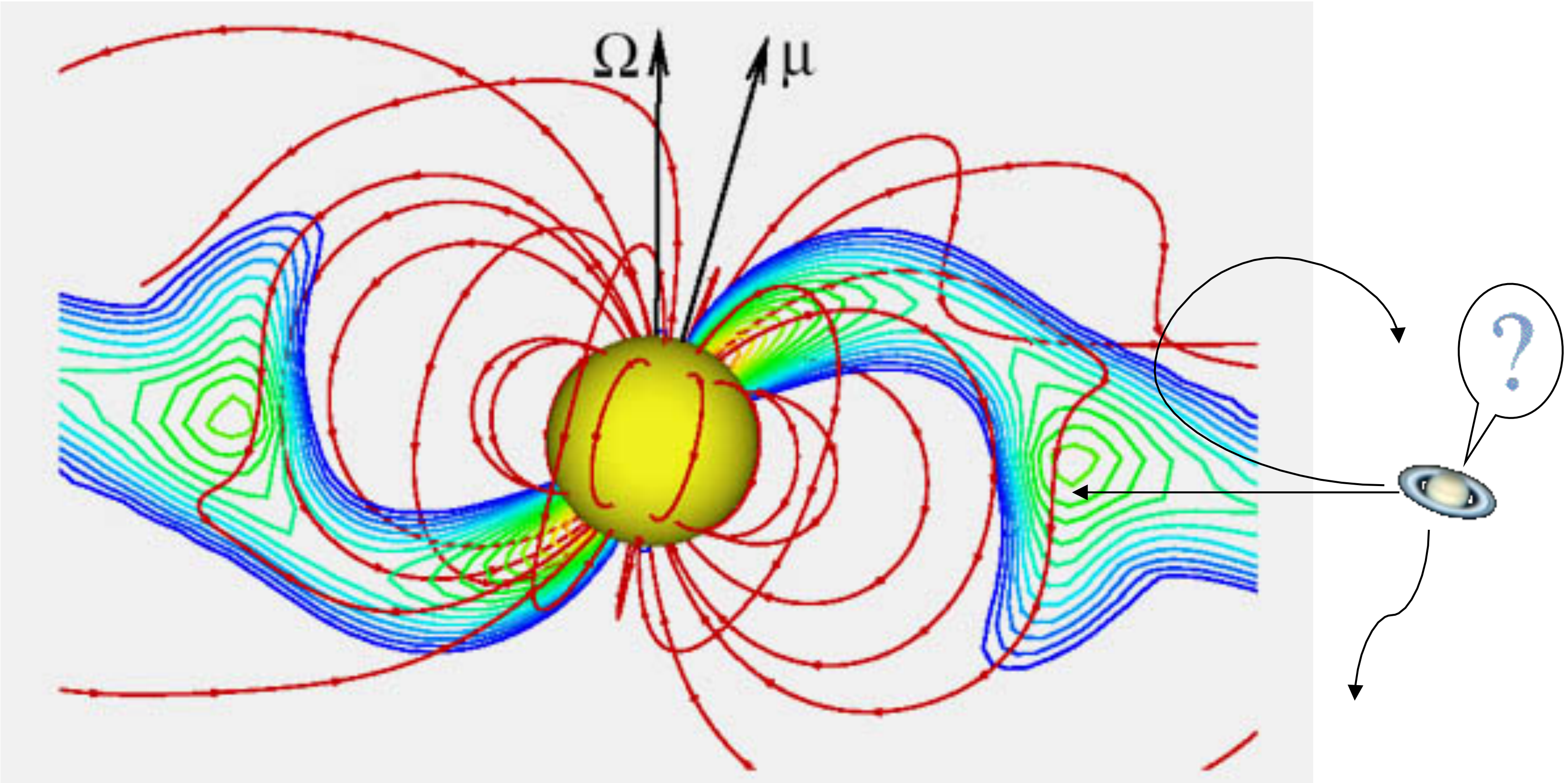
All this suggests strong disturbances in the inner disk (r ≤ a few 0.1 AU)

Do planets care ?

