Grids of Synthetic Spectra for H-poor Central Stars of Planetary Nebulae

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Abstract

We present comprehensive grids of model spectra from far-UV to IR, covering the parameter space of [WC]-type CSPNe (Keller et al. 2011) and PG1159 stars. Models are calculated with CMFGEN, accounting for non-LTE, line blanketing, winds, and clumping, and including ions previously neglected. Our uniform model set enables systematic analysis of observed spectra to constrain stellar parameters, facilitates line identification, and illustrates spectral line changes across the CSPN evolutionary phase. The grids are available at http://dolomiti.pha.jhu.edu/planetarynebulae.html. We used them to analyze UV and far-UV spectra of the hot central stars of NGC 6905 and NGC 5189. We also explore additional parameters, such as less abundant ions not included in the wider grids and the iron abundance.

Introduction

H-deficient CSPNe are commonly divided into three main classes: [WC], showing spectra very similar to those of Population I Wolf–Rayet (WR) stars, with strong carbon and helium emission lines; the PG1159 type, occupying the region at the top of the WD cooling track in the HRD and characterized by absorption lines of highly ionized He, C and O, besides UV wind lines much weaker than the ones seen in [WC] stars; and [WC]-PG1159, that are believed to be transition objects between the two other classes. They are thought to constitute an evolutionary sequence in which the [WC] CSPNe would evolve from the AGB at an almost constant luminosity, towards higher temperatures. As the stars evolve, their radii decrease until the nuclear burning ceases and the stars progress quickly as PG1159 on to the WD cooling track, while luminosity and mass-loss decrease and the wind reaches very high terminal velocities.

Species and Abundances Considered in the Grids

(Abundances within typical literature values for H-poor CSPNe).

The ionic species included in the models can vary, since they were limited to keep the models within a workable size.

All models have the following species: He I, He II, HeIII, C IV, C V, N V, N VI, O V, O VI, OVII, Ne V, Ne VI, Ne VII, Ne VIII, Ne IX, Si IV, Si V, P V, P VI, S VI, S VII, Fe VII, FeVIII, Fe IX, Fe X, Fe XI. The other ionic species, which include C II, C III, N II, N III, N IV, O II, O III, O IV, Ne II, Ne III, Ne IV, Al III, Al IV, Al V, Si III, Si VI, P IV, S III, S IV, S V, Fe IV, Fe V, Fe VI, were added as needed

Element	Mass Fraction
He	0.43
C	0.45
N	0.01
O	0.08
Ne	0.02
Al	$5.57x10^{-5}$
Si	$6.99x10^{-4}$
P	$6.12x10^{-6}$
S	$3.82x10^{-4}$
Fe	$1.36x10^{-3}$

