THE NATURE OF THE LIGHT VARIATIONS OF CHEMICALLY PECULIAR STARS

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Abstract

Chemically peculiar stars display periodic light and spectrum variations. The spectrum variations are explained by the presence of spots with peculiar chemical composition on the surface of rotating star. However, the nature of the light variations of these stars and their relationship to the spectrum variations is unknown. We show that the light variations of chemically peculiar stars HR 7224 and HD 37776 can be explained by the redistribution of emergent flux due to overabundance of helium, silicon, and iron in the surface spots. This is a promising model for the explanation of the light variability of most of chemically peculiar stars.

1. Introduction

Magnetic chemically peculiar (mCP) stars represent an important class of hot stars where the processes of radiative diffusion and gravitational settling in their subsurface layers give rise to a pronounced deviations of the chemical composition from the solar one (Vauclair 2003, Michaud 2005). Although the overabundance or underabundance of certain elements affects only their superficial layers, mCP stars are natural laboratories where the predictions of modern model atmospheres can be tested. The application of advanced modelling techniques, such as model atmospheres with magnetic fields included (e.g., Khan & Shulyak 2006), the radiative diffusion codes, and the Doppler imaging techniques (e.g., Khokhlova et al. 2000) provided us a detailed information about the surface structure of these stars.

Despite the fascinating advance in the comprehension of the mCP phenomenon during the recent decades, the light variability of these stars is still poorly understood. Consequently, we started a project aiming to explain the light variability of these stars. Here we show that the light variability caused by the inhomogeneous surface distribution of elements is a very promising mechanism for the explanation of the observed light variability of mCP stars. Namely, the inhomogeneous surface distribution of overabundant helium, silicon, and iron is able to explain the light variability of two mCP stars, HD 37776 and HR 7224 (Krticka et al. 2007, 2008).

2. Modelling

We use the code TLUSTY (Lanz & Hubeny 2003) for the model atmosphere calculations. We calculate plane-parallel model atmospheres in LTE taking into account the atomic data suitable for B type stars (Lanz & Hubeny 2007).

For each star we assume fixed values of the effective temperature and surface gravity and calculate several model atmospheres with different chemical composition corresponding to that observed on the stellar surface. For the spectrum synthesis (from which we calculate the photometric colours) we use SYNSPEC code.

3. HD 37776

For the calculation of light curves of HD 37776 we used the surface distributions and abundances of various elements derived by Khokhlova et al. (2000). As silicon and helium create areas with large overabundances, we concentrated on these two elements in our calculations.

As a result of higher opacity in the models with enhanced abundance of either helium or silicon, the temperature in the outer parts of the atmosphere increases due to the backwarming. The main influence of the enhanced abundance of helium and silicon on the atmosphere temperature stratification (in the region where the photometric flux forms) is due to bound-free transitions. The flux from the UV region is redistributed towards longer wavelengths, partly into the optical region. Consequently, the silicon or helium overabundant regions are brighter than the silicon poor ones in the photometric uvby bands.

As helium and silicon are inhomogeneously distributed on the surface of HD 37776, the modification of the emergent flux in the helium and silicon spots (together with the stellar rotation) causes the light variability (see Fig. 1). The predicted light curves reproduce the observed ones very well in their overall shape and amplitude (see Fig. 2).

