



Ankara University  
Kreiken Observatory



# Surface Inhomogeneities of the Eclipsing Binary System ER Vulpeculae

Observing Techniques, Instrumentation and Science  
For Metre-Class Telescopes II

Tatranská Lomnica, Slovakia  
September 24 - 28, 2018

*I. Özavci<sup>1</sup>, E. Bahar<sup>1</sup> and H.V. Senavci<sup>1</sup>*

<sup>1</sup>*Ankara University, Department of Astronomy and Space Sciences*

# Telescope and Instruments



## Kreiken Telescope (Meade LX200 16'')

### Technical Specifications

**Diameter:** 406 mm

**Focal Ratio:** f/10

**Focal length:** 4064 mm

**Image scale:** 51 arcsec/mm

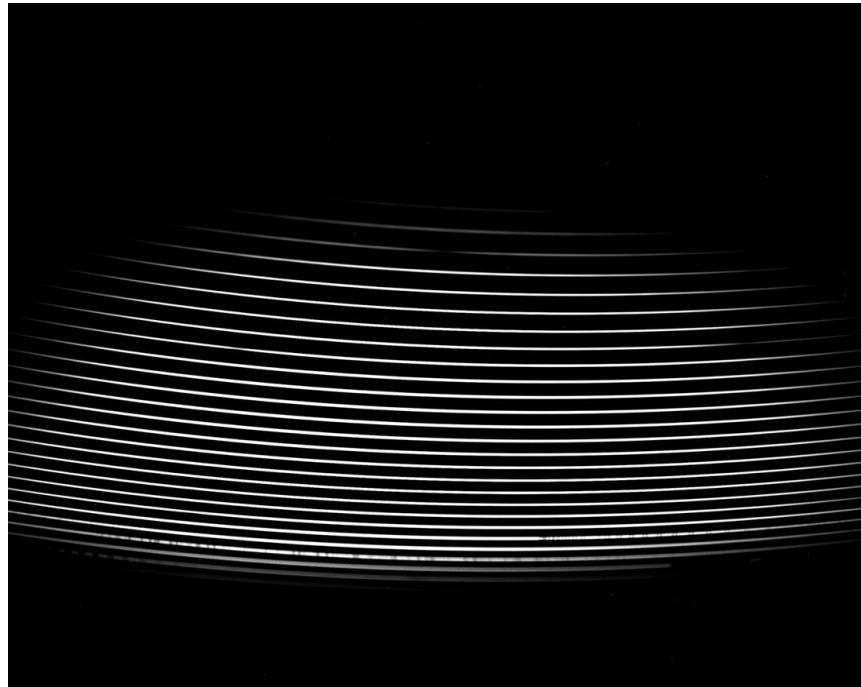
**Manufacturer:** Meade Instruments Corp.,  
California



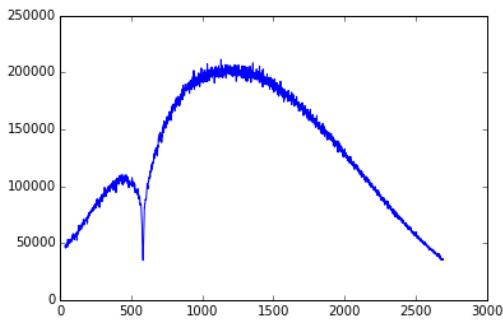
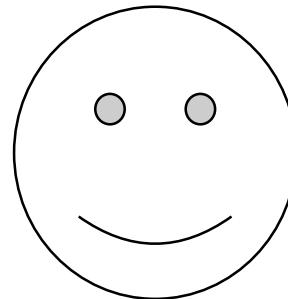
### Focal Plane Instruments

- eShel Spectrograph (Shelyak Instruments), R~14000,  
Wavelength Range: 4340-7400 Å, Brightness Limit V < 8.0 mag
- Fiber Injection and Guiding Unit (f/6)
- Halogen, LED and Thorium-Argon lamp calibration unit
- QSI 660ws CCD camera
- 2758 x 2208 pixel 4.54 micron Sony ICX694 chip
- Autoguider system
- Various eye-pieces



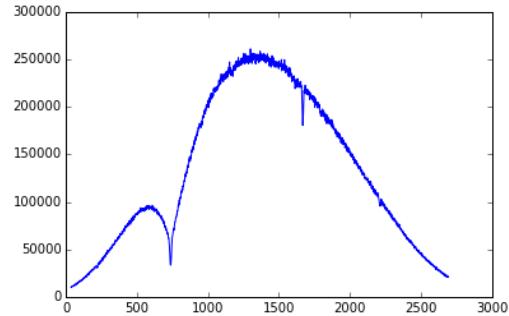


First Light  $\beta$  Leo  $m_v = 2.1$  - 90 Sec (06.04.2016)



Vega -  $H_\beta$

Vega -  $H_\alpha$



# Some of Our Studies From This Setup

THE ASTROPHYSICAL JOURNAL, 852:116 (5pp), 2018 January 10  
© 2018. The American Astronomical Society. All rights reserved.

<https://doi.org/10.3847/1538-4357/aa9f14>

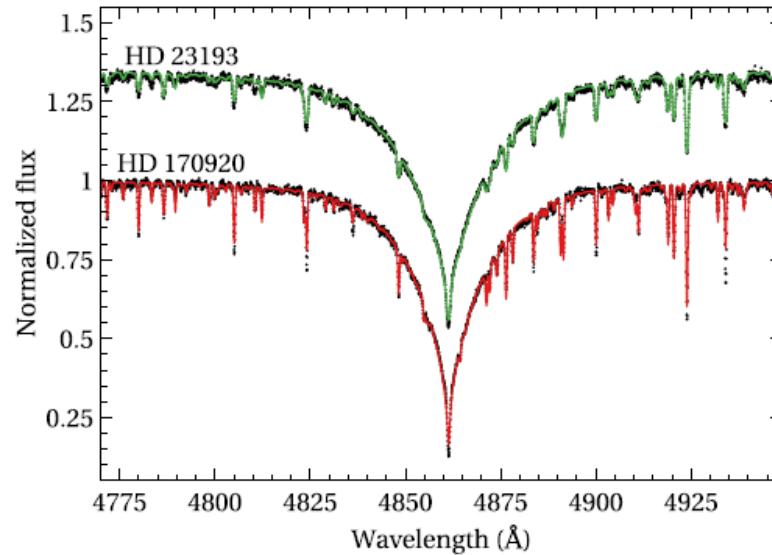


## Behavior of Abundances in Chemically Peculiar Dwarf and Subgiant A-Type Stars: HD 23193 and HD 170920\*

Tolgahan Kılıçoğlu, Şeyma Çalışkan<sup>1</sup>, and Kübraözge Ünal

Ankara University, Science Faculty, Department of Astronomy and Space Sciences, 06100, Ankara, Turkey; [seyma.caliskan@science.ankara.edu.tr](mailto:seyma.caliskan@science.ankara.edu.tr)

Received 2017 October 9; revised 2017 November 30; accepted 2017 November 30; published 2018 January 12



HD 23193 and HD170920  $H_{\beta}$  profiles and theoretical model



# Doppler Imaging and Chemical Abundance Analysis of EK Dra: Capabilities of Small Telescopes

Kılıçoğlu, T.<sup>1</sup>, Şenavci, H.V.<sup>1</sup>, Bahar, E.<sup>1</sup>, İşık, E.<sup>2</sup>, Montes, D.<sup>3</sup>, and Hussain, G.A.J.<sup>4</sup>



<sup>1</sup>Ankara University, Faculty of Science, Department of Astronomy and Space Sciences, 06520, Ankara, Turkey

<sup>2</sup>Max-Planck-Institut für Sonnensystemforschung, Justus-von-Liebig-Weg 3, 37077, Göttingen, Germany

<sup>3</sup>Dept. Astronomía, Facultad de CC. Físicas, Universidad Complutense de Madrid, Spain

<sup>4</sup>European Southern Observatory, Karl-Schwarzschild-Str. 2, 85746 Garching bei München, Germany

**SUMMARY** We investigate the chromospheric and spot activity behaviour of the young Solar-like star EK Dra via Doppler Imaging and spectral synthesis methods, using mid-resolution time series spectra of the system. We also perform the atmospheric parameters and chemical photopsheric abundances of the star. We also perform the chemical abundance analysis of the star using the solar abundances taken from Grevesse & Sauval (1998). The Thorium-Okta (TO) bands at 6000 - 7100 Å region also give clues about the spot temperatures that may be cooler than 4000 K. In addition, we also show the capabilities of small telescopes (0.4 m) and medium resolution spectrographs in terms of Doppler Imaging and chemical abundance analysis.

