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Doppler Imaging of the Active Stellar Surface of HU Virginis

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Motivation

Doppler imaging is an inversion technique to recover a 2-D image of a rapidly rotating star from a series of high-resolution spectral line profiles. We present Doppler maps of HU Virginis (HD 106225), which is a rapidly rotating K0 subgiant in a close binary system with an unseen secondary component, an orbital period of 10.4 days, and with moderately strong Li I 6707.8 Å line. Showing all the classical signs of an "active" RS CVn star, HU Vir is a good candidate for a rotational-modulation study of magnetic activity tracers like starspots and plages. Presented maps are based on spectra obtained with STELLA robotic observatory's (Teide Observatory, Tenerife, Spain) high-resolution Echelle Spectrograph (SES, R=55,000). Long-term observations between February-June 2013 cover 12 stellar rotations (124 spectra) and allow us to obtain time-series images of the surface temperature distribution.

Starspots are intrinsic noise for planet detection and for characterization of the companion planet. The influence of a spotted stellar disk for precise radial-velocity measurements can be of much higher significance than the planet-induced signal itself (Hatzes 2012, AN 323, 392). If present during the transit they can bias the determination of the planet radius and density (Czesla et al. 2009, A&A 505, 1277). On the other hand, starspots can be used to study star-planet interactions as well as inferring properties from underlying stellar dynamo.

Doppler-Images

To reconstruct temperature maps of HU Vir we have used the Doppler-Imaging code iMAP (Carroll et al. 2012, A&A 548, A95). This inversion code calculates the full radiative transfer on the basis of Kurucz-model atmospheres and inverts several spectral lines simultaneously. In this case 40 almost non-blended spectral lines were used. Figure 1 shows surface temperature maps for 3 rotational periods of HU Vir.

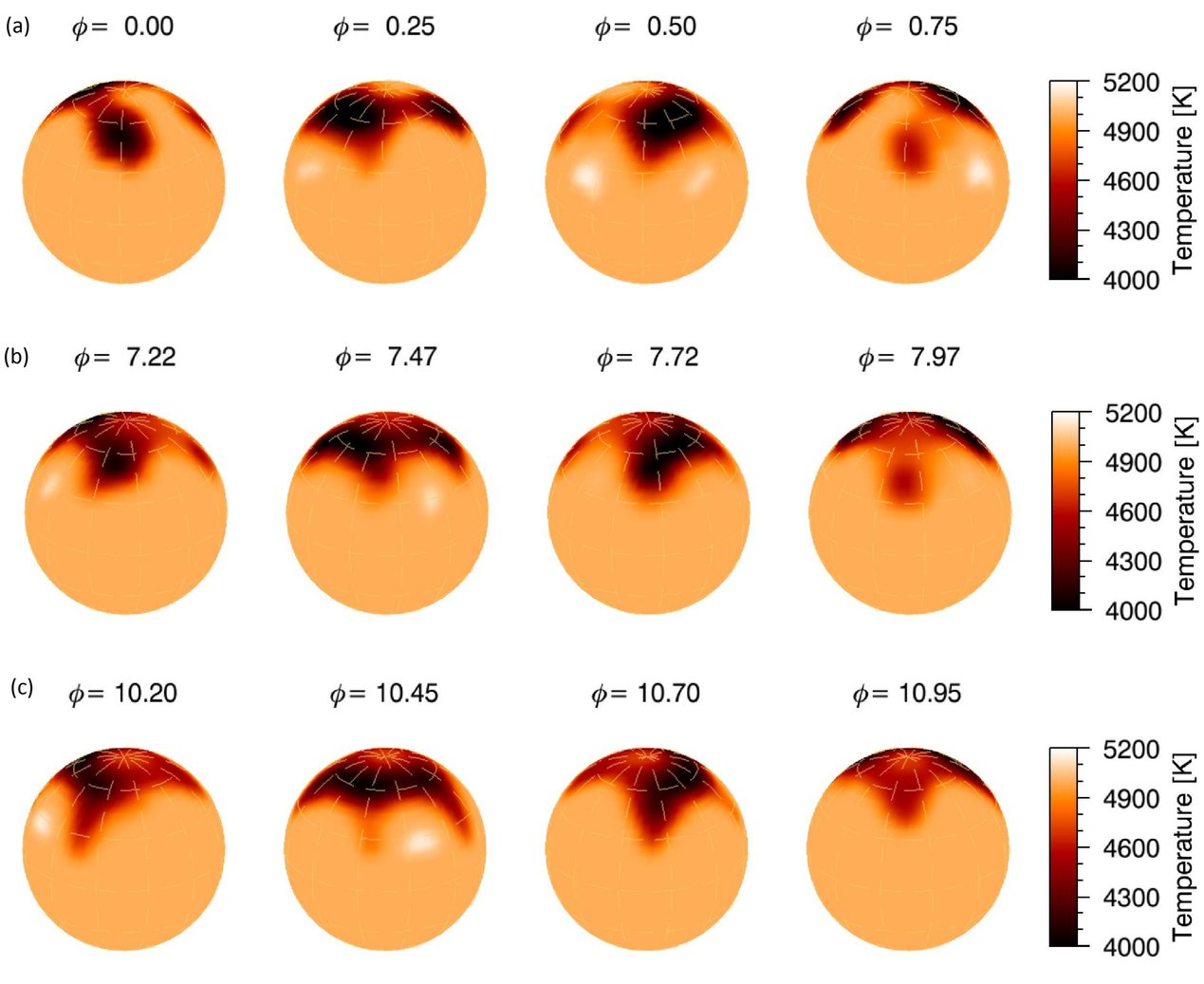

Figure 1. Surface temperature maps of HU Vir for Feb.-June 2013. Each image is shown in 4 sideviews every 90˚.The rotational shift between the individual Doppler-images is corrected, i.e. the stellar rotational orientation remains the same from map to map. The time difference is indicated in units of rotational phase ϕ.

