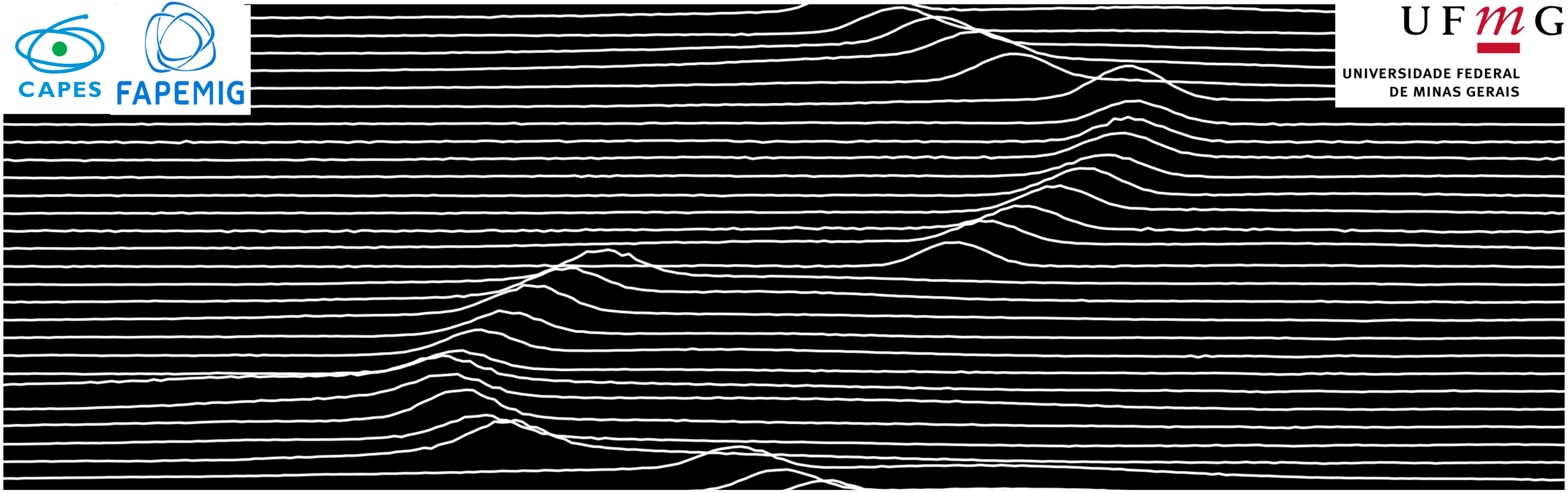

Magnetic field and magnetospheric accretion of GM Aurigae with SPIRou

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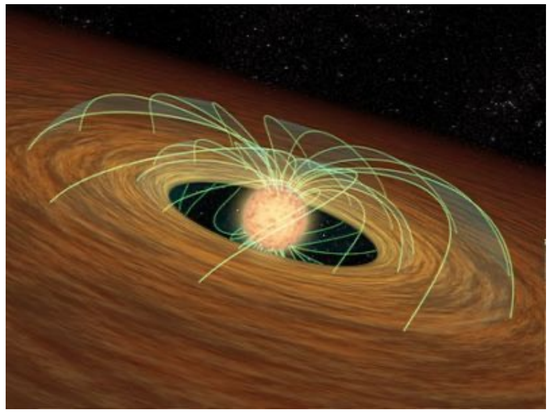
MIAPbP workshop · 10/13/23

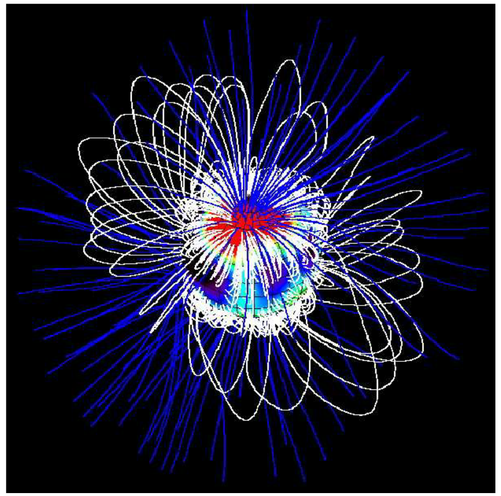
Magnetic field of young T Tauri stars

- One of the main goals of SPIRou is to « explore the impact of magnetic fields on star/planet formation, by detecting and characterising magnetic fields of low-mass PMS stars and their inner accretion discs. » (Donati et al. 2018)
  - At early stages, magnetic fields mediate the star-disc interaction.
    - they truncate the surrounding disc,
    - control the accretion process, and
    - potentially impact on planet formation.

