HYDROGEN DEFICIENT PLANETARY NEBULAE: PRELIMINARY RESULTS

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ABSTRACT. New spectra of A78 and A58 at different positions in the nebulae are presented. An abundance gradient is found in A78, extending quite close to the center. Similarly the nebulous knot near the center of A58 has considerably higher heavy element abundances than the outer regions of this nebula. The ionization state is considerably lower in A58 than A78. In A78 most of the neon is in the form of Ne^{+3} and Ne^{+4}, indicating that the standard ionization correction factor as used by Jacoby and Ford, is substantially in error. Finally, the very high infrared excesses found in this nebulae are discussed.

I. Introduction

A little more than five years ago, Jacoby (1979) reported that the material near the center of the large planetary nebulae A78 and A30 was relatively much brighter in the [O III] line λ5007 than in the Hα line. This suggested that the central regions of these nebulae may be hydrogen deficient, although this possibility was not specifically mentioned by Jacoby. The spectroscopic measurements, first of Hazard et al (1980) of A30, then of Jacoby and Ford (1983) of both A78 and A30, confirmed that the central regions of these nebulae are indeed hydrogen deficient. The Balmer lines of hydrogen were not detected at all by these authors, although the recombination lines of both He^{+} and He^{++} are easily seen.
This leads to the conclusion that He is a factor of at least 5 times more abundant than H, which is a factor 50 different that the normal H:He ratio in nebulae. Jacoby and Ford further report that the ratio of He to O, N and Ne is consistent with the hypothesis that the abundances are the same as in other nebulae with the exception that hydrogen has been converted to helium.

We have begun an investigation of the abundances in A78. The purpose originally was to determine if the outer regions of the nebula had normal chemical composition. The preliminary results are presented in section II, where it is shown that even in the central regions of this nebula a strong abundance gradient exists, and that the outer regions are still somewhat hydrogen deficient.

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In section III we discuss the unusually large far infrared excess found in these nebulae. It is shown that this excess is at least two orders of magnitude greater than the value found in normal nebulae. While the origin of this larger excess is not understood, it may be related, either directly or indirectly, to the abundances anomoly,

Finally attention is directed to another nebula which also has an unusually large infrared excess: A58. Spectra are presented of parts of the outer regions of this nebula as well as the knot near the center, which may have been ejected less than 60 years ago. A preliminary analysis of the spectra show that the outer regions are underabundant in many elements, but that the knot has considerably higher abundances.

II. ABUNDANCE IN A78.

The spectra described here were taken with the IPCS on the 2.5m telescope at La Palma. A long slit (1" wide) was used which extended across the entire nebula in a NE to SW direction. It was intended that the slit be centered at the position measured by Jacoby and Ford (1983) i.e. midway between the central star and the visual companion located 10" to the NW. A photograph taken of the slit shows it to be about 2" to 3" further away

