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The millimagnitude variability of the HgMn star φ Phe

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Abstract. The horizontally inhomogeneous chemical composition of the atmospheres of the chemically peculiar stars causes wavelength redistribution of the spectral energy in areas with increased abundance of heavier elements. Due to the rotation of the star, this usually leads to strictly periodic photometric variability in some spectral regions. We used abundance maps of the HgMn star φ Phe (HD 11753), obtained by means of the Doppler imaging, to model its photometric variability. Comparing the light curves derived from abundance maps obtained at different times, we also study how the time evolution of the surface spots affects this variability.

Key words: stars: abundances – stars: chemically peculiar – stars: individual: HD 11753 – stars: variables: general

1. Introduction

Inhomogeneous distribution of heavier elements in the atmospheres of chemically peculiar (CP) stars, together with stellar rotation, commonly causes periodic photometric variability in some spectral regions. Spectral energy, absorbed by bound–free and bound–bound (line-blanketing) transitions, mainly in the far ultra-violet (far-UV) part of the spectrum, is typically re-transmitted in the near ultra-violet and the visible regions (backwarming effect). The physical processes involved are still not entirely understood.

Techniques such as the (magnetic) Doppler imaging have been used to derive the surface distribution of the heavier elements (e.g., Rice et al., 1989; Piskunov & Kochukhov, 2002; Lüftinger et al., 2010). Using these maps, we aim to model the photometric variability of CP stars (see Figure 1). Comparing the synthesised light curves with the observed variability of the stars (if available), we hope to provide verification of the correctness of the imaging method, the accuracy of the atomic data, and our understanding of the physical phenomena involved. This method has been used in the past to show that the variability of several CP stars is caused by bound–bound and bound-free transitions of various chemical elements (Krtička et al., 2009, 2012; Shulyak et al., 2010; Prvák et al., 2015).

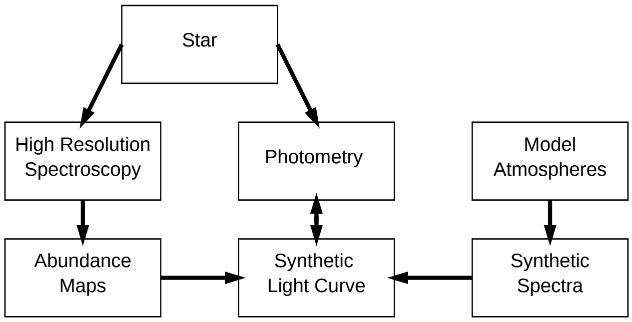

Figure 1. The workflow of synthetic light curve analysis.

Table 1. Abundances of the chemical elements with inhomogeneous surface distribution used in our calculations of the model atmospheres and the synthetic spectra.

Element	Abundances				
Cr	-6.1	-5.8			
Sr	-7.6	-7.1	-6.6		
Ti	-6.8	-6.3			
Y	-8.3	-7.8	-7.3	-6.8	-6.3

2. The star φ Phoenicis

The star φ Phe (HD 11753), an Am type (HgMn) CP star, is a primary component of a spectroscopic binary (Pourbaix et al., 2013). We adopted the following parameters: the effective temperature $T_{\mathrm{eff}} = 10\,600$ K, the surface gravity $\log g = 3.79$, the rotational period $P = 9.531$ d, and $v \sin i = 13.5\,\mathrm{km\,s^{-1}}$. Briquet et al. (2010) have shown that the abundance structures at the surface of the star evolve with time.

3. Methods

We used a set of abundance maps for chromium, titanium, strontium and yttrium, based on spectroscopy obtained using the CORALIE spectrograph at several distinct times (Korhonen et al., 2013). We generated a grid of Atlas12 LTE model atmospheres (Kurucz, 1996) and the corresponding synthetic spectra for various abundances of the chemical elements (See Tab. 1 for the complete list). Integrating the emergent flux over the visible surface of the star at several different wavelengths and at several different rotational phases, we get a light curve for the star.

