

## HD 30963: A NEW HG MN STAR

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**Abstract.** Using high dispersion high quality spectra of HD 30963 obtained with the echelle spectrograph SOPHIE at Observatoire de Haute Provence in November 2015, we show that this star, hitherto classified as a B9 III superficially normal star, is actually a new Chemically Peculiar star of the HgMn type. Spectrum synthesis reveals large overabundances of Mn, Sr, Y, Zr, Pt and Hg and pronounced underabundances of He and Ni which are characteristic of HgMn stars. We therefore propose that this interesting object be reclassified as a B9 HgMn star.

Keywords: stars: individual, stars: Chemically Peculiar

### 1 Introduction

HD 30963 ( $V = 7.23$  mag), currently assigned an B9 III spectral type, is one of the slowly rotating late B we are currently observing. This star has been little studied: one only finds 10 references in SIMBAD for HD 30963. The incentive of this project is to reclassify the late B stars in the northern hemisphere brighter than  $V = 7.5$  mag with low apparent projected velocities (less than  $60 \text{ km s}^{-1}$ ). We have previously undertaken a similar survey of the slowly rotating early A stars, whose results are published in Royer et al. (2014). An abundance analysis of high resolution well exposed spectra of these objects has sorted out the sample into 17 chemically normal stars (ie. whose abundances do not depart more than  $\pm 0.20$  dex from solar values), 12 spectroscopic binaries and 13 Chemically Peculiar stars (CP). Among the new CP stars, Monier et al. (2015) and Monier et al. (2016) have identified 5 new HgMn stars. We present here new abundance determinations for HD 30963, a slowly rotating late B star and show that this star is another new HgMn late B star.

### 2 Observations and reduction

HD 30963 has been observed on five consecutive days at Observatoire de Haute Provence (OHP) using SOPHIE in its high resolution mode ( $R = 75000$ ) in November and December 2015. A log of the observations appears in Tab. 1. Four 1800 and one 2400 seconds exposures were obtained with a signal-to-noise ratio varying from 78 up to 167. As we do not see conspicuous radial velocity variations on these spectra taken over five days, we have shifted all spectra onto a common wavelength scale (that of the first spectrum) and we have coadded the individual spectra into a mean spectrum. Assuming a radius for HD 30963 of about 3 to 4  $R_{\odot}$  and using the  $v_e \sin i$  of Zorec & Royer (2012), we derive an upper limit of 4.12 days for the rotational period of HD 30963. The observations which we secured over 5 days separated by about 24 hours each therefore cover the rotational period of HD 30963.

### 3 Reassigning a proper spectral type to HD 30963

The following spectral regions have been used to readdress the spectral type of HD 30963. First, the red wing of  $H_{\epsilon}$  from 3980 Å up to 4000 Å harbours the Hg II line at 3984 Å and two Zr II and one Y II lines likely to

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Observations log for HD 30963		
Date	UT start exposure	$\frac{S}{N}$
2015-11-28	00:00:35.307	118
2015-11-28	23:44:20.941	78
2015-11-30	00:25:54.328	140
2015-11-30	23:24:27.855	101
2015-12-01	22:29:32.033	167

**Table 1.** Log of SOPHIE observations of HD 30963

Derived abundances for HD 30963		
Wavelengths (Å)	Identification	Abundance
3982.60	Y II	1000.0 ⊙
3983.93	Hg II	150000.0 ⊙
3990.96	Zr II	150.0 ⊙
3998.82	Zr II	150.0 ⊙
4067.04	Ni II	0.10 ⊙
4077.70	Sr II	35.0 ⊙
4471.48	He I	0.20 ⊙
4478.64	Mn II	50.0 ⊙
4481.15	Mg II	2.50 ⊙
4500.00	Fe II	2.00 ⊙
4514.17	Pt II	2500.0 ⊙
4554.01	Ba II	10.00 ⊙

**Table 2.** Abundances derived for the 11 lines used in this work.

be strengthened in a late B-type star of the HgMn type (Fig. 1). Second, the region from 4470 Å to 4490 Å contains the Mg II triplet near 4481.15 Å, the He I line at 4471.48 Å and the Mn II line at 4478.64 Å (Fig. 2). We have also looked for peculiarities in the Ni II line at 4067.04 Å and the Sr II resonance line at 4077.70 Å and in the Pt II line at 4514.17 Å and the Ba II resonance line at 4554.01 Å. The eleven lines used are collected in Tab. 2 with their identifications and abundances (see Sec. 4.2) expressed as multiples of the corresponding solar abundances (labeled with the symbol ⊙). Their positions are marked by vertical lines in both figures (after a correction for the radial velocity).