## EK Dra: A Young Solar Analogue

- The first Doppler Imaging of EK Dra was performed by Shastri & Rice (1988) who used spectra with  $P = 10$  days. They found that the preferred latitudes of the disk (spotted) regions are  $+40^\circ$  and  $-70^\circ$  (for the data taken in March 1988), and noted a large core latitude of  $40^\circ$ .
- Reichart (2000) investigated the long-term variation of the star using Spitzer Infrared Sky-Polarimetry Experiment (SIP) and found that the solar brightness (B) of the star indicating its superflare activity.
- Joshi et al. (2008) found that the spots on EK Dra are grouped into two longitudes separated roughly  $180^\circ$  using the chromospheric data and the light curve inversion method. They also detected periodic variation of the total spot with a period longer than 60 days and with an additional period of 10.9 years.
- Montes et al. (2009) found that the spots on EK Dra are located at  $\sim 0.1 M_\odot$  for the primary component of the system and found  $2.76 \pm 0.030$  days periodic variation in the radial velocity for the years 2001 and 2002.
- The surface temperature map of EK Dra were obtained by Joshi et al. (2007) and revealed that the spots are  $\sim 3000$  K cooler than the photospheres.
- Arnaud & France (2010) captured several very broad profiles of highly ionized C, Si, and He, indicating highly dynamic subcoronal plasma as well as according to M being jets onto the lower atmosphere.
- A new detailed Doppler Imaging and Zeeman-Doppler Imaging of the star were finally performed by Wolfe et al. (2017).

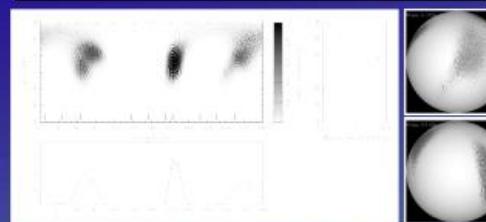


Fig. 1 Surface Map of EK Dra with latitudinal and longitudinal  $\xi$  distributions

**Fundamental parameters**

$M = 0.95 M_\odot$   
 $v_{\text{sin}i} = 1.64 \text{ km s}^{-1}$   
 $I = 60^\circ$   
 $C = 10^\circ$   
 $T_{\text{eff}} = 5750 \text{ K}$   
 $\log g = 4.40$

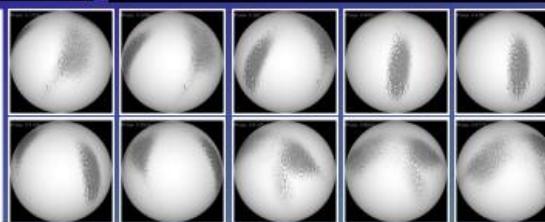


Fig. 2 Surface Images of EK Dra at different phases

## Results and Discussion

- Our surface maps of EK Dra show these dark cool regions of intermediate-high latitudes.
- Figs. 1 & 2 emphasize how much bigger these spots are compared to sunspots (diameters  $\sim 19$ ).
- Strong absorption in TO bandpass of 7000-7150 Å indicates  $T_{\text{eff}} = 4000$  K.
- We derive the abundances of EK Dra (Fig. 6) and find solar abundance except for Y and Ba which is clearly overabundant. These are the features of EK Dra as a G-type star. However, we have to consider the stellar structure of Ba and the effects of the magnetic field to clarify/reject the classification.
- As EK Dra is G-type convective mixing dominates and surface composition should reflect the stellar properties of this star. Even for the corrected this is a puzzle. We do not expect the atomic diffusion occurs in these stars, as the process has much longer timescales than that of convective motions.
- We will obtain higher resolution spectra to reveal surface maps with higher spatial resolution, confirm our abundance measurements and check for a Sr overabundance.



Fig. 3 Time series LSD profiles of EK Dra

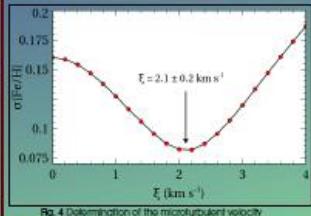


Fig. 4 Determination of the microturbulent velocity

BIBLIOGRAPHY

Arnaud, J., France, J., & De Pontieu, B. 2010, *Journal of the American Astronomical Society*, 100, 100.

Armeni, A., & Montes, D. 2017, *Journal of the American Astronomical Society*, 106, 106.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 107, 107.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 108, 108.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 109, 109.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 110, 110.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 111, 111.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 112, 112.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 113, 113.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 114, 114.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 115, 115.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 116, 116.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 117, 117.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 118, 118.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 119, 119.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 120, 120.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 121, 121.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 122, 122.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 123, 123.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 124, 124.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 125, 125.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 126, 126.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 127, 127.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 128, 128.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 129, 129.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 130, 130.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 131, 131.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 132, 132.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 133, 133.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 134, 134.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 135, 135.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 136, 136.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 137, 137.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 138, 138.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 139, 139.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 140, 140.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 141, 141.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 142, 142.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 143, 143.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 144, 144.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 145, 145.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 146, 146.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 147, 147.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 148, 148.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 149, 149.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 150, 150.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 151, 151.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 152, 152.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 153, 153.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 154, 154.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 155, 155.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 156, 156.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 157, 157.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 158, 158.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 159, 159.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 160, 160.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 161, 161.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 162, 162.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 163, 163.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 164, 164.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 165, 165.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 166, 166.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 167, 167.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 168, 168.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 169, 169.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 170, 170.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 171, 171.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 172, 172.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 173, 173.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 174, 174.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 175, 175.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 176, 176.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 177, 177.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 178, 178.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 179, 179.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 180, 180.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 181, 181.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 182, 182.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 183, 183.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 184, 184.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 185, 185.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 186, 186.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 187, 187.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 188, 188.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 189, 189.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 190, 190.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 191, 191.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 192, 192.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 193, 193.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 194, 194.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 195, 195.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 196, 196.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 197, 197.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 198, 198.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 199, 199.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 200, 200.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 201, 201.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 202, 202.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 203, 203.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 204, 204.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 205, 205.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 206, 206.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 207, 207.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 208, 208.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 209, 209.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 210, 210.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 211, 211.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 212, 212.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 213, 213.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 214, 214.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 215, 215.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 216, 216.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 217, 217.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 218, 218.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 219, 219.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 220, 220.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 221, 221.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 222, 222.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 223, 223.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 224, 224.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 225, 225.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 226, 226.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 227, 227.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 228, 228.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 229, 229.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 230, 230.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 231, 231.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 232, 232.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 233, 233.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 234, 234.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 235, 235.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 236, 236.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 237, 237.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 238, 238.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 239, 239.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 240, 240.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 241, 241.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 242, 242.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 243, 243.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 244, 244.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 245, 245.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 246, 246.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 247, 247.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 248, 248.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 249, 249.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 250, 250.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 251, 251.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 252, 252.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 253, 253.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 254, 254.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 255, 255.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 256, 256.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 257, 257.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 258, 258.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 259, 259.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 260, 260.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 261, 261.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 262, 262.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 263, 263.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 264, 264.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 265, 265.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 266, 266.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 267, 267.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 268, 268.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 269, 269.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 270, 270.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 271, 271.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 272, 272.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 273, 273.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 274, 274.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 275, 275.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 276, 276.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 277, 277.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 278, 278.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 279, 279.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 280, 280.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 281, 281.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 282, 282.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 283, 283.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 284, 284.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 285, 285.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 286, 286.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 287, 287.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 288, 288.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 289, 289.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 290, 290.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 291, 291.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 292, 292.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 293, 293.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 294, 294.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 295, 295.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 296, 296.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 297, 297.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 298, 298.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 299, 299.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 300, 300.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 301, 301.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 302, 302.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 303, 303.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 304, 304.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 305, 305.

Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 306, 306.

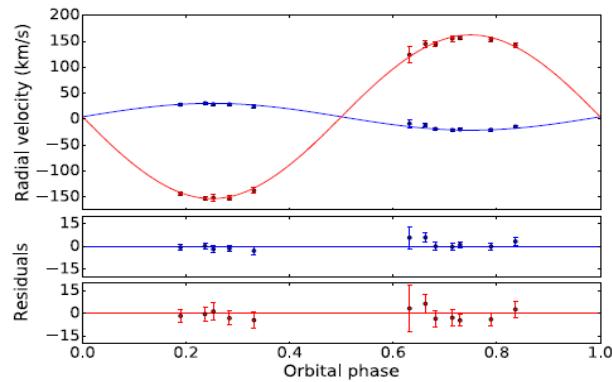
Armeni, A., & Montes, D. 2018, *Journal of the American Astronomical Society*, 307, 307.

