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Search for Spectral Variability in 28 HgMn Stars

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Abstract. Mercury–Manganese stars had been considered as stars with very stable photospheres. Since the discovery of spectral variations in the Hg II line of the star α And, a few other HgMn stars have been reported to present line profile variations. In this work we present preliminary results of a study of spectral variability in 28 single–lined HgMn stars. Using between two and six spectra per star, obtained with the FEROS spectrograph of the ESO, we quantitatively analyze the line profile variations for various chemical elements. We find that about two thirds of our star sample reveal spectral variations. The Hg II line at λ 3984 Å is the line presenting the most clear variations, while some stars also have variable lines of Mn, Y, and Sr.

Key words: stars: atmospheres, chemically peculiar, early–type, spots – stars: variables: general

1 Introduction and Observations

Until a few years ago HgMn stars, unlike CP2 stars, were considered as stars with very stable photospheres, lacking magnetic fields, and hence photometrically and spectroscopically constant. Since the discovery of spectral variations in the Hg II line λ 3984 of the star α And (e. g. Adelman et al., 2002), a few other HgMn stars have been reported to present line profiles variations, revealing inhomogeneous surface distribution of various chemical elements, mainly Y, Sr, Zr, Ti, and Hg (Hubrig et al., 2006a; Briquet et al., 2010). The first chemical abundance maps for these elements were constructed by Savanov et al. (2009) and Briquet et al. (2010) through the Doppler imaging for the stars AR Aur and HD 11753, respectively. In this work we present preliminary results of a study of spectral variability in a relatively large sample of HgMn stars. Between two and six spectra of each target were obtained with the ESO's FEROS spectrograph. Our star sample consists of 28 single–lined (single or SB1) HgMn stars for which Hg and Mn lines can be identified in the spectrum.

2 Spectral Variability Analysis

In the spectrum of each star we identified the best blend–free lines of chemical elements usually showing anomalous strength in HgMn stars (Hg, Mn, Y, Pt, Sr, Zr, P), plus a few lines of Mg, Fe, Ti, Si, Cr for comparison. The variability of spectral line profiles was evaluated by different methods:

1. Visual inspection of line profiles.

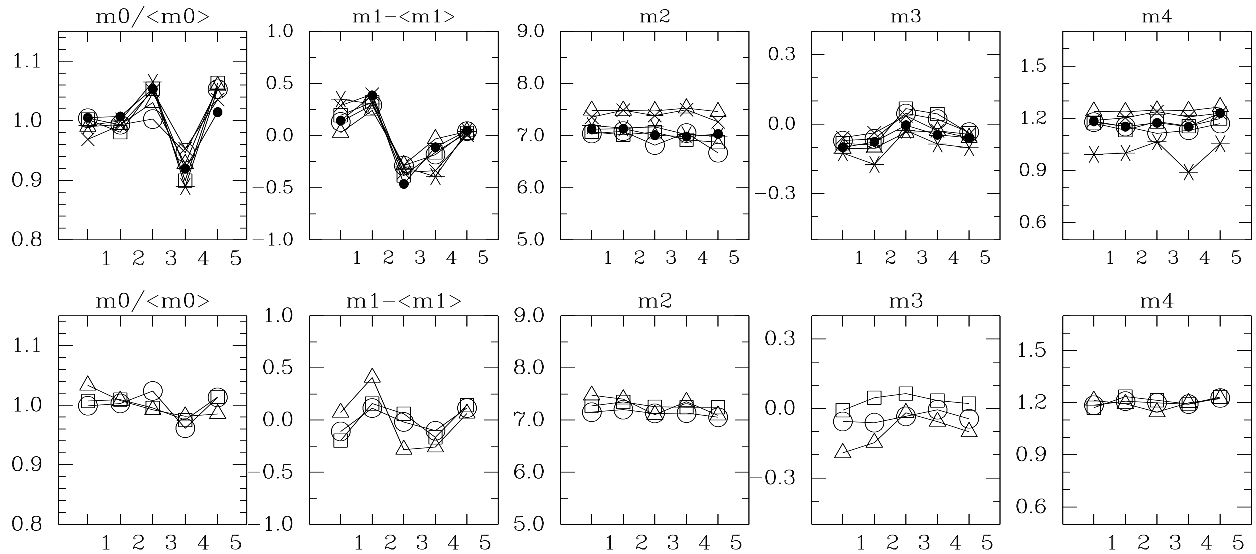

Figure 1: Statistical moments of the line profiles of seven Y II lines (upper panels) and four Fe II lines (lower panels) for the five spectra of HD 11753. Different symbols correspond to different spectral lines. The moment $m0$ has been normalized by the average intensity of each spectral line. Units are km/s for $m1$ and $m2$

2. Variance spectrum. We averaged the available spectra of the same star, calculated the deviations with respect to the average spectrum, and, finally, from them we computed the variance spectrum. A smoothing of the variance spectrum was applied according to the rotational velocity. A line was classified as variable if the RMS at the line position was at least two times higher than in the surroundings of the line.

3. Statistical moments of the line profile. We calculated the first five statistical moments (intensity, velocity, line width, asymmetry, kurtosis) of the line profiles after subtracting the continuum. The moments were defined in such a way that the first three moments are in velocity units, and the last two are dimensionless. Measurement errors were estimated from the S/N of the spectra and a χ^2 test was applied, considering as variable the moments with $P(\chi)^2 < 0.5\%$. In cases, for which several spectral lines of the same atomic species were available, the dispersion of measurements of various spectral lines was used to estimate the probable error. Figure 1 shows the statistical moments for Y II and Fe II lines in HD 11753.

3 Detecting Small Variations Through the Spectral Line Combination

Even though the results of present work are based on the analysis of individual lines, in a few cases we combined several lines of the same chemical element with the aim of improving the S/N ratio. As an illustration, Fig. 2 shows Mn line profiles of the star HD 66409, most of which do not satisfy the criteria for being classified as variable, but the mean profile clearly shows small variations.

Following the same line, we calculated the average and standard deviations of the moments, measured for various lines of the same element in a given spectrum. If the studied lines have the same behavior, the detection threshold is expected to be lowered by the square root of the number