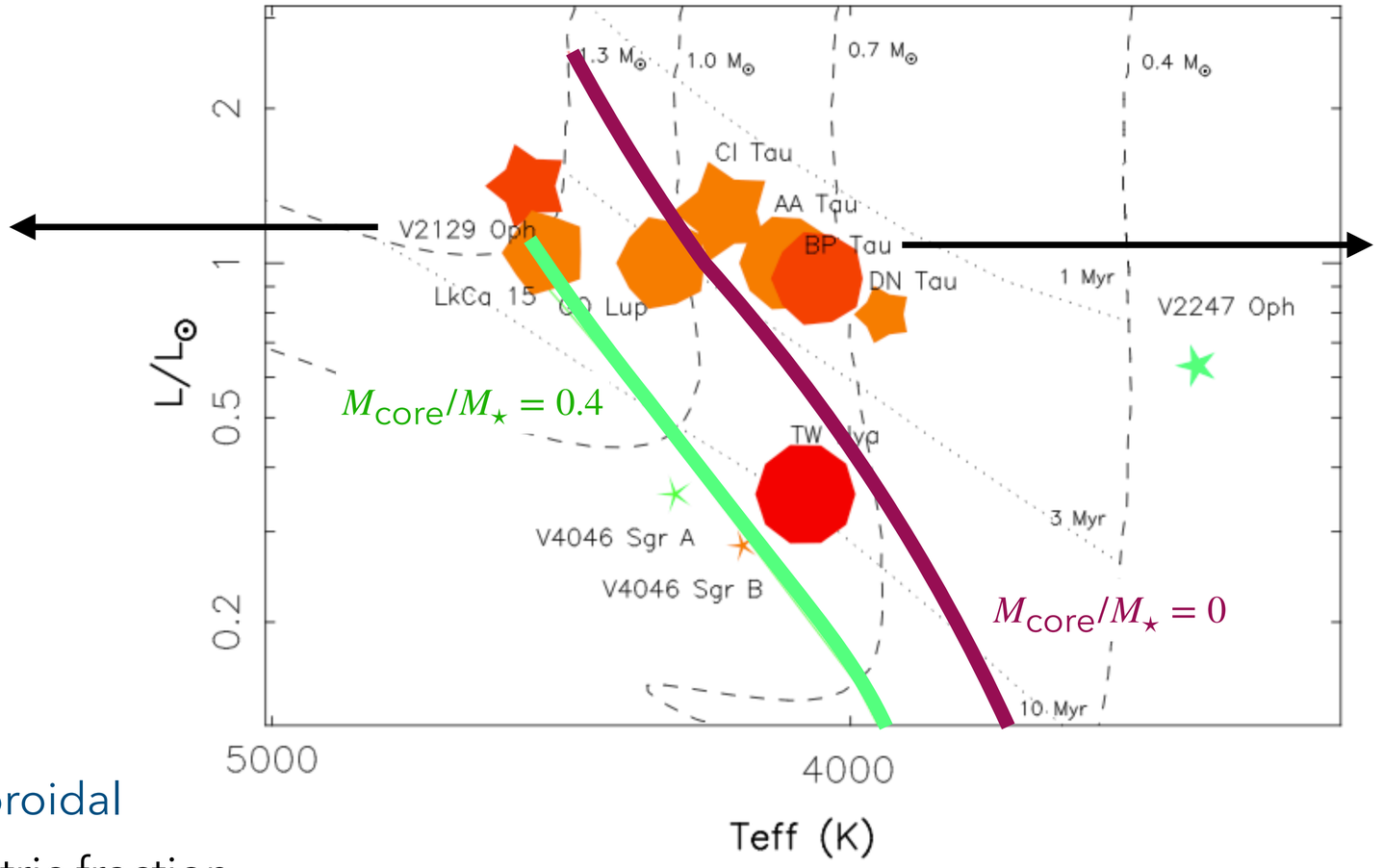


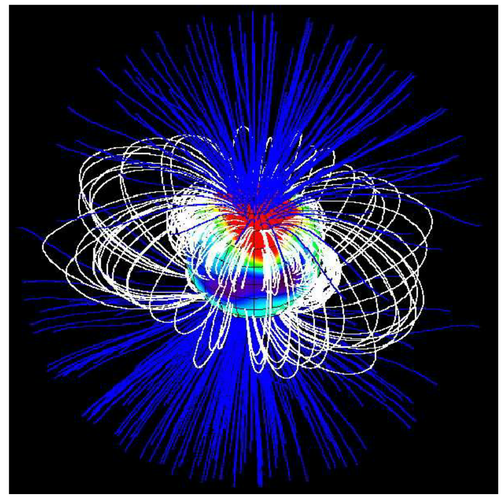
  - At all stages, magnetic fields play a key role in regulating the angular momentum evolution (accretion, winds, and jets).

Magnetic field of classical T Tauri stars



V2129 Oph (1.35M$_\odot$, 6.4 dias)
partially Convective
Dipole - 0.3 kG; Octupole - 1.2 kG
(Donati et al. 2007; Jardine et al. 2008)





BP Tau (0.7M$_\odot$, 7.6 dias)
Fully Convective
Dipole - 1.2 kG; Octupole - 1.6 kG
(Donati et al. 2008; Gregory et al. 2008)