Armeni, A., &

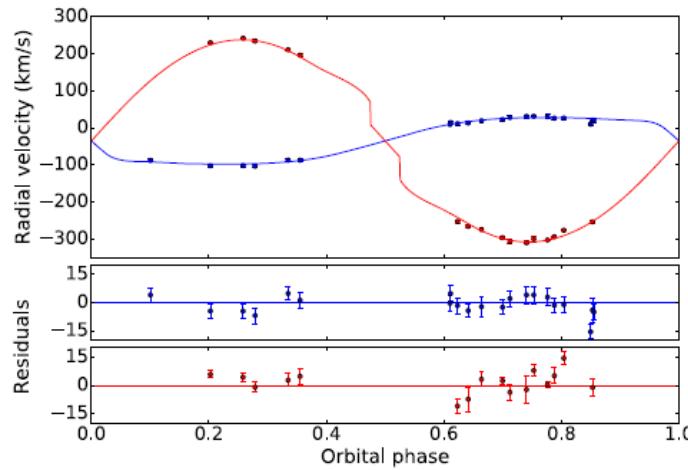
ORIGINAL ARTICLE

# A simultaneous spectroscopic and photometric study of two eclipsing binaries: V566 Oph and V972 Her

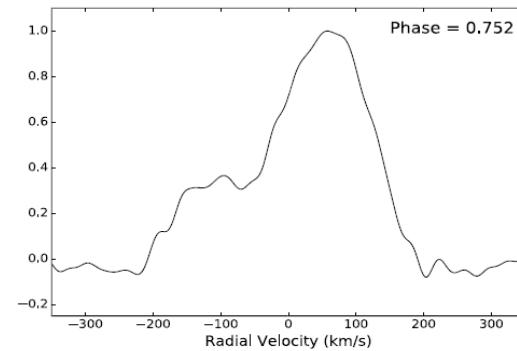
S.O. Selam<sup>1,2</sup> · E.M. Esmer<sup>1,2</sup> · H.V. Şenavci<sup>1,2</sup> · E. Bahar<sup>1,2</sup> · O. Yörükoglu<sup>1,2</sup> · M. Yılmaz<sup>1,2</sup> · Ö. Baştürk<sup>1,2</sup>



Radial velocity curve and theoretical model of V972 Her



Radial velocity curve and theoretical model of V566 Oph



V972 Her'in Broadening Function (phase = 0.752)

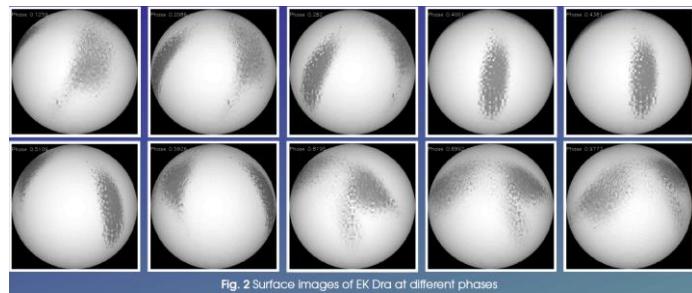
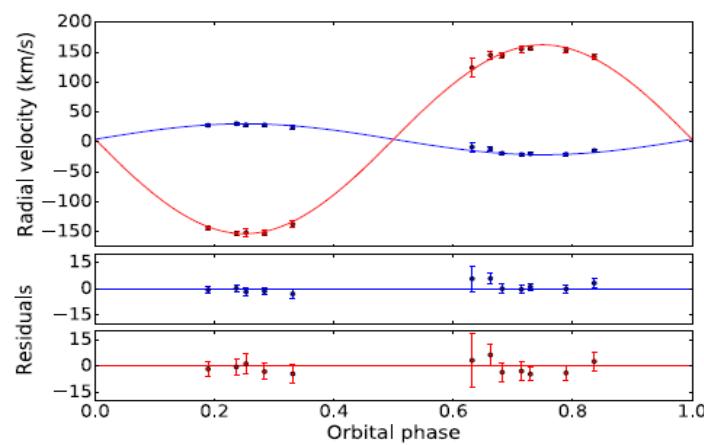
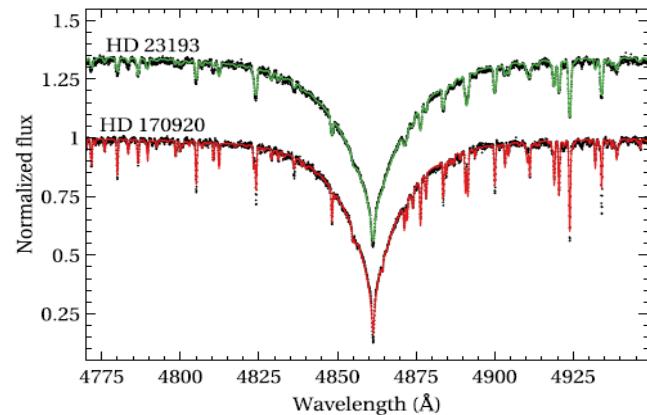


Fig. 2 Surface images of EK Dra at different phases



# Why ER Vul ?



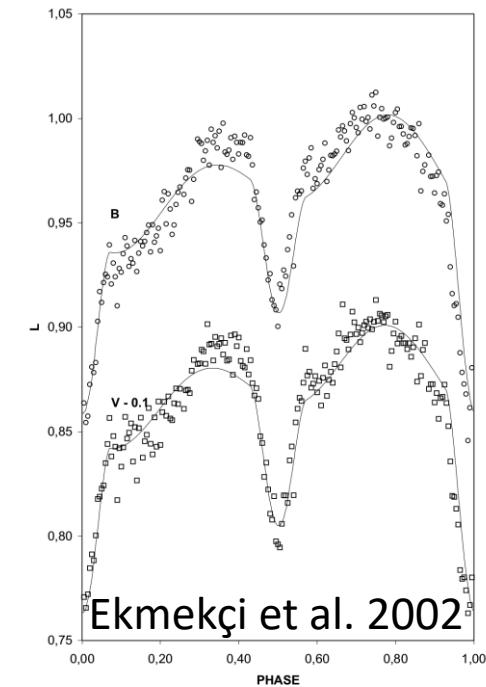
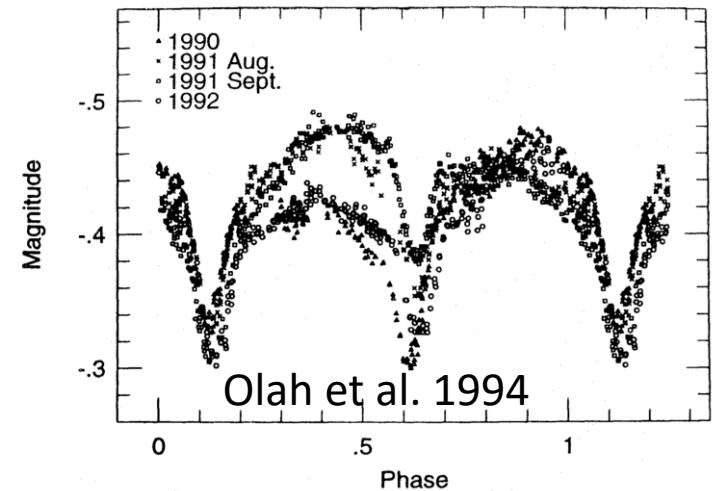
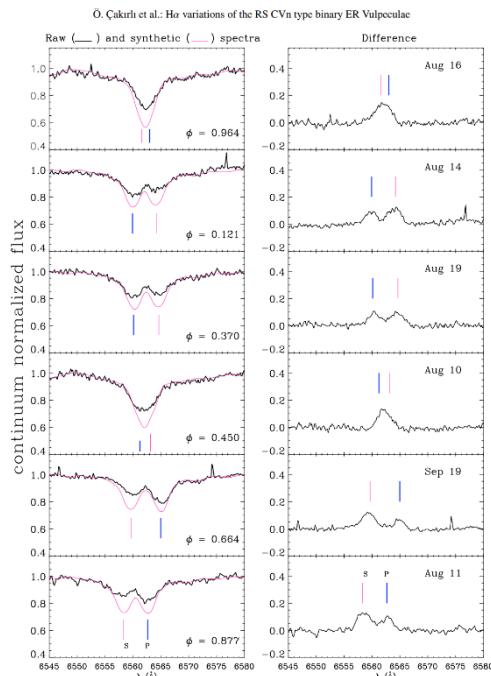
Credit: Martin Tsarev  
(<http://www.sv-cam.smolyan.info/rscvn.html>)

- Convenient for our setup (brightness) and is known to be magnetically active.
- Sun-like stars, G0V primary and G5V secondary
- Short-period ( $\sim 0.7^d$ ) RS CVn-type binary system.
- Primary star nearly fills its Roche lobe, but the binary system is still detached (Duemmler et al. 2003) .
- ER Vul is identified as a pre-contact binary system (Dryomova, Perevozkina & Svechnikov 2005)

