Monitoring the magnetic field of M dwarfs: the evolution of AD Leo, DS Leo, CN Leo and EV Lac

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Motivation

Dynamo models describing the generation of stellar magnetic fields for partly and fully convective stars are guided by observational constraints [1]. Zeeman-Doppler imaging (ZDI; [2,3]) has revealed a variety of magnetic field geometries and, for fully convective stars in particular, a dichotomy [4,5,6]: either strong, mostly axisymmetric, and dipole-dominated or weak, non-axisymmetric, and multipole-dominated. This dichotomy is explained either by dynamo bistability (that is, two coexisting and stable dynamo branches) or by long-term magnetic cycles with polarity reversals, but there is no definite conclusion on the matter [7,8].

Observations and Targets

We analysed spectropolarimetric data collected in the optical with Narval and ESPaDOns, and in the near-infrared with SPIRou. The observations were collected in circular polarisation mode between 2006 and 2022.

Name	Spectral type	Mass ($M_\odot$)	P_{rot} (d)	log R'$_{HK}$
DS Leo	M1.0	0.58	13.94	-4.16
AD Leo	M3.5	0.38	2.23	-4.00
EV Lac	M3.5	0.32	4.36	-3.75
CN Leo	M5.5	0.10	2.70	-4.01

We computed activity indicators among which the longitudinal field (B_l), that is the disk-integrated, line-of-sight component of the field. We reconstructed the large-scale magnetic topology at the surface of the four M dwarfs with Zeeman-Doppler imaging.

Results

- AD Leo – kG-strong, axisymmetric, dipolar field, whose axisymmetry decreased significantly in recent epochs
  EV Lac – kG-strong, non-axisymmetric, dipolar field, that reached almost perfect non-axisymmetry
- CN Leo – kG-strong, axisymmetric, dipolar field, that remained stable over 3-4 yr
- DS Leo – 100 G-strong, toroidal field, that transitioned to a more poloidal and dipolar configuration in recent epochs

Takeaway: M dwarfs with distinct masses and rotation periods may show signs of *magnetic* cycles, with a variety of long-term evolution of the field topology (see paper I and paper II below).

Bibliography

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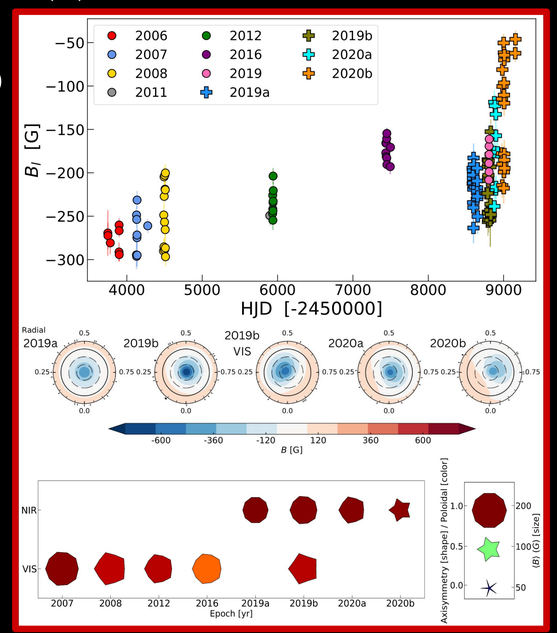
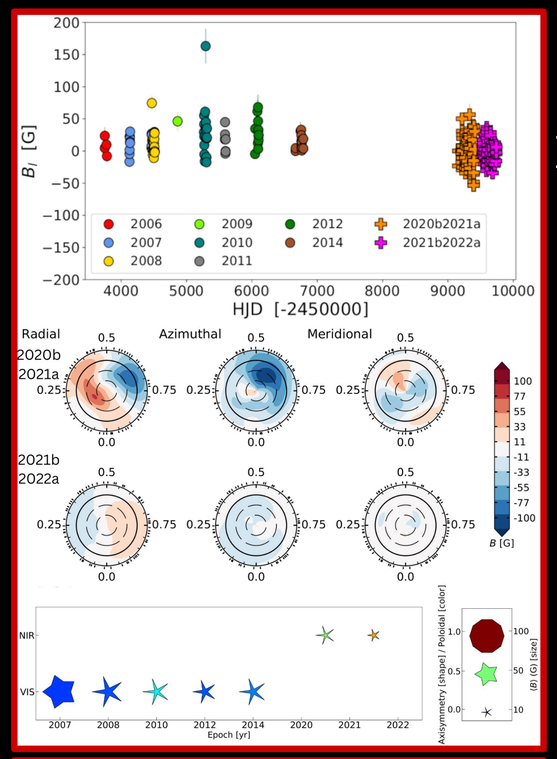
Bellotti et al., 2023, A&A, 676, A56 (paper I)
(paper II) Bellotti et al, 2024, A&A, 686, A66

