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A NEW LOOK AT CARBON ABUNDANCES IN PLANETARY NEBULAE

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RESUMEN

Presentamos y describimos un proyecto a largo plazo en el que se pretende emplear el Archivo Final de Espectros del *IUE* para estudiar la abundancia de carbono en una muestra amplia de nebulosas planetarias que tengan un gran variedad de masas de la progenitora y metalicidades. En este trabajo reportamos los resultados iniciales para PB6, Hu2-1, K648 y H4-1. Combinando muestras medidas de intensidades de la líneas UV con intensidades de líneas ópticas tomadas de la literatura, hemos determinado valores de He/H, O/H, C/O, N/O, Ne/O y S/O para cada objeto usando un modelo combinado de un átomo de 5 niveles con fotoionización. Eventualmente se analizarán las abundancias de éste y subsecuentes estudios, usando un código nuevo y mejorado que calcula la evolución de estrellas de masa baja e intermedia con el propósito de determinar el rendimiento de carbono de estas estrellas.

ABSTRACT

We introduce and describe a new long-term project whose goal is to employ Final Archived *IUE* spectra to study carbon abundances in a sample of planetary nebulae representing a broad range in progenitor mass and metallicity. In this poster we report on initial results for PB6, Hu2-1, K648, and H4-1. By combining our measured UV line strengths with optical line strengths found in the literature, we have determined values for He/H, O/H, C/O, N/O, Ne/O, and S/O for each object using a combined 5-level atom/photoionization model approach. Eventually, the abundances from this and subsequent studies will be analyzed using a newly-improved stellar evolution code for intermediate-mass stars with the goal of determining carbon yields for stars of this mass range.

Key words: **PLANETARY NEBULAE — ISM: ABUNDANCES — ULTRAVIOLET: GENERAL**

1. INTRODUCTION

Carbon production in intermediate-mass stars plays a significant role in the chemical evolution of a galaxy (Tinsley 1978). We present initial results of a program to study carbon abundances in a sample of planetary nebulae spanning a wide range in progenitor mass, with the goal of determining carbon production in intermediate mass stars. Using newly recalibrated spectra from the *IUE* Final Archive database, we are remeasuring UV line strengths including C III] λ1909 and C IV λ1549, combining these measurements with optical lines in the literature, and performing a detailed abundance analysis on each sample PN. Through the use of an empirical 5-level atom routine and a photoionization code, we are deducing the abundance ratios of He/H, C/O, N/O, O/H, Ne/O, and S/O, as well as nebular density and stellar temperature information for each of our sample objects. Once our sample is complete, we will proceed to infer the chemical yield of carbon using a detailed stellar evolution code. Currently we have completed the abundance analysis of four objects: PB6, Hu2-1, K648, and H4-1, which we report here.

2. OBSERVATIONAL DATA

At the present time, almost one-half of the ~ 300 SWP low-dispersion spectra needed for this project have been completely processed and made available through the *IUE* Final Archive. We have downloaded these spectra to our home institutions and have measured all spectral lines in each, using IRAF. In addition to intensity information, each spectrum file contains quality flag information for every data point; these allow us to identify, for example, lines that are saturated or that fall on reseaux marks. The final UV intensities are combined with optical intensities compiled from the literature. An immediate problem is the non-correspondence between the sizes and positions of the spectrograph slits for the UV and optical observations. This problem is minimized for very small PNe, such as the four discussed here, where we can be fairly confident that essentially all of the light was captured by each slit. For the larger PNe in our program (to be investigated next), we will have to take account of this issue. However, even when differences in slit size and orientation are not a problem, some discrepancy in flux measurements between the UV and optical data sets is expected because the data are acquired and reduced separately. In this case, accurate linking of UV and optical data in the absence of any spectral overlap requires knowledge of a fixed intensity ratio such as He II λ1640/λ4686 (Seaton 1978), where one line falls in each spectral region. This method was used to link UV and optical data for PB6 and H4-1. For Hu2-1 and K648, He II lines were not detected, and the two spectral regions were combined directly. Starting with raw fluxes in all cases (and in some instances decorrecting intensities when the former were not reported), we applied reddening corrections using data from Seaton (1979) and Savage & Mathis (1979).

