SPIRou - the impact of magnetic fields on star and planet formation

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C A P E S

Questions

What are the magnetic topologies of class-I, II and III stars ?

How do they correlate with the evolutionary status?

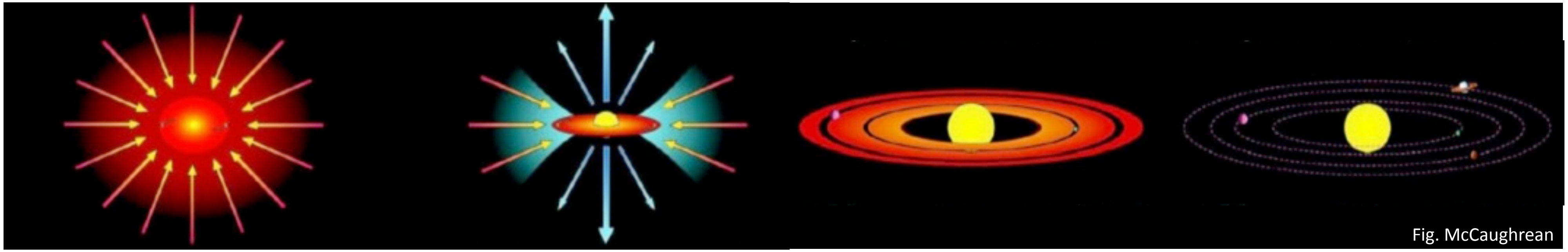
What are the fields in the internal discs of accreting PMS stars?

How frequent are hot Jupiters around PMS stars?

Can we progress in our understanding of magnetospheric accretion?

Can we improve the description of the earliest phases of angular momentum evolution ?