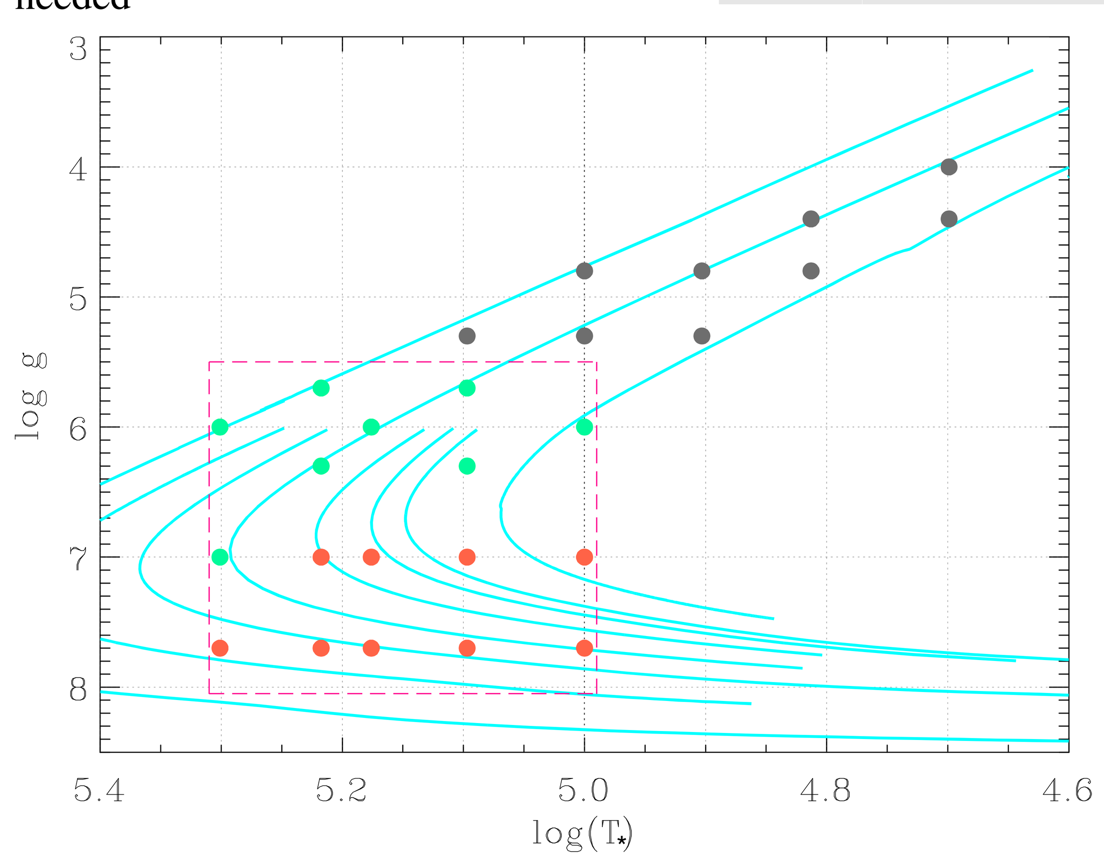
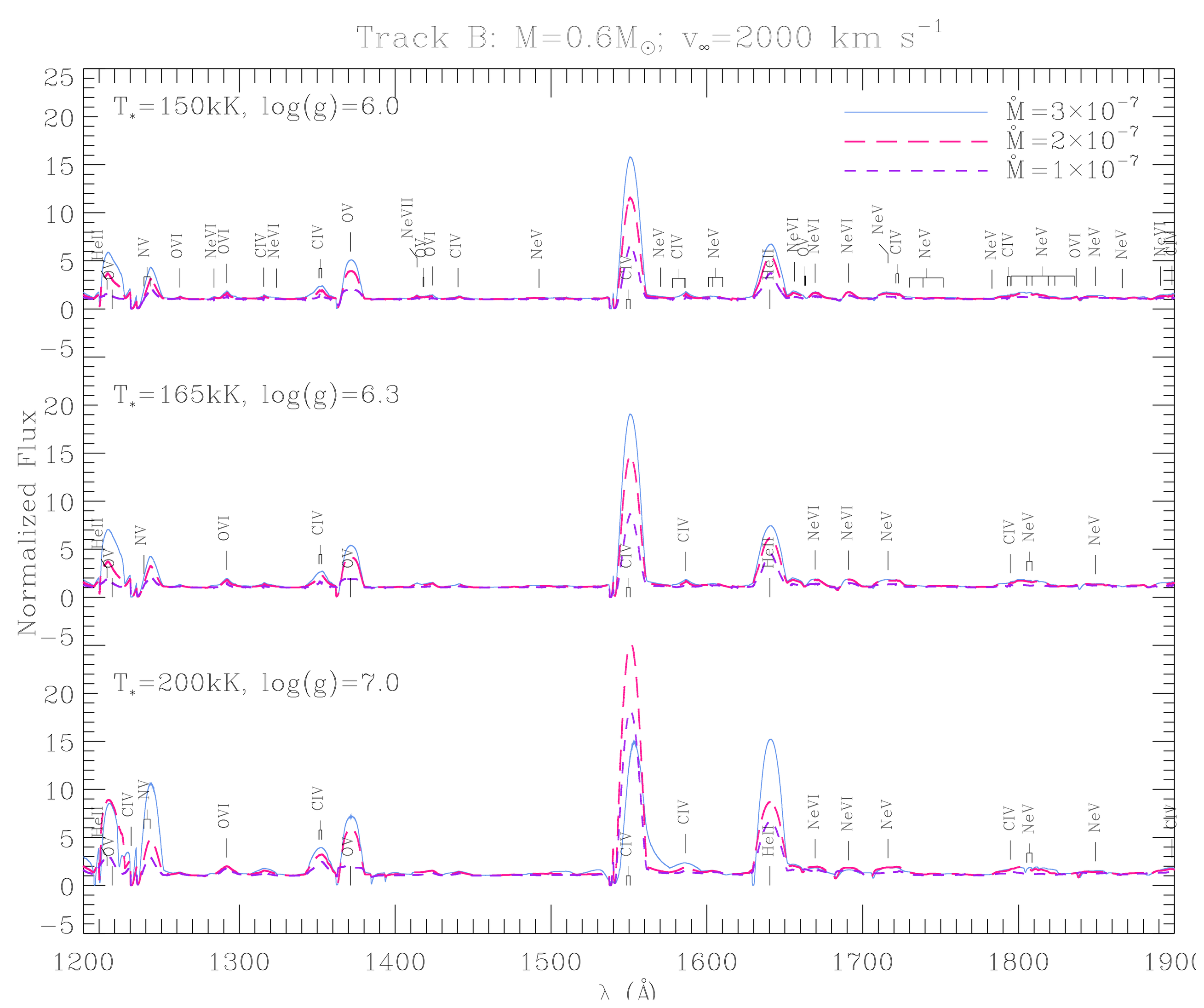
