A Newborn Multiple Magnetic System of HD 34736

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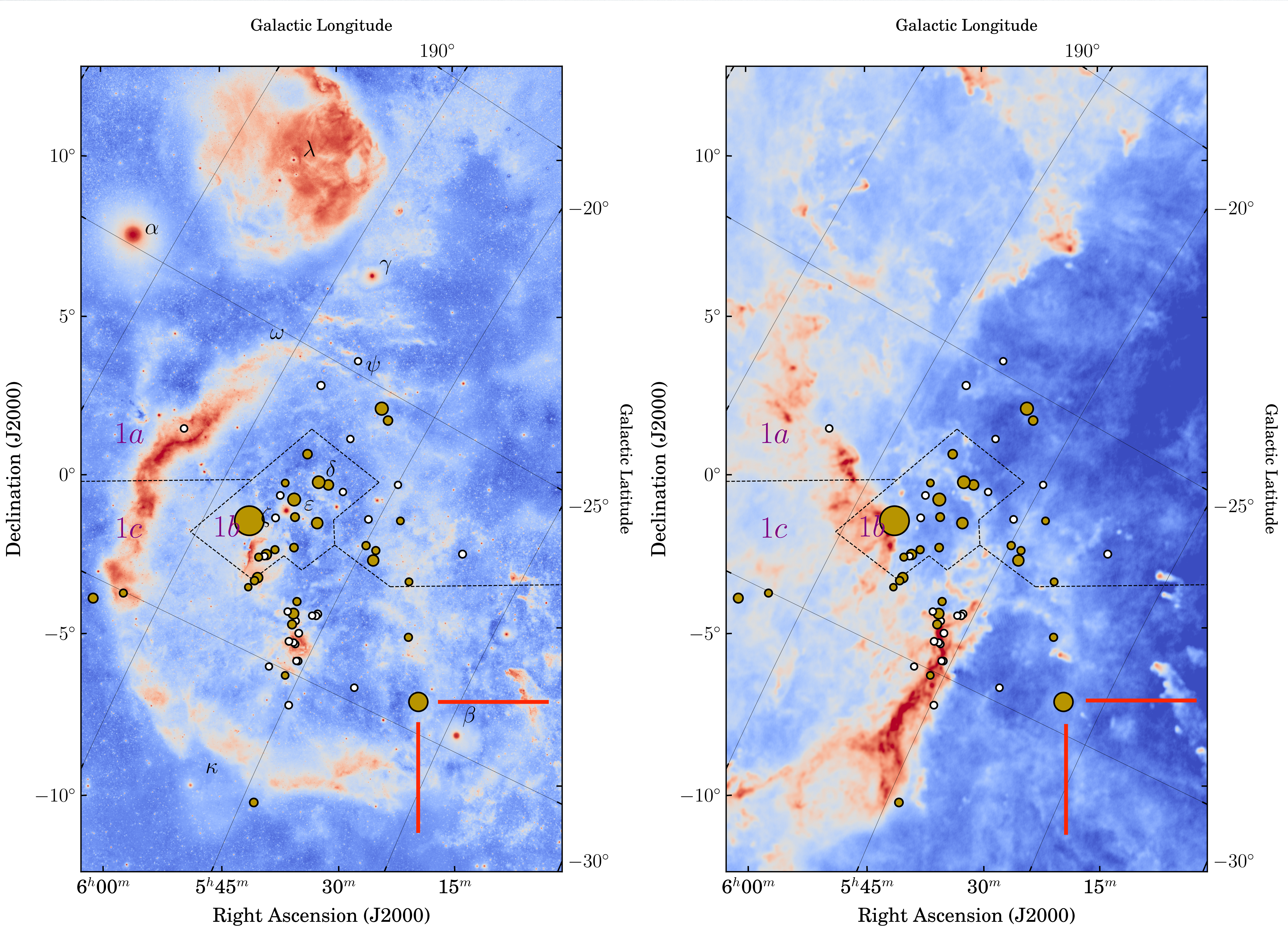
INTRODUCTION



Semenko et al. 2014 (2014AstBu..69..191S)
Semenko et al. 2022 (2022MNRAS.515..998S)

- Chemically peculiar stars are known hosts of the strong, stable, and well-organised magnetic field
- Magnetic CP stars are the Main sequence objects with T_{eff} ≈ 7000-25000 K and prominent chemical anomalies
- Magnetic fields of CP stars remain stable on a timescale of decades
- Origin of the magnetism of CP stars is unclear
- The field can have fossil (Galactic field, merging) or dynamic (turbulent ongoing processes) origin

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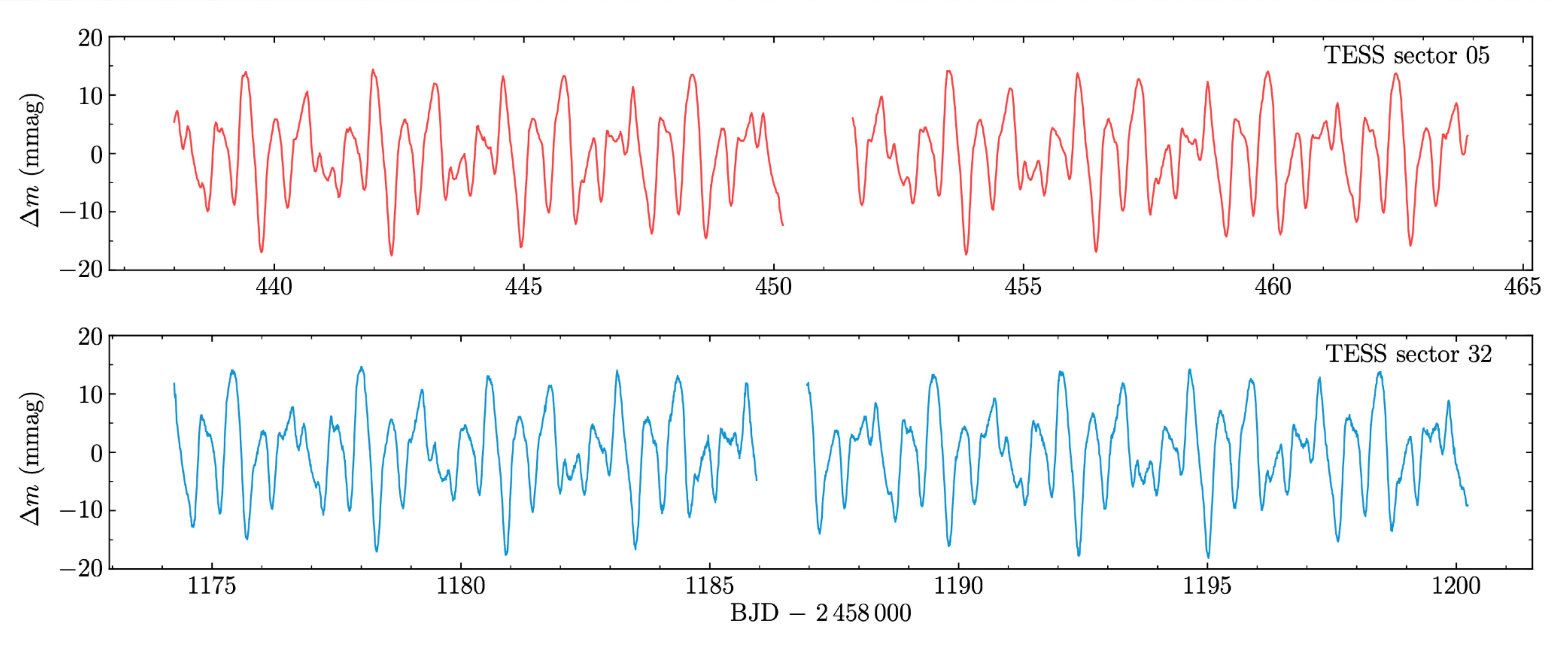
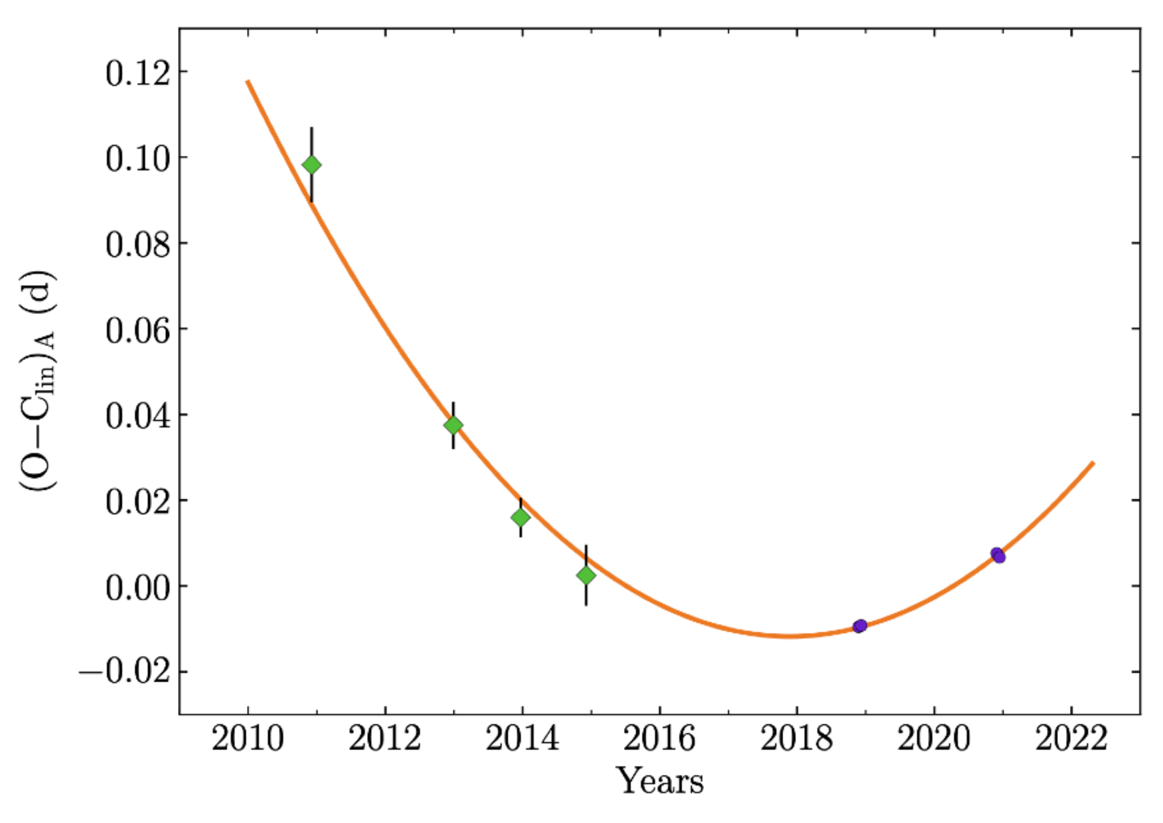
- HD 34736 is a member of the Orion OB1 association. Group OB1c of the association has the age of 4.5 Myr
- Magnetic field was detected in three observations
- HD 34736 is an SB2 system with T_{eff}(A) = 13 700 K and T_{eff}(B) = 11 500 K