Star and planet formation

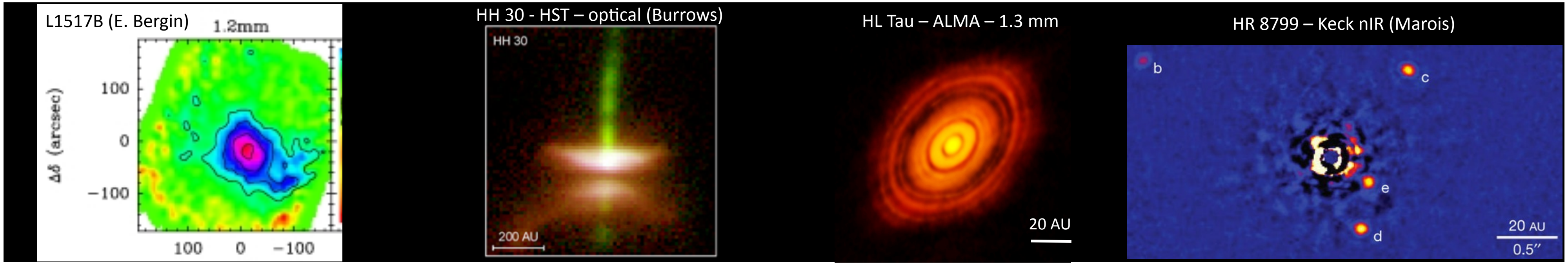


10 000 AU
t=0
Gravitational colapse

500 AU
t=10^5 – 10^6 years
T Tauri star, disk and outflows

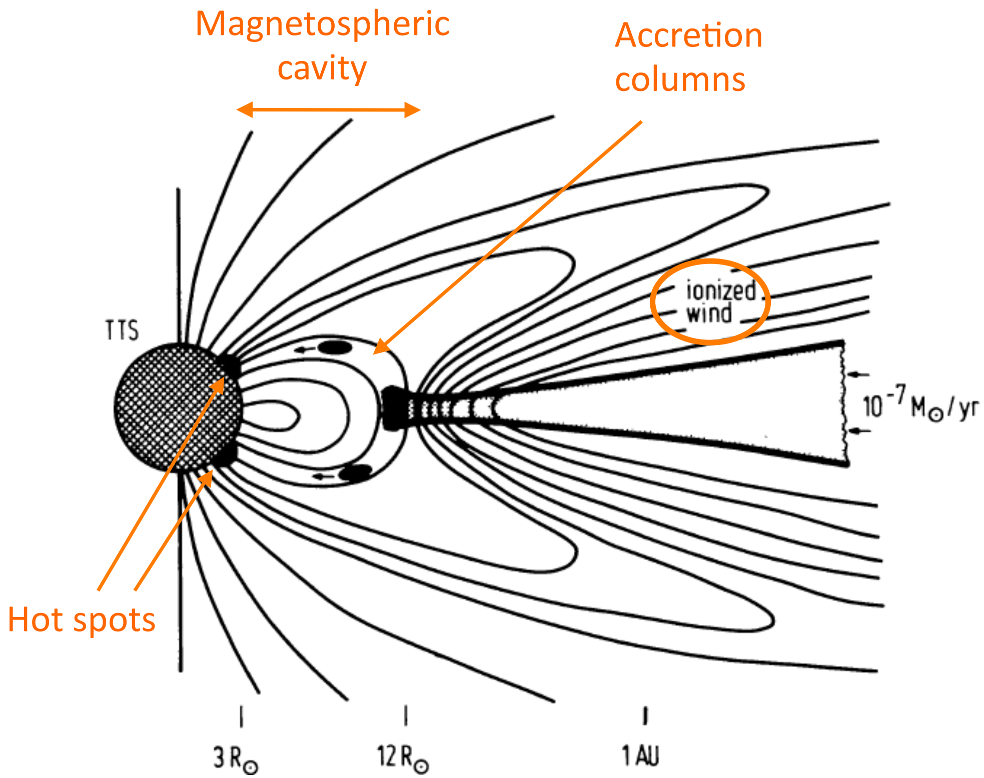
200 AU
t=10^6 – 10^7 years
Post-T Tauri, evolved disk

100 AU
t > 10^7 years
Star and planetary system



The importance of magnetic fields

- Activity
- Accretion
- Star-disk interaction
- Inner disk structure
- Outflows (stellar winds, disk winds, jets)
- Angular momentum transport



Camenzind (1990) Shu et al. (1994), Hartmann et al. (1994)
Kurosawa et al. (2006,2011), Lima et al. (2010)