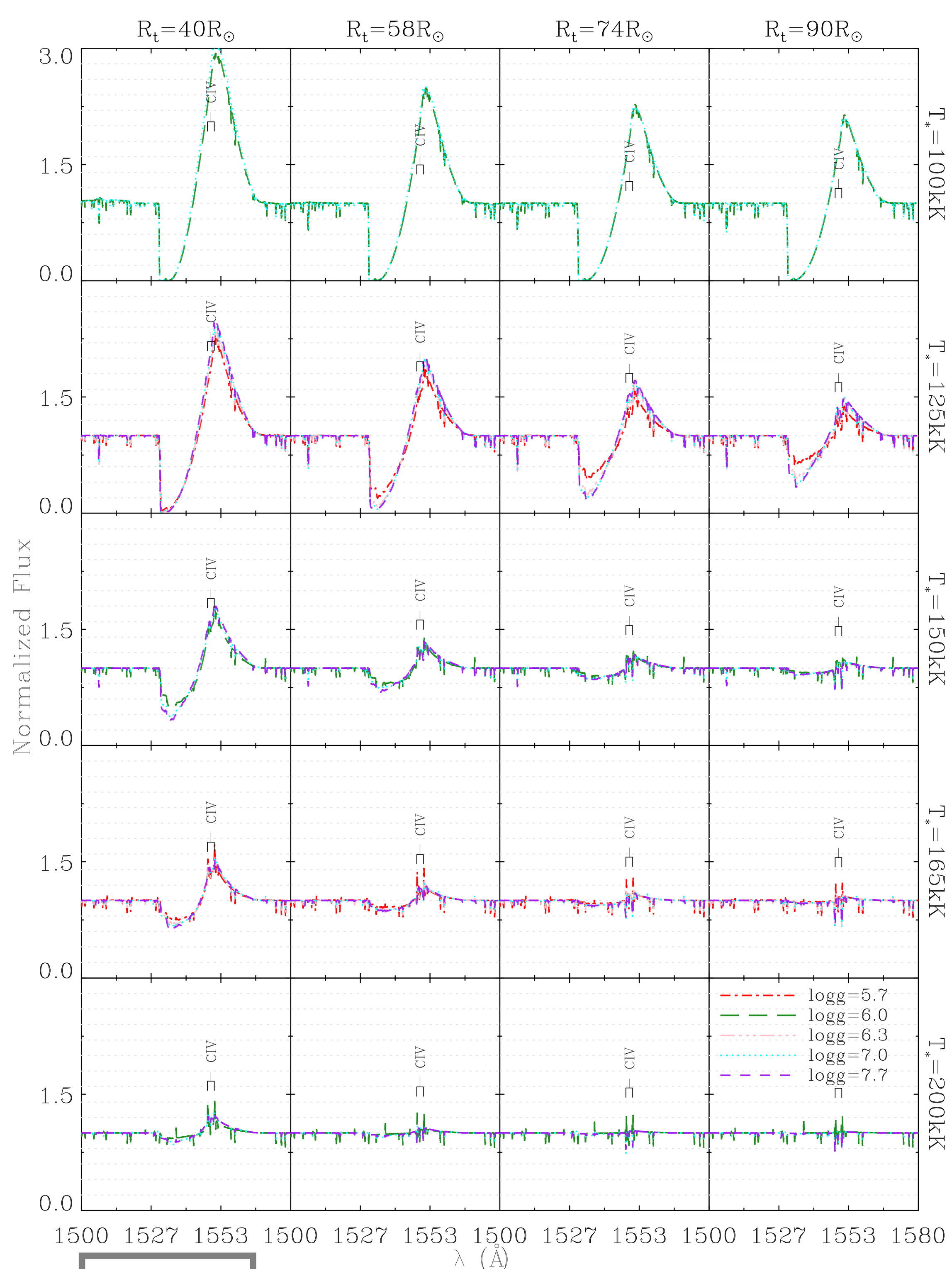