ROTATION (BY Z. MIKULÁŠEK)

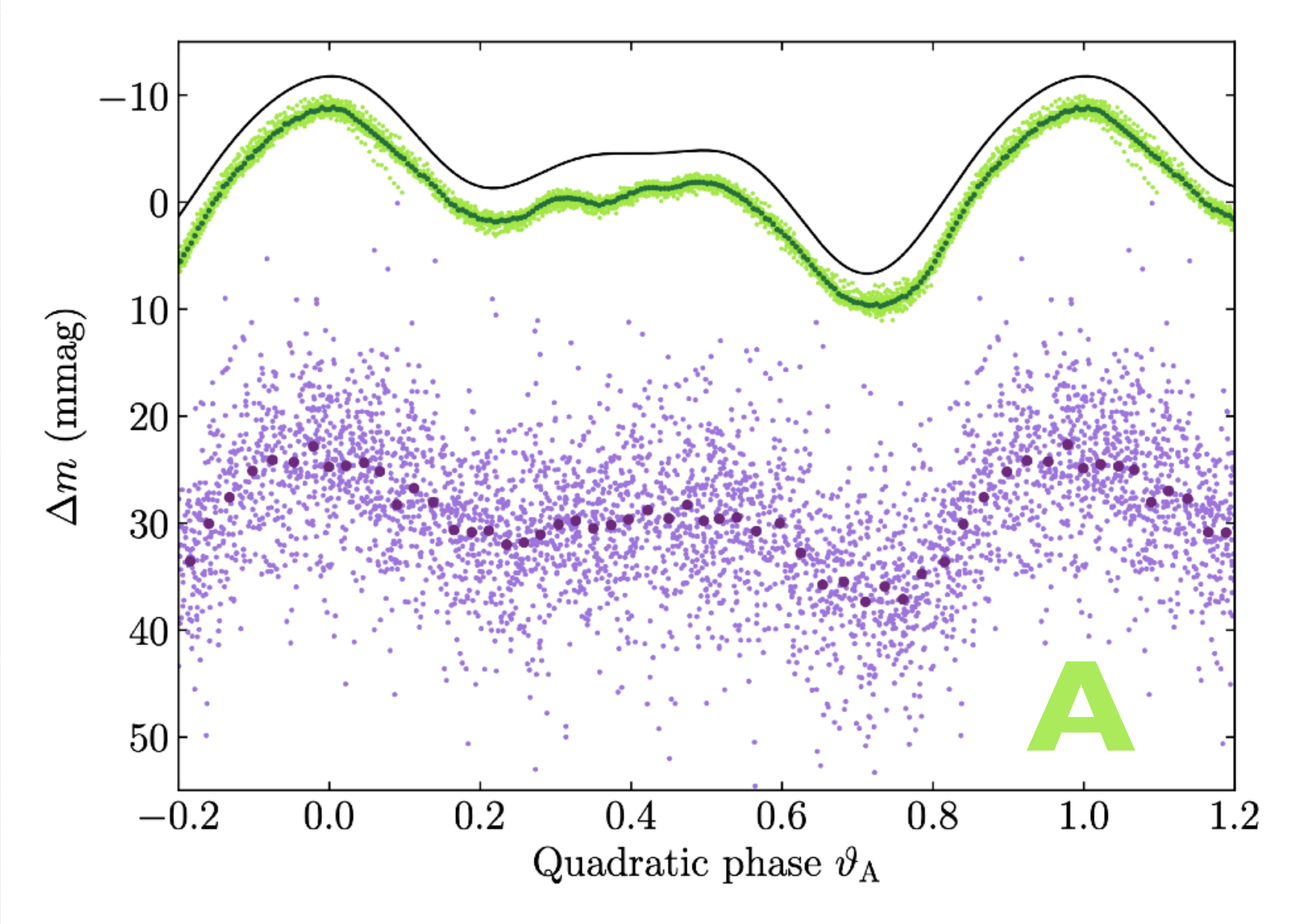


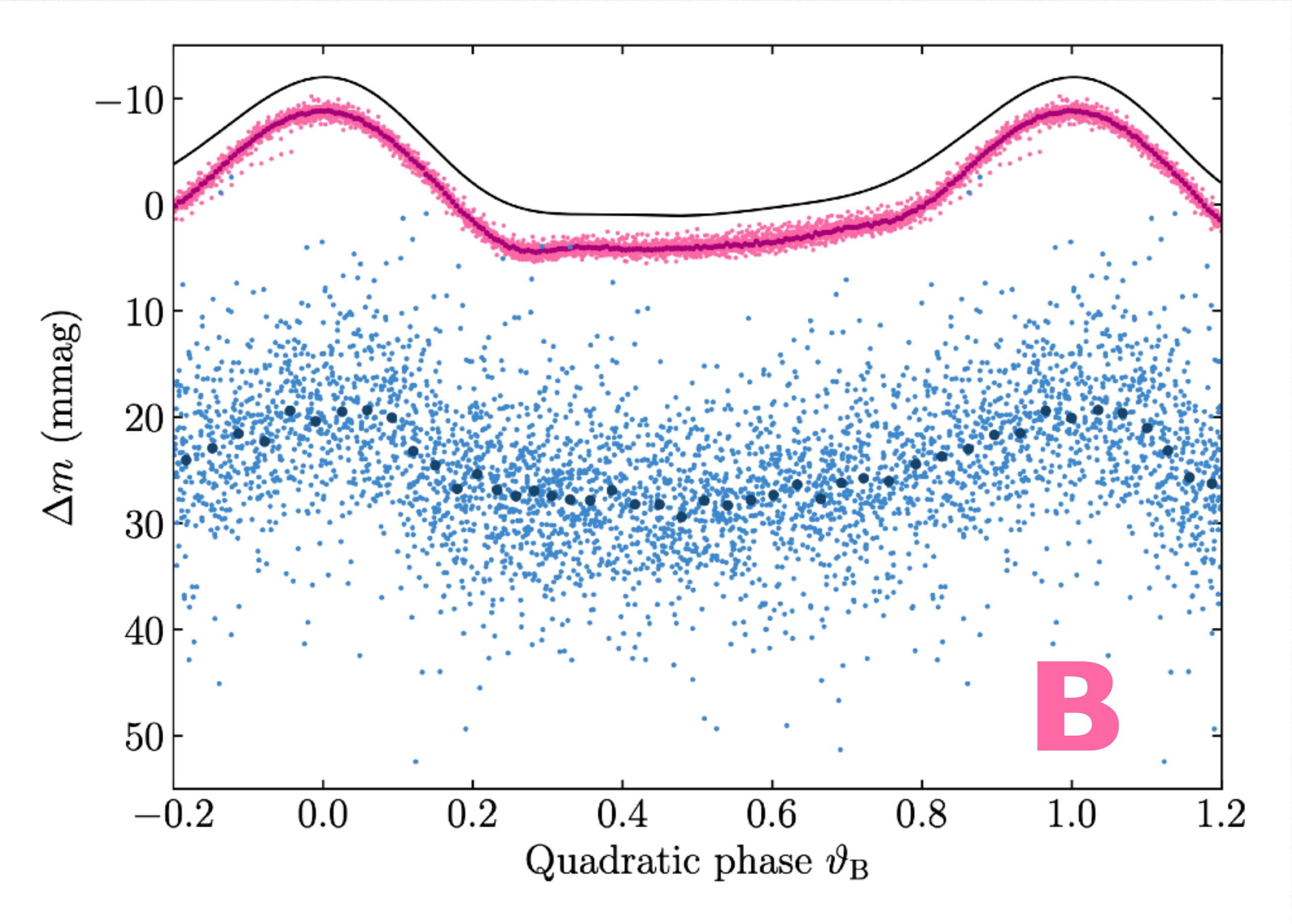
- Two visible components of HD 34736 are the major contributors in the TESS and KELT data.



Rotation of the component *A*

- $M_{1\mathrm{A}} = 2\,458\,732.907\,0(5)$
- $P_{1\mathrm{A}} = 1.2799885(11)$ days
- $\dot{P}_{1\mathrm{A}} = 3.98(17) \times 10^{-8}$