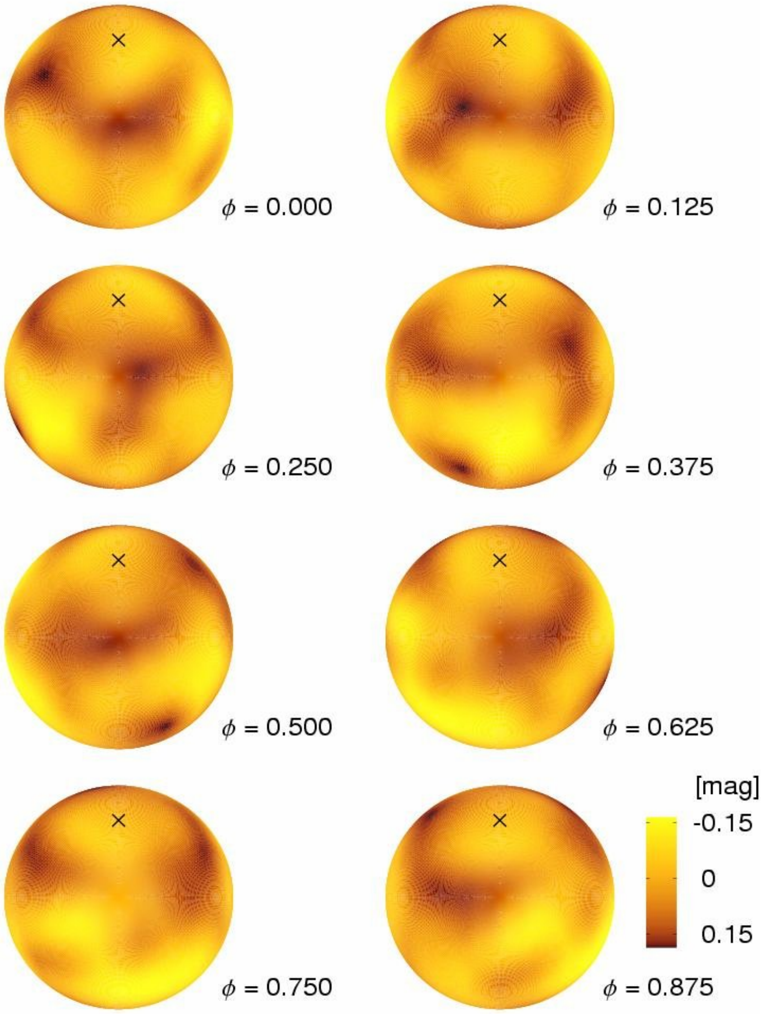

Fig. 1 *The location of the calculated photometric spots in the u colour in different rotational phases. We plot the smoothed flux emergent from the individual surface elements calculated using the observed surface distribution of helium and silicon derived by Khokhlova et al. (2000) in magnitudes. Here we do not include the limb darkening.*

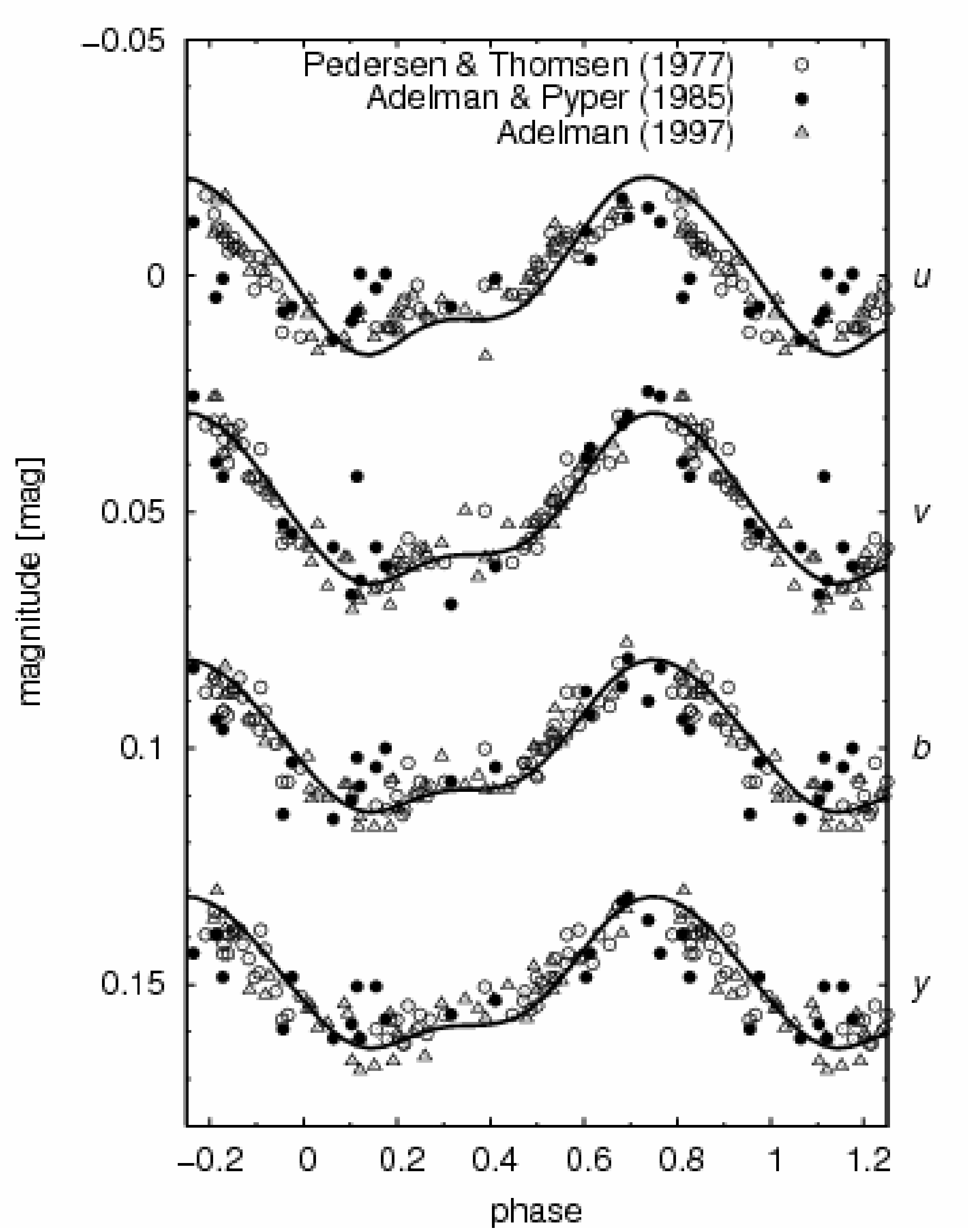

Fig. 2 *The simulated light variations of HD 37776 in different colours derived taking into account the uneven distribution of helium and silicon on its surface (solid line) compared with individual uvby observations (Pedersen & Thomsen 1977; Adelman & Pyper 1985; Adelman 1997b). All observed magnitudes are shifted in such a way that their mean value is zero. A vertical offset of 0.05 mag was applied between each consecutive filter.*

4. HR 7224

For the calculation of the light curves of HR 7224 we used the surface distributions and abundances of silicon and iron derived by Lehmann et al. (2007).