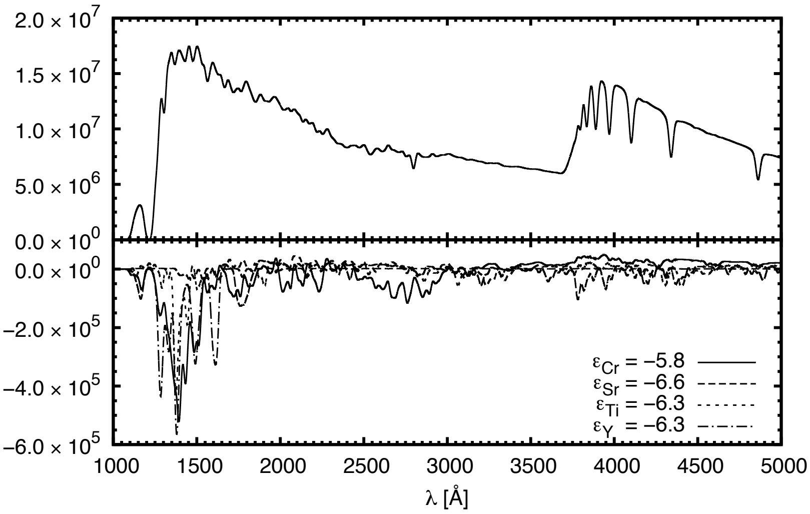

Figure 2. *Upper plot*: The emergent flux from a reference atmosphere with $\varepsilon_{\mathrm{C}r} = -6.1$, $\varepsilon_{\mathrm{S}r} = -7.6$, $\varepsilon_{\mathrm{T}i} = -6.8$, $\varepsilon_{\mathrm{Y}} = -8.3$. *Lower plot*: The emergent flux from the model atmospheres with modified abundances minus the reference model. All curves were smoothed by a Gaussian function with a dispersion of 10 Å.

4. Results

The bound–bound transitions of heavier elements, especially titanium and yttrium, absorb a significant amount of radiation in the far-ultraviolet spectral region. The influence of chromium, titanium, strontium and yttrium on the spectral energy distribution is shown in Fig. 2. The areas of the stellar surface with higher abundance of these elements appear as dark spots at short wavelenghts, while the same spots are bright in the near-UV and in the visible (see Fig. 3).

As the star rotates, we observe millimagnitude variability in most parts of the spectrum. The synthetic light curves at several wavelengths are shown in Fig. 4. The amplitude and shape of the light curves depend on wavelength, and the light curves in the near-UV and in the visible are typically in anti-phase to the variability in the far-UV. Comparing light curves derived from data obtained in October and December 2000, August 2009, and January 2010 reveals noticable changes in the variability of the star.

5. Conclusions

We have shown that the presence of heavier elements causes millimagnitude variability of the star φ Phe. This variability also changes with time due to

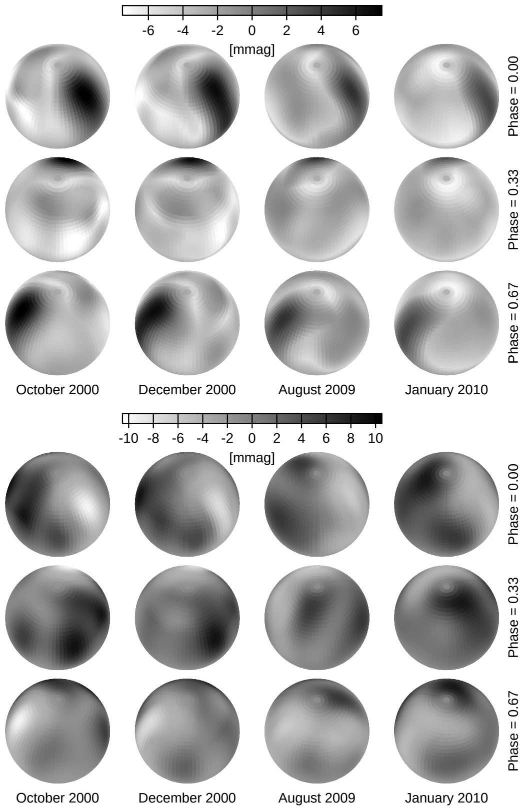

Figure 3. The emergent flux from the surface of φ Phe at 1700 Å (*upper plot*) and 3450 Å (*lower plot*) for different epochs as a function of rotational phase.