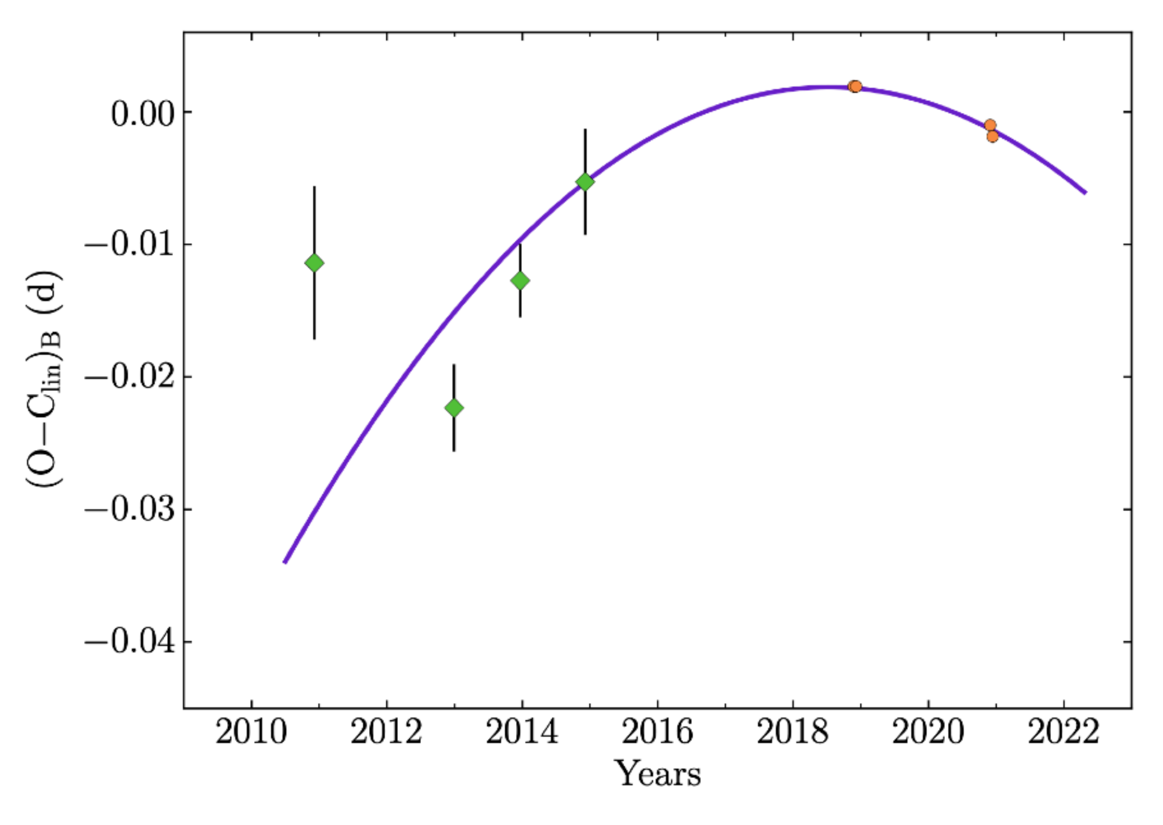




Warped lightcurves of both components

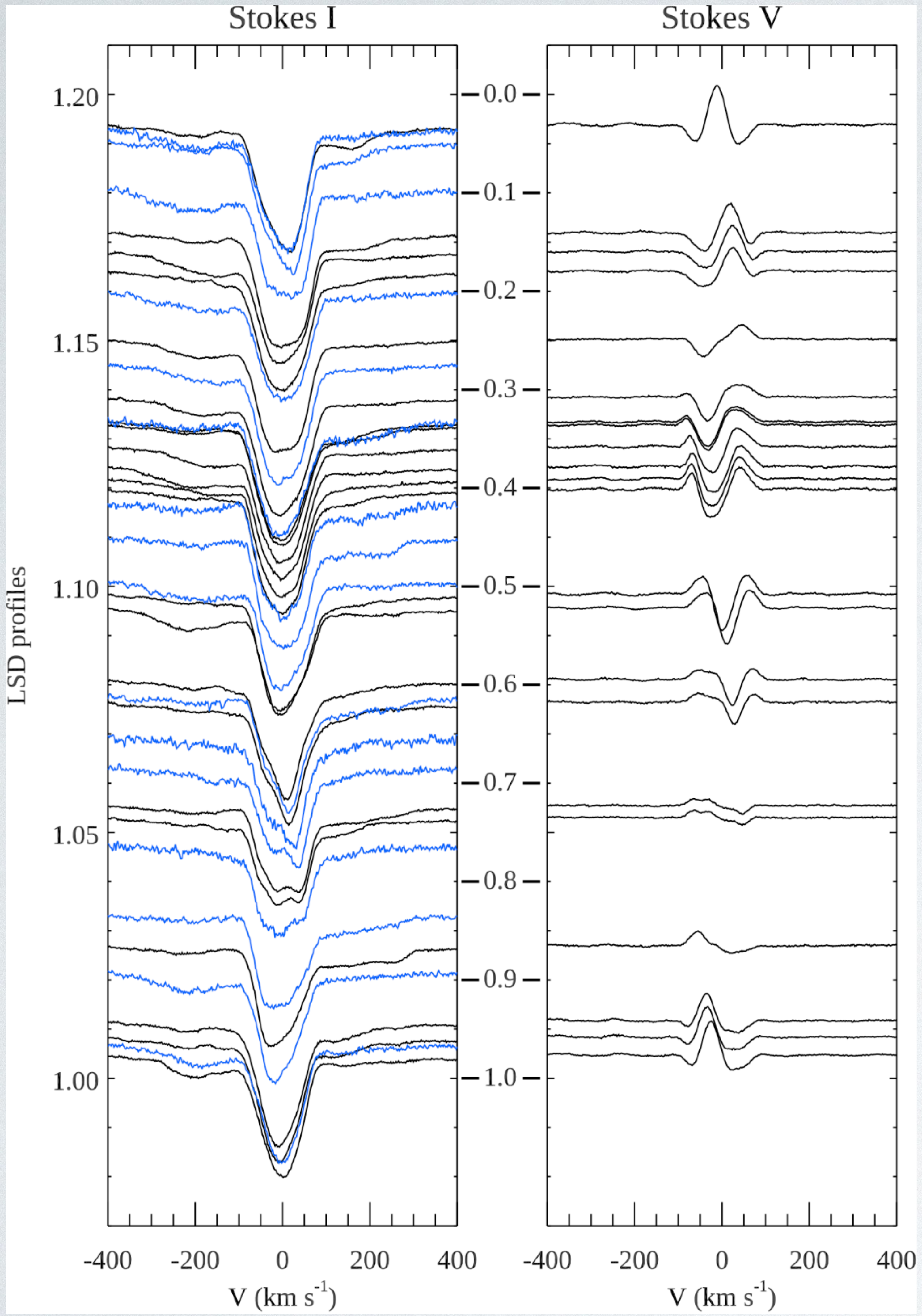
Rotation of the component *B*

- $M_{1\mathrm{B}} = 2\,458\,775.300\,0(5)$
- $P_{1\mathrm{B}} = 0.5226938(5)$ days
- $\dot{P}_{1\mathrm{B}} = -4.4(9) \times 10^{-9}$

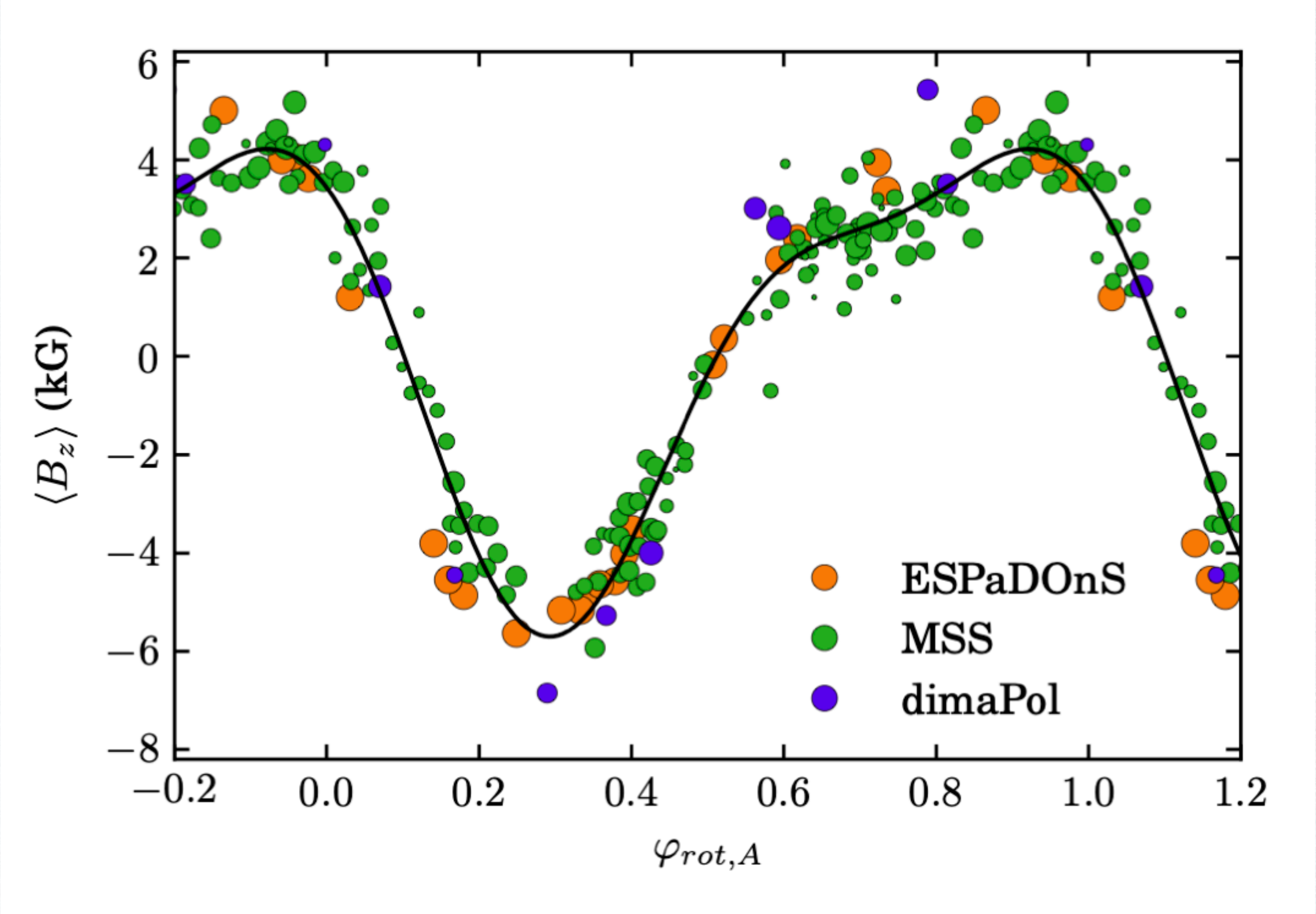


Variable rotation is common in hot magnetic stars

MAGNETIC FIELD



More than 160 spectropolarimetric observations using MSS@SAO, ESPaDOnS@CFHT, and DimaPol@DAO