Similarly to HD 37776, the silicon and/or iron overabundant regions on the surface of HR 7224 are bright in the visible due to the redistribution of the emergent flux from the ultraviolet to the visible part of the spectrum. Contrary to the silicon, in the case of enhanced iron abundance, mostly line transitions are responsible for the flux redistribution.

Due to the inhomogeneous distribution of silicon and iron on HR 7224 surface the flux emergent from individual surface elements depends on the location of these elements. Consequently, in different rotational phases we observe different elements on HR 7224 surface (Fig. 3). This effect is able to explain the light variability of this star (Fig. 4).

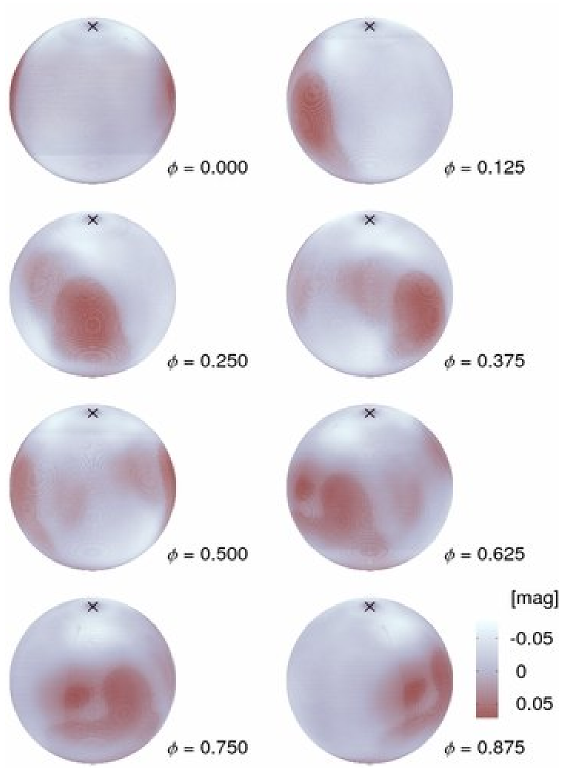

Fig. 3. The emergent flux (in the y colour) from individual surface elements of HR 7224 in individual rotational phases.

5. Conclusions

We successfully simulated the light variability of HD 37776 and HR 7224 directly using the elemental surface abundance maps derived from observations. There is a very good agreement between the observed and predicted light variability in the uvby colours of Stromgren photometric system. We did not introduce any free parameter to reach an agreement between the theoretical and observed light curves.

The light variability of studied stars is caused by the flux redistribution due to iron line (bound-bound) transitions, and helium and silicon bound-free transitions, and by the inhomogeneous surface distribution of these elements. We note that the successful modelling of the light variablity is not possible without using precise model atmospheres (Lanz & Hubeny 2007), opacity data (Kurucz 1994, Seaton et al. 1992), and precise reliable surface abundance maps.

We conclude that there is a promising possibility to explain the light variations of also other mCP stars as a result of the i) flux redistribution from the ultraviolet to the visible part of the spectrum, ii) the uneven surface distribution of the elements and iii) rotation of the star.

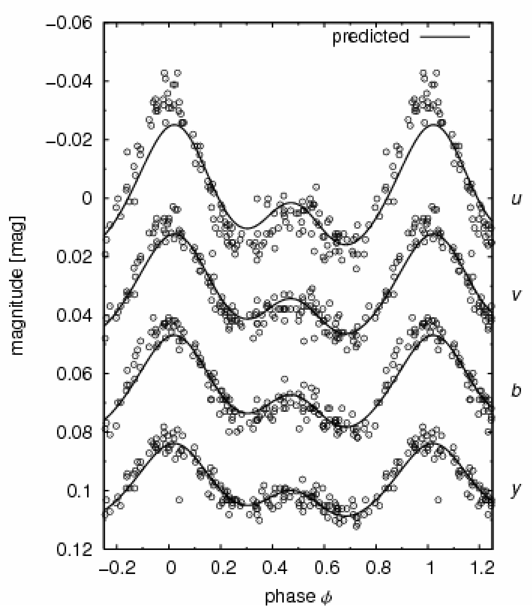

Fig. 4. *hr7224_hvvel.jpg Light variations of HR 7224 calculated from the silicon and iron surface maps of Lehmann et al. (2007, solid line). Observed light variations (circles) are taken from Adelman (1997a).*

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