We observe cool spots at high latitudes (≈60˚), with temperatures of ≈1000 K below the photospheric temperature. The Doppler-images presented in Fig. 1 have similarities both to the image shown in Strassmeier 1994 (A&A 281, 395) derived for the epoch 1991.3 and to that shown in Hatzes 1997 (A&A 330, 541) for the epoch 1995.14. In all these 3 cases one see high-latitude spots on HU Vir.

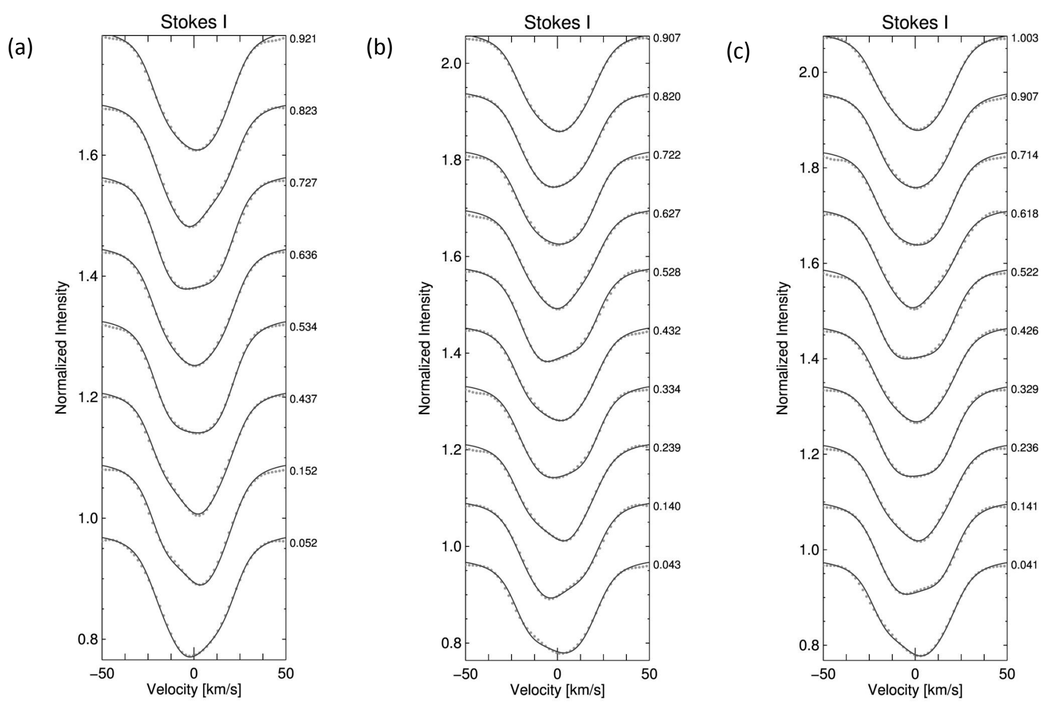

Figure 2. The mean profiles of 40 observed spectral lines (dots) and the inverted profiles (solid lines) from Doppler-imaging, whereas a, b, c correspond to Fig. 1 a, b, c, respectively

Li abundance

The presence of lithium on the surfaces of stars with a convective envelope suggests a fairly young stellar system that has not had time yet to deplete its surface lithium. However, there is substantial observational evidence that evolved, active stars with large starspots also show enhanced lithium abundances. Figure 3 shows Li I 6707.8 Å region of HU Vir spectrum. Substraction of a spectrum of the K0.5III standard star 16 Vir resulted in an equivalent width of 40±5 mÅ for the lithium line of HU Vir. This equivalent width was converted to an abundance of result log n (Li) ≈ 1.36 using the curves of growth of Pallavicini et al. 1987, A&A 174, 116 for T_{eff} = 5000 K and log g = 2.7 (Strassmeier 1994, A&A 281, 395). Using the non-LTE curves of growth from Pavlenko & Magazzù 1996, A&A 311, 961 we calculated an abundance log n (Li) ≈ 1.66. Thus, HU Vir has a significant amount of lithium left on its surface.

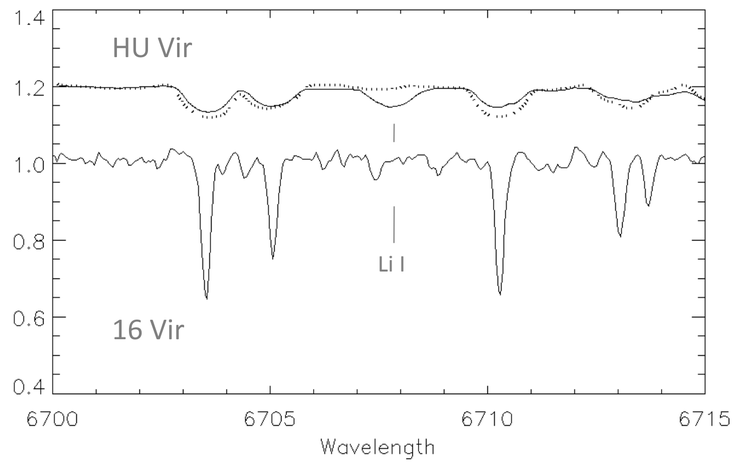

Figure 3. The mean SES spectrum of the lithium region of HU Vir (upper spectrum; full line) and a broadened and shifted spectrum of the inactive standard star 16 Vir (dotted line). The Li I line of HU Vir is marked and has an equivalent width of 40 mÅ.