The importance of magnetic fields

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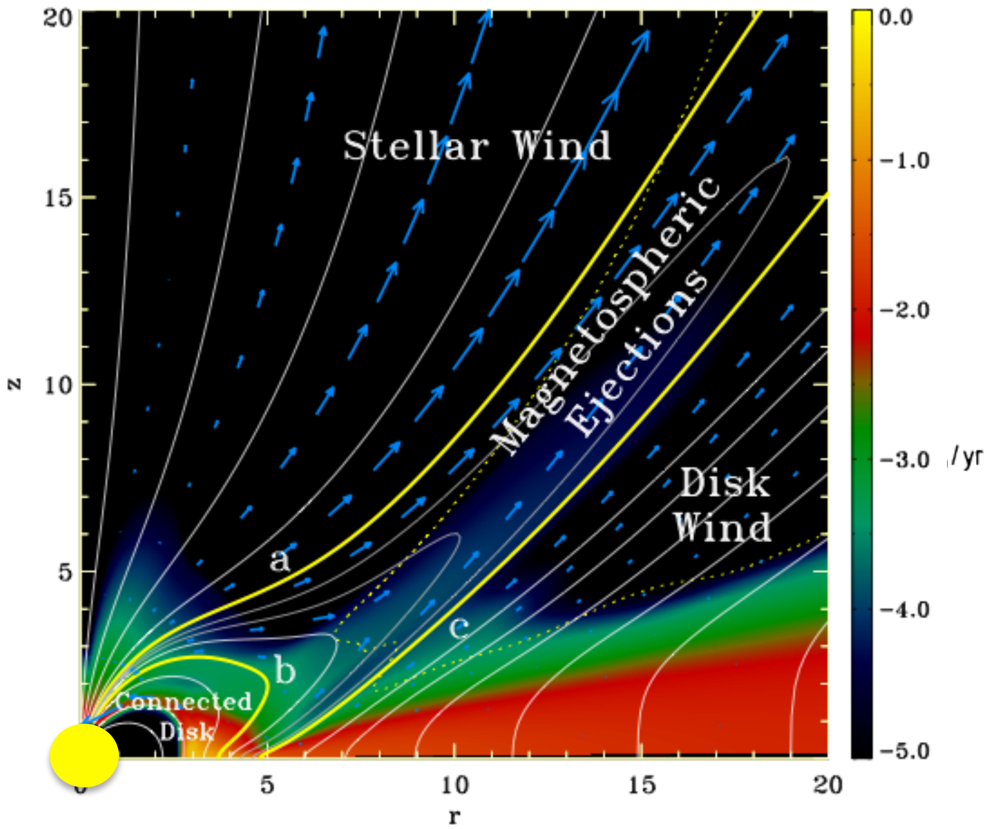
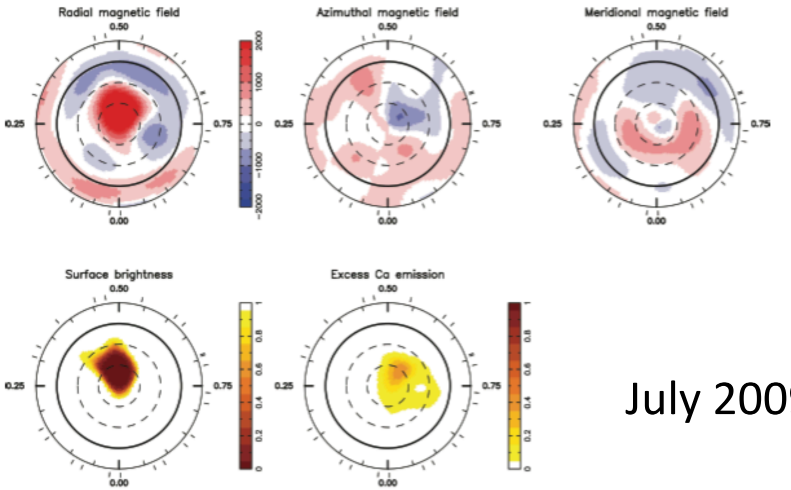


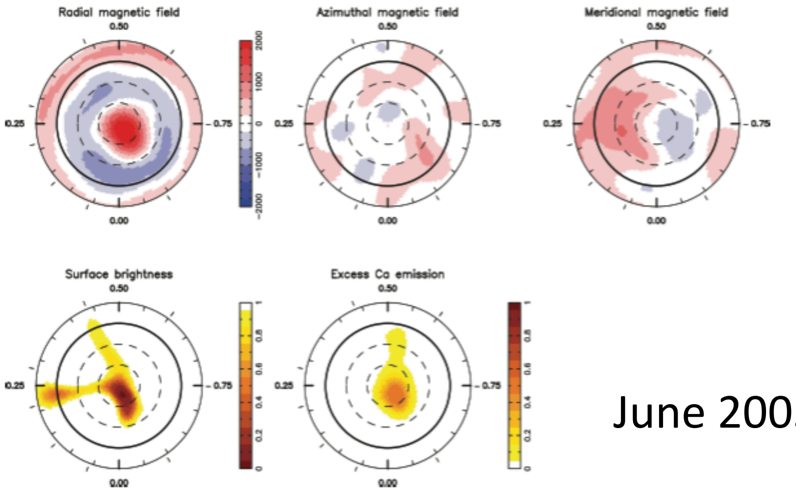
Zanni & Ferreira (2013)