Distorted dipolar configuration

$i = 68°$

$\beta = 83°$

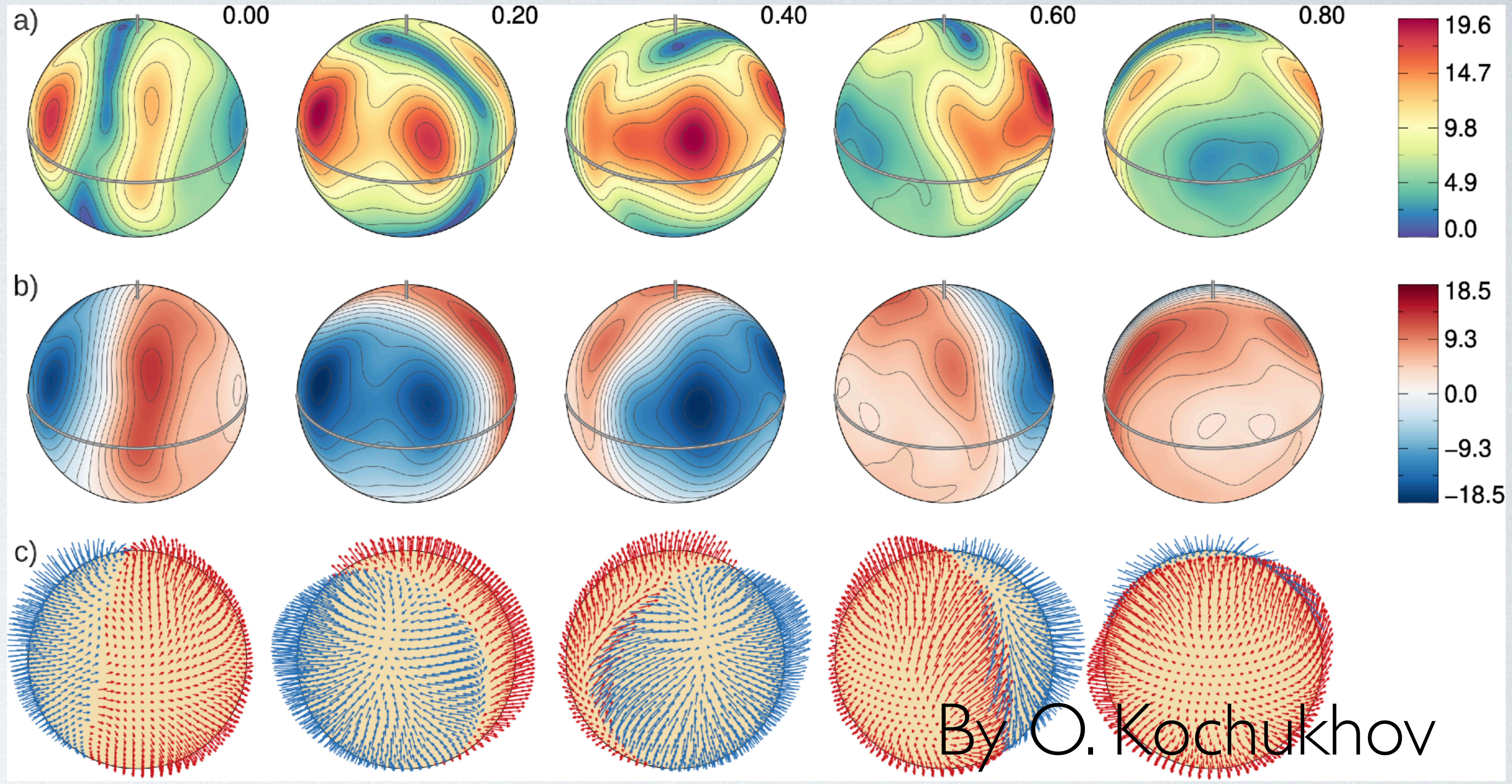
B_d = 19 kG

$\langle B \rangle$ = 9 kG

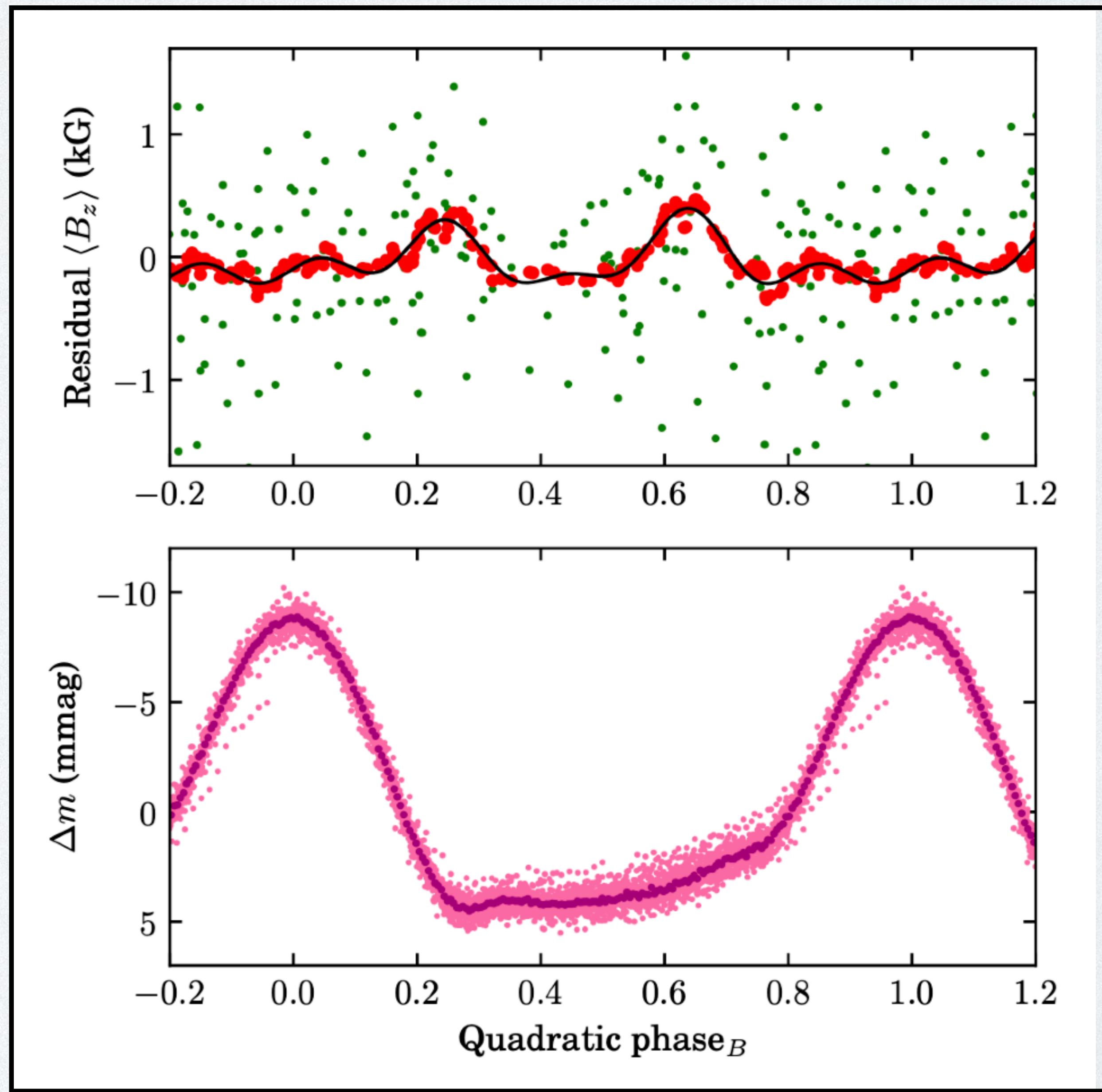
dipole: 63%

quadrupole: 22%

octupole: 7%



By O. Kochukhov

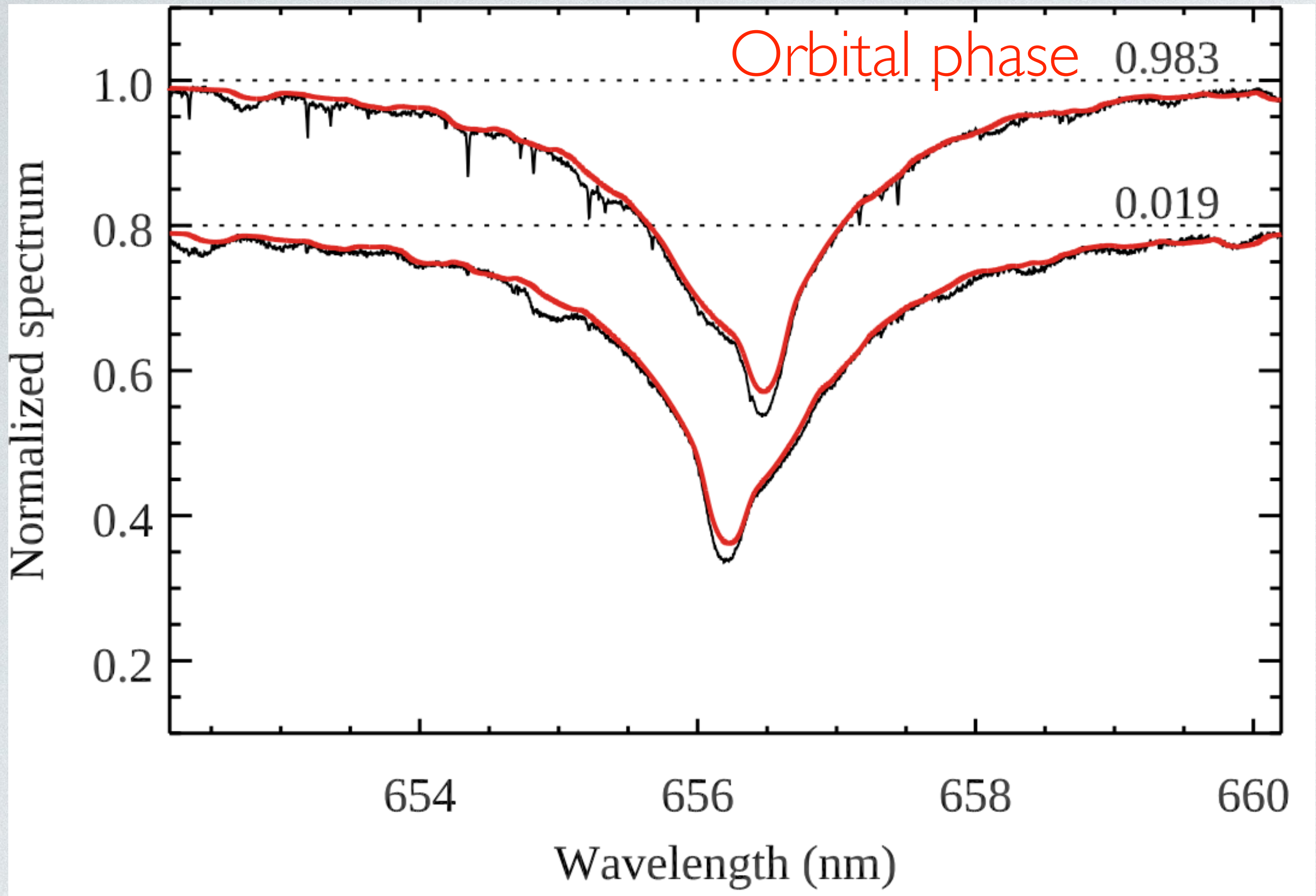


Indirect signal of the secondary's magnetic field in the residuals.

