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Spectral analysis of the O(He)-type central stars of the planetary nebulae K 1-27 and LoTr 4

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Abstract. The four known O(He) stars are the only amongst the hottest post-AGB stars whose atmospheres are composed of almost pure helium. Thus, their evolution deviates from the hydrogen-deficient post-AGB evolutionary sequence of carbon-dominated stars like e.g. PG 1159 stars. The origin of the O(He) stars is still not explained. They might be either post-early AGB stars or the progeny of R Coronae Borealis stars. We present preliminary results of a non-LTE spectral analysis based on FUSE and HST/COS observations.

Keywords. stars: abundances, stars: AGB and post-AGB, stars: atmospheres, stars: evolution, planetary nebulae: individual (K 1-27, LoTr 4).

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1. Introduction

Quantitative spectral analyses of hot, post-AGB stars revealed two distinct evolutionary sequences. Besides the well known "usual" hydrogen-rich sequence, a hydrogen-deficient sequence was discovered. It is composed of Wolf-Rayet type stars that evolve into PG 1159 stars and finally might envolve into non-DA white dwarfs. But the evolutionary status of a small fraction of the hottest hydrogen-deficient stars, namely the O(He) stars, is as yet unexplained. Their spectra are dominated by He II lines. So far, only four stars have been identified as O(He) stars, two CSPNe (K 1-27 and LoTr 4) and two objects without a PN (HS 1522+6615 and HS 2209+8229). While (very) late thermal pulse evolutionary models can explain the observed He/C/O abundances in Wolf-Rayet and PG1159 stars, they could never reproduce He-dominated surface abundances. For their evolution different scenarios are thinkable: They could be the long sought hot successors of RCrB stars, that are relatively cool stars with He-dominated atmospheres. If this is true, we can expect similar metal abundances. An alternative explanation is that O(He) stars are post early-AGB stars, that depart from the AGB just before they experience their first thermal pulse which will then occur as a late thermal pulse. This would be a link to the low-mass He sdO stars and low-mass, particularly He-rich PG 1159 stars.

2. Observations and analysis

Most of the strategic metal lines of hot post-AGB stars are located in the UV. FUV observations with FUSE in 2002 (ProgID: C178) showed a strong contamination by interstellar line absorption and the S/N ratio was not sufficient for a precise spectral analysis. HST/COS observations in 2010 (ProgID: 11699) have a much better S/N ratio which allows a precise determination of the photospheric C, N, O, and Si abundances.

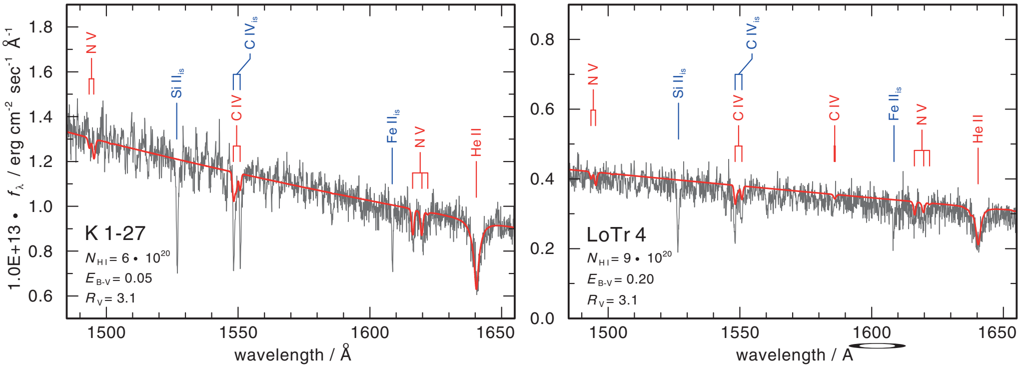

Figure 1. COS spectra of K 1-27 and LoTr 4 compared with preliminary theoretical models. The locations of photospheric and interstellar lines are marked.

Table 1. Parameters of the four O(He) stars. Typical uncertainties are $\Delta T_{\rm eff} \pm 10\%$, $\Delta \log g \pm 0.5$. The last two lines give the mean abundances of the RCrB stars (Rao 2005).

Object	$T_{\rm eff}$ kK	log g cm/sec^2	log (H/He)	log (C/He) number	log (N/He) ratio	log (O/He)	log (Ne/He)
K 1-27	120	6.0	−1.00	−3.70	−2.30	< −5.00	< − 3.30
LoTr 4	120	5.5	−0.30	< −2.56	−2.26	< −3.60	< − 4.00
HS 1522 + 6615	130	6.0	−1.48	−3.18	−4.48	−3.48	< − 5.18
HS 2209 + 8229	110	6.0	−1.60	−4.60	−3.43	−4.30	− 4.60
Majority RCrBs			−5.40	−2.63	−2.87	−3.37	− 3.24
Minority RCrBs			−0.84	−2.04	−4.04	−3.04	− 3.64

We used the Tübingen NLTE Model-Atmosphere Package (*TMAP*, Werner *et al.* 2003; Rauch & Deetjen 2003) to compute plane-parallel, line-blanketed model atmospheres in radiative and hydrostatic equilibrium. The models include so far the elements H, He, C, N, O, and Ne. Based on the literature values of the four stars, we computed a grid varying effective temperature, surface gravity, and elemental abundances. We then compared the synthetic spectra to the FUSE and COS observations.

Table 1 shows the stellar parameters that we determined for all four O(He) stars so far. For K 1-27 a higher effective temperature as well as a lower value for log g were found (previously published values: $T_{\rm eff} = 105$ kK, $\log g = 6.5$). In former publications Rauch *et al.* (1994, 1998) had the problem that the CSPN did not provide enough hard photons to ionize the nebula. With this higher effective temperature, we got a more consistent PN ↔ CSPN model.

For LoTr 4, we confirmed the literature values for $T_{\rm eff}$ and $\log g$ (Rauch *et al.* 1996). For nitrogen, we determined a higher value (N/He = 0.005 instead of 0.001) and for the O/He ratio we defined a new, reduced upper limit (former value: log(O/He) = −2.10).

Acknowledgements

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