V2129 Oph – MaPP Large Program at CFHT

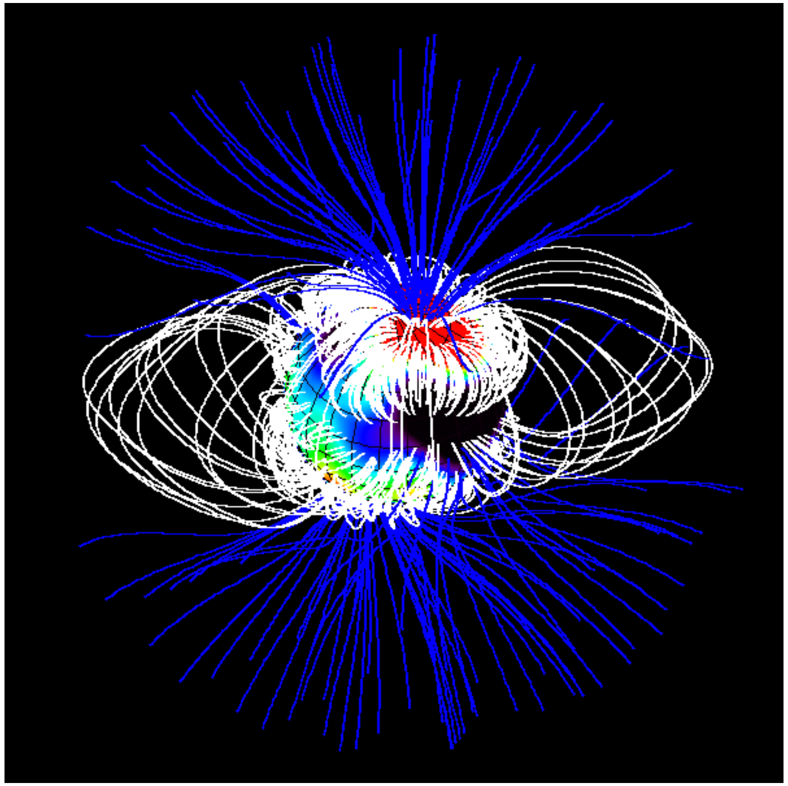
Axisymmetric, poloidal magnetic field, dominated by the octupole. The dipole and octupole components varied between the two epochs of observation.



July 2009



June 2005

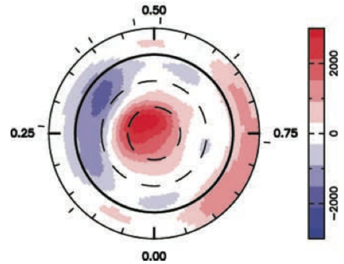


Donati et al. (2007, 2011), Jardine et al. (2008), Gregory & Donati (2011)

Magnetic field structure in CTTSs

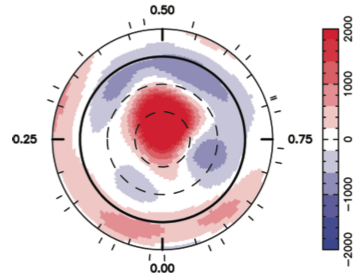
MaPP Large Program at CFHT

1. Fully convective star
Dynamo: strong axisymmetric dipole - AA Tau, BP Tau, GQ Lup
Slow rotation rates (p~8d)
Donati et al. (2008, 2010, 2012), Chen & Johns-Krull (2013)



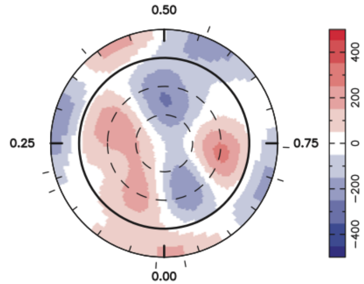
BP Tau

2. Convective shell with depths > 0.5 R$_*$
Dynamo: strong axisymmetric octupole – TW Hya, V2129 Oph, DN Tau
Start to spin-up (p~4d to 6d)
Donati et al. (2011, 2012, 2013)



V2129 Oph

3. Convective shell with depths < 0.5 R$_*$
Dynamo: weak non-axisymmetric multipole - V4046 Sgr, CV Cha, CR Cha
High rotation rates (p~2d)
Hussain et al. (2009), Donati et al. (2011)



