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MKDNAZ002

Summary : The far-ultraviolet spectra of two hot PG1159 stars by K. Werner, T. Rauch and J.W. Kruk

The aim of this paper is to evaluate the element abundances of the two stars, PG1520+525 and PG1144+005, and to analyze elements not previously considered in the PG1159 star group by developing new non-local thermodynamic equilibrium model atoms. Identification of spectral lines not observed before in stellar spectrum is another priority of this paper. The prototype star of this group is also re-evaluated for comparison and analysis.

Two PG1159 stars apart from the prototype star were previously studied, in Warner et al. 2015 (PG1424+535, PG1707+427), these combined with the prototype and the two stars studied in this paper make an exhaustive list of the PG1159 stars which have had comprehensive element determinations. Spectral analysis of PG1520+525 and PG1144+005 confirm the abundances of the elements we expected from previous studies of the PG1159 stars, He, C, O and Ne.The results obtained from analysis of Si, P and S absorption features have been improved, and abundance upper limits were derived for Na, Al and Cl for the first time. The spectra of PG1520+525 and PG1144+005 are similar to that of the prototype star and dominated by the broad absorption lines, HeII, CIV and OVI, therefore the spectra can easily be matched to the prototype.The absorption features are caused by bound free electron scattering, where photons emitted by the source star is absorbed by the gas of outer layers of the star. The elements that make up this gas have electrons at different energy levels, some of the photons emitted by the star are absorbed at specific wavelength depending on the energy needed to move the atom to a higher energy state or for ionization.

The evolutionary models by Shingle and Karakas (2013) are in agreement with both the stars analyzed in this paper and the three comparison stars also mentioned in this paper. The three stars were observed to agree with the model in Warner and Rauch (2014), and since the two stars analyzed in this paper have similar element abundances they are in agreement as well and follow the same evolutionary model.

Table 1. Final adopted parameters for the program stars PG 1144+005 and PG 1520+525. The results are compared to the prototype of the PG 1159 spectral class (PG 1159–035) and the Sun.[a]

	PG 1144+005	PG 1520+525	PG 1159–035	Sun[b]
T_{eff} / K	150 000	150 000	140 000	
log g	6.5	7.5	7.0	
H	< 0.10	< 0.10	< 0.02	0.74
He	0.38	0.43	0.33	0.25
C	0.57	0.38	0.48	2.4×10^{-3}
N	0.015	$< 1.5 \times 10^{-4}$	0.001	6.9×10^{-4}
O	0.016	0.17	0.17	5.7×10^{-3}
F	1.0×10^{-5}	1.0×10^{-4}	3.2×10^{-6}	5.0×10^{-7}
Ne	0.02	0.02	0.02	0.0013
Na	< 0.01	—	—	2.9×10^{-5}
Al	$< 1.0 \times 10^{-3}$	$< 3.2 \times 10^{-4}$	$< 3.2 \times 10^{-4}$	5.6×10^{-5}
Si	6.6×10^{-4}	6.6×10^{-4}	3.6×10^{-4}	6.6×10^{-4}
P	$< 3.0 \times 10^{-5}$	$< 3.0 \times 10^{-5}$	$< 6.4 \times 10^{-6}$	5.8×10^{-6}
S	1.0×10^{-4}	3.1×10^{-4}	3.1×10^{-4}	3.1×10^{-4}
Cl	$< 1.0 \times 10^{-3}$	$< 1.0 \times 10^{-3}$	$< 1.0 \times 10^{-3}$	8.2×10^{-6}
Ar	$< 8.0 \times 10^{-5}$	$< 8.0 \times 10^{-5}$	$< 3.2 \times 10^{-5}$	7.3×10^{-5}
Fe	1.3×10^{-3}	1.3×10^{-3}	1.3×10^{-3}	1.3×10^{-3}

Notes. [(a)] Abundances in mass fractions and surface gravity g in cm s^{-2}. [(b)] Solar abundances from Asplund et al. (2009). Parameters for PG 1159–035 from Jahn et al. (2007) and references therein, except for the abundances of Fe (from Werner et al. 2011) and Al, S, Cl (this work). Upper limits for H in PG 1144+005, PG 1520+525, and PG 1159–035 from Werner & Heber (1991); Werner et al. (1991, 1996).

PG1144+005 has an interesting feature shared by some other PG1159 stars, the large Nitrogen abundance it has signals the last of the thermal pulses of this star occurred after it has become a white dwarf.

Table 1 displays the element abundance results obtained from spectral analysis of the two stars and compares them to the prototype star and the sun. A lack of precise atomic data and relatively high uncertainty in the mass determination result in only upper limits for some of the elements.