Size - B^2

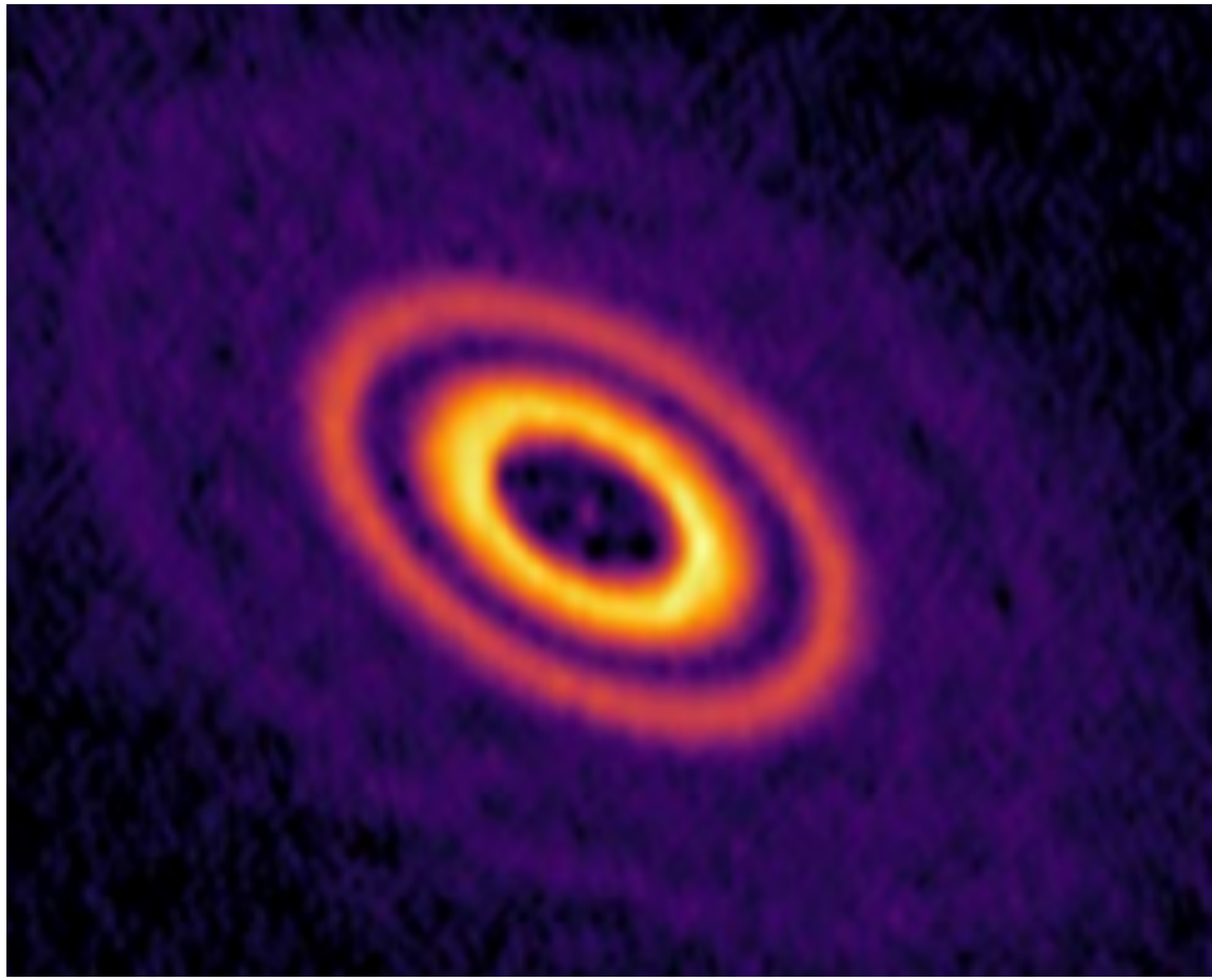
Color - Poloidal/Toroidal

Shape - Axisymmetric fraction

Donati et al. (2019)

GM Aurigae

- Classical T Tauri star: young, low-mass star that is still accreting material from its surrounding disc.
  - ~2 Myr; 0.95 $M_{\odot}$
  - P_{rot}~6 days (Artemenko et al. 2012)
  - $\dot{M} = 0.7 \times 10^{-8} M_{\odot} \mathrm{yr}^{-1}$ (Bouvier et al. 2023)
- Disc:
  - Inclination of 53.2^{o} (Huang et al. 2020);
    - No evidence of inner to outer disc misalignment (Bohn et al. 2022);
  - Large (dust) cavity of 20-30 AU;
    - Cleared out by a forming planet?
    - Presence of gas within the cavity.

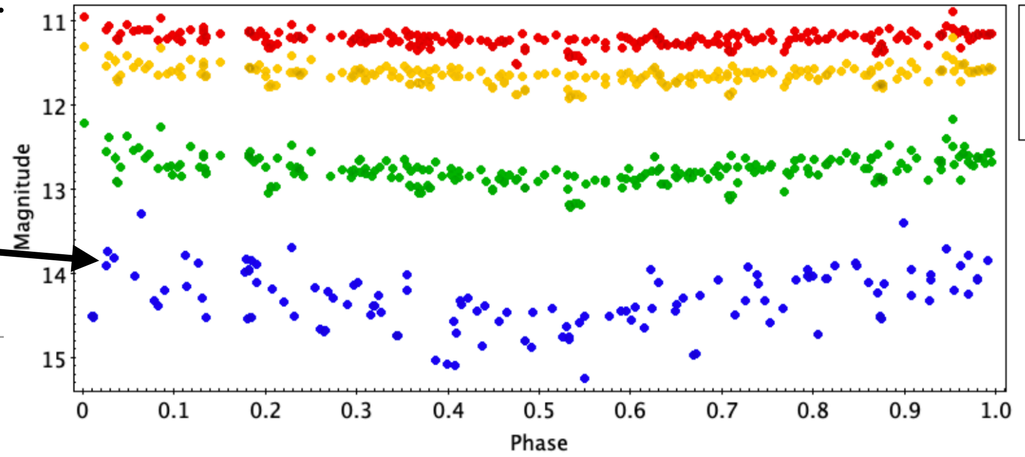


Huang et al. (2020)