the changes of the surface abundance structure. Unfortunately, no observed photometry is available for comparison.

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References

Briquet, M., Korhonen, H., González, J. F., Hubrig, S., & Hackman, T. 2010, *Astron. Astrophys.*, **511**, A71

Korhonen, H., González, J. F., Briquet, M., et al. 2013, *Astron. Astrophys.*, **553**, A27

Krtička, J., Mikulášek, Z., Henry, G. W., et al. 2009, *Astron. Astrophys.*, **499**, 567

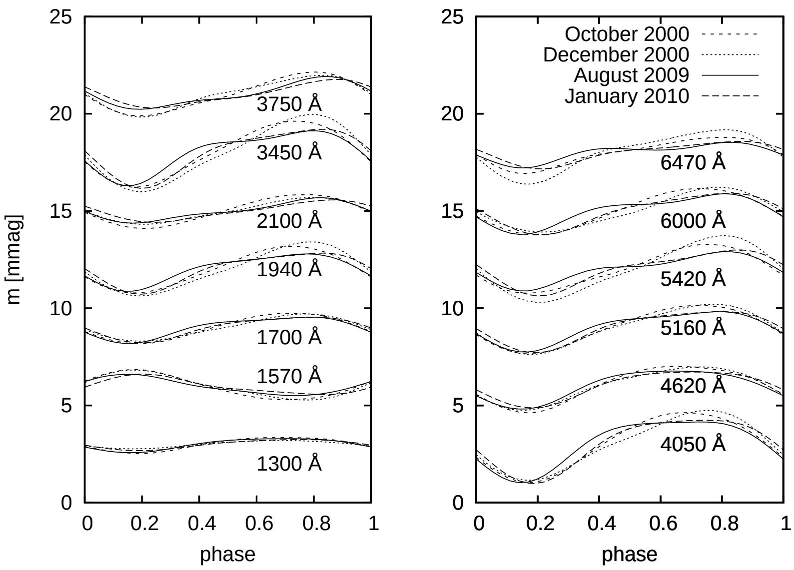

Figure 4. Synthesized light curves of φ Phe at various wavelengths at different observational epochs.

Krtička, J., Mikulášek, Z., Lüftinger, T., et al. 2012, *Astron. Astrophys.*, **537**, A14

Kurucz, R. L. 1996, in ASP Conf. Ser., Vol. **108**, *M.A.S.S., Model Atmospheres and Spectrum Synthesis*, ed. S. J. Adelman, F. Kupka, & W. W. Weiss, 160

Lüftinger, T., Kochukhov, O., Ryabchikova, T., et al. 2010, *Astron. Astrophys.*, **509**, A71

Piskunov, N. & Kochukhov, O. 2002, *Astron. Astrophys.*, **381**, 736

Pourbaix, D., Boffin, H. M. J., Chini, R., & Dembsky, T. 2013, *Astron. Astrophys.*, **556**, A45

Prvák, M., Liška, J., Krtička, J., Mikulášek, Z., & Lüftinger, T. 2015, *Astron. Astrophys.*, **584**, A17

Rice, J. B., Wehlau, W. H., & Khokhlova, V. L. 1989, *Astron. Astrophys.*, **208**, 179

Shulyak, D., Krtička, J., Mikulášek, Z., Kochukhov, O., & Lüftinger, T. 2010, *Astron. Astrophys.*, **524**, A66