# Some Light Curves of ER Vul

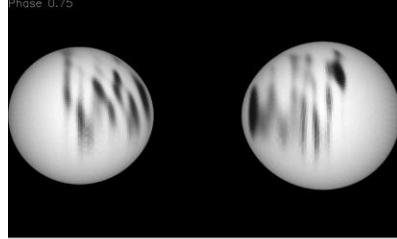
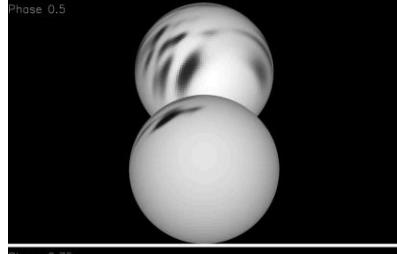
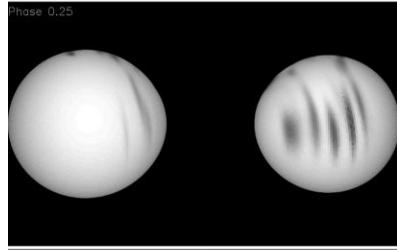
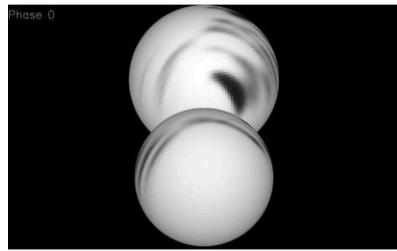
ER Vul V 1990-91-92

- Hall (1976) → RS CVn type
- Olah et al. (1994), Ekmekçi, et al. (2002) and Wilson & Raichur (2011) → Light curve
- Çakırlı et al. (2003) → the secondary star is more active than the primary one.

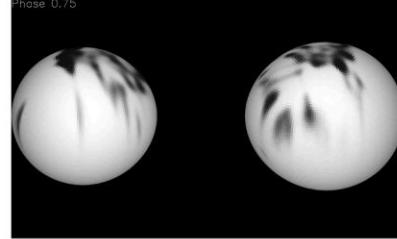
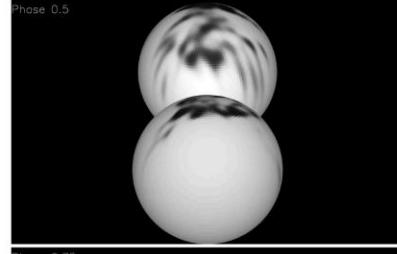
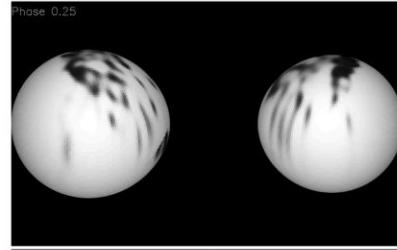
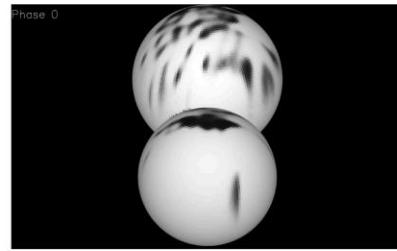


Piskunov → 1996, 2001 and 2008 and performed Doppler imaging

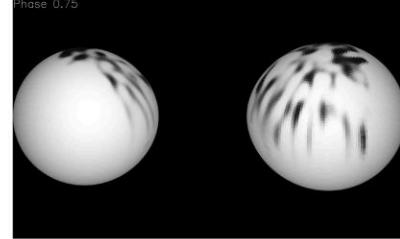
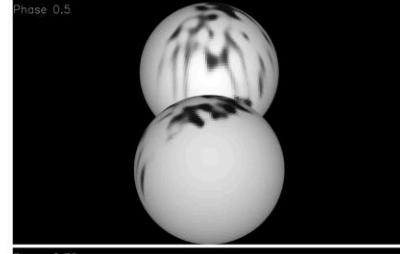
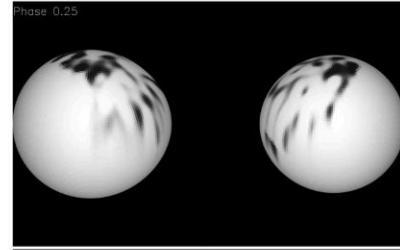
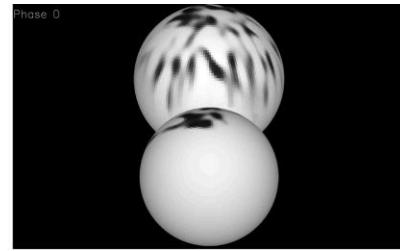
Xiang 2015 → the most recent Doppler imaging



(a)



(b)



(c)