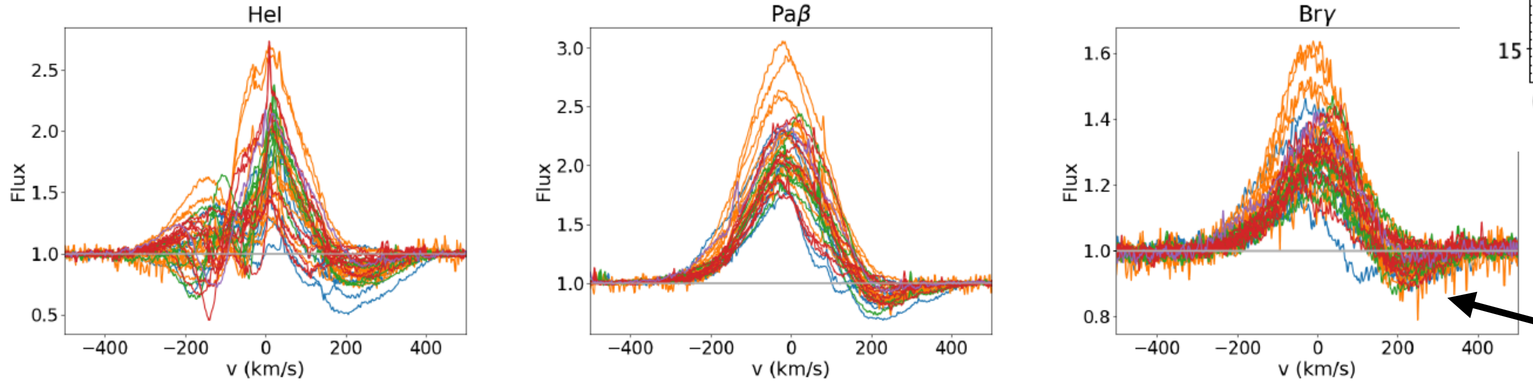
Accretion lines

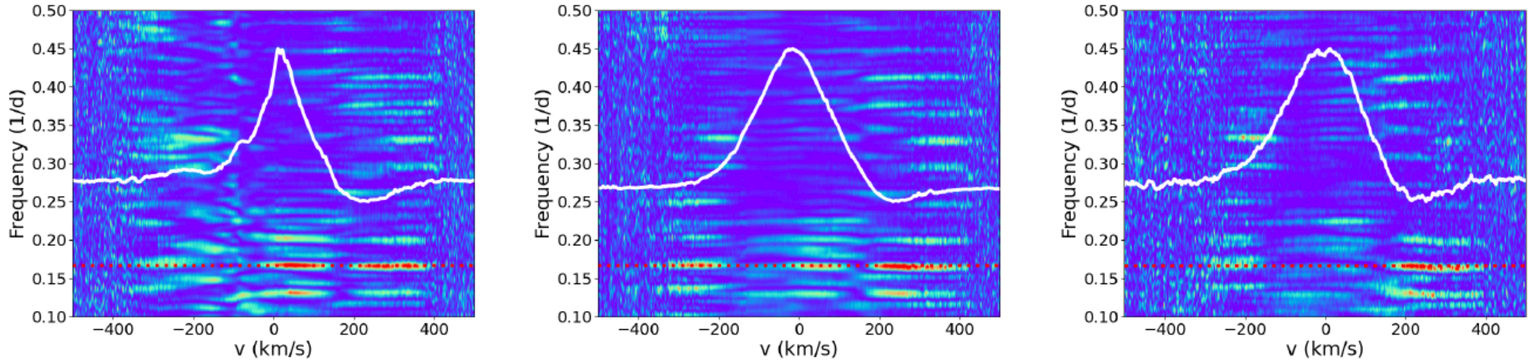
- Stable magnetospheric accretion for at least 15 rotation cycles.
  - Rotation period of 6.04 d
  - Hot spot facing phase 0.

LCOGT light curve



Emission lines (HeI, Paβ, Brγ)



