Line synthesis of the UV spectrum of HD 72660 and determination of the abundances of several chemical elements

Audric Lemonnier and Richard Monier
audric.lemonnier@obspm.fr, richard.monier@obspm.fr

l'Observatoire de Paris

Introduction

70% of A stars are classified as Chemically Normal and 30% are Chemically Peculiar. The archival high resolution and high Signal-to-Noise HARPS and STIS spectra of the A0Vm star HD 72660 have been synthesized using model atmospheres and synthetic spectra in order to derive the abundances of several key chemical elements. In particular we have derived abundances of elements which have their strongest lines in the UV like Al, Sn, Yb, Au, Pb and Bi.

Spectra and methods

- The UV spectrum, retrieved from the MAST archive, was obtained by Ruth Peterson with the high resolution mode $R = 114000$ of the spectrograph STIS on the Hubble Space Telescope from 1625Å until 1901Å.
- The optical spectrum, retrieved from the ESO archive, was obtained with the high resolution spectrograph HARPS ($R = 125000$).
- Abundances for 40 elements were derived using the elemental abundances derived by spectrum sythesis of the HARPS spectrum by Monier et al. (2018). These abundances served as initial abundances, called AB0, for the synthesis of the STIS spectrum.
- A Kurucz ALTAS9 (72 layers) model atmosphere [1] was computed assuming LTE, RE and HE for the fundamental parameters derived in Monier *et al* (2018) [2].
- Synthetic spectra were first computed for the solar abundances, then the AB0 set using Synspec49 to model unblended lines with reliable atomic data.
- Individual abundances were varied for each selected transition until the best fit was achieved between the synthetic and the observed spectrum.

Conclusion

New abundances have been derived for several elements which have hardly any lines in the optical range: As, Ru, Sn, Yb, Pt, Au, Pb and Bi. The found overabundances for the very heavy elements (and the underabundances for light elements) suggest an efficient action of radiative diffusion which support these elements in the line formation region of HD 72660. Future line synthesis of the UV spectrum of HD 72660 is envisaged to derive more abundances from this very rich spectrum.

References

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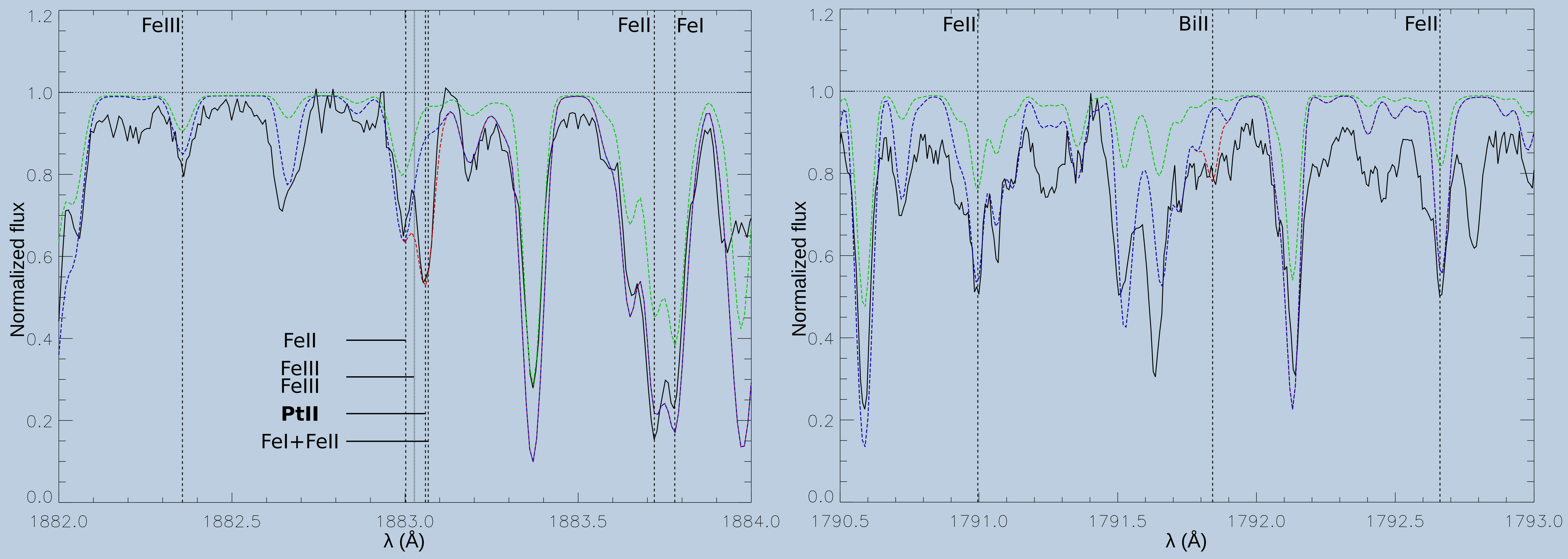
Overabundances of heavy elements