Fig.1 Stellar parameters covered by our grids of CMFGEN models. The blue lines correspond to evolutionary tracks from Miller Bertolami, & Althaus (2006) for H-deficient CSPNe of different masses. The grid covering the parameter space of the [WC]-type CSPNe is represented by gray and green dots. The grid covering the PG1159 stars' parameter space is represented by green and orange dots. Each dot corresponds to several models of different of mass-loss rates and terminal velocities.



[WC] Grid

Fig. 2 Example of models from the grid covering the parameter space of [WC]-type CSPNe (Keller et al. 2011) for temperatures above 50 kK. For each combination of stellar temperature and surface gravity, models differing in mass-loss rate and terminal velocity of the wind were calculated.



PG1159 Grid

Fig. 3 Example of models from the grid covering the parameter space of PG1159 stars.

NGC6905 and NGC5189

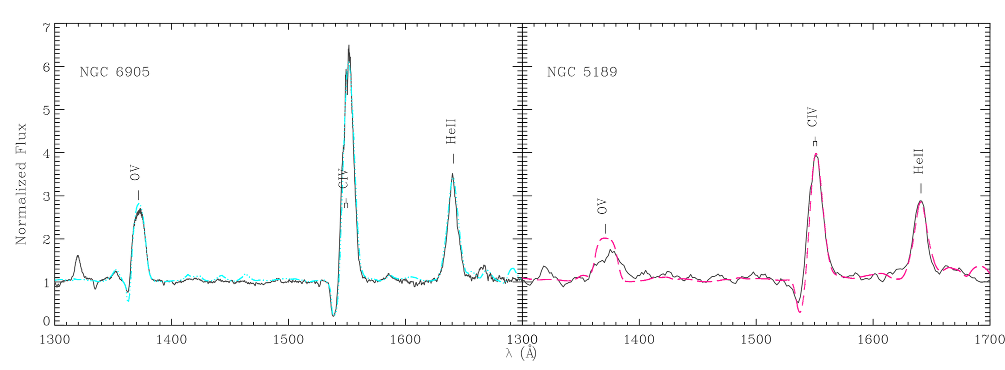
We analysed UV and far-UV spectra of the central stars of NGC6905 and NGC5189 using the [WC] grid to constrain their main physical parameters.

Data

Object	Instrument	Resolution [Å]	Aperture [arcsec]	Range [Å]
NGC 6905	FUSE	~0.06	30x30	905-1187
	STIS+G140L	~1.20	52x0.5	1150-1736
	STIS+G230L	~3.15	52x0.5	1570-3180
NGC 5189	FUSE	~0.06	30x30	905-1187
	IUE	~7.0	9.3x20.7	1851-3349
	IUE	~6.0	8.9x21.6	1151-1979

Derived Stellar Parameters

Object	T_*[kK]	Rt[$R_\odot$]	v_∞[km/s]	X_{He}	X_C	X_O
NGC6905	150	10.7	2000	0.44	0.45	0.08
NGC5189	165	10.5	2500	0.58	0.25	0.12



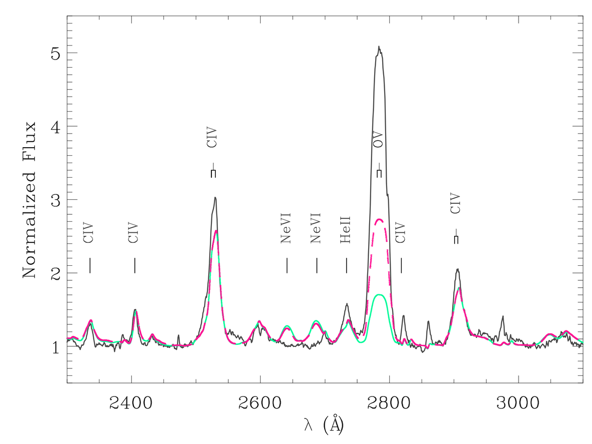


Fig. 4 (upper figure) Observed spectra (black line) of the central stars of NGC 6905 (left panel) and NGC 5189 (right panel) and our best fit models (colored lines).