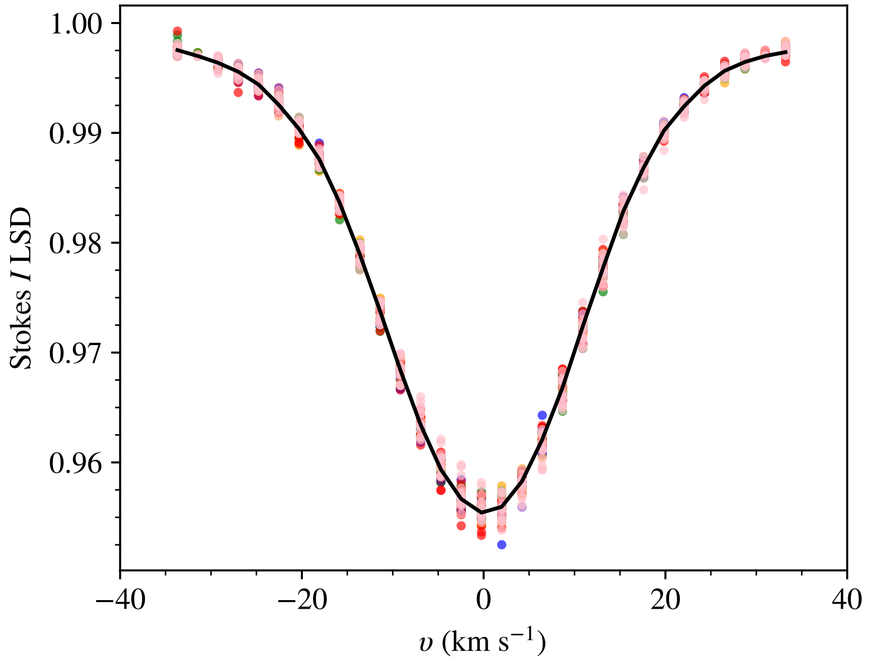


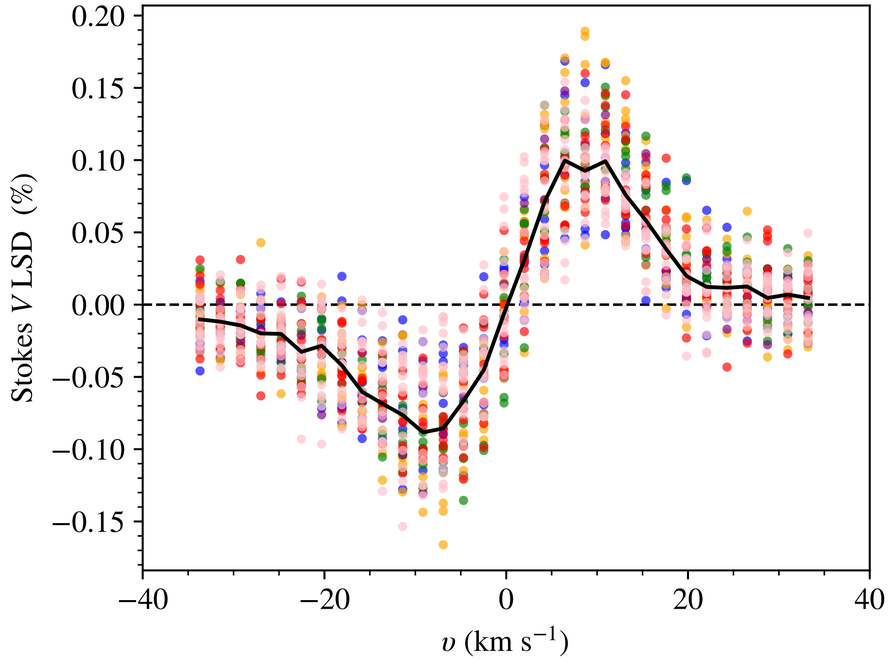
- inverse P Cygni profiles: presumably tracing the accretion funnel flow.

Bouvier et al. (2023)

Spectropolarimetric observations of GM Aur

- GM Aur was observed with **SPIRou** from September 2021 to January 2023;
  - We collected 47 spectra in the **near-IR** wavelength domain;
- We applied the least-squared deconvolution procedure to compute **photospheric Stokes I and V LSD** profiles with enhanced SNR (Donati et al. 1997).