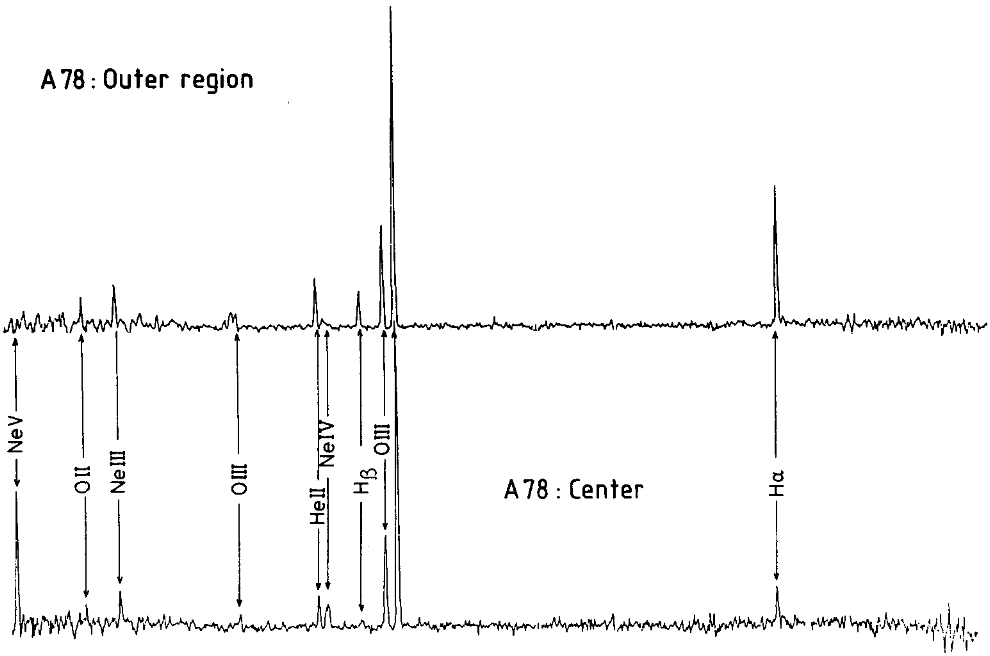

Fig. 1. The spectrum of A78. The above spectrum (a) shows a region 30" SW of the center in the outer nebula, while the lower spectrum (b) is a region near the center. Note the weakness of Hβ near the center.

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from the central star however. This is probably 1" to the north of the edge of the 3".2 aperture used by Jacoby and Ford. Thus we have not measured precisely the same region.

The reason for comparing the relative position of the two measurements so closely is that our spectrum is substantially different than that measured by Jacoby and Ford. We can see the Balmer lines clearly, as shown in Fig. 1b, while they could not, indicating that these lines were much weaker on their spectrum. Furthermore they report seeing the [N II] line at λ6584 Å which we see only weakly if at all. We both see the [Ne IV] line (two pairs the strongest of which is at λ4725 Å) in considerable strenth. This line is much weaker in most nebulae and it is very unusual to see it so strongly.

In Fig. 1a we show the spectrum of the nebula at a position far from the central star, in the somewhat brighter region about 30" SW of the center. As can be seen, the spectrum is much different at this outer position. The Balmer lines are much stronger here. Furthermore the strong [Ne V] line at λ3425 Å seen near the center has completely disappeared here. The [Ne IV] lines discussed above are also much weaker and they are now blended with, or perhaps replaced by, [Ar IV] lines which are usually stronger in most nebulae. The [O II] lines near λ3727 Å clearly seen in the outer regions.

To obtain an approximation to the abundances we have performed a preliminary calibration of the spectra. The electron density in both the central and outer region is low enough so that its precise value need not be known. The electron temperature is obtained from the [O III] lines. The resultant abundances are given in Table 1.

TABLE 1: CHEMICAL COMPOSITION A78 : $^X/H$

ELEMENT	OUTER REGION	CENTRAL REGIONS PRESENT	JACOBY FORD
HELIUM	0.21	1.2	> 6.0
OXYGEN	1×10^{-3}	1.4×10^{-2}	2×10^{-1}
NEON	2.5×10^{-4}	2.8×10^{-3}	1×10^{-1}

As can be seen from the table, there is a large abundance difference between the central position we have measured and that measured by Jacoby and Ford, which was to be expected because of the presence of the Balmer lines in our spectra. (It must be noted that we have used the measurements of Jacoby and Ford but not their derived abundances. This is because they correct for the missing ionization states in neon and oxygen (other than Ne^+ and O^{+2}) using the ratio of H^+ to He^{++} as a measure of the ionization of these elements. For neon however we have measured 3 ionization stages and can show that the traditional correction for missing ionization must be seriously in error.)

III. INFRARED EXCESS OF A30 AND A78.

Fig.2 is a plot of the total infrared flux emitted by almost 100 planetary nebulae vs. the 6cm. radio continuum emission of that nebula. A

