Doppler imaging of HD 218153 and HK Lac

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Abstract. We present preliminary results of Doppler imaging of the rapidly–rotating, long-period giants HD 218153 and HK Lac. Both stars exhibit cool spots at high latitudes with average temperatures of 800 K and 1000 K below the photospheric temperature of 4700 K and 4800 K for HD 218153 and HK Lac, respectively. Latitude–dependent differential rotation is detected from our Doppler maps for both stars and indicate faster rotation at the pole than at the stellar equator.

1. Scientific motivation

To find a relation of magnetic activity indicators with astrophysical parameters of active late–type stars, it is necessary to study a wide sample of targets to find indicators such as differential-rotation laws or surface-temperature distributions. For Doppler imaging, which is the method we use to study magnetic activity, the applicability is determined by the projected stellar rotational velocity (> 20 km s⁻¹) and the stellar rotation period (c.f. constrained by the number of days for a single observing run).

The two stars in this poster are HD 218153 (P_{rot} = 25.3 days, v sin i = 29.5 km s⁻¹) and HK Lac (P_{rot} = 24.4 days, v sin i = 23.5 km s⁻¹). They are currently the stars with the longest rotation periods that have a Doppler image and, therefore, present an important extension of the parameter space towards smaller dynamo numbers.

2. Data acquisition

Our spectroscopic observations were obtained at National Solar Observatory (NSO) at the McMath–Pierce main telescope using the stellar spectrograph from October 31, 1996 to January 8, 1997. The resolving power was ≈40,000 and the useful wavelength range about 45 Å. Additional spectra were obtained at Kitt Peak National Observatory (KPNO) using the coudé feed telescope in December 1997 to January 1998. These spectra have a resolving power of 38,000 and a useful wavelength range of 80 Å. Radial velocities were derived from cross correlating the HD 218153 and HK Lac spectra with spectra of the IAU velocity standard α Ari (K2 III), 16 Vir (K0.5 III), and β Gem (K0 III).

The photometric data in Fig. 1 was obtained with the Amadeus 0.75-m automatic photoelectric telescope (APT), one of the two University of Vienna twin...
Figure 1. Top: 1996/97 APT data. Light and color curves (panel a), the phased V-lightcurve (panel b) and the periodogram and window function (panel c). The vertical lines in panel a mark the times of spectroscopic observations and the two arrows labeled 1 and 2 show the time span used for map 1 and map 2, respectively. Bottom: 1997/98 APT data. Light and color curves (panel d), the phased V-lightcurve (panel e) and the periodogram and window function (panel f). All phases have been calculated with $P_{\text{phot}} = 25.258 \pm 0.082$ and $T_{\text{phot}} = 2450359.3$.

APTs at Washington Camp in Southern Arizona. All photometry was transformed to match the Johnson-Cousins $V(RI)_C$ system.

3. Results

3.1. HD 218153

Fig. 2 shows the average maps for HD 218153 from two consecutive stellar rotation. The individual maps were computed from three different spectral line regions (Fe I 6421, Fe I 6430 and Ca I 6439). Both maps exhibit a very similar spot configuration with only small differences in spot temperature and position. Altogether six spots between latitudes of +30 and +60º, and a polar spot, are visible.

By cross correlating the two maps at successive latitudes, we derive the latitude-dependent differential rotation of HD 218153. A least-squares $\sin^2 b$ ($b$ latitude)
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Figure 2. Left: Average Doppler image of HD 218153 from the first (top image) and the second (bottom image) stellar rotation. Right: Cross correlation of the two consecutive Doppler images of HD 218153. The solid line is a least-squares \( \sin^2 b \) (b latitude) fit for the phase lags versus stellar latitude.

Table 1. Improved orbital elements for HK Lac

<table>
<thead>
<tr>
<th>Orbital element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P ) (days)</td>
<td>24.428551±0.000004</td>
</tr>
<tr>
<td>( T_0 ) (HJD)(^a)</td>
<td>2,439,986.766±0.003</td>
</tr>
<tr>
<td>( \gamma ) (km s(^{-1}))</td>
<td>-22.7550±0.0009</td>
</tr>
<tr>
<td>( K ) (km s(^{-1}))</td>
<td>34.304±0.001</td>
</tr>
<tr>
<td>( e )</td>
<td>0.0 (adopted)</td>
</tr>
<tr>
<td>( a_1 \sin i ) (km)</td>
<td>11.5233±0.0003 \times 10^6</td>
</tr>
<tr>
<td>( f(M) ) (M(_\odot))</td>
<td>0.102163±0.000009</td>
</tr>
</tbody>
</table>

\(^a\)Time of the primary's maximum positive radial velocity

fit for the phase lags versus stellar latitude is shown as a full line in Fig. 2. Low-latitude regions obviously rotate slower than high-latitude regions.

3.2. HK Lacertae

Our preliminary Doppler images for HK Lac are derived from only one spectral line region (Fe I 6430) but for three different epochs. The first two maps are for two consecutive stellar rotations in November-January 1996/97 while the third one is from a data set also spanning just one rotation but taken one year later in December-January 1997/98.
Figure 3. Left: Doppler image of HK Lac for the first of the two consecutive rotations in 1996/97. Middle: Doppler image of HK Lac for the second of the two consecutive rotations in 1996/97. Right: Doppler image of HK Lac for 1997/98.

The three Doppler maps, together with the line-profile fits and the light-curve fits, are shown in Fig. 3. While the first two maps look very similar, the third map – taken one year later – appears significantly different. It shows a larger areal spot coverage which seems also to account for the larger light-curve amplitude.

Again, by cross correlating the two maps from the two consecutive rotations in 1996/97, we derive a latitude-dependent differential-rotation law for HK Lac. As for HD 218153, zones at higher latitudes appear to rotate faster than the equatorial zones.

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