Iron Abundance in Hydrogen-Rich Central Stars of Planetary Nebulae

A. I. D. Hoffmann, I. Traulsen, T. Rauch, K. Werner, S. Dreizler, and J. W. Kruk

1 Institut für Astronomie und Astrophysik, Universität Tübingen, Sand 1, 72076 Tübingen, Germany
2 Dr.-Remeis-Sternwarte, Universität Erlangen-Nürnberg, Sternwartstr. 7, 96049 Bamberg, Germany
3 Institut für Astrophysik, Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany
4 Department of Physics and Astronomy, The Johns Hopkins University, Baltimore, MD 21218, USA

Abstract. We report on an on-going analysis of high-resolution UV spectra of hot hydrogen-rich central stars of planetary nebulae (CSPN), obtained with the Hubble Space Telescope and FUSE. Since UV spectra of many CSPN are dominated by Fe and Ni lines, we intend to use them as temperature indicators to check the CSPN temperature scale we have derived earlier from CNO ionization balances. Furthermore, the observed line strengths of heavy metals show large variations between different objects suggesting a possible spread in abundances. We will determine abundances of iron group elements by quantitative spectral analyses with non-LTE model atmospheres.

1. Introduction

Unlike the optical spectra of hot CSPN, which are characterized by lines of hydrogen, helium and some light metals, the ultraviolet spectra are dominated by Fe and Ni lines (Schönberner & Drilling 1985). Their observed strengths show large variations between different objects suggesting a possible spread in abundances. Iron group lines are ideal temperature indicators (Fig. 1), which is important to set up a reliable temperature scale for the hottest CSPN. Effective temperatures of the hottest central stars are known with low accuracy only. As a temperature indicator one usually takes the relative strength of neutral and ionized helium lines in optical spectra, however, at very high temperatures neutral helium lines disappear.

The sample of stars in our study includes seven very hot hydrogen-rich CSPN. These are the same objects that are investigated by Traulsen et al. (these proceedings) to derive temperature and gravity by utilizing UV lines from light metals, namely C, N, and O. This sample covers the hottest phase of post-AGB evolution ($T_{\text{eff}} > 70000$ K) and includes four objects, which have been observed with FUSE and HST/STIS.
The FUSE spectra cover the range 910 – 1180 Å with a resolution of about 0.1 Å. Fig. 2 displays a section of the available spectra. They are ordered by increasing effective temperature (starting from NGC 1360 with 97 000 K, up to NGC 6853 with 126 000 K) which becomes obvious in the shift of the iron ionisation balance. Only lines of Fe vi and Fe vii are labeled in this figure, and the numbers next to the identification bars are the respective log $g_f$ values. We also detect lines of C, N, O and of other elements of the iron group. As yet unidentified spectral lines are possibly absorptions of Co vi (1139.4 Å), Ni vi (1096.6 Å, 1121.9 Å, 1125.4 Å, 1141.9 Å, 1145.0 Å, 1148.9 Å) and Mn vi (1088.7 Å, 1128.5 Å).
Figure 2. FUSE spectra of our programme stars. NGC 1360 (dashed line) is compared to solar Fe abundance model.
In addition to the FUSE observations, Fig. 2 displays a model spectrum which is plotted over the spectrum of NGC 1360. The model has solar abundances, and includes, besides H and He, lines from Fe\textsuperscript{vi} and Fe\textsuperscript{vii}. Temperature and gravity of the model (\(T_{\text{eff}} = 95,000\) K and \(\log g = 5.50\)) are close to those derived from the CNO analysis mentioned above.

Note the H\textsubscript{2} contamination of the FUSE spectra other than NGC 1360. The very broad troughs in LSS 1362 are H\textsubscript{2} lines, and one can see the matching (relatively weak) absorption in NGC 7293. A large fraction of the absorption features in NGC 6853 are from warm H\textsubscript{2}, which will have to be deblended to obtain the photospheric spectrum.

The spectra are analyzed using NLTE metal line blanketed model atmospheres in order to determine \(T_{\text{eff}}\), surface gravity, and chemical composition. For model calculations we use the Tübingen NLTE Model Atmosphere Package TMAP (Werner & Dreizler 1999) and the atomic data files of the iron group ions were prepared with the Iron Opacity Interface “IrOnIc” (Rauch & Deetjen 2003). The large number of iron lines calls for a statistical treatment of opacities. We include data from Kurucz’s (1991) line list. The final synthetic spectra contain only lines whose wavelength position is accurately known from laboratory measurements (so-called POS tables of Kurucz). So far, all models have solar abundances and include H and He, plus lines from Fe\textsuperscript{vi}, and Fe\textsuperscript{vii}.

2. First Results

The possibility of using the Fe\textsuperscript{vi}/Fe\textsuperscript{vii} ionisation equilibrium as a temperature indicator can be seen by the disappearance of Fe\textsuperscript{vi} lines and the increasing strength of Fe\textsuperscript{vii} lines in the spectra of models with increasing effective temperature (Fig. 1). The decrease of the Fe\textsuperscript{vii} line strengths in the hottest model is explained by a shift of the ionization balance from Fe\textsuperscript{vii} to Fe\textsuperscript{viii}. (All models have \(\log g = 7\).) Our first calculations seem to confirm that the temperature of NGC 1360 is indeed lower than previously thought. The study of CNO lines arrived at a similar result. The iron abundance in NGC 1360 is apparently close to solar.

In future we will perform detailed model fits to the FUSE spectra and will expand the analysis to the HST/STIS spectra as well.

Acknowledgments. T.R. is supported by DLR (grant 50 OR 0201), and J.W.K by the FUSE project, which is funded by NASA contract NAS5-32985.

References

Kurucz, R. L. 1991, in Stellar Atmospheres: Beyond Classical Models, ed. L. Crivellari, I. Hubeny, D.G. Hummer, NATO ASI Ser. C 341, Kluwer, Dordrecht, p. 441
Rauch, T., & Deetjen, J. L. 2003, in Stellar Atmosphere Modeling, eds. I. Hubeny, D. Mihalas, & K. Werner, ASP Conference Proceedings, 288, 103
Schönberner, D., & Drilling, J. S. 1985, ApJ, 290, L49
Werner, K., & Dreizler, S. 1999, in Computational Astrophysics, eds. H. Riffert & K. Werner, Journal of Computational and Applied Mathematics, 109, 65