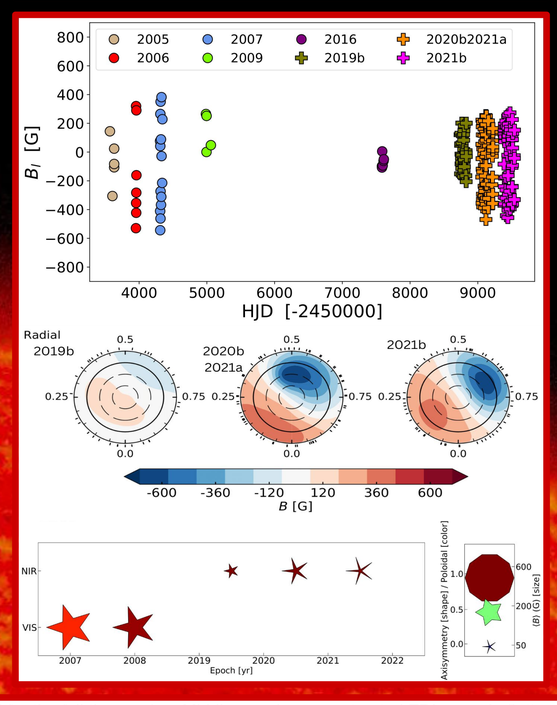
AD Leo



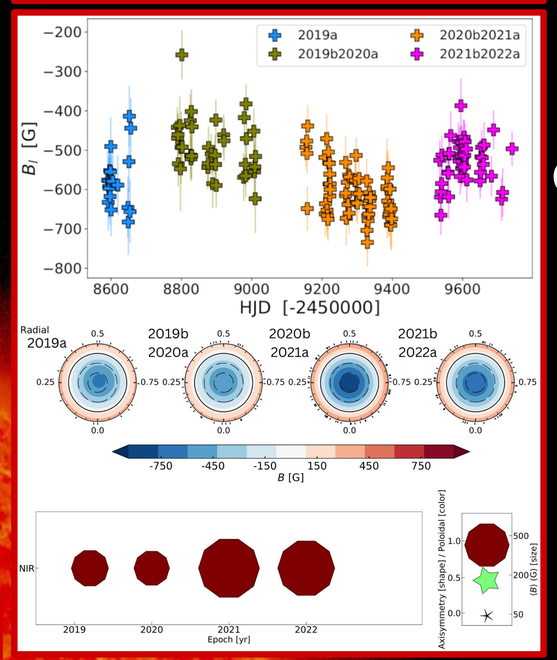
DS Leo



EV Lac



CN Leo



Top panels: longitudinal magnetic field for the full time series. Middle panels: reconstructed ZDI maps in flattened polar view. In each column, the radial component of the magnetic field vector is displayed (also azimuthal and meridional for DS Leo), with the radial ticks located at the rotational phases of the observations. The concentric circles represent different stellar latitudes: -30° , 0°, +30°, and +60°. Positive and negative polarity are shown in red and blue. Bottom panels: magnetic topology over time, with the data point size, colour and shape encoding the strength, poloidal-to-toroidal fraction and dipolar axisymmetric fraction (more circular = more axisymmetric).