Spectral analysis of PG 1034+001, the exciting star of Hewett 1

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Abstract. PG 1034+001 is an extremely hot, helium-rich DO-type star that excites the planetary nebula Hewett 1 and large parts of the surrounding interstellar medium. We present preliminary results of an ongoing spectral analysis by means of non-LTE model atmospheres that consider most elements from hydrogen to nickel. This analysis is based on high-resolution ultraviolet (*FUSE*, IUE) and optical (VLT/*UVES*, Keck) data. The results are compared with those of PG 1034+001's spectroscopic twin, the DO star PG 0038+199.

Keywords. stars: abundances, stars: AGB and post-AGB, stars: atmospheres, stars: evolution, stars: individual (PG 1034+001, PG 0038+199), planetary nebulae: individual (Hewett 1)

1. Introduction

PG 1034+001 is an extremely hot, helium-rich DO-type star that was discovered in the Palomar Green Survey. It is surrounded by the planetary nebula Hewett 1 (Hewett *et al.* 2003) and at least one big emission shell (Rauch *et al.* 2004). PG 1034+001 is located at the hot end of the white dwarf cooling sequence and, thus, it is well suited to provide constraints on stellar evolutionary theory studies. First LTE and non-LTE stellar model-atmosphere calculations were performed by Wesemael *et al.* (1985, $T_{\rm eff} = 80\,000\,{\rm K}, \log g \geqslant 6$) and Werner *et al.* (1995, $T_{\rm eff} = 100\,000\,{\rm K}, \log g = 7.5$). Improved model atoms and increased computational power now allow for a precise reanalysis.

PG 0038+199 was also discovered in the Palomar Green Survey. Like PG 1034+001, it is an extremely hot, DO-type star. The first non-LTE model-atmosphere analysis was performed by Dreizler & Werner (1996, $T_{\rm eff} = 115\,000\,{\rm K}, \log g = 7.5$).

2. Observations and Analysis

The main data source for the analysis of PG 1034+001 and PG 0038+199 is *FUSE* (Far Ultraviolet Spectroscopic Explorer, ProgID: P104). *FUSE* operated in the far ultraviolet range from about 905–1187 Å with a resolution of ≈ 0.06 Å. This region exhibits many iron-group lines that are, due to the high resolution, well resolved. UV spectra from IUE (International Ultraviolet Explorer) and optical spectra are used for checks.

TMAP (Tübingen NLTE Model-Atmosphere Package†) is a tool to compute non-LTE model atmospheres. It assumes that atmospheres are plane-parallel and in hydrostatic and radiative equilibrium. *TMAP* can consider elements from hydrogen to nickel with about 1500 NLTE levels. Ready-to-use model atoms are provided by *TMAD* (Tübingen

† `http://astro.uni-tuebingen.de/~TMAP/TMAP.html`

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Table 1. Preliminary results of T_{eff} (kK), $\log g$ (cm/sec^2), and abundances (mass fraction) of PG 1034+001 and PG 0038+199. The errors are about 15% for T_{eff}, 0.3 for $\log g$, and 0.3 for abundances.

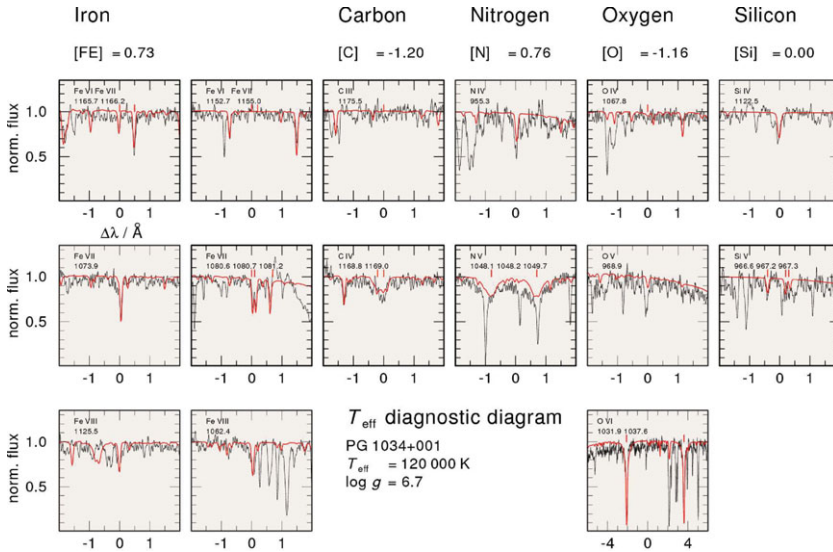| Object	T_{eff}	$\log g$	H	He	C	N	O	Ne	Si	S	Ar	Fe
PG 1034+001	120	6.7	$\leqslant$1.2E-02	9.8E-01	1.5E-04	4.0E-03	4.0E-04	1.3E-03	6.7E-04	3.1E-04	7.3E-05	7.0E-03
PG 0038+199	135	7.0	4.9E-02	9.3E-01	2.8E-04	1.0E-02	1.0E-03	1.3E-03	6.7E-04	3.1E-04	7.3E-05	1.0E-02

Figure 1. Diagram to determine T_{eff} of PG 1034+001. The model accounts for opacities of the elements H, He, C, N, O, and Ca–Ni. Si is included in a line-formation procedure. The abundances [X] are given as logarithm relative to the solar abundance.

Model Atom Database ‡). Due to the many lines and levels of iron-group elements their cross sections are computed with the program *IrOnIc* using a statistical method and then included into the *TMAP* calculations. We use the ionization balance of several elements to determine T_{eff}. Especially iron is very sensitive to temperature changes and exhibits three ionization stages (VI–VIII, Fig. 1). The abundances (Tab. 1) are in agreement with expectations of evolutionary models (Werner & Herwig 2006). The inclusion of iron-group opacities and the availability of high resolution FUSE data lead to the revised values of T_{eff} and $\log g$. The change in T_{eff} is comparable to the uncertainties, but the decrease in $\log g$ is significant.

Acknowledgements

References

Dreizler S. & Werner K. 1996, *A&A*, 314, 217
Hewett, P. C., Irwin, M. J., Skillman, E. D., *et al.* 2003, *ApJ*, 599, L37
Rauch T., Kerber F., & Pauli E.-M. 2004, *A&A*, 417, 647
Werner, K. & Herwig, F. 2006, *PASP*, 118, 183
Werner K., Dreizler S., & Wolff B. 1995, *A&A*, 298, 567
Wesemael F., Green R. F., & Liebert J. 1985, *ApJ*, 307, 659

‡ `http://astro.uni-tuebingen.de/~TMAD/TMAD.html`