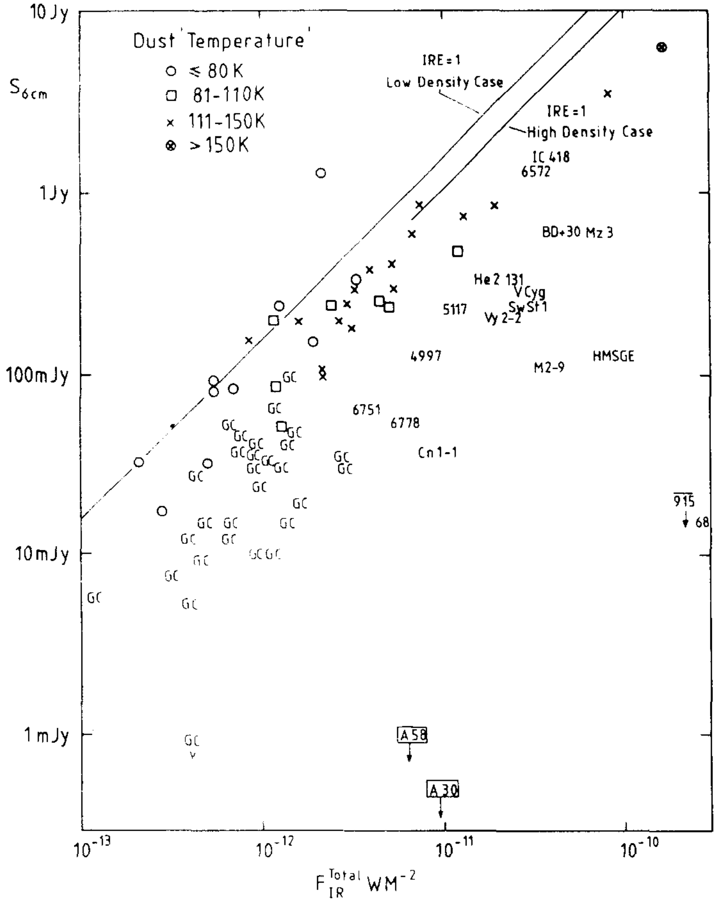

Fig. 2. The total infrared flux is plotted against the 6cm radio emission of many planetary and protoplanetary nebulae. Note the rather different positions of A30 and A58.

similar plot has been made and discussed by Pottasch et al. (1984). A30 is also plotted on the diagram using the IRAS far infrared measurements and an upper limit to the radio flux density as measured in Westerbork (Zijlstra, 1985). A78 is not plotted because its far infrared flux has never been measured (IRAS missed that part of the sky), but its position must be similar to A30. The upper limit to the radio flux densities is similar to A30 (Zijlstra, 1985) while the infrared flux shortward of 20 µm is also very similar (Cohen and Barlow, 1974). Thus the infrared radiation is at least two orders of magnitude higher than what normally would be expected from a nebula with such low radio continuum emission.

This difference cannot be due to an absence of hydrogen ions in the central regions, because helium ions will produce radio emission as well. But the reason for the discrepancy does not concern us here. What is important is that this property can be used in attempting to identify similar systems. A58 is one such system.

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IV. ABUNDANCES IN A58

The central object in this nebula was first known as V605 Aql and became visible in 1917, reaching a magnitude of about 10 in 1919 (Lundmark, 1921). It faded thereafter and was last observed in 1923. The nebula is in Abell's (1966) list and is clearly a symmetric planetary. The expansion velocity of the 44" x 33" nebula is less than 40 km s^{-1} (Kamaswara Rao, unpublished) and the nebulae must therefore have existed long before the outburst. At present there is a star-like object near the center, whose spectrum (see below) shows it to be a nebula. There is a very faint star about 1" north of the central nebula (Seiter, 1984) which may be what remains of V605 Aql. There is no other obvious candidate for the central star of this nebula. The faint star is probably not hot enough (see below) to ionize the nebula.

We have taken spectra of the outer nebula and the central knot with the 1.9 m telescope in S.Africa (2" x 6" slit) and La Palma (long slit 1" wide). Here only the results of the former observation are discussed. These spectra are shown in Fig. 3a (outer region of the nebula in the bright SW region) and Fig. 3b (central knot). Both spectra are clearly nebular emission of medium excitation, but they are quite different. Especially the oxygen lines, [O III] and also [O I] are considerably stronger in the central knot than in the outer nebula.

