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Light Metals in PG1159 Central Stars

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Abstract. We present results of a quantitative spectral analysis of a sample comprising eleven hydrogen deficient post-AGB stars of the spectral type PG 1159 with state-of-the-art NLTE model atmospheres. For all objects high resolution spectra obtained with the Far Ultraviolet Spectroscopic Explorer (FUSE) are available. The FUV spectra of PG 1159 stars are dominated by lines of helium, carbon and oxygen, and for the first time we also identified lines of several trace elements as sulfur and silicon which allow to determine the abundances of light metals in the atmospheres of these stars. As these stars show nuclear processed former intershell matter on their surface, the determined abundances also allow us to constrain the predictions of evolutionary models and element abundances in AGB stars.

Keywords. stars: abundances, stars: AGB and post-AGB, stars: atmospheres

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1. Introduction

Quantitative spectral analyses of post-AGB stars during the last decade revealed two distinct evolutionary sequences. Besides the hydrogen-rich sequence which is established by CSPN from early post-AGB to the hot white dwarf stages, a hydrogen-deficient sequence has been discovered. It is composed of Wolf-Rayet-type central stars which evolve into PG 1159 stars and finally might evolve into non-DA white dwarfs. PG 1159 stars are extremely hot post-AGB stars with effective temperatures between 75 000 and 200 000 K and surface gravities between 5.5 and 8.0 (cgs). Today 40 members of this spectroscopic class are known. State-of-the-art NLTE spectral analyses by means of model atmosphere techniques showed that the main constituents of PG 1159 atmospheres are helium, carbon and oxygen. Quantitative spectral analyses revealed a "typical" abundance pattern He:C:O of 33:50:17 by mass (Werner *et al.* 1991). Recent evolutionary calculations have shown that the hydrogen-deficiency is caused by a (very) late helium-shell flash which brings the star back to the AGB (Iben *et al.* 1983; Herwig *et al.* 1999). During this phase, the complete envelope is mixed and the entire H-rich shell (about $10^{-4}\,M_\odot$) is diluted or burned. These stars therefore provide a direct view onto the former intershell material which is now exhibited at the stellar surface. A new spectral analysis of FUSE spectra (900–1200Å, $R \approx 20\,000$) of eleven PG 1159 stars allows us to investigate this intershell matter and to derive the photospheric abundances of light metals like Ne, S, Si, and P. Werner & Herwig (2006) have computed new evolutionary models that predict abundances for these light elements; our analysis confirms the predictions for Si and P, but for S we find a significant underabundance that is not matched by the model. This allows us to constrain the predictions of evolutionary theory and to achieve information about the nuclear processed material which is returned into the interstellar medium via PNe and thus determines the chemical evolution of our Galaxy.

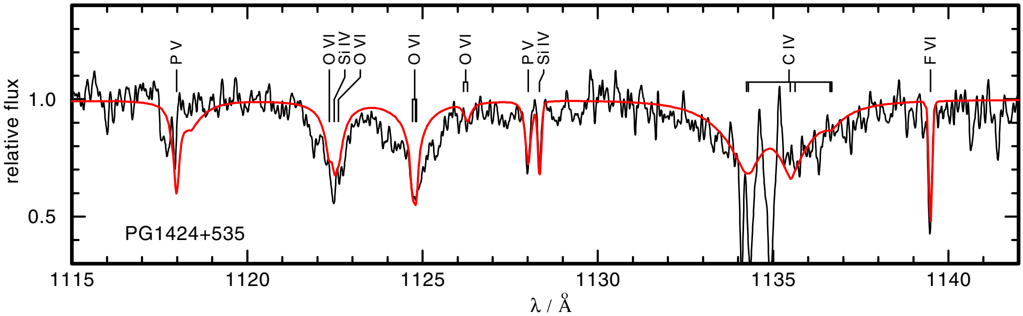

Figure 1. Fit of light metal lines to the FUSE spectrum of PG 1424+535. We derive a solar Si abundance from the Si IV doublet (1122.5/1128.3 Å) and a 1.5×solar P abundance from the P V doublet (1117.9/1128.0 Å). The fit of the F VI line at 1139.5 Å suggests a highly oversolar (120×solar) F abundance.

2. Abundances of light metals

The spectroscopic class of PG 1159 stars was first established by Wesemael *et al.* 1985. Their spectra are characterized by the lack of hydrogen Balmer lines and dominated by lines of He II, C IV, and O VI. Due to the high effective temperatures of the PG 1159 stars line-blanketed NLTE modeling is required. We therefore calculated homogeneous, plane-parallel, static NLTE model atmospheres using the Tübingen Model Atmosphere Package (TMAP, Werner & Dreizler 1999), regarding the most abundant elements H, He, C, N, O and Ne. Furthermore, the light metals S, Si, P and F are included without backreaction on the atmospheric structure. This is sufficient as these species are only trace elements. The abundances of these trace elements are of special interest, as PG 1159 stars give the opportunity to investigate abundance changes due to s-process neutron capture in the intershell region of the precursor AGB star. For Si and P we determine a roughly solar abundance, which corresponds with the predictions of evolutionary models. For F a wide spread of abundances is found (Werner *et al.* 2005), with high overabundances in some cases. However, for S we find a strong underabundance, e.g. only 2% of the solar value for the prototype PG 1159-035 (Jahn *et al.* 2006). Although a slight underabundance is expected, the evolutionary models can not reproduce such low abundances (Werner & Herwig 2006).

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References

Herwig, F., Blöcker, T., Langer, N., & Driebe, T. 1999, *A&A* (Letters) 349, L5
Iben, I., Kaler, J. B., Truran, J. W., & Renzini, A. 1983, *ApJ* 264, 605
Jahn, D., Rauch, T., Reiff, E., Werner, K., Kruk, J. W., & Herwig, F. 2006, *A&A* submitted
Werner, K. & Dreizler, S. 1999, in: H. Riffert & K. Werner (eds.), *Computational Astrophysics, Journal of Computational and Applied Mathematics* 109, 65
Werner, K., Heber, U. & Hunger, K. 1991, *A&A* 244, 437
Werner, K. & Herwig, F. 2006, *PASP* 118, 183
Werner, K., Rauch, T., & Kruk, J. W. 2005, *A&A* 433, 641
Wesemael, F., Green, R. F., & Liebert, J. 1985, *ApJS* 58, 379