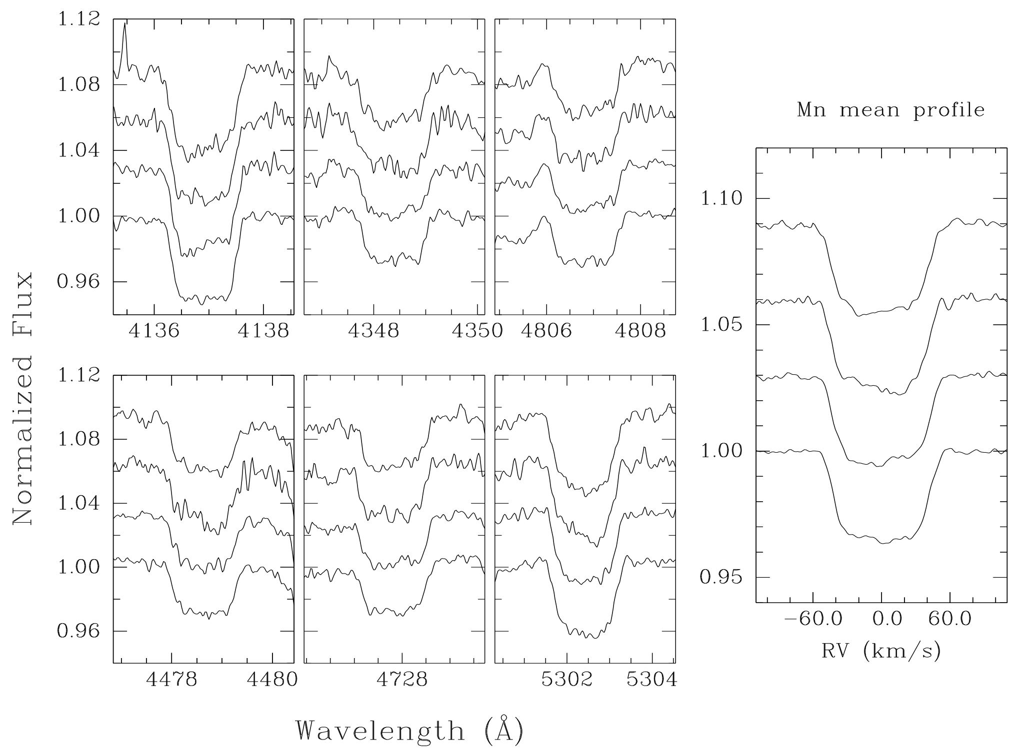

Figure 2: Left: Profiles of 6 Mn lines in the spectrum of HD 66409 (shifted for clarity). Right: Mean profile, calculated combining Mn spectral lines in the velocity scale.

of lines involved. These strategies will be applied in a future paper to the chemical elements with suspected small variations and to the weak spectral lines, in order to confirm or discard profile variability in some marginal cases.

4 Results

Sixty seven percent (19/28) of the studied HgMn stars show line profile variability. Mercury is the most frequently variable element. In Fig. 3 we present the line profile of the Hg II line for some of the variable stars. For each star, the available spectra are overplotted in the upper panels, while the standard deviation is shown in the lower panels. The Hg II line at $\lambda\,3984$ showed variations in 57% (16/28) of our sample, while only three stars revealed variations in other elements, but were constant in Hg. Other elements, presenting line profile variations are Mn (eight cases), Y (four cases), and Sr (three cases).

The typical flux variations are of the order of $1-2\%$ of the continuum level, and reach $2-4\%$ in six stars: HD 7374, HD 33904, HD 70235, HD 101189, and HD 110073, which show strong variations in Hg II, and HD 11753, which is strongly variable in Y II and Sr II. Our detection limit is, in the best cases, about 1% of the continuum level near $\lambda\,3984$, hence, smaller variations cannot be discarded for any star of our sample. The best spectral–constant candidates are HD 194783 and HD 202149, for which we have only two spectra each, the difference if which does not exceed 1% in the region of the Hg II line λ3984.

HD 101189 present pronounced line profile asymmetry and notable spectral variation in different chemical elements, particularly Hg, Y, Sr, Mn, and Ti.