The peaks location correlates with the features in the lightcurves

Expected maximum of B_z is 500 G

CHEMICAL COMPOSITION



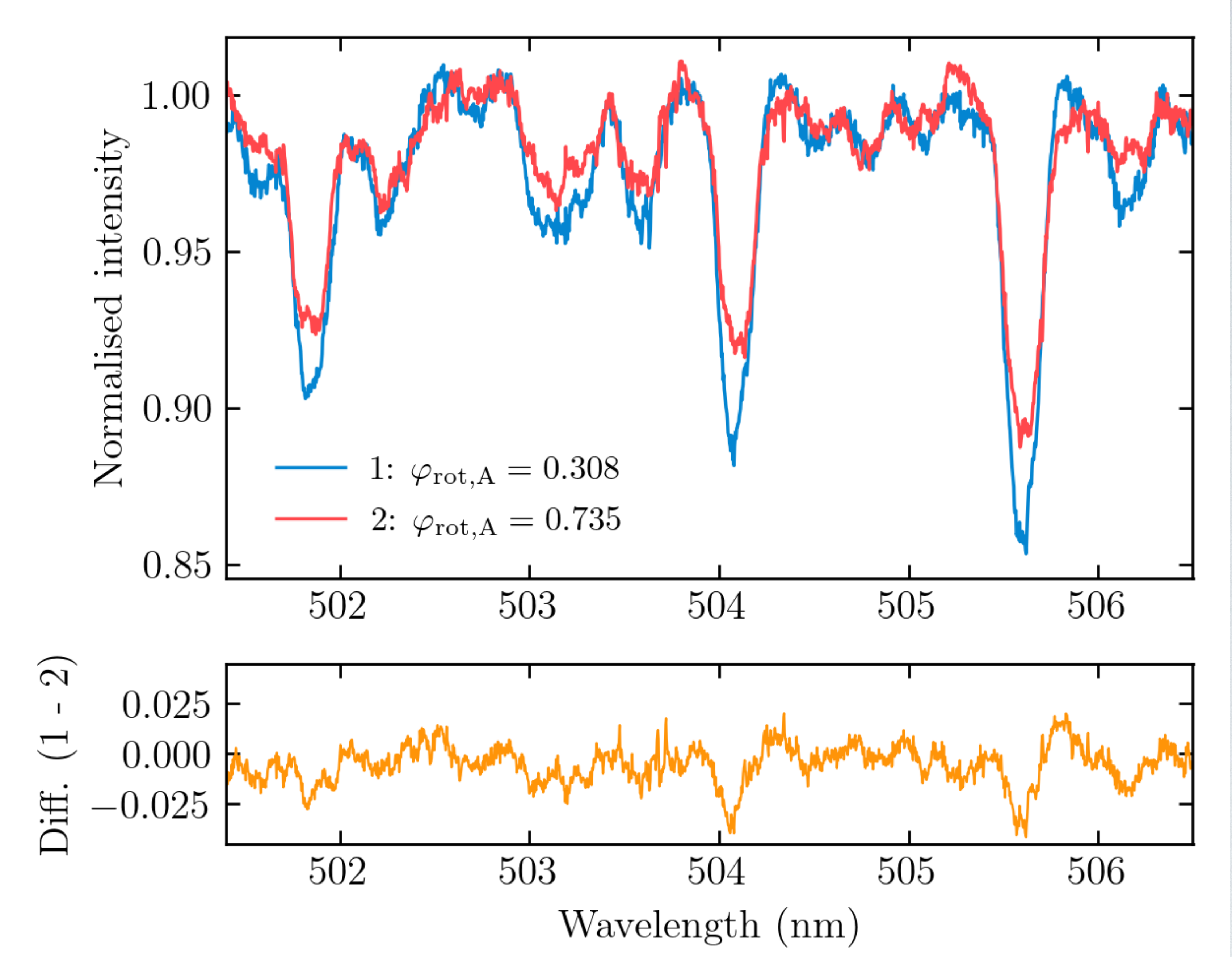
T_{eff}(A) = 13 000 ± 500 K

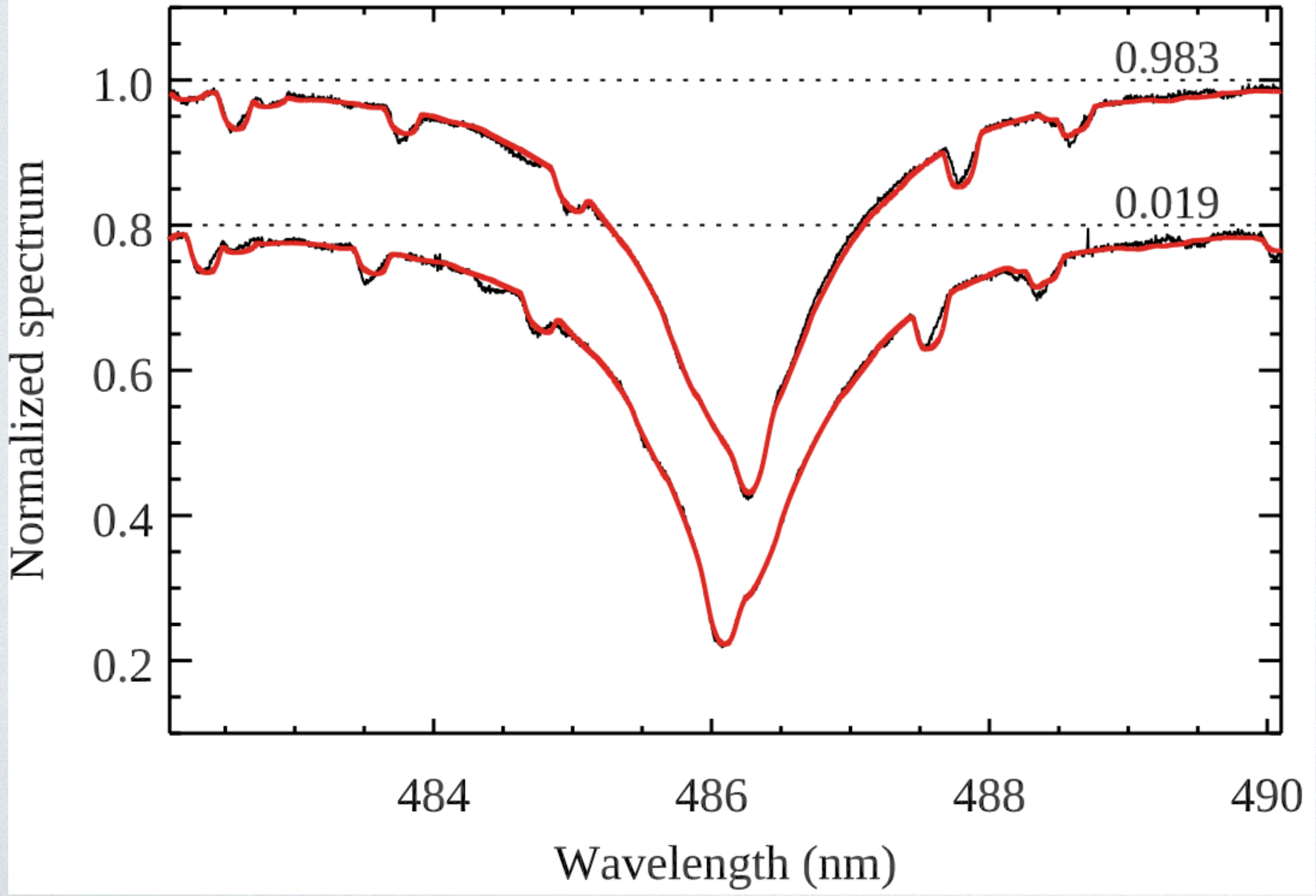
T_{eff}(B) = 11 500 ± 1 000 K

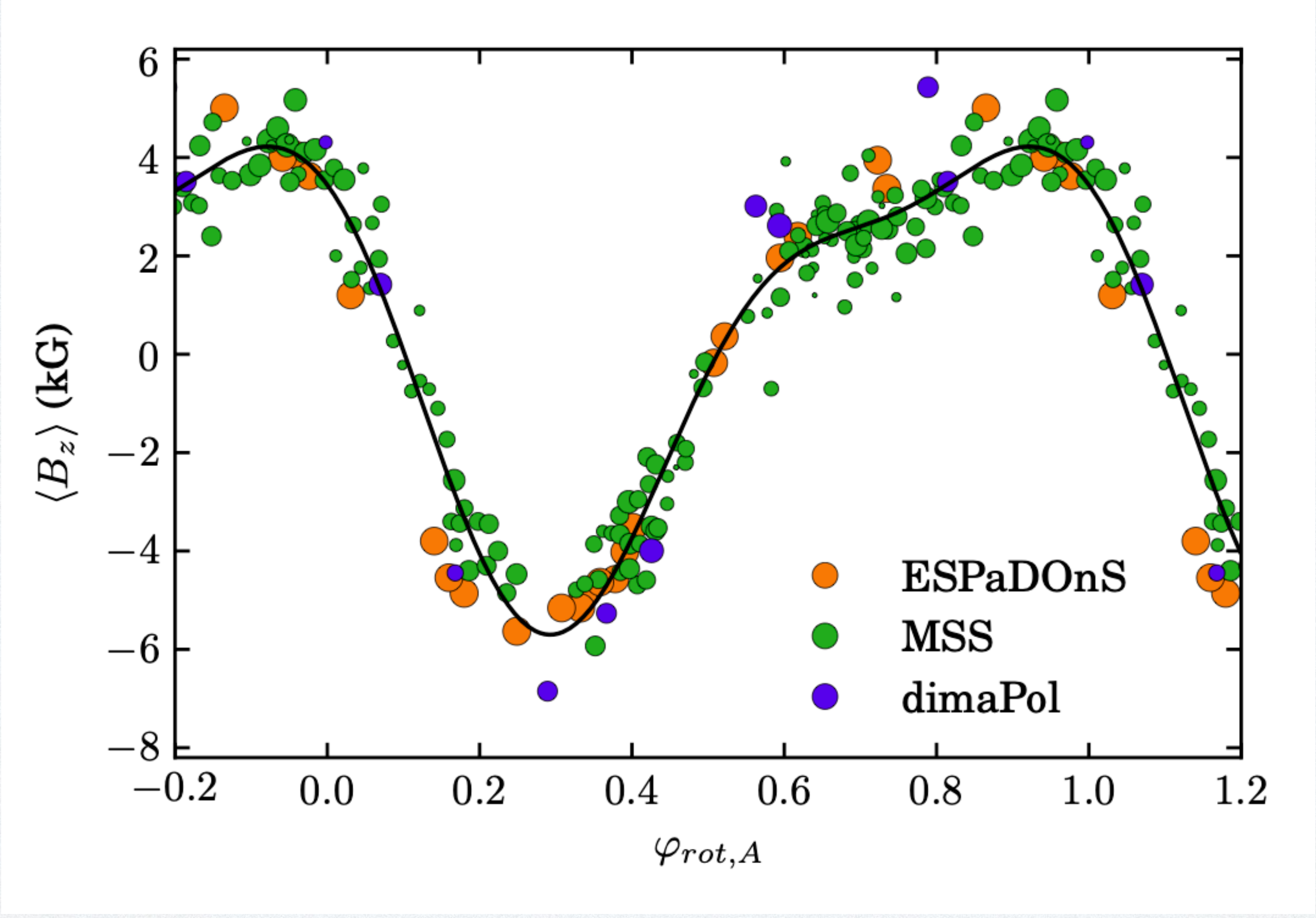
log g = 4.0 (fixed)

