Investigating magnetic activity in very stable stellar magnetic fields: a study of the fully convective M4 dwarf V374 Peg

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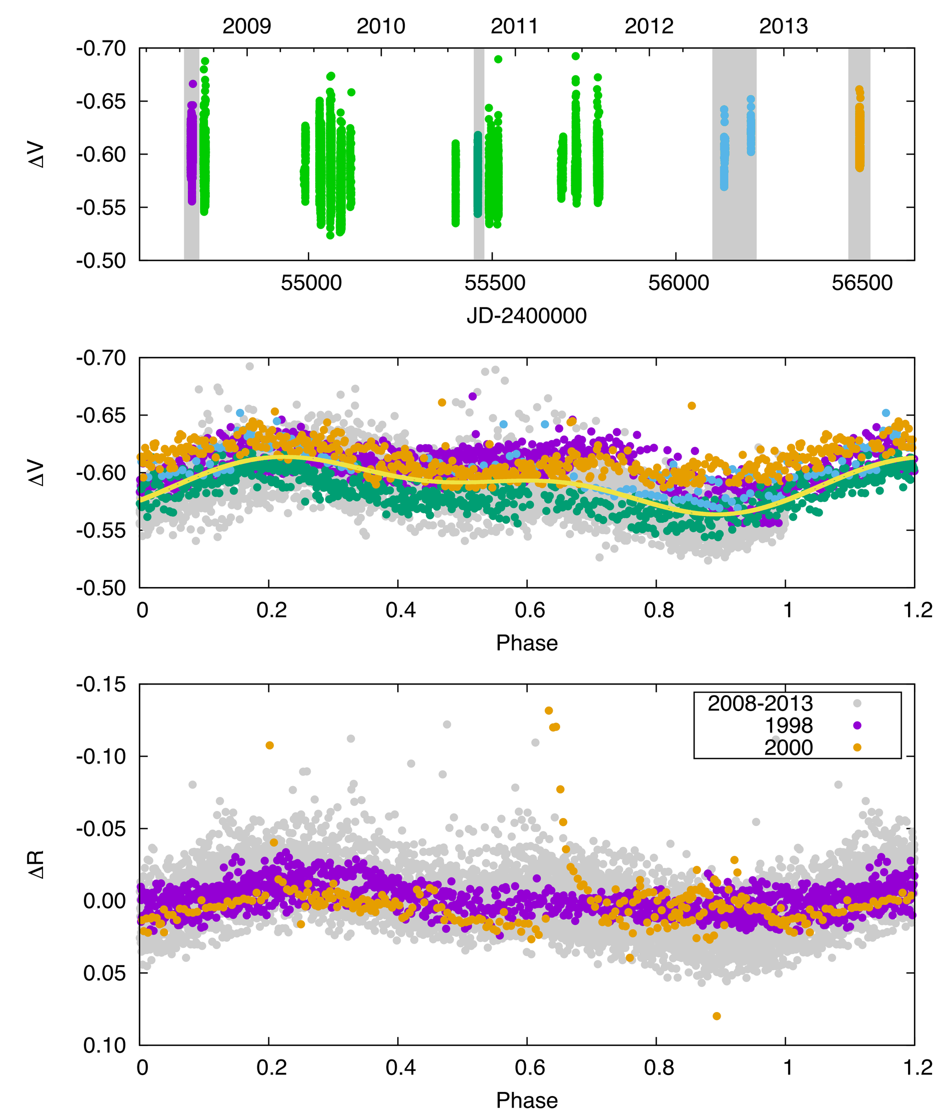
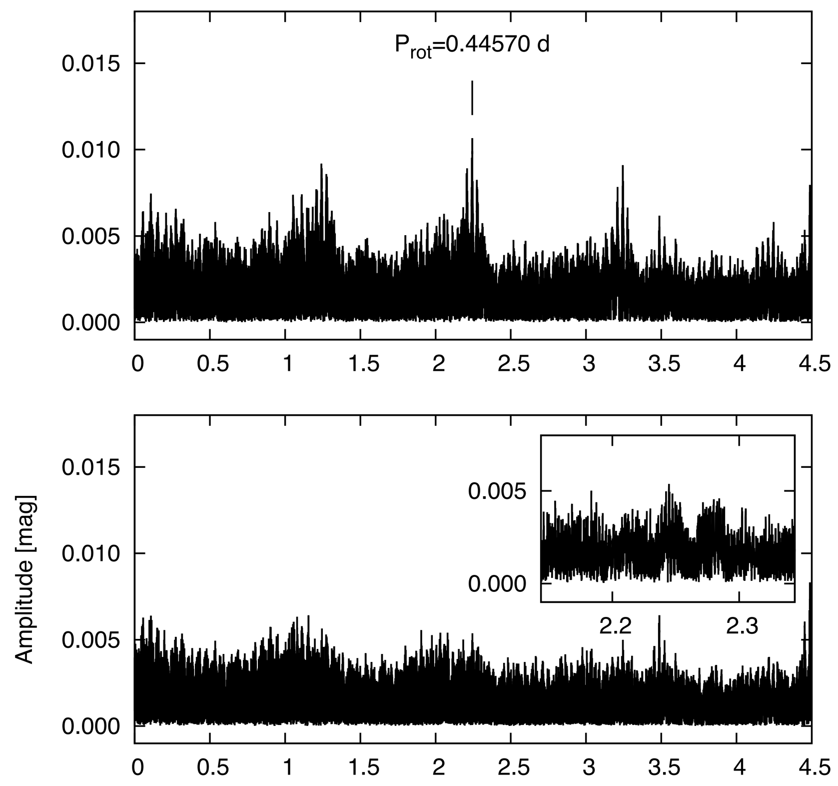
The ultrafast-rotating ($P_{rot} \approx 0.44$ d) fully convective single M4 dwarf V374 Peg is a well-known laboratory for studying intense stellar activity in a stable magnetic topology. Donati et al. (2006) studied the magnetic field of V374 Peg using Zeeman–Doppler imaging for data covering three nonconsecutive rotations. They found, that the star was rotating as a solid body and that it has a dipole-like axisymmetric magnetic field. Based on observations from three epochs spanning more than a year, Morin et al. (2008) detected a very weak differential rotation and concluded that the magnetic field of V374 Peg is stable on this timescale.