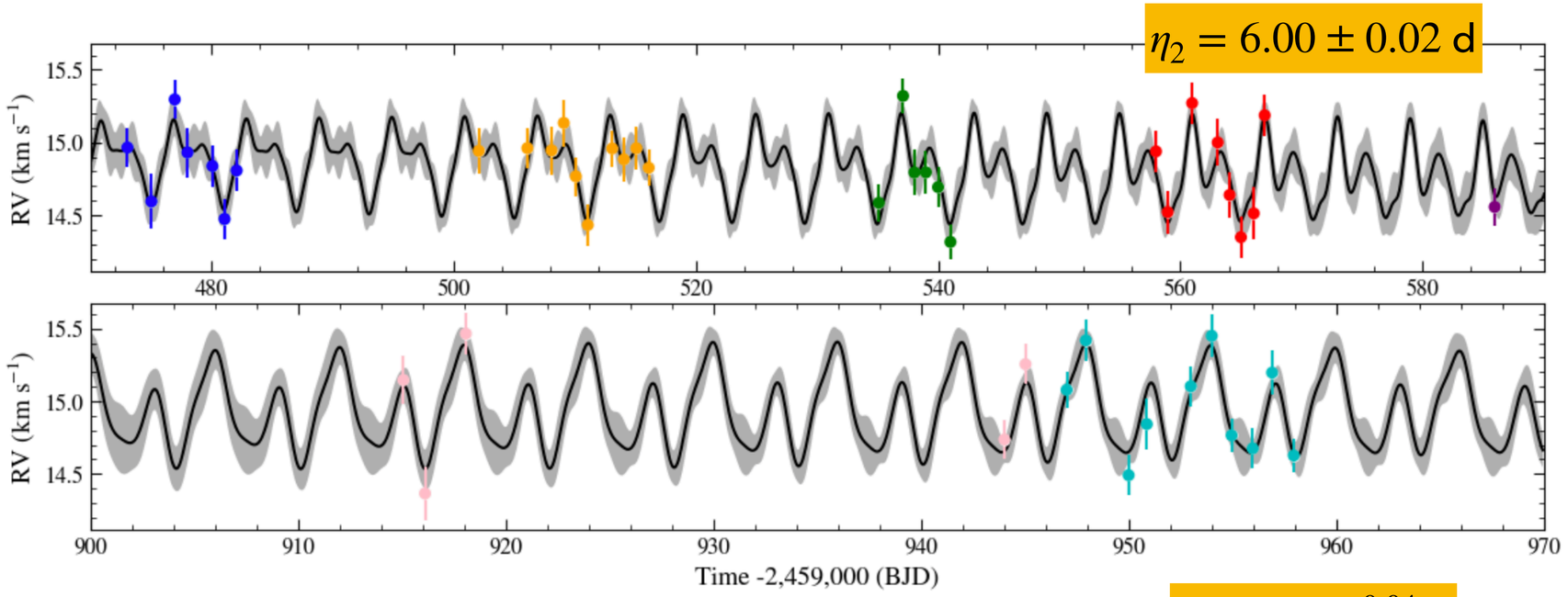


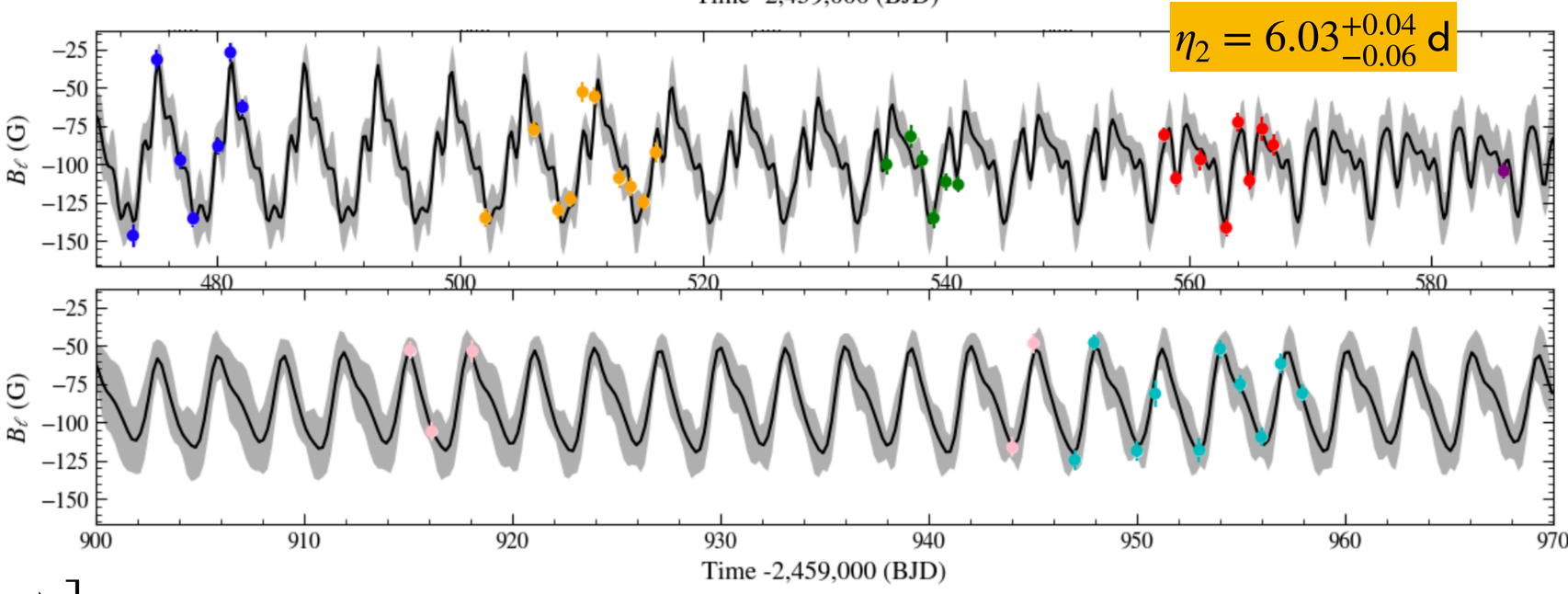


Zaire et al. (in prep)

Gaussian Process

- Model the evolution of RV and B_ℓ using a Quasi-periodic kernel:
  - Amplitude, η_1
  - Rotation period, η_2
  - Decay time, η_3
  - Smoothing factor, η_4
  - Jitter, η_5

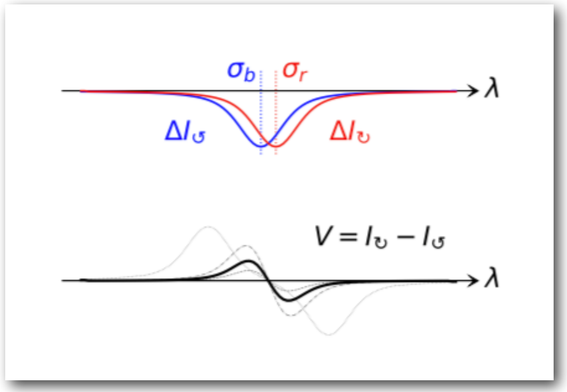




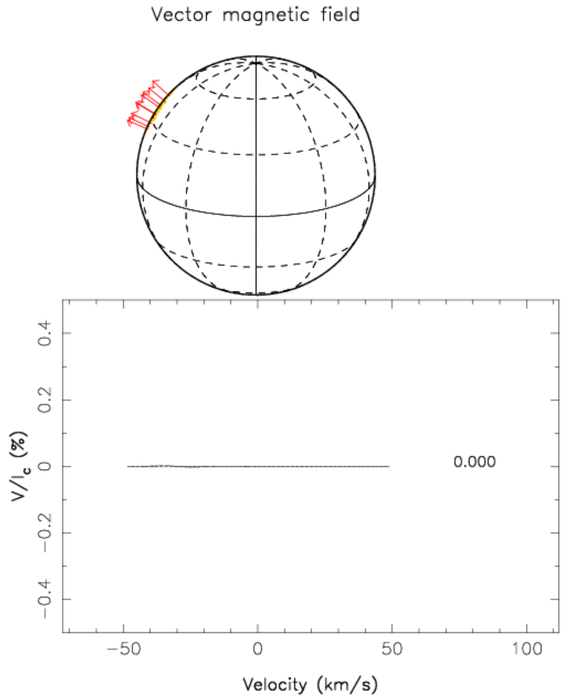
$$K(t,t') = \eta_1^2 \exp\left[-\frac{(t-t')^2}{\eta_3^2} - \frac{1}{\eta_4^2}\sin^2\left(\frac{\pi(t-t')}{\eta_2}\right)\right] + \eta_5^2\delta(t-t')$$

