Non-LTE Model Atmosphere Analyses of Faint PN Central Stars Observed with Keck HIRES

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We are engaged in using the HIRES echelle spectrograph (Vogt *et al.* 1994) on the 10 m Keck I Telescope to significantly increase the number of central stars of planetary nebulae (CSPN) studied spectroscopically at high resolution and signal-to-noise ratio. With Keck we are able to extend our previous work (Méndez *et al.* 1988, 1992; McCarthy 1988) to much fainter magnitudes. In short, comparisons of the observed HI Balmer, HeI, and HeII line profiles to the Munich grid of plane-parallel non-LTE model atmosphere line profiles provide distance- and nebula-independent determinations of CSPN effective temperature, surface gravity, and helium abundance. For CSPN showing wind emission, the comparisons are made to new "unified" models (reviewed by Kudritzki *et al.*, this meeting) which include radiation-driven winds. The first results of this on-going program are shown below.

Table 1: Field CSPN studied with Keck HIRES

Name	$T_{\rm eff}$ (K)	$\log g$	y	$v \sin i$ (km/s)	M_* ($M_\odot$)	$t_{\rm evol}$ (y)	d (kpc)
Vy 1-1	60,000	4.2	0.07	< 50	0.76	800	6.2
IC 289	100,000	5.6	0.09	< 50	0.58	8,700	1.3
A 7	100,000	6.6	0.05	< 50	0.55	275,000	1.2
J 320	85,000	4.7	0.09	< 50	0.79	900	5.9
NGC 2022	100,000	5.3	0.05	< 50	0.64	1,600	4.7
PuWe 1	110,000	7.0	0.02	< 50	0.58	7,800	0.88
A 15	110,000	5.7	0.06	< 50	0.59	6,200	4.5
M 1-11	29,000	3.0	0.10	< 50	0.74	1,100	4.6
NGC 2610	100,000	5.8	0.09	< 50	0.56	27,000	3.3
NGC 3587	110,000	6.7	0.09	< 50	0.56	55,500	1.5
A 39	110,000	6.3	0.11	< 50	0.55	78,900	2.0
KO 1 = DdDm1	37,000	3.4	0.09	180	0.76	1,100	—
NGC 6720	80,000	7.0	0.09	< 50	0.54	500,000	0.52
NGC 7293	90,000	7.0	0.02	< 50	0.55	400,000	0.27

The CSPN masses and post-AGB evolutionary ages are derived from evolutionary models in the distance-independent $\log T_{\rm eff} - \log g$ plane (Figure 1). The spectroscopic distances are the result of comparing the emitted flux from the best-fit NLTE model atmospheres to the observed V-magnitudes of the central stars, corrected for interstellar extinction. The reliability of these distances, which we estimate to be $\sim 20\%$ typically, is supported most convincingly by recent results from the USNO parallax program (Harris *et al.*) for 3 objects in Table 1 and from our own study of K648 in M15 (McCarthy *et al.*), both reported at this meeting.

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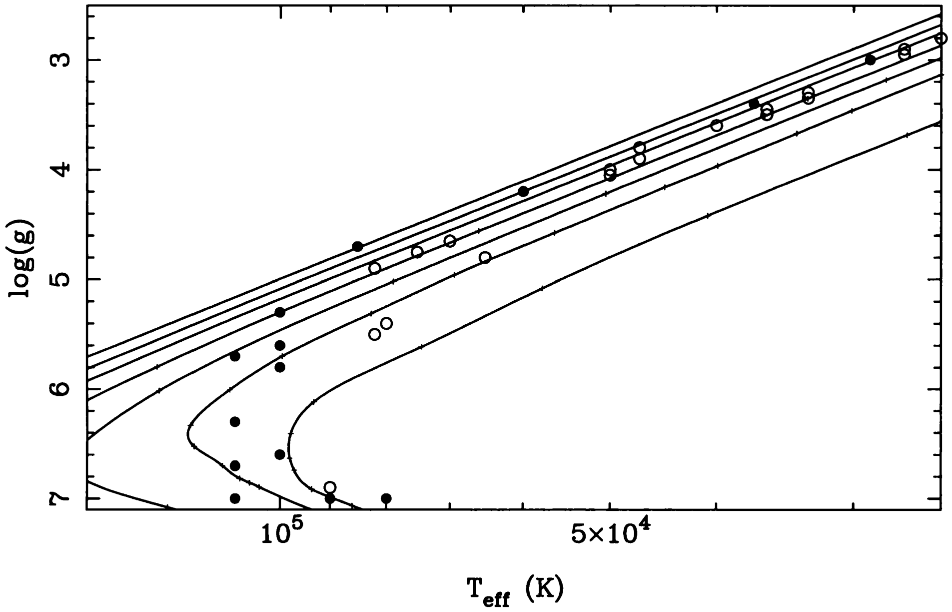

Figure 1: The distribution of CSPN observed with Keck HIRES 1994–96 (filled circles) in the $\log T_{\rm eff} - \log g$ plane compared with our previous sample (open circles). Tracks are for masses 0.89, 0.76, 0.70, 0.644, 0.598, 0.565, and $0.546\,M_\odot$.

Note from Figure 1 that the Keck HIRES sample includes many more CSPN with high effective temperature, which are fainter in the optical bandpasses owing to large bolometric corrections. It is not the case that the Keck sample is significantly more distant overall than the optically brighter sample studied previously. Most intriguing, however, is the continuing absence of *cool* low mass CSPN in our sample (first noted by Méndez *et al.* 1988). The combined sample of 38 objects currently contains no CSPN below the $0.64\,M_\odot$ track with $T_{\rm eff} < 60,000\,$K. As we continue to expand the Keck sample of faint CSPN, this becomes increasingly harder to explain as a magnitude-limited selection effect, given the large number of *hot* low mass CSPN our sample now includes. McCarthy *et al.* (1990) speculated that this might mean the residual envelope mass at the end of the superwind phase does not vary so strongly with core mass — in any case, the existence of nebulae around the CSPN with $t_{\rm evol} > 50,000$y in Table 1 is difficult to explain if the standard post-AGB evolutionary and transition timescales are correct. Alternatively, the distribution of points in Figure 1 could be an indication that CSPN are helium-burning stars following evolutionary tracks of greater slope.

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