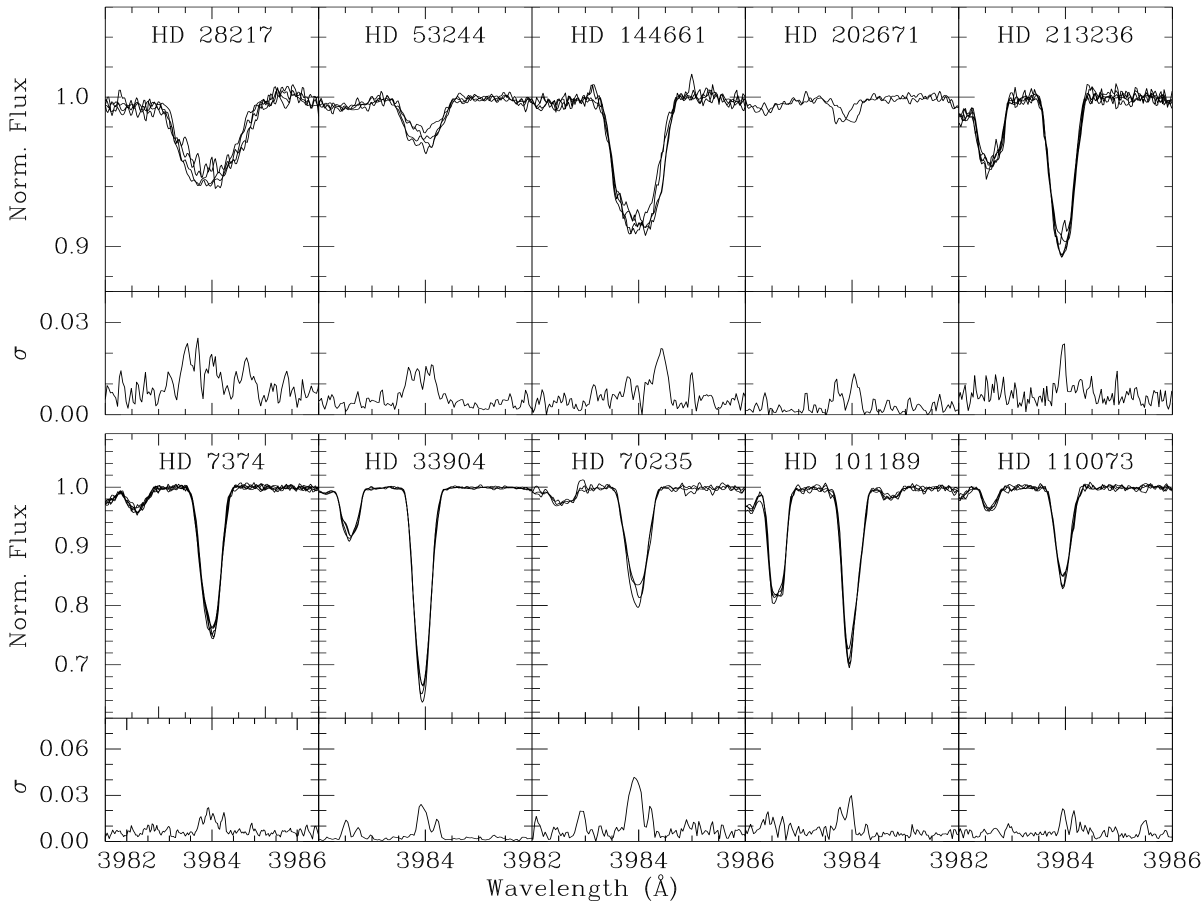

Figure 3: Line profile variability of the Hg II line $\lambda\,3984$ for ten stars of our sample

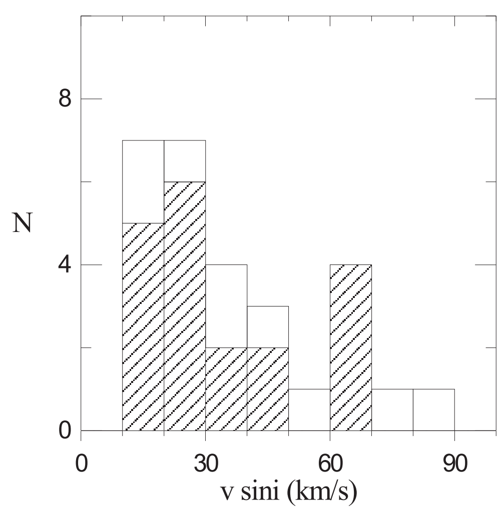

Figure 4: Histogram of rotational velocities. Open histogram: constant stars, hatched area: variable stars.

5 Discussion

Our results show that line profile variability is a general characteristic of HgMn stars, rather that an exception. Interpreting the line profile variation as a result of chemical spots on the surface of a rotating star, we can assert that most HgMn stars present a non-uniform distribution of one or more chemical elements. In CP2 stars, it is accepted that chemical spots are related to large–scale organized magnetic fields. However, in HgMn stars the presence of measurable magnetic fields is controversial. Hubrig et al. (2006b, 2010) reported the detection of magnetic fields of a few hundred Gauss in four HgMn stars and in the eclipsing binary AR Aur, while Wade et al. (2006) and Makaganiuk et al. (2011) obtained negative results.

Fig. 4 shows the distribution of rotational velocities of variable and constant stars. There is no clear connection between variability and stellar rotation. For a more detailed analysis, the dependence of the variability detection threshold on the rotational velocity for a given signal–to–noise ratio should be considered. In sharp–lined stars, intensity variations are expected to be more easily detected, since the effective signal–to–noise ratio of lines is higher. However, shape variations are harder to detect in slow-rotating stars. On the other hand, we did not find clear correlation between variability and temperature or evolutionary status within the main sequence.

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