PLANETARY NEBULAE: RECENT RESULTS

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RESUMEN. Se presenta una revisión somera de resultados de investigación recientes sobre nebulosas planetarias. Se hace hincapié en los siguientes resultados: a) las NP de Tipo I forman un grupo homogéneo con masas iniciales en el intervalo comprendido entre 2.4 y 8 $M_\odot$; b) se discuten observaciones recientes de NGC 2346, NGC 6302 y CRL 618 las cuales concuerdan con la hipótesis de la formación de NP de Tipo I basada en dos etapas de pérdida de masa cuando menos, con la última siendo confinada por un toroide producido por la anterior; c) las NP de Tipo I aparentemente son deficientes en O lo cual implica que casi todo su N es de origen secundario pero producido a partir del O y no del C; d) las NP de tipo IV, población de halo, presentan C recién hecho en sus envolventes, produciéndolo a una tasa dada por $1.5 < \Delta Y/\Delta X_{12} < 7$,por lo tanto a partir de ΔX_{12} no es posible determinar ΔY con precisión; e) las NP son responsables de la mayor parte de la producción de C en el medio interestelar de la vecindad solar.

ABSTRACT. A brief review of some recent results on planetary nebulae research is presented. The following results are stressed: a) Type I PN form a homogeneous group with initial masses in the 2.4 to 8 $M_\odot$ range; b) recent observations of NGC 2346, NGC 6302 and CRL 618 are discussed which are in agreement with the hypothesis of the production of Type I PN by at least two stages of mass loss, with the last one being confined by a toroid produced by the previous one; c) Type I PN seem to be O deficient which would imply that most of their excess N is of secondary origin, but produced from O and not from C; d) Type IV PN, halo population, present freshly made C in their envelopes, producing it at a rate $1.5 < \Delta Y/\Delta X_{12} < 7$, therefore from their excess C alone it is not possible to accurately determine their excess helium; e) PN are responsible for most of the C production present in the interstellar medium of the solar vicinity.

I. INTRODUCTION

In this review a brief account will be given of PN research related to chemical abundances. We will follow the classification by Peimbert (1978) which divided PN into four types: Type I (He-N rich), Type II (intermediate), Type III (high velocity) and Type IV (halo population). From a variety of arguments related to stellar dynamics and stellar evolution it seems that this scheme is not only a chemical composition classification but that it corresponds to progenitor stars of different masses in the main sequence, M_i, with the following approximate values in solar units: Type I (2.4-8), Type II (1.2-2.4), Type III (1-1.2), Type IV (0.8-1.0). Other reviews based on this classification and dedicated to different aspects are those by Peimbert (1981, 1984), by Peimbert and Torres-Peimbert (1983) and by Torres-Peimbert (1984).

In §II we will discuss recent results on PN of Type I that bear on the formation of these objects and on the mass of their progenitor stars in the main sequence. In §III we will compare the observed abundances of H, He, C, N and O with those predicted by stellar evolution theory. In §IV we will discuss the effect of PN enrichment on galactic chemical evolution.

II. TYPE I PN

a) *General Characteristics*

PN of Type I have been defined as those objects with N(He)/N(H) $\geqq$0.125 or log N/O $\geqq$ -0.3 (Peimbert 1978; Peimbert and Torres-Peimbert 1983). Most He and N rich PN are very filamentary and show a bipolar structure (Greig 1971; Peimbert and Torres-Peimbert 1983; Kaler 1983*a*) which has been given several names: B, bipolar, binebulous, biaxial, or hourglass. Moreover, in general their spectra present very strong forbidden lines ranging from [O I], [N I], and [S II] up to [Ne V].

Only a few central stars of Type I PN have been placed in the HR diagram, and in general their locations correspond to tracks of more massive cores than those of most PN nuclei (Kaler 1983*a*). Méndez and Niemela (1982) have classified PN central stars with WR spectra of the WC sequence and find that they fall into two distinct groups: those with spectra in the WC2-WC4 range and those with spectra in the WC8-WC10 range; of those objects classified in the first group NGC 5189, NGC 2452 and NGC 5315 are Type I PN (PTP 83) while NGC 7026 is of Type II (Kaler 1978, 1979); while those classified in the second group NGC 40 and BD+30°3639 are of Type II (Clegg *et al.* 1983, Torres-Peimbert and Peimbert 1977). Greig (1971) finds that almost all PN with WC spectra are of B type, and Heap (1982,1983*a*) concludes that central stars of PN with WC spectra may be among the most massive stars of the sample of central stars of PN studied with IUE. Peimbert and Serrano (1980) from the binary nature of NGC 2346 and NGC 3132 and the possibility that NGC 2818 belongs to the open cluster with the same name, have estimated that the lower mass limit to produce He-N rich PN is about 2.4 $M_\odot$. Greig (1972) based on the galactic kinematical properties of class B PN found that these objects have the most massive progenitors of all PN and that they are of Population I. Acker (1980,1983) from the study of He-N rich PN found that their spatial and kinematical parameters correspond to $M_i \sim 3\ M_\odot$.

