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Physical Conditions and Abundances in Abell 30

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1. Introduction

Abell 30 is one of a small number of PN known as born-again PN, which appear to be old nebulae whose central star has undergone a further ejection of highly processed material. It consists of a large, faint, spherical shell, in which several bright knots are embedded. The knots were first noted by Jacoby (1979), and analysis of their abundances by Hazard et al (1980) and Jacoby & Ford (1983) showed that they are extremely hydrogen-deficient.

The study of planetary nebulae has long suffered from two problems: the temperature of the gas measured from the [O III] forbidden line ratio is typically higher than that measured from the hydrogen Balmer jump; and abundances derived from optical recombination lines (ORLs) are usually higher than those derived from collisionally excited lines (CELs). The problems are related: Liu et al (2001) show that the greater the temperature discrepancy, the greater the abundance discrepancy. Recent work by Liu et al. (2000) and Liu (this volume) finds that a model consisting of a normal nebula with cool, metal-rich knots embedded within can solve both problems, with CELs being almost entirely emitted by the normal component of the nebula, and ORLs being emitted mostly by the cool knots. It is possible that the proposed metal-rich knots, unseen in most nebulae, could be of similar origin to the knots in Abell 30.

We present analysis of UV and optical spectra of two of the knots, J1 and J3, which according to Jacoby and Chu (1989) are polar knots. We find that forbidden line diagnostics give a much higher temperature than the ratios of moderately temperature sensitive Helium lines and O II ORLs. Abundances from ORLs are much higher than those from CELs.

2. Analysis

Greenstein (1981) first noted that the extinction towards Abell 30 in the UV is anomalous, with much less absorption than the standard galactic law would indicate, and with a peak at around 2500Å instead of the normal 2200Å. Greenstein derived an extinction curve by comparing observed fluxes to those of a black body at a temperature of 2×10^5 K, and we use his curve to deredden the spectra of the knots. A value of 0.6 for the logarithmic extinction at Hβ, c, was derived by dereddening the spectrum of the central star to match a black body of 2×10^5 K.

The temperature of the knots in Abell 30 was derived in three ways: from the ratio of the [O III] forbidden lines; from the weakly temperature-sensitive

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helium line ratios $\lambda6678/\lambda4471$ and $\lambda5876/\lambda4471$; and from the ratio of the O II recombination lines at $\lambda4649$ and $\lambda4089$. The forbidden line temperatures are much higher than the helium temperatures, while the O II temperature is very low indeed in both knots. The temperatures are given in Table 1.

Table 1. Temperature measurements in Abell 30

Knot	T_e([O III])	T_e(5876/4471)	T_e(6678/4471)	T_e(O II)
J1	17960	4900	4300	500
J3	16680	9240	8450	2100

Abundances were derived from both ORLs and CELs, for ions of helium, carbon, nitrogen, oxygen and neon. For the CEL calculations, the [O III] temperature was used, while for the ORL calculations, temperatures of 8850 K and 4600 K were adopted, from the helium temperatures. The O II temperatures were not used as they are based on weak fluxes and may have large errors. Electron densities of 2840cm^{-3} (J1) and 3200cm^{-3} (J3) were adopted, from standard diagnostics. Unobserved ionisation stages were taken into account using the ionisation correction scheme of Kingsburgh & Barlow (1994). The results are presented in Table 2.

Table 2. Elemental Abundances in units such that log$N$(H) = 12.0

	J1		J3	
Ion	ORLs	CELs	ORLs	CELs
He	13.03		13.07	
C	11.70		11.72	8.95
N	10.55	8.78	10.43	9.01
O	10.03	9.16	10.10	9.32
Ne		9.65		9.65

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