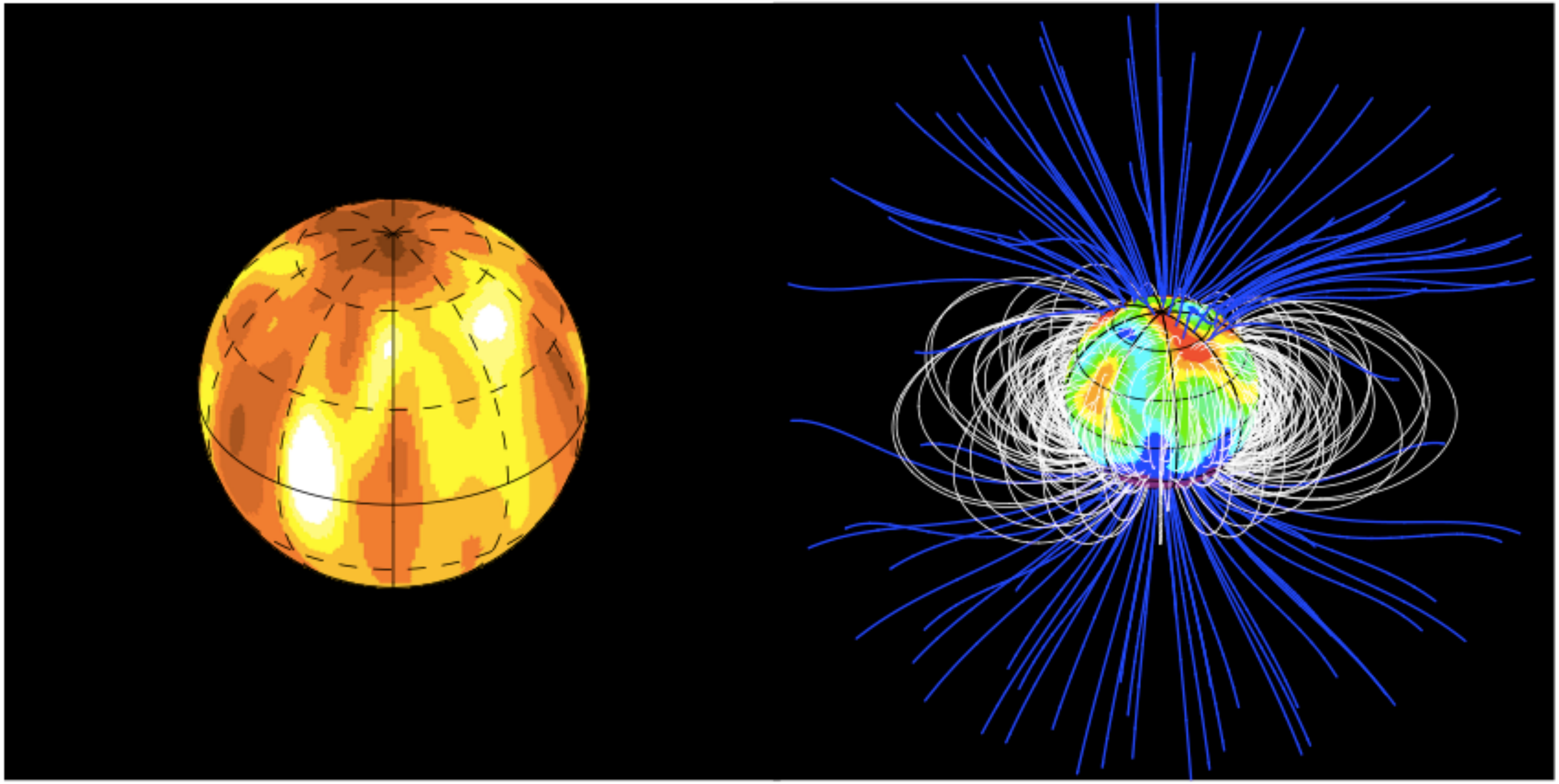
V4046 Sgr

Similar results obtained for Main-Sequence stars (Morin et al. 2010, 2011)