b) *Formation*

It is thought that asymptotic giant branch (AGB) stars, lose their outer layers to form PN and to expose their nuclei which will be responsible for the ionization of the nebular envelopes. The low velocity of expansion of the nebular matter in PN led Shklowsky (1956) to suggest that the ejection took place while the parent star was a red giant, moreover on the basis of the luminosity of the central stars of PN Paczynski (1971) suggested that AGB stars undergoing double-shell burning are the immediate progenitors of PN.

PN envelopes are formed by stellar mass loss in the form of winds and at least three types of winds have been discussed in the literature (see Iben 1984 for a review): i) all single stars on the AGB of $M_i < 9\ M_\odot$ are thought to lose mass more or less continuously by an ordinary wind, ii) just after the AGB phase a hot wind is emitted that compresses the material previously ejected by the ordinary wind (Kwok, Purton, and Fitzgerald 1978; Kwok 1982, 1983), iii) the main ejection event is due to a superwind with a mass loss rate at least an order of magnitude larger than that of the ordinary wind (Renzini 1981, 1983). It seems that there are at least two different ways of producing PN: by mass ejection at a high rate (superwind) and by mass ejection at a lower rate (ordinary wind) followed by hot wind compression.

A substantial fraction of Type I PN show bipolar structures consisting of low density material with filaments, lobes, and ansae along the major axis and of higher density material along the minor axis. Several ideas have been proposed in the literature to explain this configuration. In what follows we will discuss four of them: i) two phases of wind ejection by a single star (Heap 1982; Calvet and Peimbert 1983), ii) two phases of wind ejection by a binary system (Morris 1981; Livio 1982; Renzini 1983), iii) stellar rotation and gravitational braking (Phillips and Reay 1977), and iv) bipolar ejection by a single star (Pişmiş 1974, 1979). The first two mechanisms need a thick toroid that acts as a focussing element for the stellar wind, as that included in the model of Cantó (1980), while the last two mechanisms do not require such a toroid.

Calvet and Peimbert (1983) note that main sequence stars with $M > 2.4\ M_\odot$ have high rotation velocities and that a large fraction of their angular momentum can be lost on the AGB phase by mass loss. A slow stellar wind with a preferential ejection along the equatorial plane creates an anisotropic circumstellar envelope in the form of a toroid. When the central star evolves to the PN nuclei stage a fast stellar wind is generated that interacts with the circumstellar envelope previously formed and that shapes a bipolar nebula along the axis of rotation.

A similar idea was developed by Heap (1982) to explain the bipolar morphology present in most PN with WC central stars, she notes that rotationally enhanced mass-loss has been discussed for a long time in connection with young WR stars and that observations of these objects indicate a concentration of the wind toward the equatorial plane (Rumpl 1980). If this mechanism plays a role in the central stars of PN, then rotationally-enhanced ejection would result in a nebula initially concentrated in a plane and the fast wind phase no longer rotationally dominated would enhance the asymmetry by pushing out most effectively the less dense polar regions (Mathews 1978).

Heap (1983*b*) has found that if angular momentum in red giants is conserved, and the core spins-up, then the outer edge of the core (the external parts of the PN central star) would rotate at 10 km s^{-1} if M_i = 1.5 $M_\odot$ and at 800 km s^{-1}if M_i = 3.5 $M_\odot$; this implies that rotationally enhanced ejection might play a role in PN with massive progenitors. Renzini (1984) has suggested that for objects with $M_i > 2$ $M_\odot$ the interaction of a nonaxial symmetric spinning core with the envelope could be so violent as to lead to the rapid ejection of the envelope itself. In this context Peimbert (1983*a*) has argued that if the core spins-up, for objects with M_i > 2-3 $M_\odot$ we should expect three phases in the mass loss process, the first one being more or less spherically symmetric, the second one with mass loss preferentially occurring along the equatorial plane, and the third one with confinement near the equator but not near the poles, owing to the presence of material ejected during the second phase. NGC 2440 shows evidence of these three phases; it has an outer spherical halo, very faint and smooth, a bright ring or disk near the center, and lobes or ansae, presumably produced by the confinement of the disk. The presence of multiple shell PN (e.g., Kaler 1974) also indicates the presence of several phases of mass loss.