Zeeman-Doppler Imaging

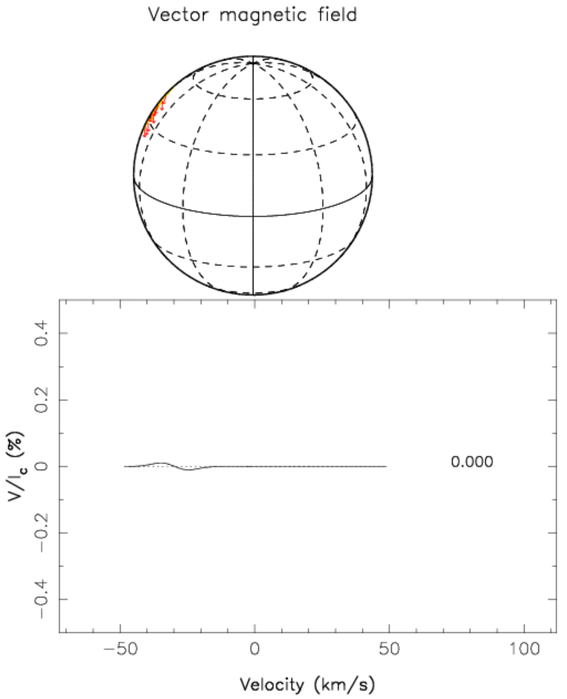
Zeeman Effect



Radial field



Azimuthal field

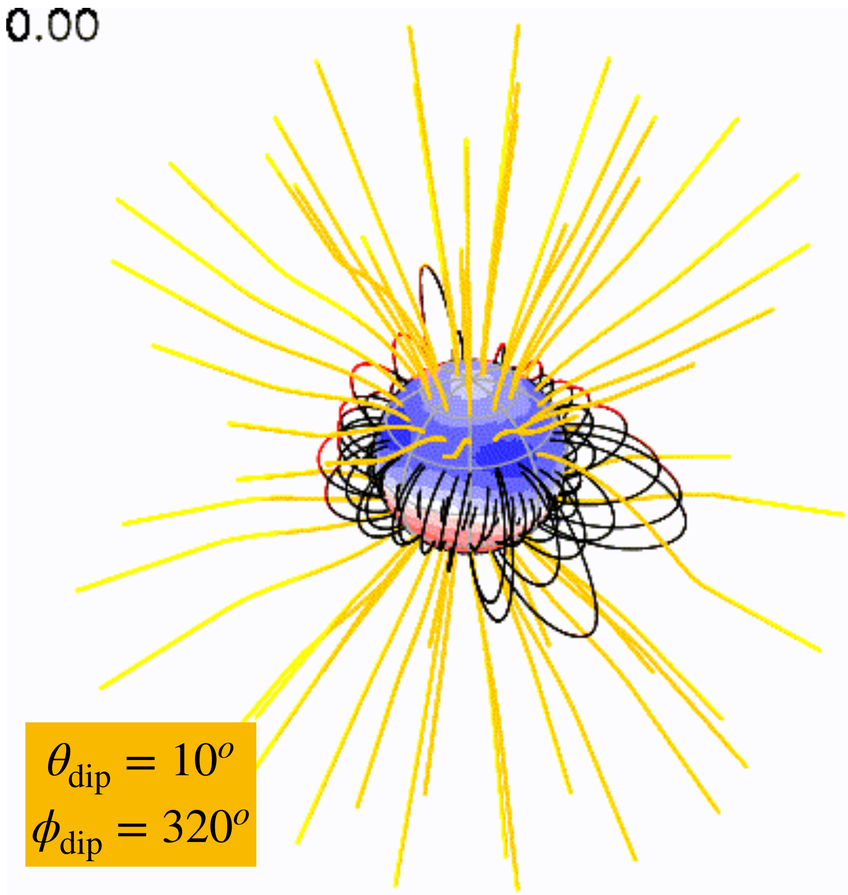


Credits: Jean-François Donati

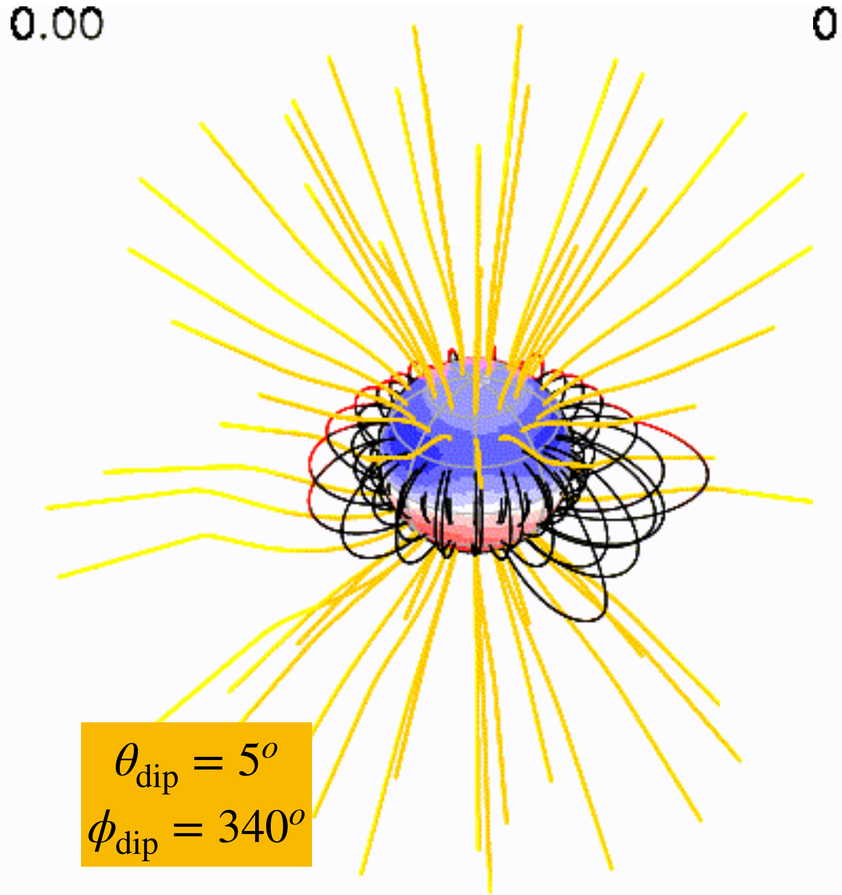
Bdip ~ 500 G
E_{Pol} ~ 97% E_{Tot}
Axisymmetry ~ 90 % E_{Pol}

Large-scale magnetic field

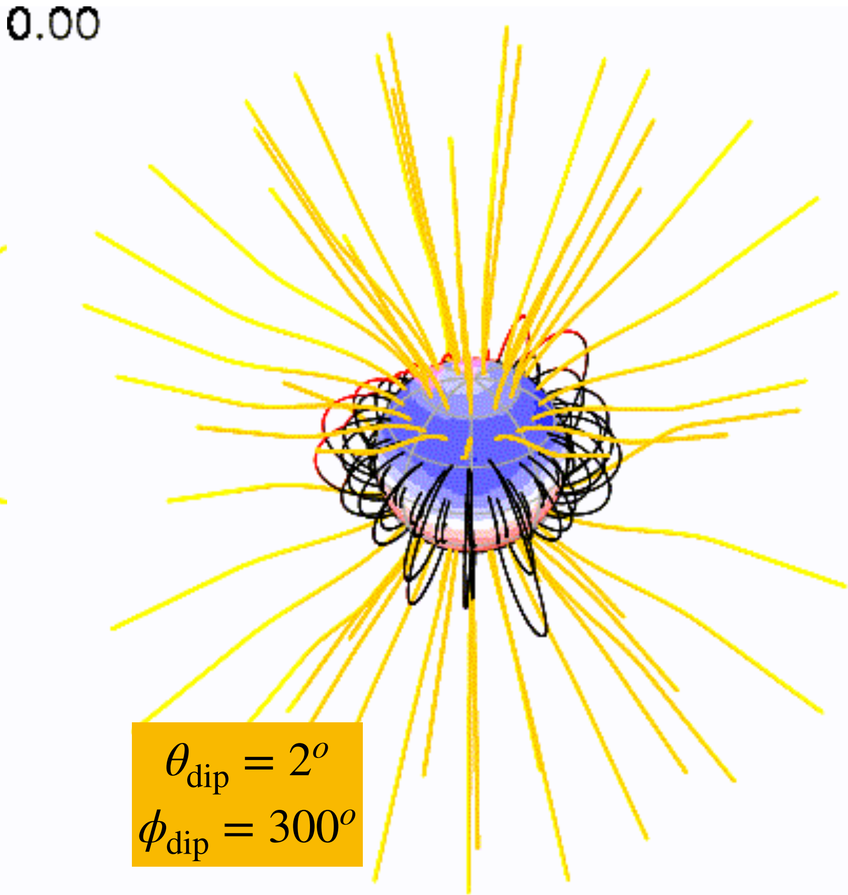
2021
Sept. & Oct.



2021
Nov. & Dec.

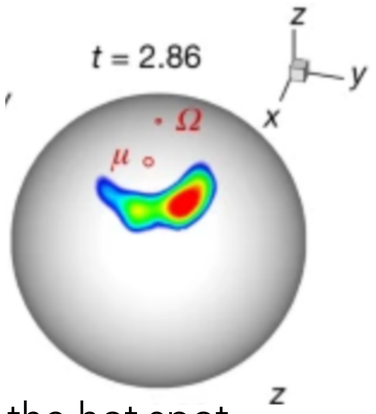


2022 Dec &
2023 Jan



Summary

- From the temporal evolution of RV and B_ℓ, we inferred rotation periods of 6.00 ± 0.02 d and $6.03^{+0.04}_{-0.06}$ d, respectively.
- We observed a short term evolution in the longitudinal field of GM Aur.
- We obtained brightness and magnetic maps of GM Aur:
  - All maps revealed a simple magnetic field configuration with a strong axisymmetric dipolar component;
  - Hints of **dipolar excursion** (akin to the Earth). The tilts we derive point towards rotation phases ~ 0.90, which is consistent with the findings of Bouvier et al. (2023), who found brightening events for rotational phases ranging from 0.85 to 1.15.
  - We found that the simple dipolar field configuration is **compatible** with the **high latitude hot spot** predicted from RV variations of He I 587nm that traces the accretion shock (McGinnis et al. 2020).



Espaillat et al. (2021):

- Density gradients inside the hot spot