Magnetic field structure in WTTSs

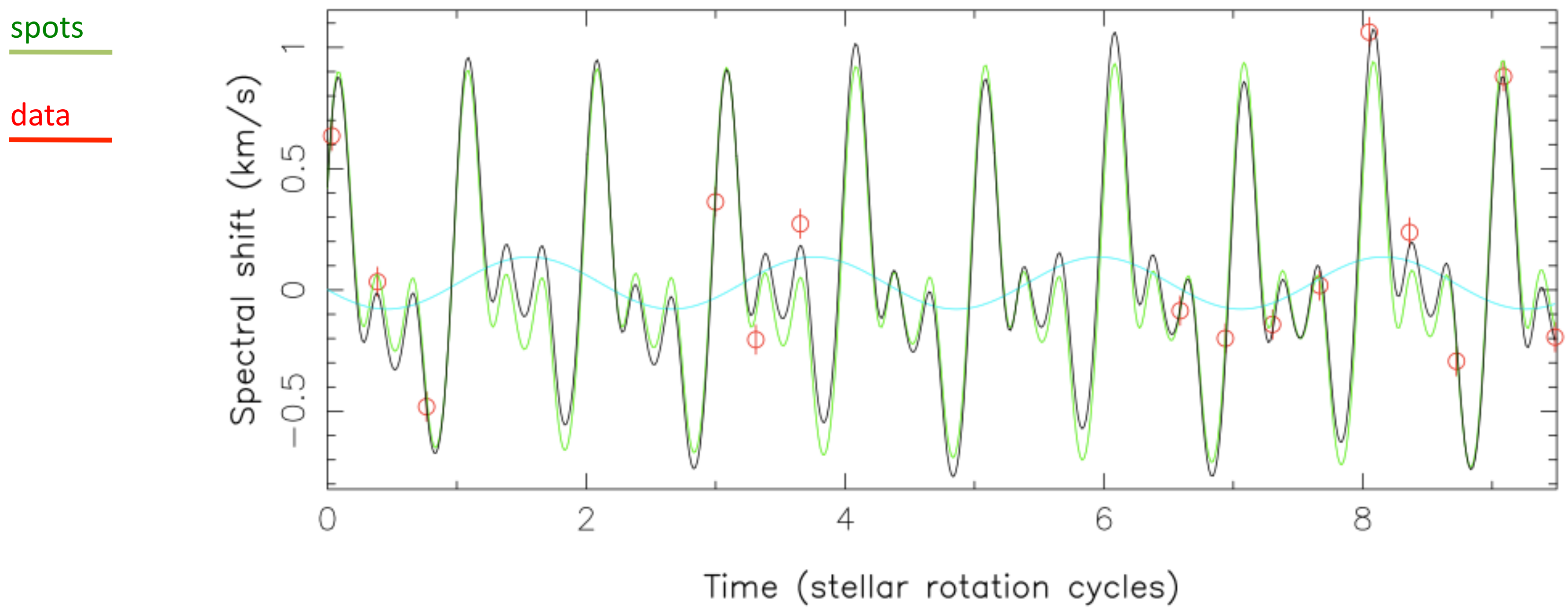
MaTYSSE Large Program at CFHT and ESO

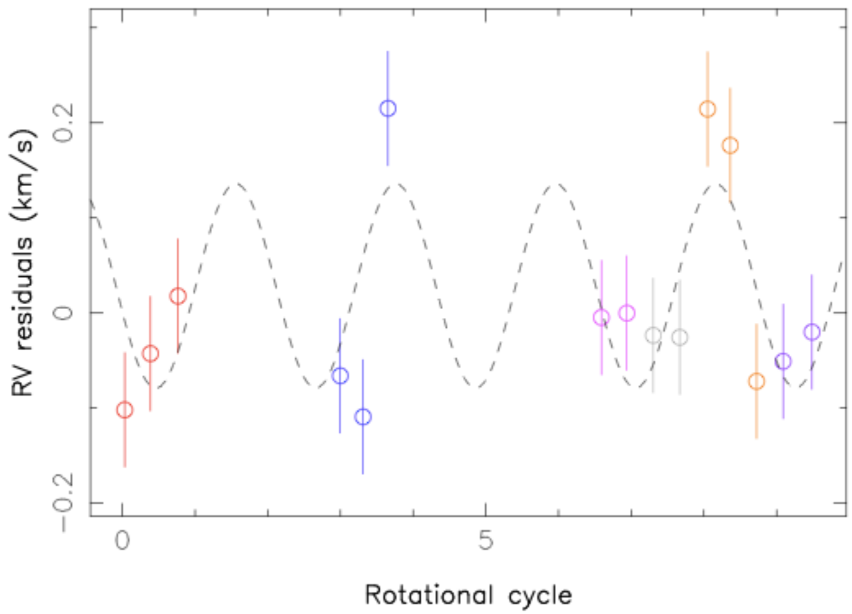
V830 Tau



Donati et al. (2015)

V830 Tau



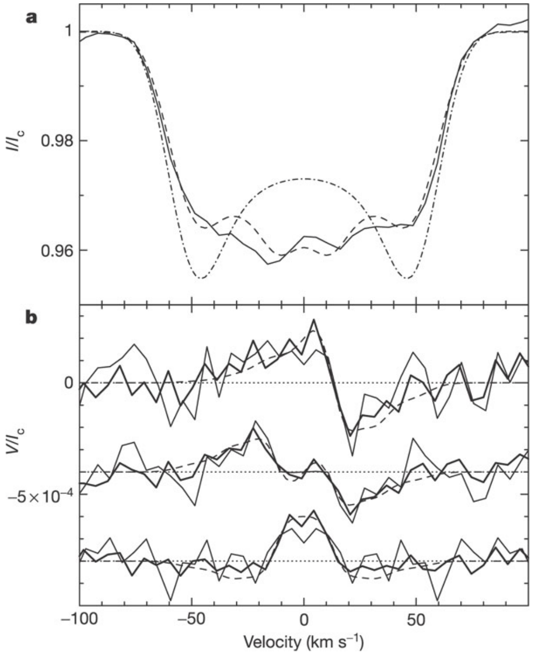