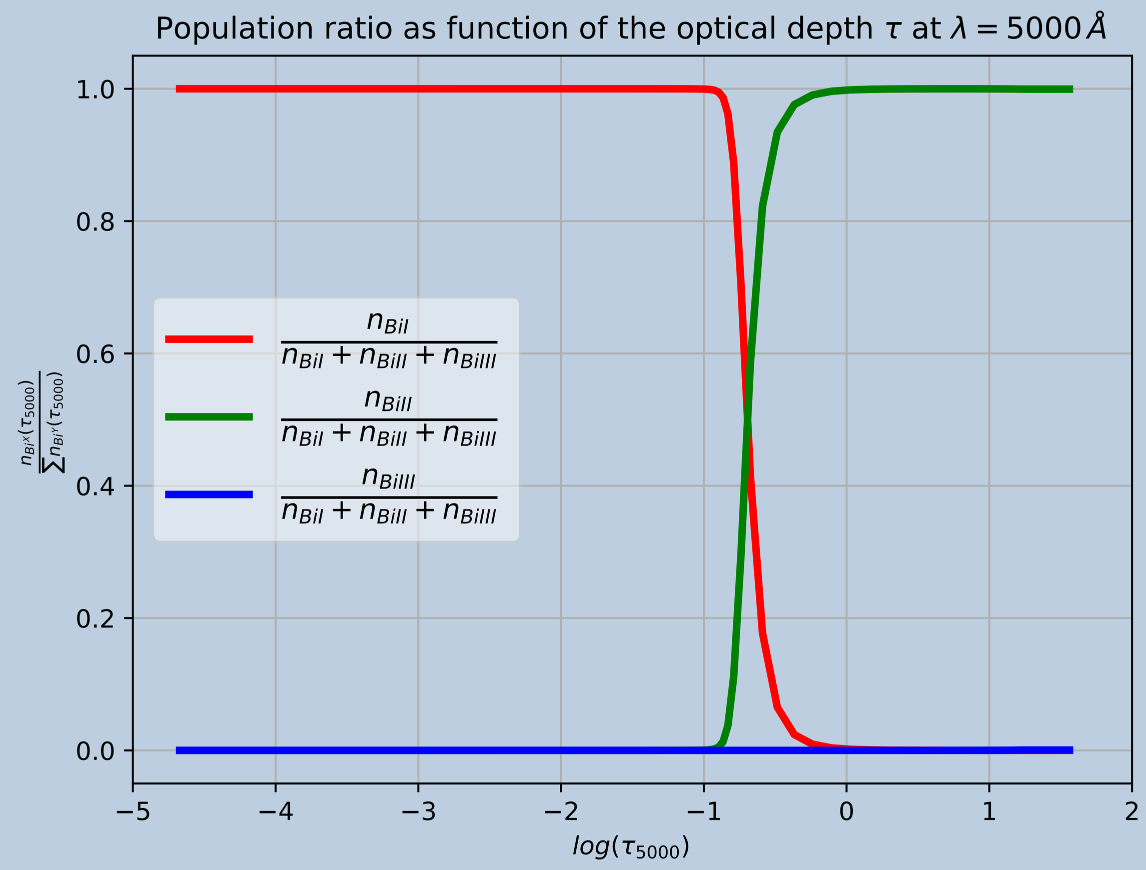


Figure 1 – Comparison of the observed STIS spectrum and synthetic spectra to derive the abundances of Pt and Bi. Normalized flux is depicted as function of wavelength: the observed spectrum is in black; the green, blue and red one are the synthetic spectra for solar, AB0 and those derived in this work. Saha's equation yields the ionization ratios as a function of optical depth in the atmosphere.