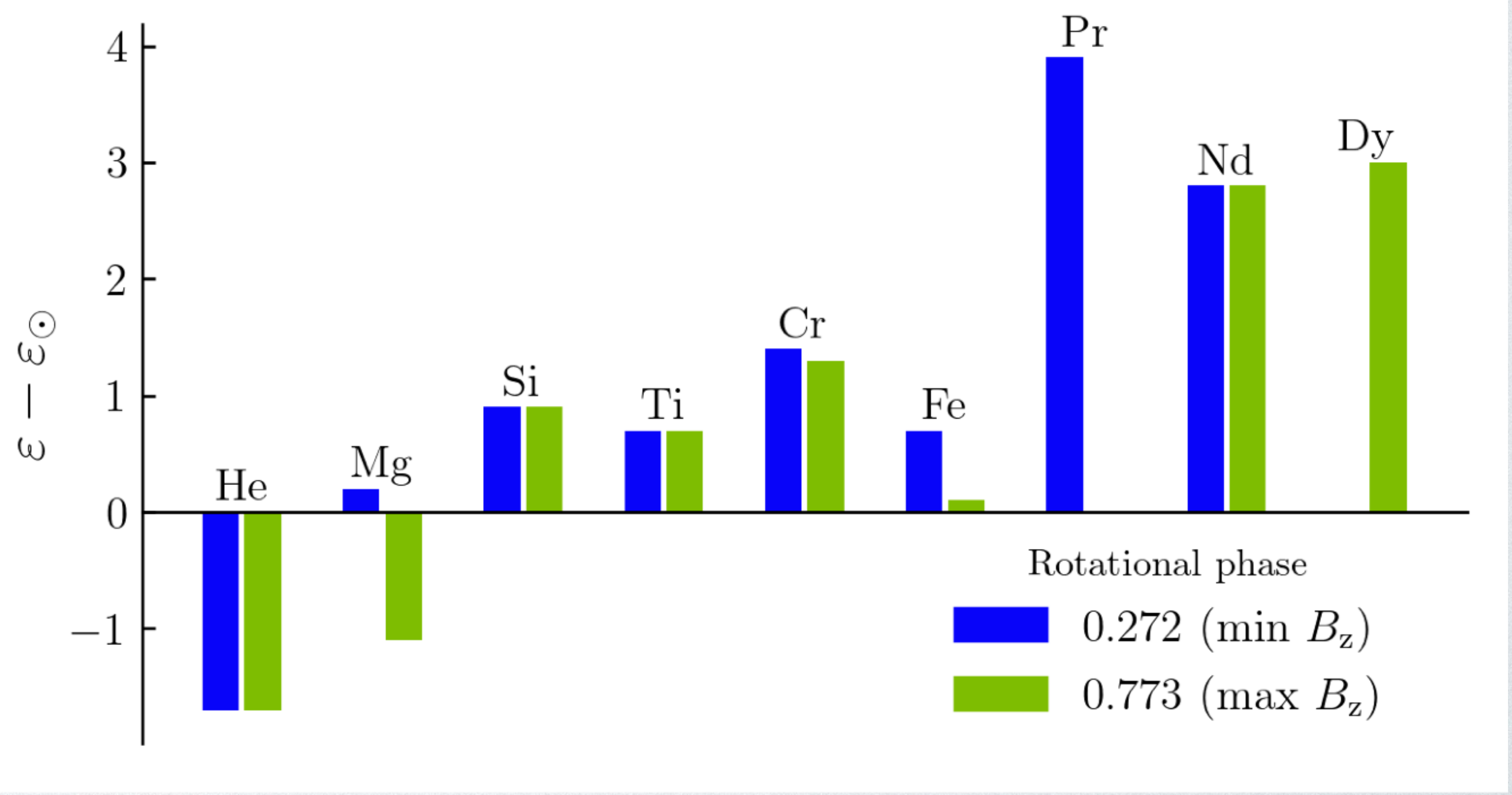
$v_e \sin i$(A) = 75 ± 3 km/s

$v_e \sin i$(B) = 110-180 km/s

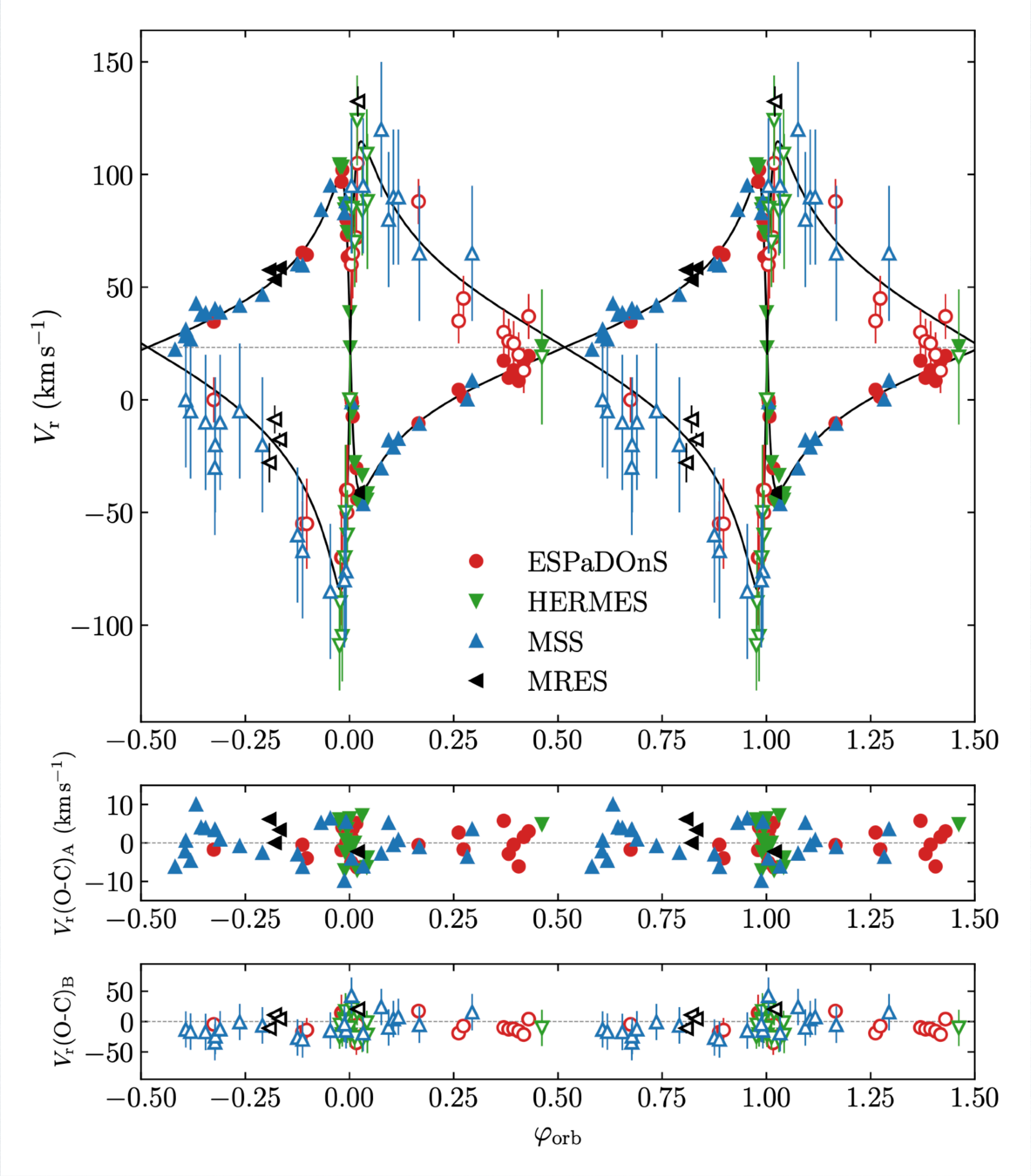








VISIBLE SYSTEM OF HD 34736



Orbital solution from Mg II

T_p = 2457415.3460 (0.003)

P = 83.2193 (0.0030) days

e = 0.8103 (0.0003)

K_A = 69.74 (0.07) km/s

K_B = 99.57 (3.15) km/s

γ = 23.28 (0.05) km/s

ω = 84.2° (0.1°)

M_B/M_A = 0.70 (0.02)

$M_A \sin^3 i$ = 4.9(0.3) $M_\odot$

$M_B \sin^3 i$ = 3.5(0.1) $M_\odot$

T_{eff}(A) = 13 000 ± 500 K

T_{eff}(B) = 11 500 ± 1 000 K

log g = 4.0 (fixed)

$\upsilon_e \sin i$(A) = 75 ± 3 km/s

$\upsilon_e \sin i$(B) = 110-180 km/s

From $\upsilon_e \sin i$(A) = 75 km/s,
R = 2.05* $R_\odot$,
and $P_{A,rot}$ = 1.2799885 d,

$i_{rot} \approx 68°$

No eclipses visible, hence $i_{orb} < 88°$

Assuming $i_{orb} = i_{rot} = 68°$,

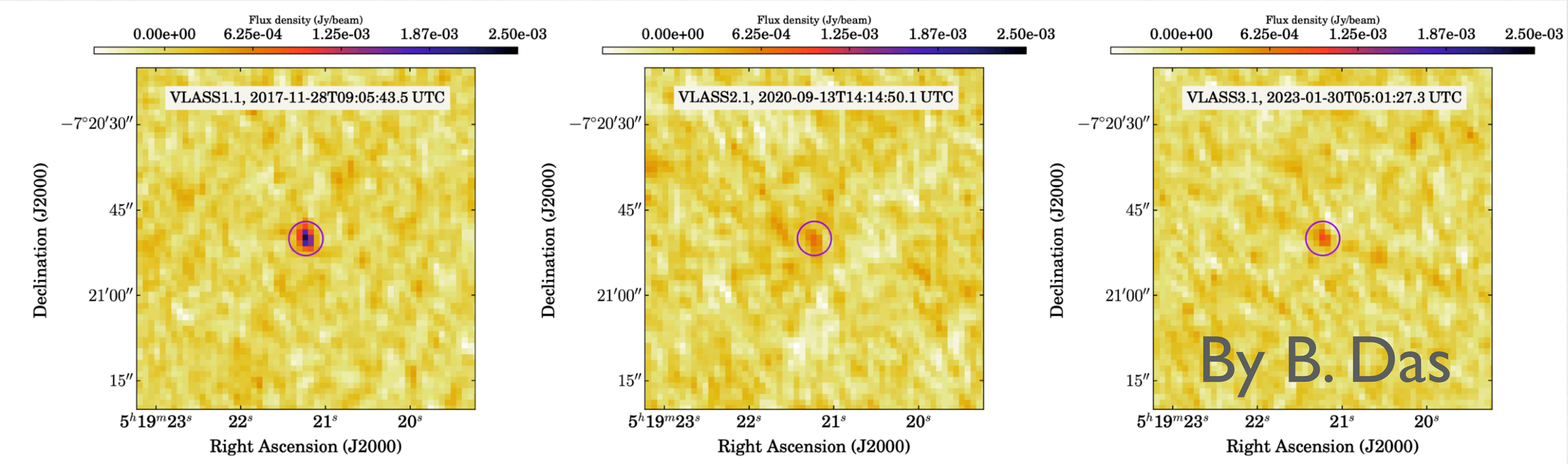
M_A = 6.1 $M_\odot$ ⇒ B4V (Obs. B7V)

M_B = 4.4 $M_\odot$ ⇒ B7V (Obs. B8V)

*Interpolated from MIST (t = 6.4 Myr)

Excessive mass is 0.4-1 $M_\odot$ (T Tau?)