Residuals from spot model

In agreement with a 1.4 M_{Jup} planet orbiting the star with p=6 days at 0.07 AU

Donati et al. (2015)

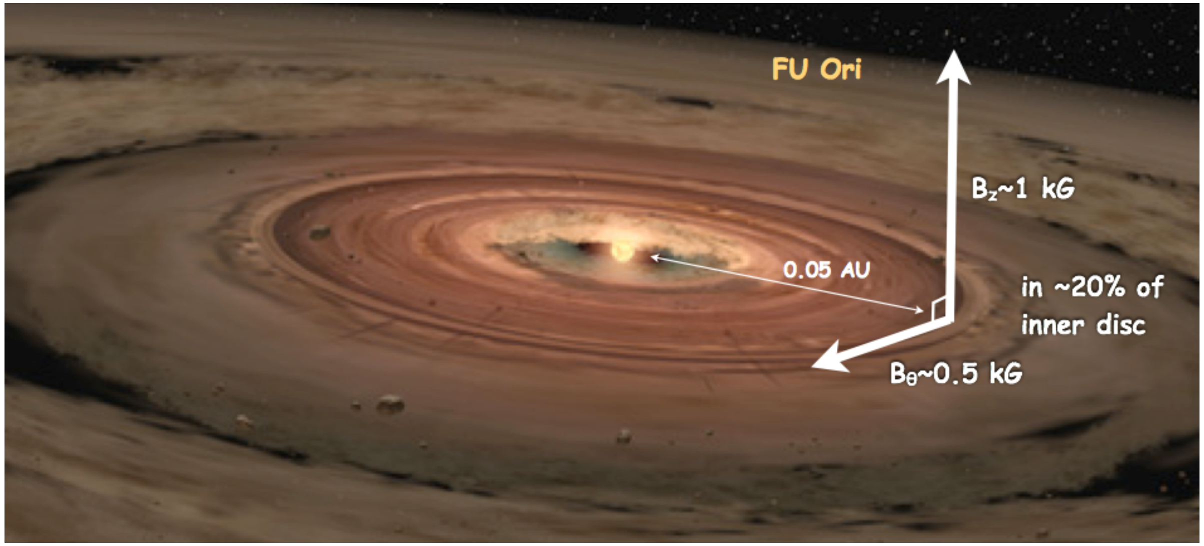
FU Ori – magnetic field in the inner disc – ESPaDOnS at CFHT