Morris (1981) and Livio (1982) (see also Renzini 1983) have considered the possibility of forming bipolar nebulae by binary systems. Morris (1981) argues that the most attractive origin for a bipolar nebula is provided by a binary system in which the primary is evolving up the red giant branch to the point at which its radius approaches its tidal value; he has developed models which are consistent with the mass loss rate and terminal outflow velocities of observed bipolar nebulae. Alternatively Livio (1982) has discussed the following mechanism: as a result of mass transfer and expansion of the secondary a wide binary is transformed into a contact binary with a common envelope; a mass-loss instability at the outer Lagrangian point L_2 develops, via which, mass and angular momentum are lost at a high rate. This mechanism can produce a nebula on a time scale of $\sim 10^3$ years, with mass and expansion velocity characteristics that agree well with observations. The ejected matter should be concentrated toward the orbital plane at the time of ejection and as the nebula ages another less massive nebular component produced by the wind, and moving at a somewhat higher speed is expected in the direction of the orbital axis.

The two (or several) winds ejection models, either in the single star or in the binary system mode, will produce clumps and filaments by the Rayleigh-Taylor instability (Capriotti 1973; Kahn 1983) which is also a predominant feature in Type I PN.

Maybe both mechanisms, the single star and the close binary one, proposed to explain the morphology of Type I PN are in operation, but it has not been proven. There are several arguments that indicate that Type I PN form a homogeneous group that includes the most massive progenitors of PN (those with M_i > 2.4 $M_\odot$): i) the location of their central stars in the HR diagram, ii) their galactic distribution and kinematics, and iii) their He-N abundances (see §III). If the single star hypothesis to form bipolar objects is correct it naturally follows that the discontinuity in the angular momentum of main sequence stars around 2.4 $M_\odot$ is responsible for the morphological appearance of all PN; nevertheless specific models including the nature of the ejection and the stellar stage of evolution have to be made. Alternatively there are several aspects that have to be explored regarding the close binary hypothesis: i) to explain the galactic structure and kinematics of Type I PN the average masses of the primary stars would have to be $\sim$ 3 $M_\odot$, i.e., a reason has to be found for having most of the massive stars in close binary systems and producing PN, and for not having most of the less massive stars (those that produce PN of Types II, III and IV) in close binary systems; ii) stellar evolution models of such systems are needed to compare the predicted abundances to the observed ones.

Phillips and Reay (1977) have investigated the structural development of nebular shells ejected from rotating stars where the principal mechanism determining shell development is gravitational braking, these models can produce bipolar nebulae and could be used as the first stage of mass ejection which would be followed by another stage in which the star is losing mass in a more or less isotropic fashion.

Pişmiş (1974, 1979) has proposed that the bipolar nature of the H II regions NGC 6164-5, NGC 2359 and M1-67 was produced by ejection from the ends of a diameter of the central star, where the agent funneling the ejecta is a dipolar magnetic field along the direction of ejection. Models of this type may explain nebulosity along a major axis of Type I PN but not the toroid along the minor axis.

c) *Individual Objects*

Roth *et al.* (1984) present evidence that indicates that the central star of NGC 2346 and a small circumstellar cloud of warm dust may be eclipsed by a condensation of cold dust which could be a fragment of a toroid orbiting parallel to the minor axis of the PN; these observations support the two stage model of mass loss for NGC 2346 by Calvet and Peimbert (1983).

An explanation for the bipolarity of the Type I PN NGC 6302 in terms of the model by Cantó (1980) has been given by Meaburn and Walsh (1980) and Barral *et al.* (1982). These authors required the presence of a dense thick disk to produce the observed morphology. Rodríguez and Moran (1982) detected neutral hydrogen in absorption in the direction of the center of NGC 6302 from VLA observations at an angular resolution $\sim 10'' \times 20''$. They interpret the -40 km s^{-1} component as coming from a ring with an expansion velocity of about 10 km s^{-1}. The mass in atomic hydrogen of the ring is $\sim 0.06\ M_{\odot}$. Recent observations with the VLA and a resolution of $\sim 3'' \times 14''$ confirm the previous results (Rodríguez *et al.* 1984). Lester and Dinerstein (1984) from broad band infrared observations at 1.25, 2.2, 3.4 and 10 μm find evidence for a disk of material with its long axis oriented perpendicular to the bipolar flow. They interpret this result as an expanded fossil toroid that once confined the flow or as stellar envelope material that was not in the path of the bipolar flow.