Derived abundances for HD 72660

Using the fundamental stellar parameters[a], a model atmosphere of HD 72660 was computed with ATLAS9 (Kurucz, 1970 [1]) with 72 layers. This model atmosphere was then used to compute synthetic spectra with Synspec49 (Hubeny & Lanz, 2003 [6]). The synthetic spectra were then convolved using Rotin3 with the FWHM of the gaussian profile of the instrument and the apparent projected rotationnal velocity taken from Monier *et al* (2018) [2].

In order to choose suitable unblended lines, we have relied on previous studies of HD 72660 by Golriz and Landstreet (2016) [3] and of Sirius A by Cowley *et al* (2016) [5]. In order to avoid departures from LTE, one should use, for a given element, the ion which is the most important ionization stage in the atmosphere.

Once unblended lines were identified, we have altered the abundance until the best fit was achieved between synthetic spectra and the observed spectrum.

In order to establish accurately the wavelength scale in the vicinity of synthesized lines, we have selected Fe II lines on each side of the modeled lines. These Fe II lines have accurate laboratory wavelength.

The following table collects the abundances derived in this work. The first column is the wavelength of the lines selected for the abundance determinations, the second the abundances with an incertitude up to ± 0.20 dex[b c] and the third is the ratio of the abundance of HD 72660 versus the solar ones (Grevesse and Sauval (1988) [4]). We find an underabundance of the Carbon and overabundances of heavy elements like Platinum, Lead and Bismuth, which might be the signature of radiative diffusion.

Line list used to determine chemical abundances.

Ion	λ (Å)	$\langle log(\frac{n_X}{n_H})\rangle$ (dex)	$\langle[\frac{n_X}{n_H}]\rangle$ (dex)	$10^{\langle[\frac{n_X}{n_H}]\rangle}$
C I	1656.267			
C I	1656.929			
C I	1657.008			
C I	1657.379			
C I	1657.907			
C I	1658.121	-1.05	-4.53	0.09
Al II	1760.104			
Al II	1761.975	0.5	-5.03	3.16
As I	1890.429	0.66	-8.97	4.57
Zr III	1790.113	1.40	-8.00	25.12
Ru II	1875.560	1.49	-10.50	30.90
Sn II	1899.898	0.02	-9.98	1.05
Yb III	1873.879	1.29	-9.63	19.50
Pt II	1883.06	1.85	-8.35	70.79
Au II	1740.47	1.17	-9.92	14.79
Pb II	1682.12	1.85	-8.20	70.79
Bi II	1791.84	1.78	-9.51	60.26

[a] $T_{eff} = 9650 \pm 250$ K - $v \cdot sin\, i = 5.0 \pm 0.5\,\mathrm{km \cdot s^{-1}}$ - $\log g = 4.05 \pm 0.25$ dex - $\xi = 2.20 \pm 0.20\,\mathrm{km \cdot s^{-1}}$. Monier *et al* (2018) [2].

[b] $< log\, \frac{n_X}{n_H} > := \frac{\sum_i log\, \frac{n_X}{n_H} \sigma_{tot_i}^{-2}(\lambda_i)}{\sum_i \sigma_{tot_i}^{-2}}$ and $\sigma_{tot_i}^2 = \sigma_{log\, gf_i}^2 + \sigma_{T_{eff_i}}^2 + \sigma_{log\, g_i}^2 + \sigma_{vsini_i}^2 + \sigma_{\xi_i}^2$

[c] $\left[\frac{n_X}{n_H}\right] := log\, \frac{n_X}{n_H} - log\, \frac{n_X}{n_H}\Big|_{\odot}$ and $log\, n_H := 12$.