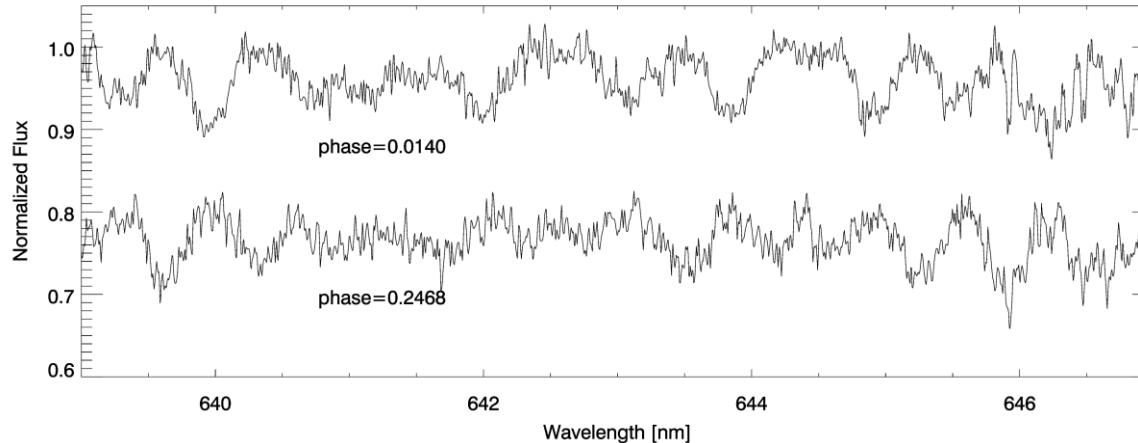
# Observations

**Table 1.** Log of spectroscopic observations.

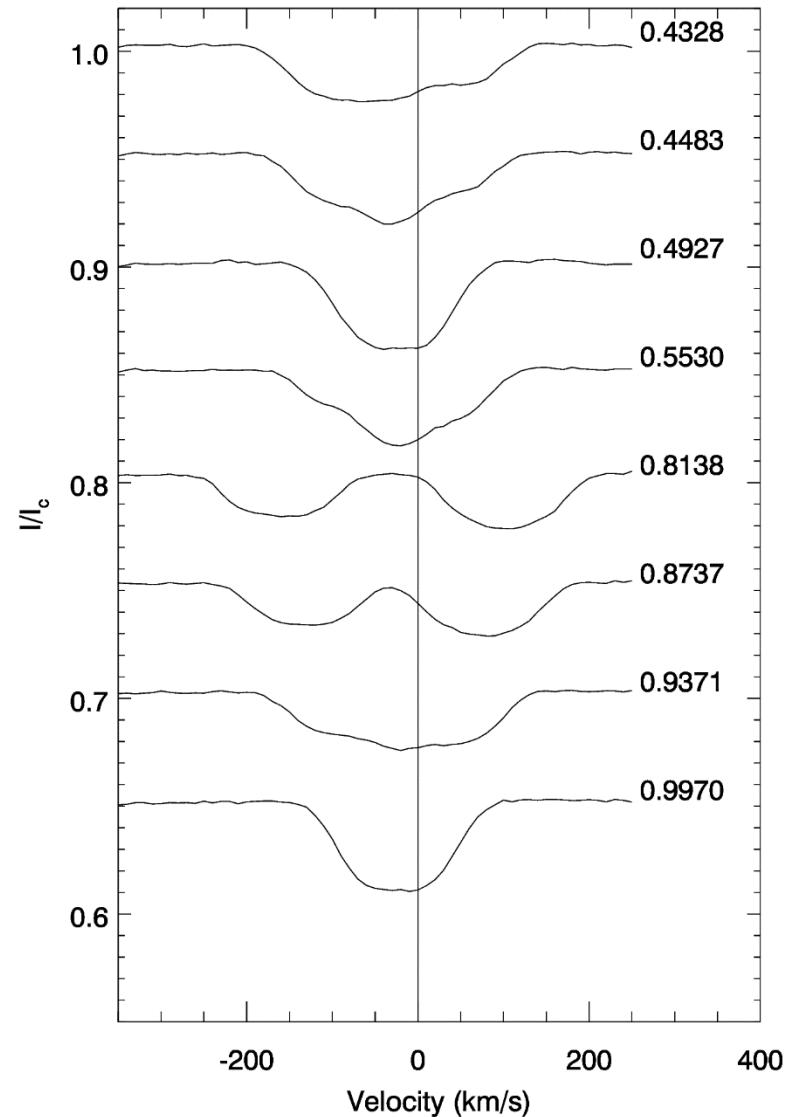
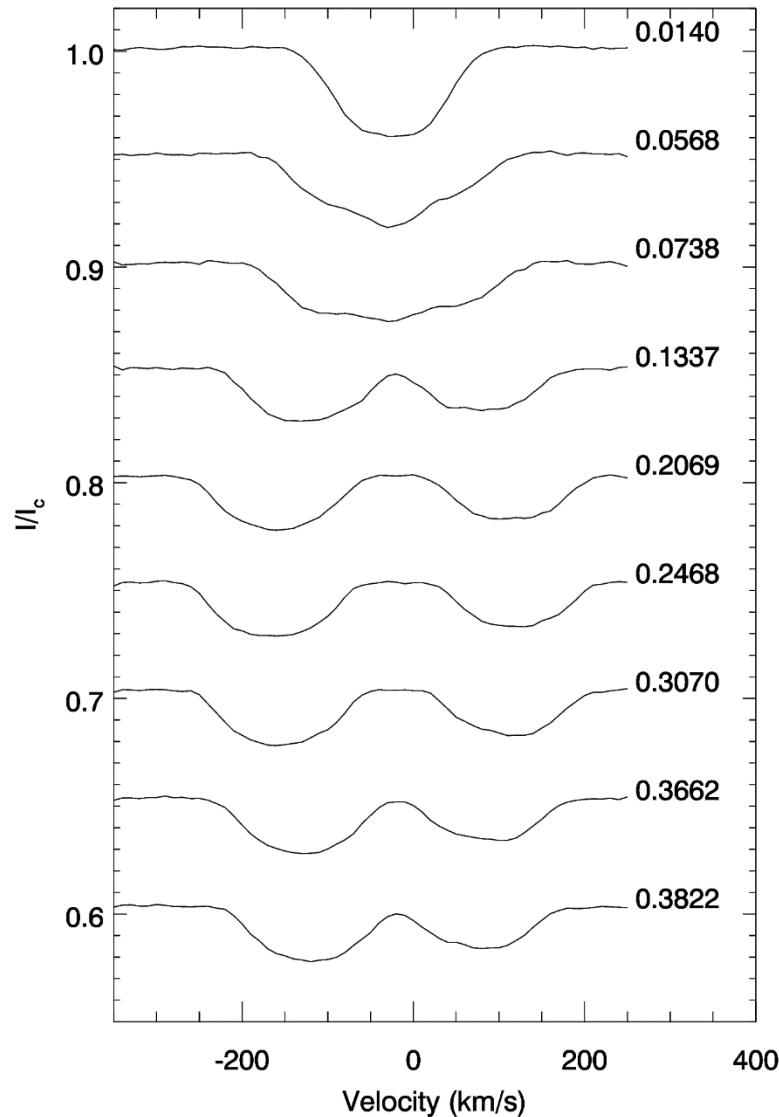
Date	HJD-2400000	Phase	SNR Input	SNR LSD
	Mid Time			
01/07/18	58301.3235	0.0140	77.78	1588
01/07/18	58301.3653	0.0738	71.22	1641
01/07/18	58301.4071	0.1337	58.76	1532
01/07/18	58301.4582	0.2069	94.86	1922
04/07/18	58304.3618	0.3662	84.55	1857
04/07/18	58304.4083	0.4328	80.16	1766
04/07/18	58304.4501	0.4927	75.07	1603
04/07/18	58304.4922	0.5530	67.67	1610
06/07/18	58306.3727	0.2468	77.72	1756
06/07/18	58306.4147	0.3070	99.14	1781
06/07/18	58306.4672	0.3822	77.06	1806
06/07/18	58306.5134	0.4483	62.39	1686
17/07/18	58317.3260	0.9371	85.31	1732
17/07/18	58317.3678	0.9970	65.51	1549
17/07/18	58317.4096	0.0568	58.35	1508
19/07/18	58319.3342	0.8138	86.46	1834
19/07/18	58319.3760	0.8737	81.13	1771

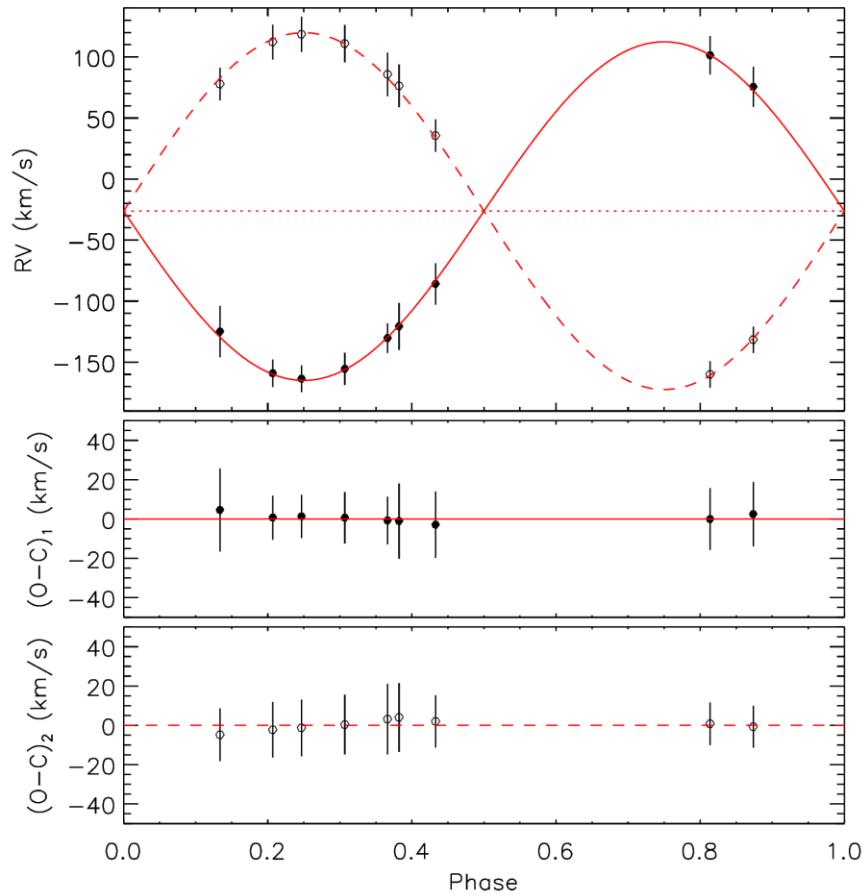
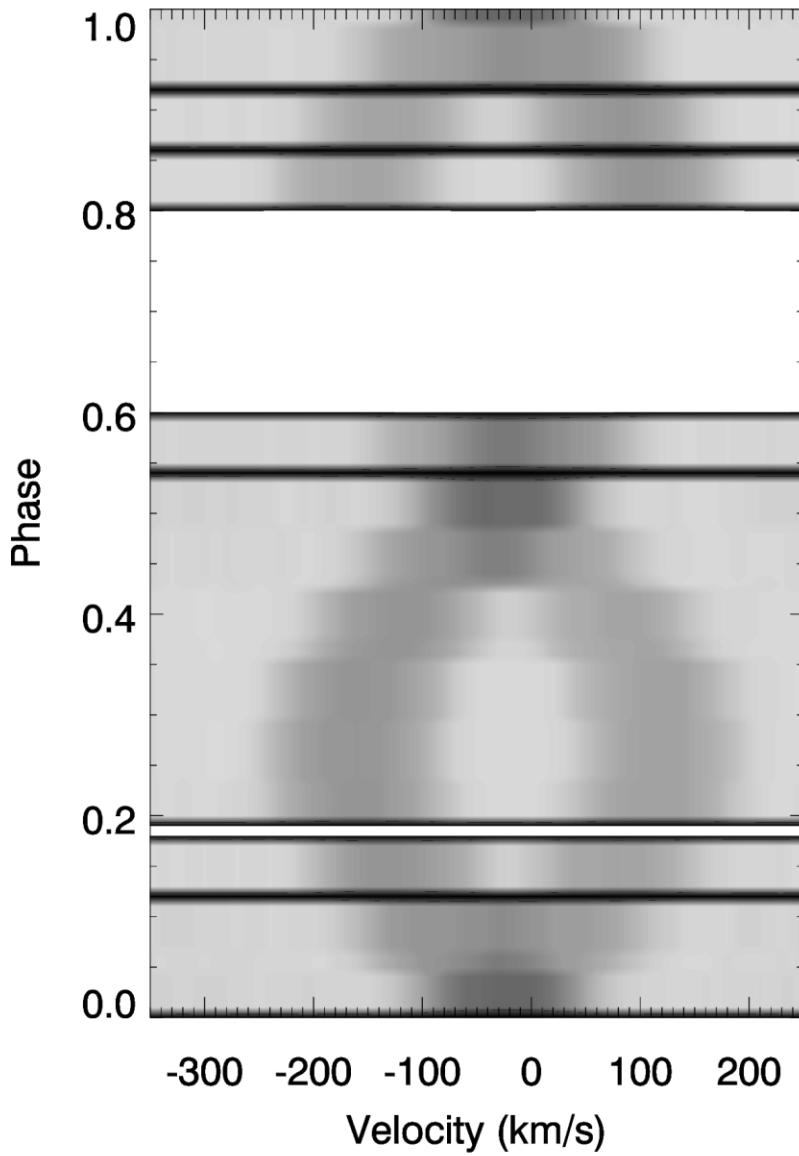
Because the two-temperature model is used in our image reconstruction, we also observed several inactive slowly rotating template stars by using the same instrument setup.