Calvet and Peimbert (1983) found that the protoplanetary nebula CRL 618 is N rich and therefore a PN of Type I. From observations of the kinematics of H_2 Persson *et al.* (1983) conclude that the stellar wind probably forms the H_2 clumps at the inner boundary of the dust toroid in CRL 618, and carries them into the lobes, which supports the colliding wind model of Kwok (1982) for the early evolution of PN. Similarly Beckwith *et al.* (1984) argue that the H_2 emission is excited in shock waves produced in the lobes of the visible nebula by fast winds from the central star which overtake slower moving material lost in a slow wind during the red giant phase. Kwok and Bignell (1984) from VLA observations of CRL 618 suggest that it is a proto-PN whose rotating red-giant progenitor had been ejecting wind material predominantly in the equatorial plane; they conclude that consistent with the model of Calvet and Peimbert (1983) for bipolar PN, CRL 618 is likely to have descended from a high mass progenitor with $M_i \sim 3\ M_{\odot}$ and that the present mass of its central star is $\sim 0.8\ M_{\odot}$.

III. OBSERVED ABUNDANCES AND STELLAR EVOLUTION PREDICTIONS

Renzini and Voli (1981), have computed the evolution of the surface abundances of He, C, N and O for intermediate mass stars, IMS, i.e., those stars developing a degenerate carbon-oxygen core and experiencing helium shell flashes during their AGB phase, considering the three dredge-up processes and the envelope burning process, but not mixing processes which may be induced by rotationally-driven instabilities (see also: Iben and Truran 1978; Becker and Iben 1979, 1980; Iben and Renzini 1983; Renzini 1984). The computations by Renzini and Voli (1981) have been made considering two parameters: $\alpha = \ell/H$, the ratio of the mixing length to the pressure scale height, and η which multiplied by the Reimers' rate (1975) gives the mass loss rate during the AGB phase; the computations were made for $\eta = 1/3$ and 2/3 and $\alpha = 0$, 1, 1.5 and 2, with most of them for $\eta = 1/3$ and $\alpha = 0$ and 1.5. It has been estimated semiempirically that η is in the 1/3 to 3 range and that for stars with $M_i < 2\ M_{\odot}$ it is in the 1/3 to 1/2 range (e.g., Renzini 1984; Iben 1984, and references therein). The values of α and η are not well known and they may vary with stellar evolution stage, initial stellar mass and chemical composition. Values of α and η can be determined by comparing the stellar evolution predictions with observed abundances in AGB stars and PN, as well as with observed abundances in the interstellar medium that depend on models of galactic chemical evolution. Aller (1983), Kaler (1983), Peimbert (1981, 1984) and Torres-Peimbert (1984) have compared these predictions with observations of galactic and Magellanic Clouds PN. In what follows we will review the main aspects of these comparisons.

a) Type I PN

The observed range of He/H values in Type I PN is well accounted for by the theory and implies that these objects have progenitors with $M_i > 3\ M_\odot$. This result is in agreement with the other criteria that indicate that Type I PN have the most massive progenitors. For PN with good abundance determinations the He/H and C/O observed values are in fair agreement with predictions for $0<\alpha<2$ and $\eta = 1/3$ in the 3-5 $M_i/M_\odot$ range; with the exception of NGC 6302 and N97 that can be matched with models for $\alpha \sim 2$, $\eta = 1/3$ and $M_i \sim 8\ M_\odot$, which makes them the two well observed PN with the highest M_i values known.

There is a well established positive correlation between the He/H and N/O ratios. This correlation implies that for $\eta = 1/3$, α diminishes from 2 to 1 as M_i increases from ~ 3 to $\sim 6\ M_\odot$. It is also possible to explain the He/H versus N/O correlation with $\alpha \sim 2$ and η increasing with M_i. We prefer the second explanation as will be argued in §IV. At a given M_i, an increase of η decreases the primary and secondary production of N.