As an observable proxy for the stellar magnetic field, we studied the stability of the light curve, hence the spot configuration. We analysed spectroscopic observations, $BV(RI)_C$ photometry covering 5 yrs, and additional R_C photometry that expands the temporal base over 16 yr.

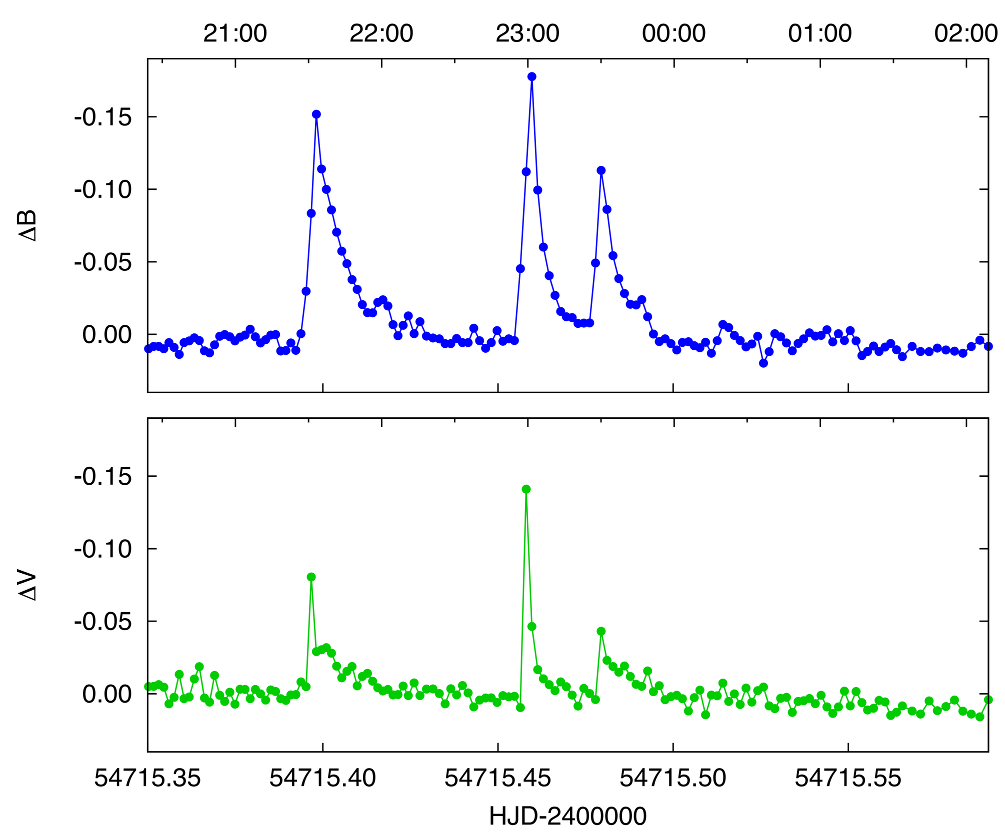
The light curve suggests an almost rigid-body rotation and a spot configuration that is stable over about 16 yrs, confirming the previous indications of a very stable magnetic field. We observed small changes on a nightly timescale (could be due to emerging and decaying flux ropes) and frequent flaring at every rotational phase, including a possible sympathetic flare. Spectral data suggest a coronal mass ejection (CME) rate that is much lower than expected from extrapolations of the solar flare–CME relation to active stars. Our findings are in good agreement with the recent theoretical dynamo model for fully convective stars of Yadav et al. (2015), who suggest that fully convective stars have stable magnetic fields, very small differential rotation, polar spots, and active regions distributed throughout the stellar phase (implying flare distribution independent of rotation phase).