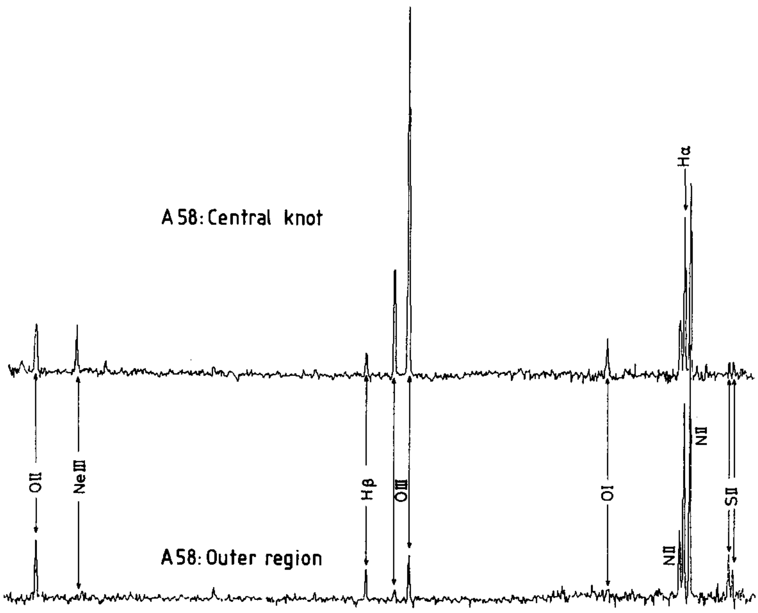

Fig. 3. (a) Spectrum of the central knot of A58 and (b) that of a bright patch in the outer nebula, Relative to Hβ, the O III and Ne III lines are extremely strong in the knot.

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A preliminary analysis of this data, which will be discussed in detail in a future paper, gives abundances shown in Table 2. It may be seen from the table that the abundances in the outer parts of the nebula

TABLE 2: ABUNDANCES IN A58

ELEMENT	OUTER REGION	CENTRAL KNOT
HELIUM	0.081	0.22
OXYGEN	6×10^{-5}	1.3×10^{-3}
NITROGEN	6×10^{-5}	4×10^{-5}
NEON	4×10^{-5}	5×10^{-4}

are slightly lower than solar, with oxygen even somewhat lower. In the central knot, however, the abundances are an order of magnitude higher. Since it is likely that the central knot was recently ejected, probably at the time of the 'outburst' in 1917, it seems that this is also a case of relatively hydrogen poor material being ejected late in the nebular evolution. The hydrogen poorness is not as extreme as in A78 and A30, however.

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DISCUSSION

HUNGER: As to the interpretation of your abundances, when you go for A78 from the central part to the outer part, then all the abundances are roughly increasing by a factor of 10. What is the implication of that?

POTTASCH: The abundances seem to be increasing from the more central parts, as Jacoby and Ford have measured, to the position a second or so of an arc away, that we have measured. The simplest interpretation is that this star is emitting increasingly hydrogen poor material as time goes on. This second of arc difference between the two positions means that the steep abundance gradient corresponds to a very short time scale for the change of composition of the ejected material. A second of arc corresponds to 100 yrs or few 100 yrs in time.

LIEBERT: Can you say anything about the relative masses of the outer nebulae and inner knots?

POTTASCH: I think Jacoby tried to do that. In A78 the mass within 10" of the exciting star is probably close to 10^{-3} M_o while the total mass is of the order of 10^{-1} M_o for the nebula. The knot in A58 probably has a relatively smaller mass because of its smaller size. Because both the density and the distance are poorly determined, these values should only be taken as indications.

FEAST: What would that mean to the bolometric luminosity?

POTTASCH: I would place it in the order of 3 x 10^3 L_o, with large uncertainties.

FEAST: Is it just possible that these central stars are evolving to R CrB stars? I mean their luminosities do not rule it out.

SCHÖNBERNER: I do not think so. The central star is evolving towards a white dwarf.

RAO: For Abell 58, the distance estimate by Ford is 3.5 kpc. From the reddening estimates, Van den Berg also gives about 4 kpc. I think after correcting for the reddening, the luminosity of the central star could be, when it was brightest around M_v = -5.

RAO: A30 has an IR disc around it. Is there such an evidence found for A58 and A78?

POTTASCH: Well it is not clear with A58 where the IR is coming from. IRAS observations have shown the strong infrared excess. There is no spatial information. I would not be surprised if the emitting region was much smaller than the nebula itself. A78 was not measured by IRAS. The indication in the near IR is that it is similar to A30 although these measurements have not been made in such detail. The IR may come from a region smaller than the total nebula.

MENDEZ: I want to know whether there is any evidence for expansion velocities in the central parts of A58.

POTTASCH: I do not think there is any direct measurement of A58, except for limits placed by the line width. I think, A58 does not look totally different from normal planetary nebulae, in the sense that the line width is certainly less than 40 kms^{-1}. A78 also does not have any radial velocity above normal for Planetary nebula.

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