HD 34736 IN RADIO AND X-RAY

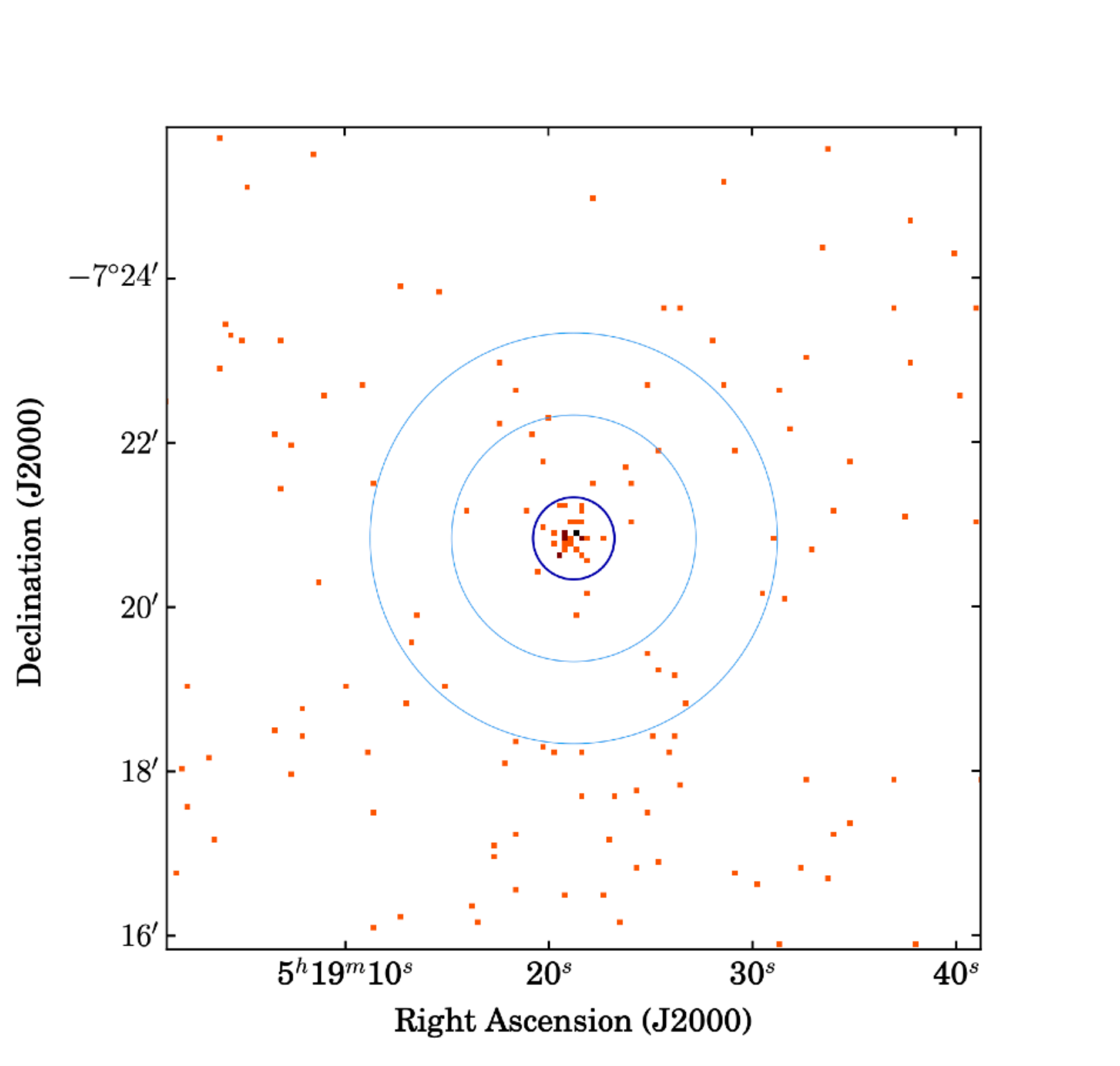


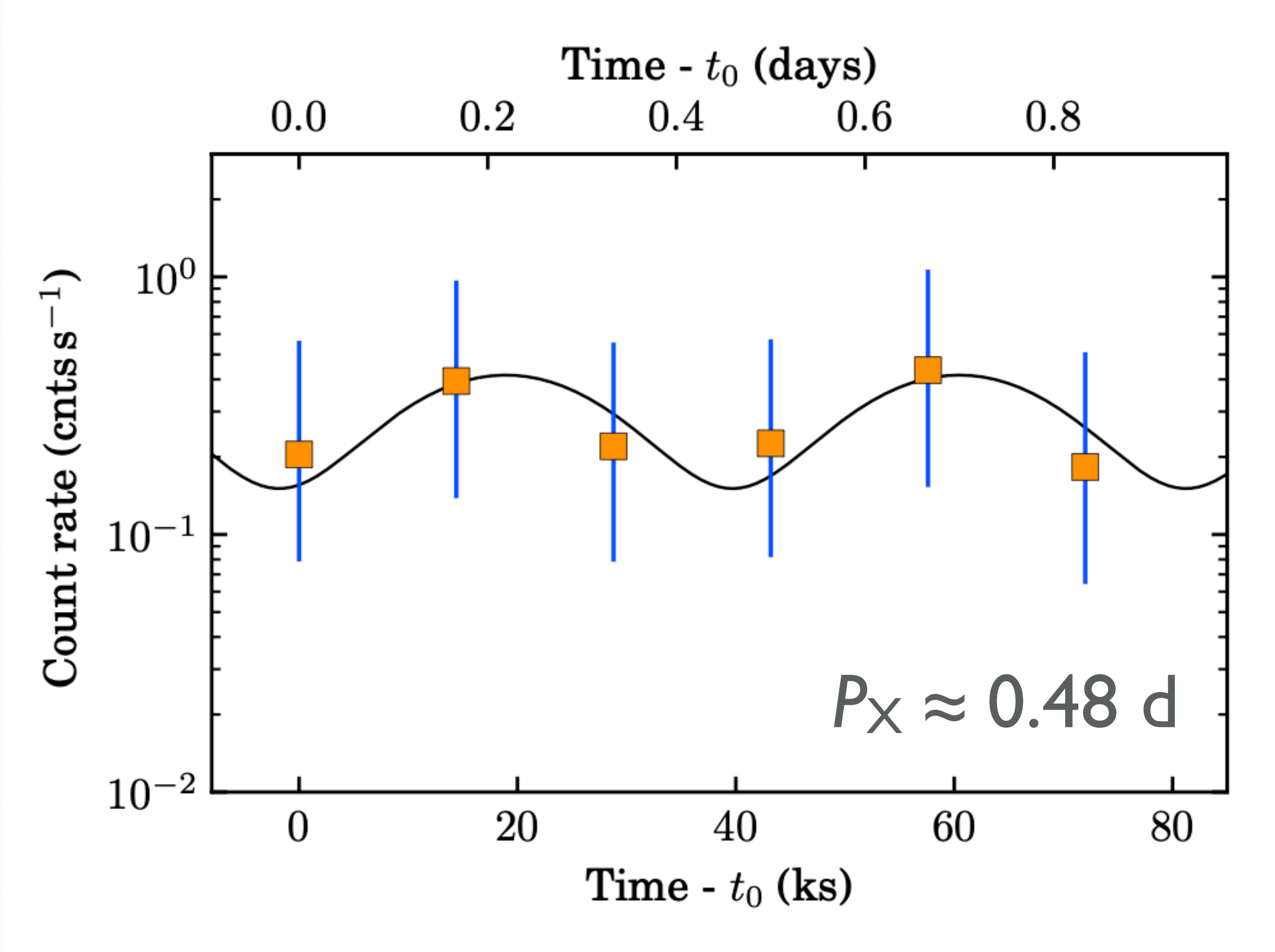
NVSS: S_ν = 2.3 ± 0.4 mJy
VLASS1.1: S_ν = 2.2 ± 0.3 mJy
VLASS2.1: S_ν = 0.9 ± 0.2 mJy
VLASS1.1: S_ν = 1.0 ± 0.2 mJy

log L_R = 17.63 [erg/s]

IPC@Einstein: log L_X = 30.59 [erg/s] (Grillo et al. 1992)
XRT@Swift: log L_X = 29.6 [erg/s] (Evans et al. 2020)
eROSITA@SRG: log L_X = 30.62 [erg/s] (Merloni et al. 2024)

log L_X = 30.27 [erg/s]





HD 34736 IN THE CONTEXT

HD 34736 is likely a triple stellar system comprising two genuinely CP stars with directly or indirectly detected magnetic field, and a potentially magnetic and active YSO.

Activity of T Tau-type

$$\frac{L_\mathrm{X}}{L_\mathrm{R}} = \kappa \times 10^{15.5\pm1}[\mathrm{Hz}]$$

For HD 34736, $\kappa = 0.001$, which is common for YSOs

YSO approaching the MS must show strong X-ray emission indicating the field of a simple configuration (Stuart & Gregory 2023)

Models from Waterfall et al. (2019) predict $B_s = 5$ kG

Levels of $L_X = 29.6$–30.62 correspond to $M_{YSO} = 0.3$–$1.6\ M_\odot$ (Preibisch et al. 2005)

Magnetospheric activity

Centrifugal breakout events (Owocki et al. 2022) and centrifugal magnetospheres (Petit et al. 2013) as the source of the X-ray and radio emission.