- Primary photosphere temp (6000 K) ==> HD 143761
- Secondary photosphere temp (5750 K) ==> HD 139777
- Spot temp (5000 K) ==> HD 32147



- In order to increase the S/N of the observed spectra, we used the Least - Squares Deconvolution technique (LSD; Donati et al. 1997)
- This technique to combine all available photospheric lines in each spectrum.
- The line list for ER Vul and standard stars were obtained from Vienna Atomic Line Database (VALD; Kupka et al. 1999).

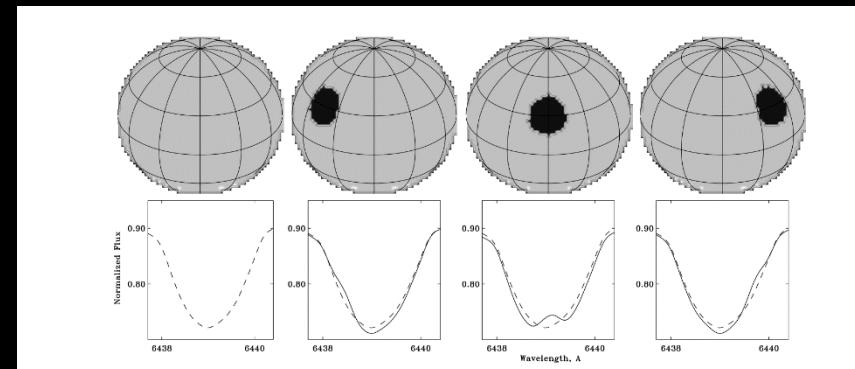
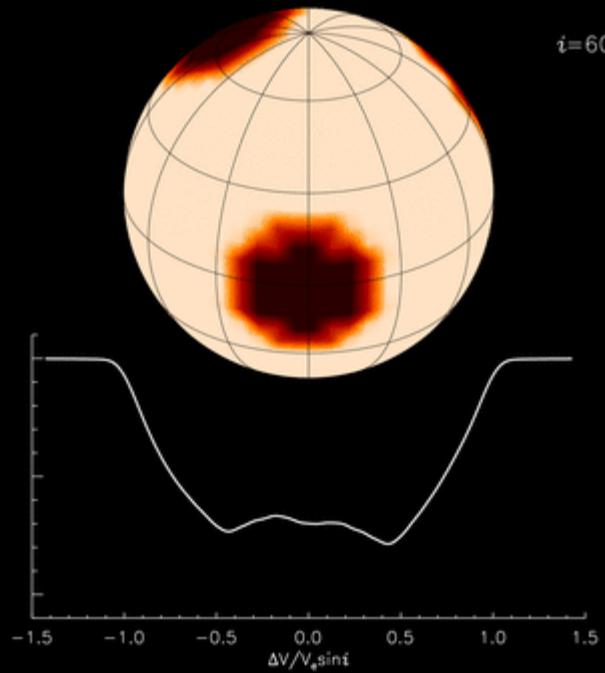




**Table 2.** Some parameters of ER Vul.

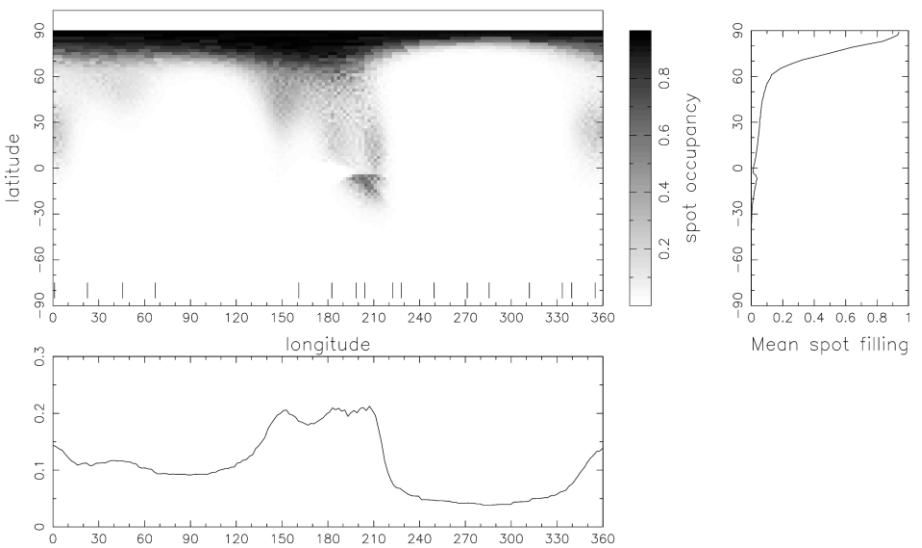
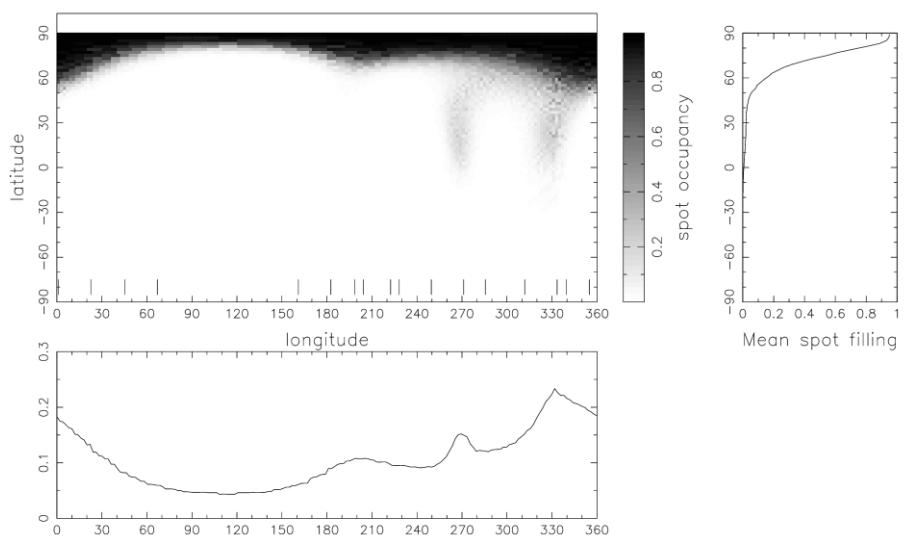
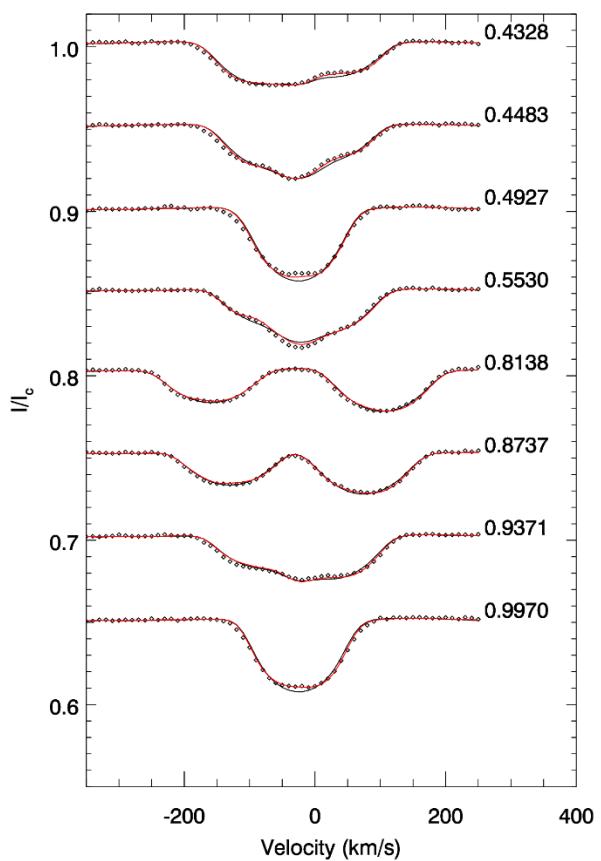
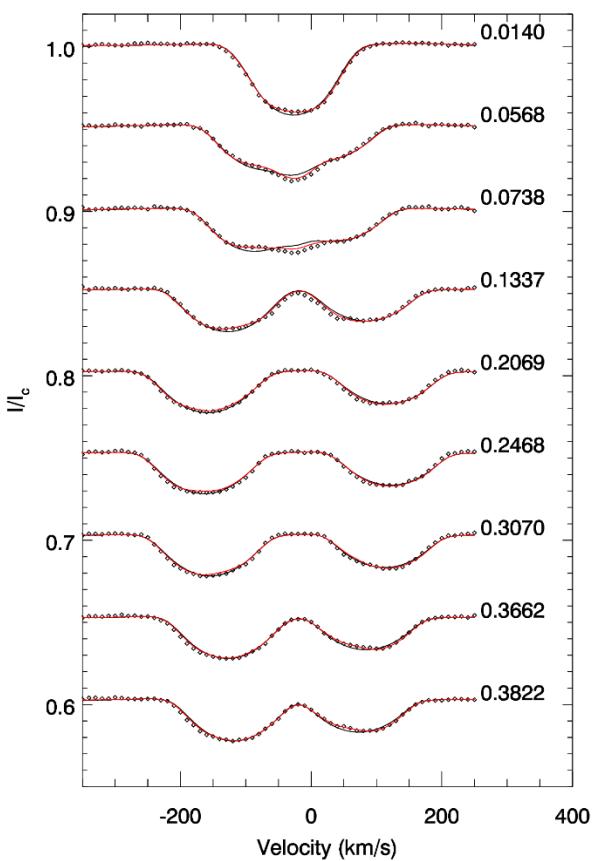
Parameter	Value	Reference <sup>1</sup>
$q = M_2/M_1$	$0.949 \pm 0.056$	This Study
$K_1(km/s)$	$138.67 \pm 6.18$	This Study
$K_2(km/s)$	$146.13 \pm 8.70$	This Study
$i [^\circ]$	66.63	a
$V_\gamma [km/s]$	$-26.26 \pm 3.72$	This Study
$T_0(HJD)$	2445220.40964	This Study
$P(d)$	0.698095	This Study
$T_{\text{eff},1}(K)$	6000	a
$T_{\text{eff},2}(K)$	5750	a