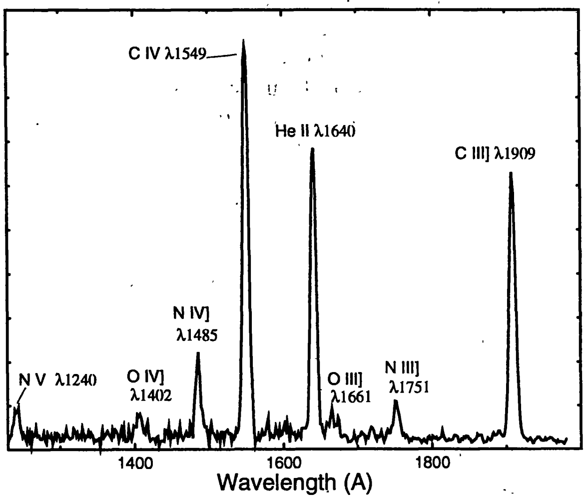

Fig. 1. *IUE* Final Archive Spectrum SWP36242. This 60 min spectrum of PB6 shows strong lines of C IV, He II, and C III]. Also visible are lines of N V, O IV], N IV], O III], and N III].

3. ABUNDANCE CALCULATIONS

We have developed an abundance-determining routine whereby our newly compiled and dereddened planetary nebula line intensities are used to infer the abundances of He, C, N, O, Ne, and S in the gas. We make use of ABUN, a 5-level-atom program detailed in Henry (1990), that takes observed line intensities as input and returns abundances (using standard ionization correction recipes) as well as electron temperatures and densities. We also use the photoionization code CLOUDY (Ferland 1990) to construct a consistent model of the nebula in order to further correct abundances derived using ABUN. The process flows as follows for each object being studied:

1. ABUN is used to get a preliminary set of abundance ratios;
2. CLOUDY is used to produce a photoionization model which closely matches four important diagnostics:

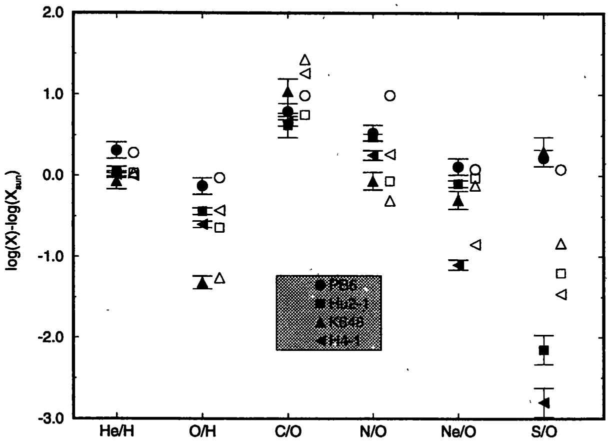

Fig. 2. Derived abundance ratios for our four objects. Values on the vertical axis are normalized to solar levels using data from Grevesse & Anders (1989) and are presented logarithmically, where X corresponds to one of the ratios shown along the horizontal axis. Filled symbols are our results. Open symbols show abundances published previously by Kaler et al. (1991; PB6); Barker (1978; Hu2-1); Lutz (1981; Hu2-1); Adams et al. (1984; K648); Barker (1983; K648, H4-1); and Torres-Peimbert & Peimbert (1979; H4-1).

{[O II] λ3727 + [O III] $\lambda\lambda$4959, 5007}/Hβ; [O III] λ4363/[O III] λ5007; [S II] λ6716/λ6731; and [O II] λ3727/[O III] $\lambda\lambda$4959, 5007. Model input abundance ratios are X_{in};

3. ABUN is then used along with model output emission line intensities to obtain abundance ratios X_{out};
4. Abundance ratios from 1. are then multiplied by X_{in}/X_{out} to obtain our final values.

4. RESULTS

Figure 1 shows an example of a final archived *IUE* spectrum (for PB6) with relevant emission lines identified. Line strengths were measured in each of the spectra of the four PNe. These data are available in Henry, Kwitter, & Howard (1996). Figure 2 shows our final abundances, where the ratios are expressed logarithmically and normalized to their solar values. Solid symbols are our results; open symbols are those of others as noted.

Figure 2 shows that our abundances are reasonably consistent with those previously determined by other studies with the notable exception of S/O in Hu2-1, K648, and H4-1. The sulfur line strengths of all four objects are extremely weak, and the large discrepancies are undoubtedly related to that factor. Our sample of four objects includes a Type I (PB6), a Type II-III (Hu2-1), and two halo PNe (K648 and H4-1). Metallicity generally decreases along the sequence Type I, Type II, Type III, halo, and our derived oxygen abundances are consistent with this pattern. Note also the carbon enhancement in all four objects as well as the nitrogen enrichment in all but K648. Further details and results pertaining to this study are available in Henry, Kwitter, & Howard (1996).

5. SUMMARY

We have demonstrated our PNe abundance analysis, illustrating the method we are employing in our program to reexamine the carbon abundance in PNe. We are measuring *IUE* Final Archive spectra and supplementing the UV data with optical spectrophotometry from the literature. A combination of 5-level-atom calculations and photoionization modeling allows the abundances and physical parameters of the PNe to be determined. The ultimate goal of the project is to assess carbon production in the PNe progenitors — the intermediate-mass stars — as a function of stellar mass.

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