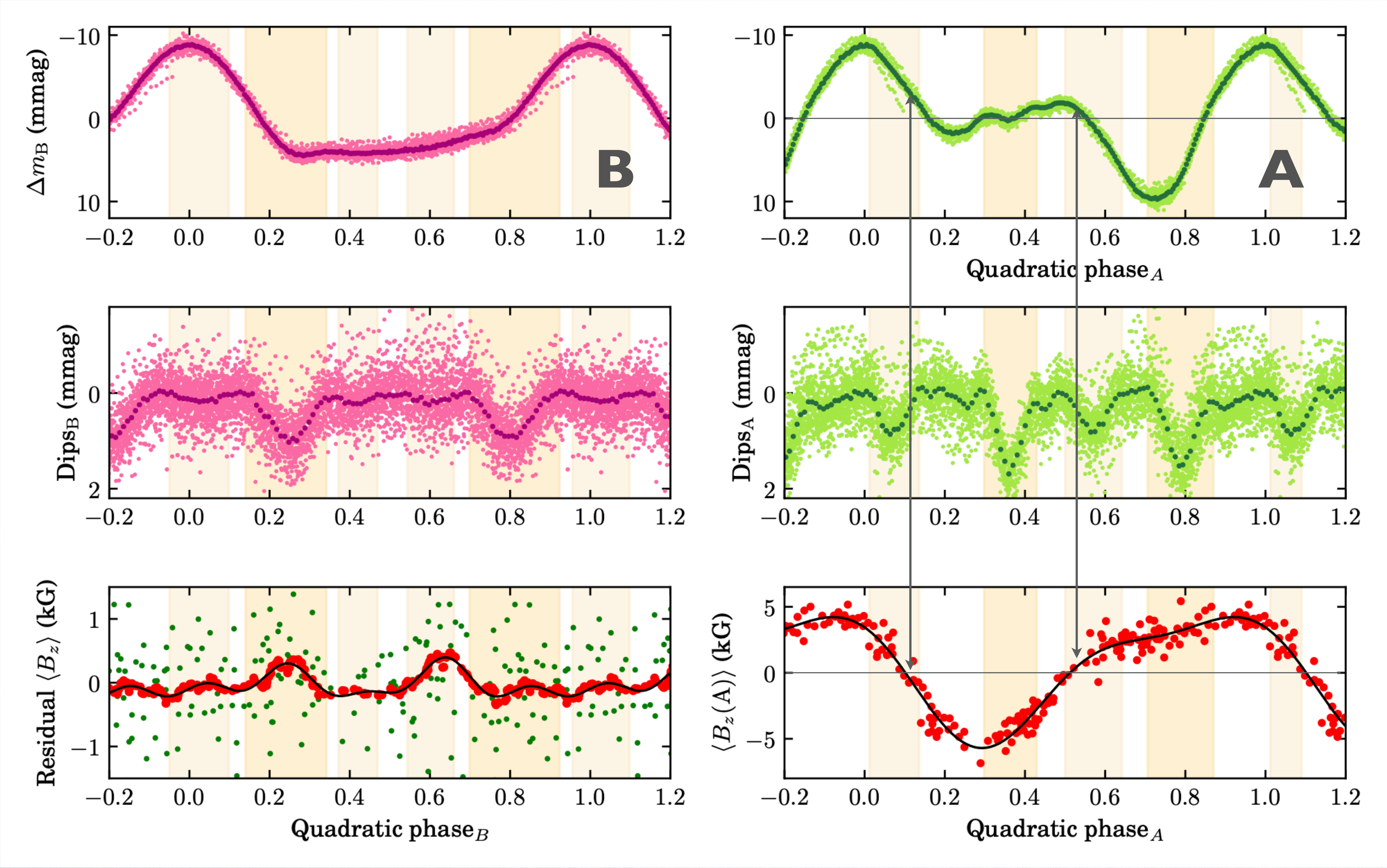
Comp. *A*: $R_K = 3.6\ R_*$ & $R_A = 79\ R_*$, $B_s = 8.9$ kG ⇒ capable

Comp. *B*: $R_K = 1.8\ R_*$ & $R_A = 37\ R_*$, $B_s = 1.5$ kG ⇒ capable

log L_X/L_R = 12.64 (12.0 for CU Vir, Robrade et al. 2018)

HD 34736 IN THE CONTEXT. DIPS

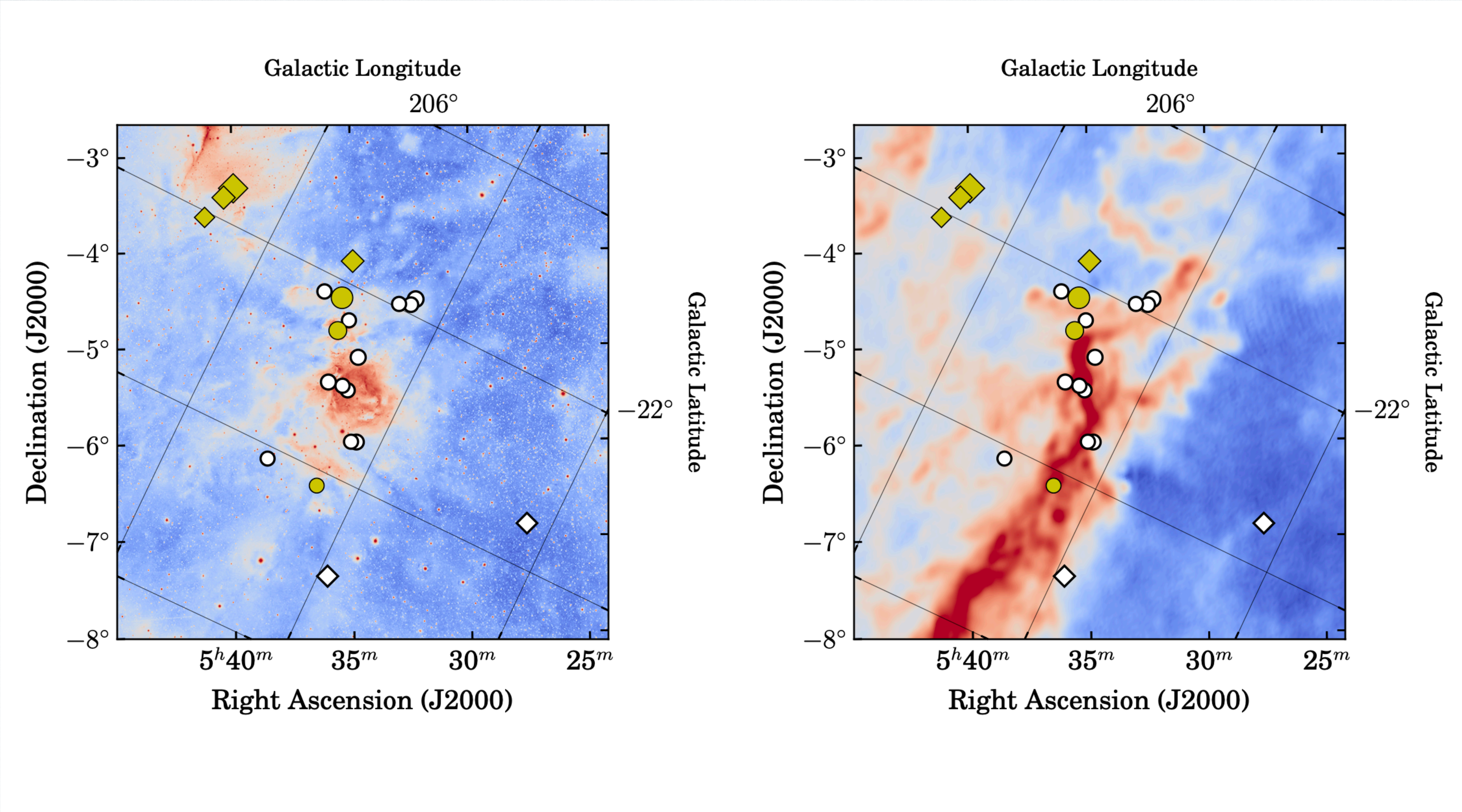
HD 34736 is likely a triple stellar system comprising two genuinely CP stars with directly or indirectly detected magnetic field, and a potentially magnetic and active YSO.



1. Location of the dips in the lightcurve of the primary component correlates either with the regions where the longitudinal field change the sign or with the extrema of the field.
2. Dips in the lightcurve of the secondary star also coincide with the feature of the 'residual' field.
3. **Therefore, the dips probably originate from the relatively cold circumstellar clouds of material trapped by the magnetic field.**

HD 34736 IN THE CONTEXT. EVOLUTION

HD 34736 is likely a triple stellar system comprising two genuinely CP stars with directly or indirectly detected magnetic field, and a potentially magnetic and active YSO.



Magnetic fields in the Orion Nebula, shown as streamlines over an infrared image taken by the Very Large Telescope in Chile, are regulating the formation of new stars. SOFIA's HAWC+ instrument is sensitive to the polarized emission from dust grains, which is aligned by magnetic fields. Researchers can use HAWC+ data to infer the direction and strength of these magnetic fields.

Credit: NASA/SOFIA/D. Chuss, et al., and European Southern Observatory/M.McCaughrean, et al.

- Magnetic CP stars in Orion can serve as a link between the distribution of the Galactic magnetic field and stellar formation

SUMMARY

HD 34736 is likely a triple stellar system comprising two genuinely CP Si+ or He-wk stars with directly or indirectly detected magnetic field, and a potentially magnetic and active YSO.

1

Rotation of the component *A*

- $M_{1A} = 2\,458\,732.907\,0(5)$
- $P_{1A} = 1.2799885(11)$ days
- $\dot{P}_{1A} = 3.98(17) \times 10^{-8}$

Rotation of the component *B*

- $M_{1B} = 2\,458\,775.300\,0(5)$
- $P_{1B} = 0.5226938(5)$ days
- $\dot{P}_{1B} = -4.4(9) \times 10^{-9}$

2

- $T_{eff}(A) = 13\,000 \pm 500$ K
- $T_{eff}(B) = 11\,500 \pm 1\,000$ K
- log g = 4.0 (fixed)
- $v_e \sin i(A) = 75 \pm 3$ km/s
- $v_e \sin i(B) = 110$-180 km/s

3

Distorted dipolar configuration

- $i = 68°$
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- $B_d = 19$ kG
- $\langle B \rangle = 9$ kG
- dipole: 63%
- quadrupole: 22%
- octupole: 7%

4

- Indirect signal of the secondary's magnetic field in the residuals.
- The location of the peaks correlates with the features in the lightcurves

- Photometric dips probably originate from the relatively cold circumstellar clouds of material trapped by the magnetic field.

5

Radio and X-ray source

log L_R = 17.63 and log L_R = 17.63 [erg/s]

- An invisible component of 0.4-1 $M_\odot$ (T Tau?)
- Levels of $L_X = 29.6$–30.62 correspond to $M_{YSO} = 0.3$–$1.6\ M_\odot$