# Doppler Imaging



Berdyugina 2005

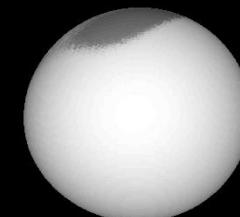
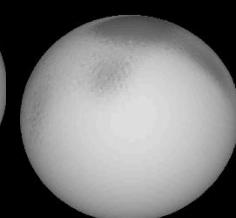
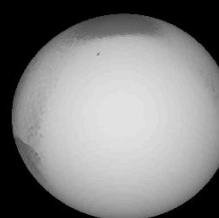
[http://www.astro.uu.se/~oleg/di\\_scheme\\_a.html](http://www.astro.uu.se/~oleg/di_scheme_a.html)



Phase 0.2468



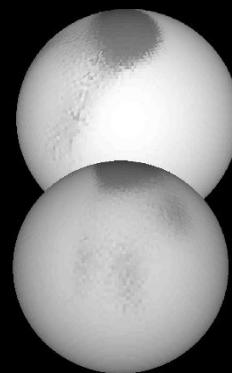
Phase 0.8138



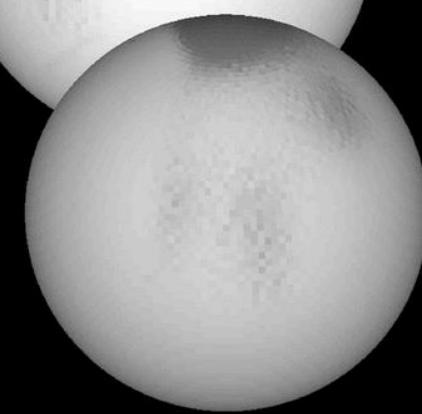
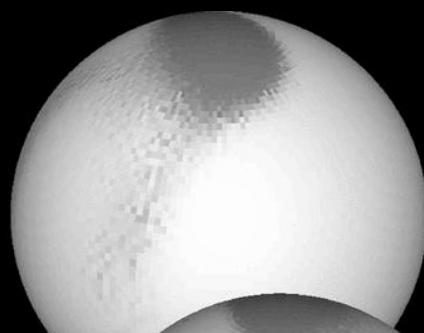
Phase 0.4927



Phase 0.997

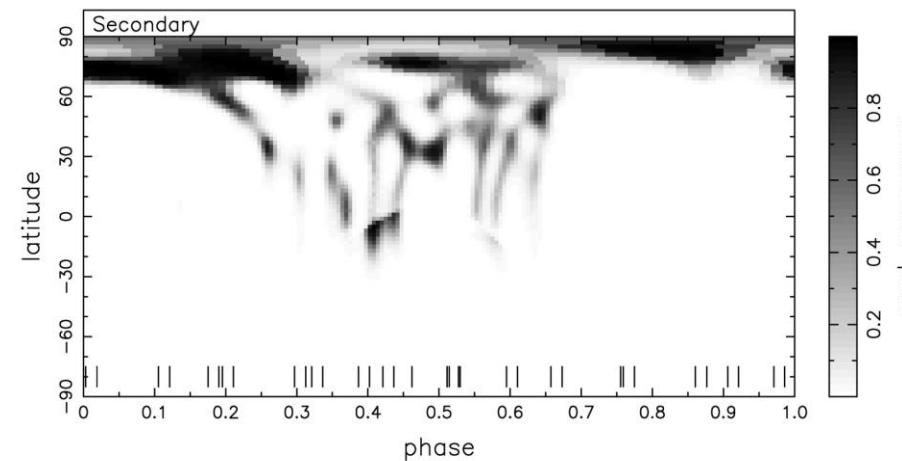
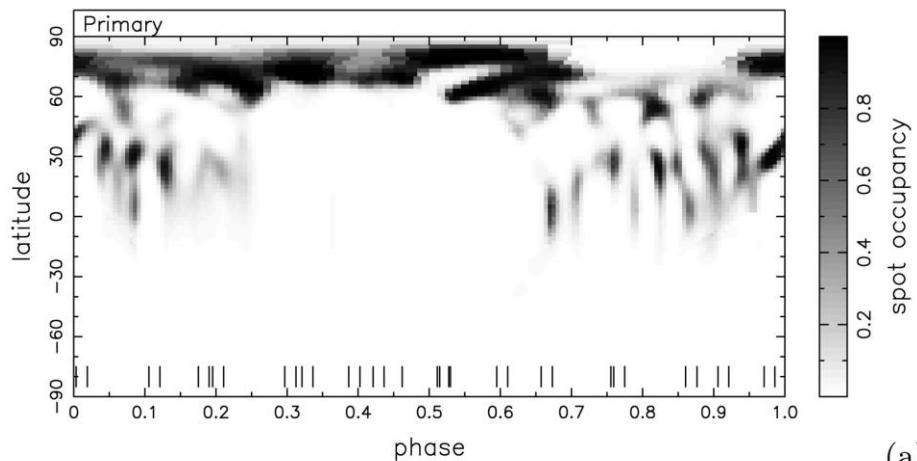