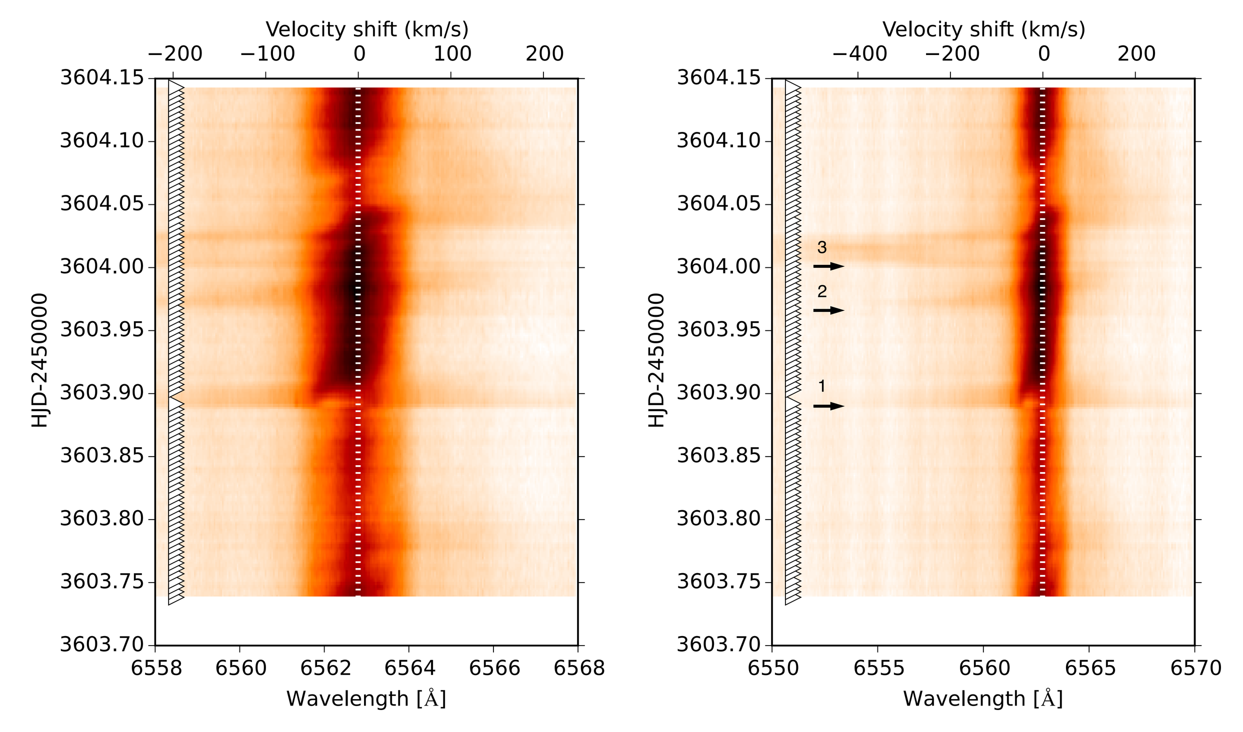
ΔV light curve of V374 Peg (top) and the marked parts phased (middle). Continuous line shows a basic model fit with two spots. Bottom: additional ΔR photometry from 1998 and 2000 plotted over the observations between 2008–2013. The data suggest two large active regions on the surface. The overall shape of the light curve, thus the global spot and the magnetic configuration is stable over 16 years.



Fourier spectrum of the ΔR light curve (top), the spectrum pre-whitened with the rotation frequency (bottom), the inset showing a zoom-in to the rotation area. There is only one significant peak in the power spectrum that corresponds to the stellar rotation and an additional small amplitude signal close to it. If we accept this small peak as a signal that also stems from the rotation, this would yield an almost rigid-body differential rotation shear: $|\alpha| = |\Delta P/P| \geq 0.0004$. There is no sign of activity cycles in the Fourier spectrum.



A complex flare observed in the photometric data in multiple passbands. The light curves show data after subtracting an analytic spot model. This event is probably a sympathetic flare (a flare resulting from a transient phenomenon occurring elsewhere on the stellar surface), similar to events observed on the Sun. This is supported by the energy ratios in different passbands. Note that the light curve level between the individual events does not return to its quiescent state.



Dynamic Hα spectra of V374 Peg from 2005 (observations from the CFHT archives), showing strong flare events (the two plots show different wavelength range). The CME signatures – the blue wing enhancement – are marked in the right plot. The complex eruption event indicates falling-back and re-ejected material (event #1 & #2) and a CME a maximal projected velocity of ~675 km s^{-1} (event #3). We estimated that the mass of the ejecta is higher than 10^{16} g, which is comparable to the strongest solar CME masses.

Check the animation of the CME over the astronomer-friendly magic wireless internet!

End of coffee break? Download the poster!

Interested? Read the whole paper!

Acknowledgements

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