Fig. 5 (left figure) Synthetic spectra with (red line) and without (green line) the inclusion of Mg, Na, Co, and Ni in the calculations is compared with the observed one (black line). The effect is seen on the O V lines.

Iron Abundance

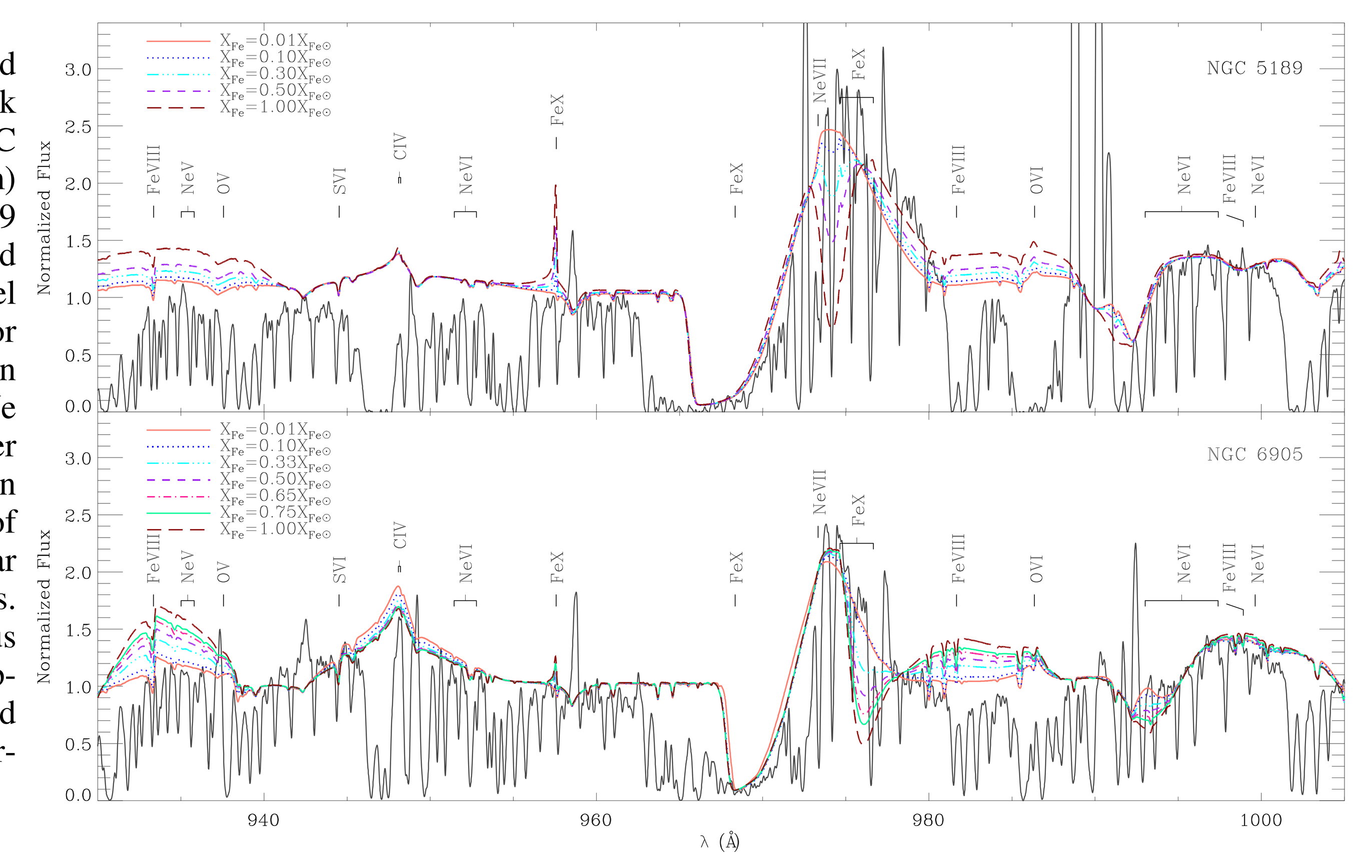


Fig. 6 Observed spectra (black line) of NGC 6905 (bottom) and NGC 5189 (top) compared with model spectra for different iron abundances. We find an upper limit to the iron abundance of 0.3 times solar in both stars. The numerous narrow absorptions observed are from interstellar H_2.

References

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Miller Bertolami, M. M., Althaus, L. G., 2006. A&A, 454, p. 845

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