Phase 0.014

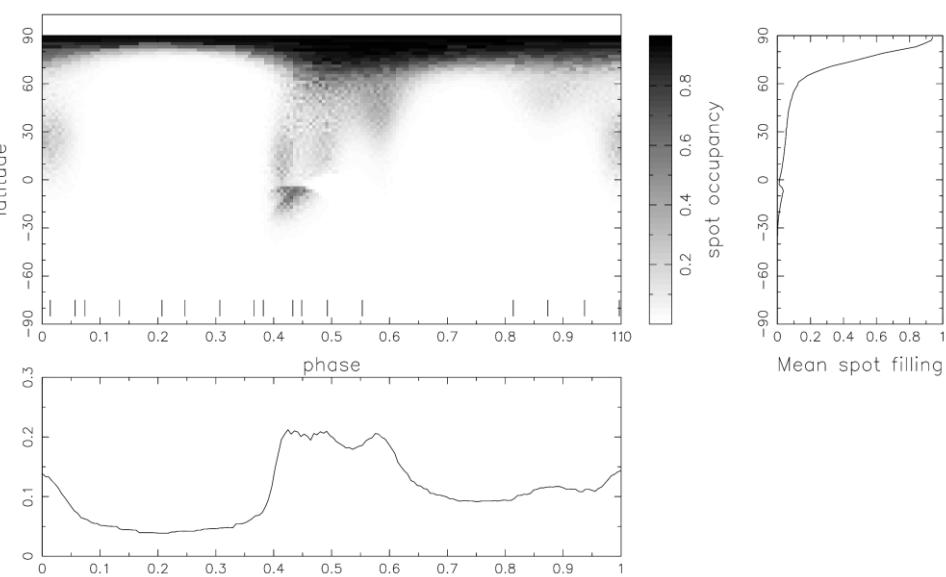
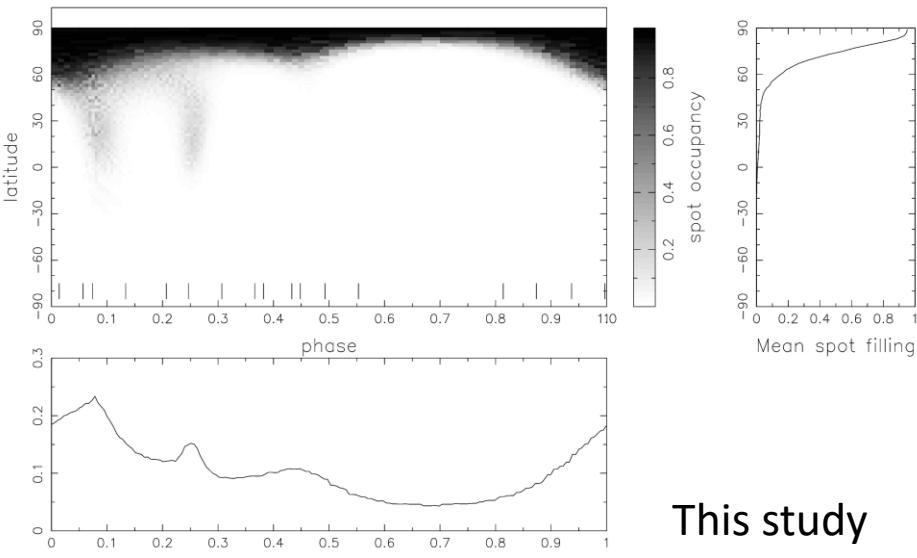


# Comparison with latest surface maps from literature

Xiang et al. 2015

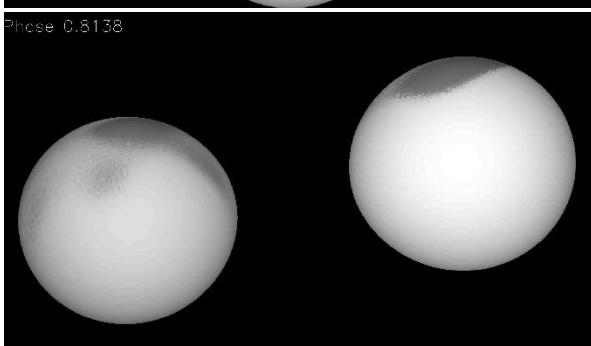
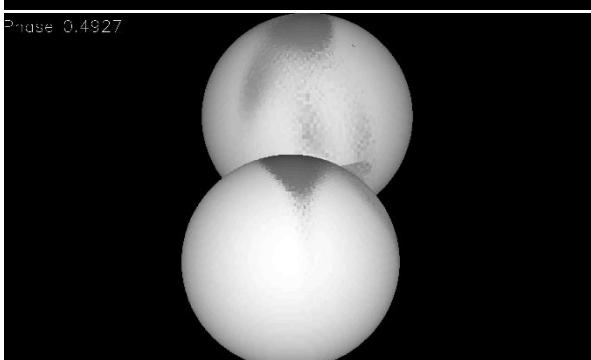
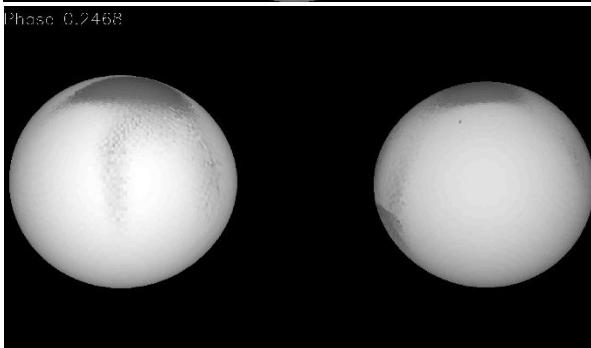
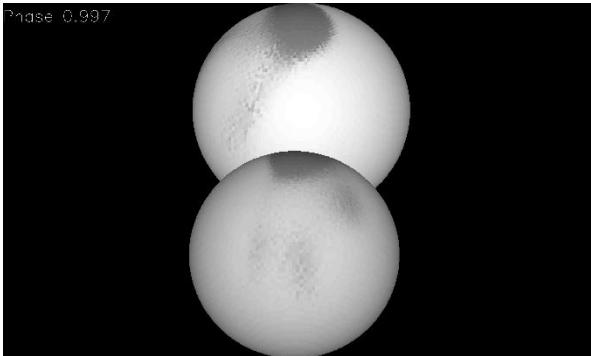


(a)

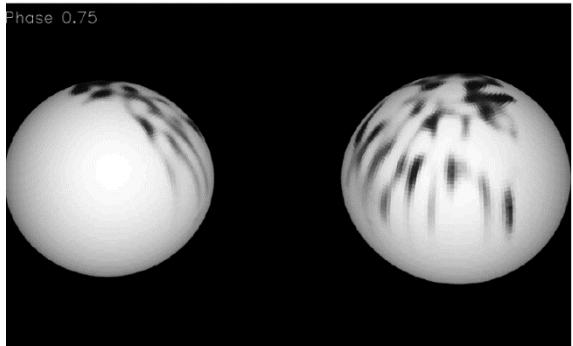
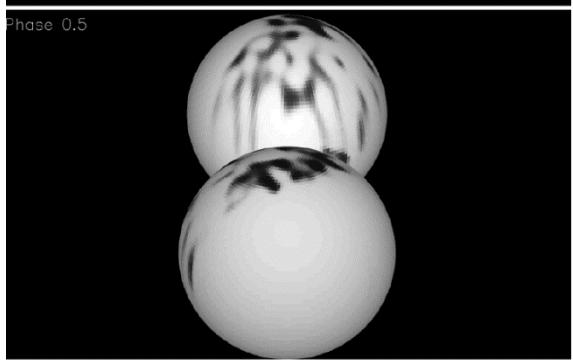
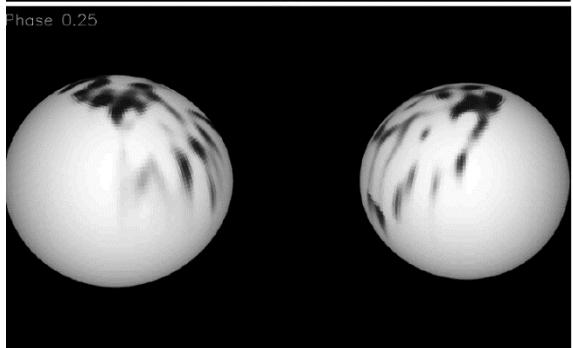
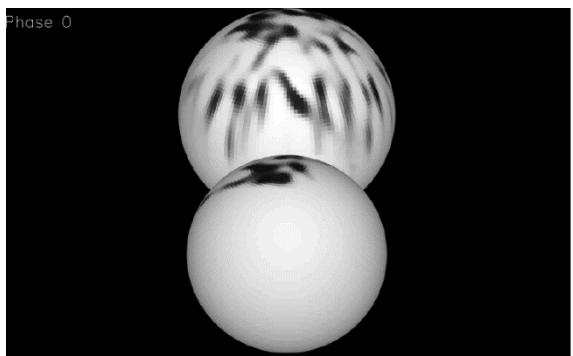


This study

This Study



Xiang et al. (2015)



Thank you very much for your patience...



- The authors acknowledges the support by The Scientific And Technological Research Council Of Turkey (TUBITAK) through the project 1001- 115F033