## 4 Abundance determinations

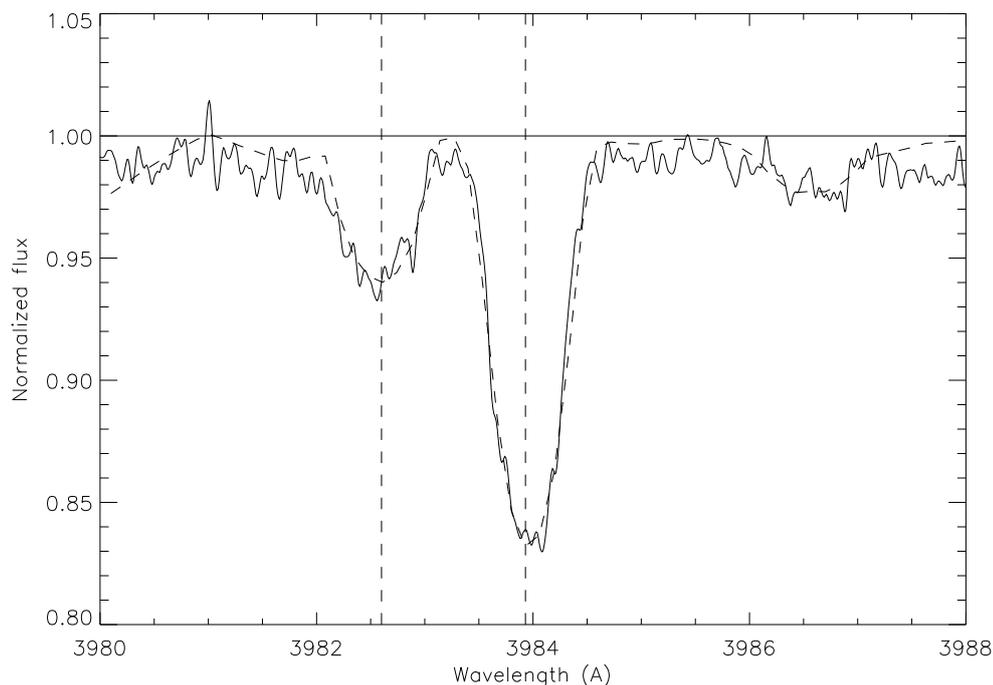
### 4.1 Model atmospheres and spectrum synthesis

The effective temperature  $T_{\text{eff}}$  and surface gravity  $\log g$  of HD 30963 were taken from Huang et al. (2010) survey of field B stars. These authors have derived  $T_{\text{eff}} = 11476$  K and  $\log g = 3.66$  for HD 30963 by adjusting the observed  $H_{\gamma}$  profile to grids of synthetic spectra. A 72 layers plane parallel model atmosphere assuming radiative equilibrium and hydrostatic equilibrium has been first computed for these values of  $T_{\text{eff}}$  and  $\log g$  using the ATLAS9 code (Kurucz 1992), specifically the linux version using the new ODFs maintained by F. Castelli on her website. The linelist was built starting from Kurucz's (1992) gfhyperrall.dat\* file which includes hyperfine splitting levels. This first linelist was then upgraded using the NIST Atomic Spectra Database † and the VALD‡ database operated at Uppsala University (Kupka et al. 2000). A grid of synthetic spectra was then computed with SYNSPEC48 (Hubeny & Lanz 1992) to model the eleven lines listed in Table 1 adopting a null microturbulent velocity. The synthetic spectra were further convolved using the routine ROTIN3 provided along with SYNSPEC48 using  $v_e \sin i = 37$  km s<sup>-1</sup> (Zorec & Royer 2012) and the appropriate FWHM for SOPHIE. The unknown abundance  $[\frac{X}{H}]$  was varied until minimisation of the chi-square between the observed

\*<http://kurucz.harvard.edu/linelists/>

†<http://physics.nist.gov/cgi-bin/AtData/linesform>

‡<http://vald.astro.uu.se/vald/php/vald.php>



**Fig. 1.** Synthesis of the Hg II 3983.93 Å line (observed: thick line, models: dashed lines)

and synthetic spectrum.