Disc with sub-keplerian rotation

Axisymmetric magnetic field in about 20% of the inner disc

Donati et al. (2005)



SPIRou - near infrared spectropolarimeter

Star and planet formation

Impact of stellar and disc magnetic fields on

Accretion and outflows
Internal structure and rotation
Formation, migration and survival of planets

Goals

Detect and map magnetic topology of protostars and accretion discs
Constrain accretion, outflows, dynamos
Origin and evolution of magnetic field
Angular momentum evolution
Model activity and activity jitter of WTTSs and search for hot Jupiters

SPIRou Legacy Survey

Star and planet formation

Monitoring of 20 Class-I, 40 Class-II and 80 Class-III PMS stars and their accretion discs, selected in the 3 closest star forming regions (e.g., Taurus/Auriga, TW Hya Association, ρ Oph), for a total of about 125 nights

- Use the unprecedent sensitivity of SPIRou to PMS stars and magnetic fields to carry-out full-size surveys following the MaPP & MaTYSSE explorations

- Include Class I systems

- Disc magnetic fields

SPIRou Legacy Survey

Class I

Sample of 20 Class I systems

- How magnetospheric accretion behaves when accretion is both much stronger and more episodic than for CTTSs, and how the stars react to this process

- Measure spin rates of class-I protostars and study how they depend on large-scale fields and accretion rates

- Unveil the early angular momentum evolution of accreting PMS stars, and assess the role played by magnetic fields.

SPIRou Legacy Survey

Class II (CTTSs)

Sample of 40 CTTSs

- How the large-scale fields and accretion patterns of cTTSs change with masses, ages and accretion rates

- The physics of dynamo and the impact of accretion

- How magnetic fields control the angular momentum evolution of CTTSs

- The connection between magnetospheric accretion/ejection
X-winds, diskwinds, accretion-powered winds

SPIRou Legacy Survey

Class III (WTTSs)

Sample of 80 WTTSs

- How the large-scale magnetic field varies with mass and age
- Dynamo models
- Angular momentum evolution
- Survival of hot Jupiters

Clean the RV curve from the activity jitter
Find hot Jupiters at an early age
Study planet formation/migration

SPIRou Legacy Survey

Discs

- Detect spectral signatures from the innermost regions of accretion discs of high mass accretion stars (Class-I and CTTSs)

- Characterize the large-scale fields of inner accretion discs, focussing in particular on their vertical and toroidal components

- Map magnetic fields and mass densities in the innermost regions of accretion discs, to constrain the origin of the fields (dynamo vs fossil) and to study their impact on planet formation with MHD simulations

SPIRou Legacy Survey

WP3: the SLS Magnetic PMS star/planet

WP3 – Silvia Alencar, Jean-François Donati, Jérôme Bouvier

Work packages
WP3.1 / input catalog (J. Bouvier, E. Alecian, S. Alencar)
WP3.2 / large-scale fields of low-mass PMS stars (J.-F. Donati, G. Hussain)
WP3.3 / fields of inner accretion discs (F. Ménard, M. Takami, C. Baruteau)
WP3.4 / search for hot Jupiters (J.-F. Donati, I. Boisse)
WP3.5 / complementary observations and modeling (S. Alencar, C. Dougados)