- Yes, in at least 2 ways.
- **Planets form in disks** : disk disturbances, small scale inner warp, large scale (spiral) waves, variable disk illumination (photo evaporating winds, chemistry), …
- **Planet migrate in disks** : density waves, surface dead zones, magnetospheric cavity, time variable acccretion-outflow, …

Inner disk warps

induced by the interaction with an inclined magnetosphere

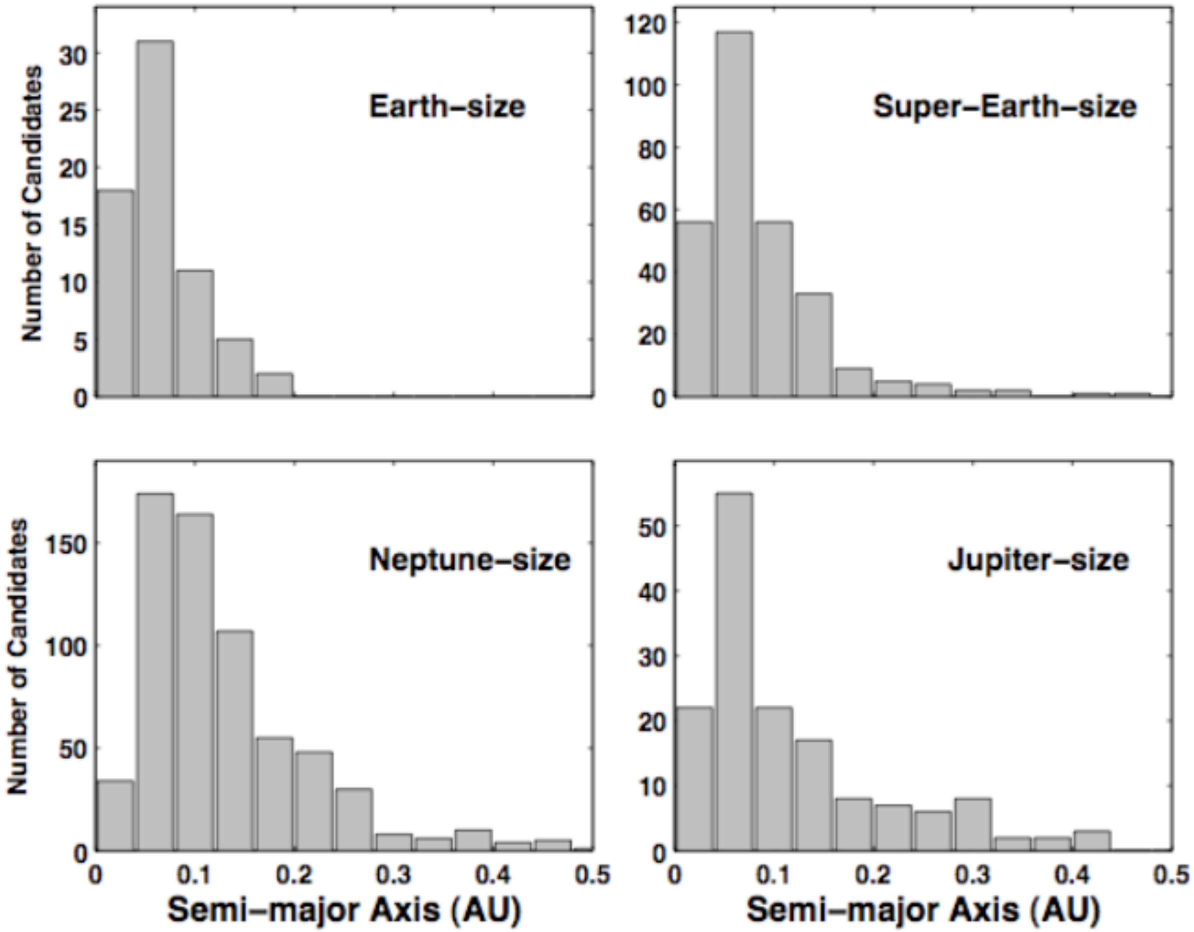


Halting the planet migration ?

"Hot Jupiters" (or Saturns…)?

Issues : impact on planet formation ?

1235 planetary candidates from Kepler



Semi-major axis distribution of transiting planetary candidates peaks at : **a ≤ 0.1 AU**

Is there a link between the orbital radius of planetary orbits and the magnetospheric truncation radius : **Rm~0.05-0.1 AU ?**

Borucki et al. (2011)

Conclusions

Disks are neither flat nor monotonic.

Disks are not steady.

At some point, complexity must be introduced in the (SED, chemistry, migration, structure, visibility, etc.) models.