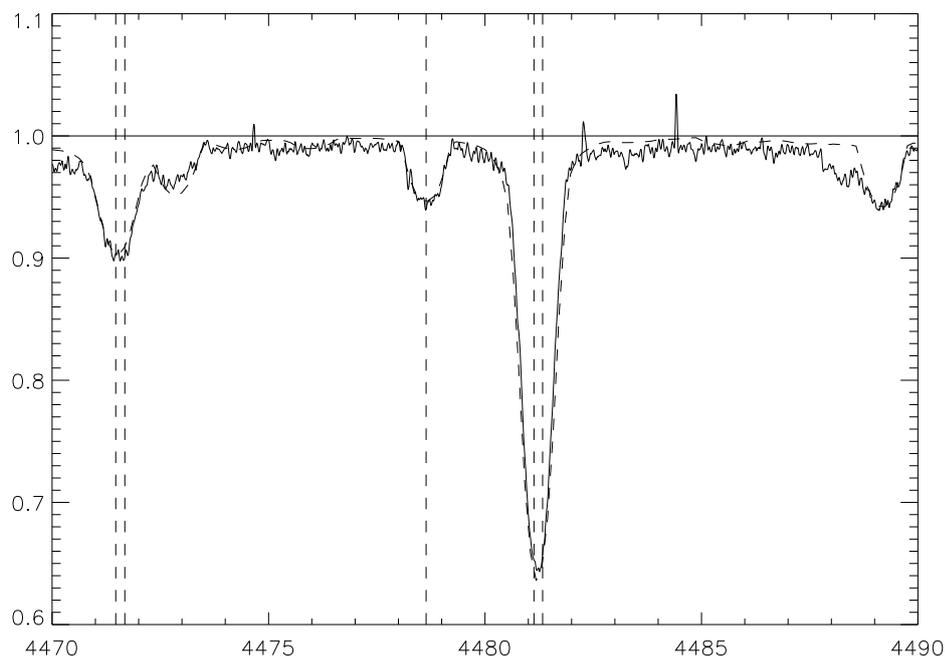
#### 4.2 Evidence for strong excesses in Mn, Y, Zr, Pt and Hg

We find that five elements, Mn, Y, Zr, Pt and Hg, have strong excesses, ie. larger than 50 times the solar values. The synthesis of the Mn II line at 4478.64 Å in Fig. 2 yields an overabundance of 50 times the solar abundance. This is a substantial excess and it may be revised to a lower value when we will model Mn II lines having atomic data for several isotopes and hyperfine structure. The Hg overabundance is derived from the synthesis of 11 transitions next to 3983.84 Å representing the hyperfine structure of various isotopes of Hg in a similar manner as (Castelli & Hubrig 2004) modeled HD 175640. The abundance that best fits the observed line profile is very large (150000  $\odot$ ) as can be seen in Fig. 1. This is one of the strongest Hg excess we found in the new HgMn stars (Monier et al. 2015; Monier et al. 2016).

The abundance of Zr derived from the 2 lines in Table 1 is about 150  $\odot$ . The Yttrium abundance derived from Y II 3932.44 Å is also very important (1000  $\odot$ ). While modeling the Fe II lines in the 4500 Å- 4600Å region, we noticed a 1.5 % feature at about 4514.15 Å which we identify as one of the strongest Pt II line expected at 4514.17 Å listed in VALD. No other "easier" identification (ie. in terms of a lighter element) can reproduce the observed line depth at this wavelength. We are currently looking for other lines of Pt II lines at shorter wavelengths to confirm the presence of platinum in HD 30963. We also checked that a model computed for a solar platinum abundance and one without the Pt II line yield no absorption at all at 4514.17 Å. From the 4514.17 Å line only, a provisional excess of platinum is derived to be about 2500  $\odot$ . We also find considerable deficiencies in He (0.2  $\odot$ ) and Ni (0.1  $\odot$ ). The excesses in Mn, Y, Zr, Pt and Hg and the deficiencies in He and Ni are characteristic of an HgMn star.

## 5 Conclusions

Whereas it was up to now classified as a normal late B9 III star, our analysis of HD 30963 shows that it has very peculiar over and underabundances. The overabundances in Mn, Sr, Y, Zr, Pt and Hg are characteristic of an HgMn star. It displays large overabundances of the Sr, Y and Zr triad which is however inverted compared



**Fig. 2.** Synthesis of the He I (4471.4 Å), Mn II (4478.64 Å) and Mg II (4481.15 Å) lines

to the solar system triad. The synthesis of the Hg II and Pt II lines reveals large overabundances of Pt and Hg. We are currently performing a detailed abundance analysis of HD 30963 to complement the first abundances presented here.

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