There is an anticorrelation between the O/H and the N/O observed ratios that seems to be real. The observed O/H ratio has been derived from the O^+ and O^{++} ions, in order to correct for the higher stages of ionization, the following approximation has been used

$$\frac{N(O)}{N(H)} = i_{cf}(O)\,\frac{N(O^+)+N(O^{++})}{N(H^+)} = \frac{N(He^+)+N(He^{++})}{N(He^+)}\;\frac{N(O^+)+N(O^{++})}{N(H^+)} . \qquad (1)$$

Even if there is a systematic increase of the ionization correction factor of O, $i_{cf}(O)$, with N/O, which implies that in general the higher the N/O value the hotter the central star, we consider that equation (1) is valid under very different conditions; it holds for PN of high degree of ionization (see the models for NGC 3918 by Torres-Peimbert *et al.* 1981, and the models for NGC 7662 by Harrington *et al.* 1982), for power law spectra (Stasinska 1984; Kallman and Mc Cray 1982), and even for very hard spectra producing X-rays such as a 10 keV bremsstrahlung and a 4 keV blackbody where the Auger effect has been taken into account (Kallman and Mc Cray 1982).

The O/H versus N/O anticorrelation cannot be explained by the available models. The O depletion reaches factors of 2 to 3 while the most favorable theoretical models produce depletions of a factor of 1/3 (Renzini and Voli 1981; Renzini 1984). The O depletion increases with α and the highest depletion is obtained for the model with $\alpha = 2$, $\eta = 1/3$, case A, Y = 0.28, Z = 0.02. For this particular model in the 6 to 8 $M_\odot$ range about 80% of the excess N is of primary origin, and about 20% of secondary origin; of the N of secondary origin about one half comes from C and one half from N. In this framework it is possible to increase the O depletion by increasing α and to reduce the N overproduction by increasing η; the net effect would be to increase the N secondary production and to reduce the N primary production. That is, the O/H versus N/O anticorrelation implies that most of the N is of secondary origin but that it comes from O and not from C. This result is very important for metal-poor galaxies where the C/O ratio is considerably smaller than in the solar vicinity (see §IV).

b) Type II PN

The observed range of He/H values in Type II PN is well accounted for by theory and implies that those objects have progenitors of $M_i < 3\ M_\odot$.

From the average C/H values it is possible to predict the average M_i value, which turns out to be somewhat higher than the average value derived from their galactic distribution. This result indicates that the third dredge-up phase is more efficient for low mass stars than predicted by Renzini and Voli (1981); recent theoretical developments indicate that this is the case (i.e., Iben and Renzini 1983), therefore the C/H and He/H predictions by Renzini and Voli (1981) for objects with $M_i < 2.5\ M_\odot$ should be used with caution (Renzini 1983).

There are well established positive correlations between the He/H and N/O ratios and the O/H and N/O ratios. These correlations are in agreement with a secondary production of N and with different initial He, C and N abundances produced by galactic chemical evolution and galactic abundance gradients.

c) *Type IV PN*

There are four well established halo PN that have been extensively studied, the following average abundance values have been derived for them: N(He)/N(H) = 0.099, N(C)/N(O) = 10 and N(O)/N(H) = 10^{-4}; while their S/H and Ar/H values are about two orders of magnitude smaller than the Orion nebula and the sun. The very small S/H and Ar/H values imply that these objects were formed with almost no C and consequently their very large C/O values indicate that C is freshly made; there is no explanation for this result because, according to present theory, stars with $M_i \sim 0.8 - 0.85\ M_\odot$ should lose their envelope before experiencing the third dredge-up. If the excess C comes from the convective helium shell, some computations for the third dredge-up indicate that $\Delta Y^3/\Delta X_{12} \sim 3$ where ΔY^3 and ΔX_{12} are the excess He and the excess C, by mass, produced by the third dredge-up; this prediction is in excellent agreement with observations of the hydrogen-poor regions of the PN A30 where it is found that $Y/X_{12} = 3.3 \pm 1.1$ (Peimbert 1983*b*). Peimbert (1983*b*) has obtained the pregalactic helium abundance, Yp, by measuring the excess X_{12} in Type IV PN and by assuming that the helium made by the third dredge-up is given by $\Delta Y^3 = 3.3\ \Delta X_{12}$. The dispersion in the Yp values apparently indicates that the $\Delta Y^3/\Delta X_{12}$ ratio is not the same for all PN (see also Adams *et al.* 1984).

It is possible to invert the problem and to assume the Yp value derived from H II regions in the Magellanic Clouds, Yp = 0.228 (Peimbert and Torres-Peimbert 1976) and to determine $\Delta Y^3/\Delta X_{12}$; the ratios derived lie in the 1.5 to 7.4 range. This range should be explained by future models of stellar evolution.

IV. GALACTIC CHEMICAL EVOLUTION

Recent discussions on the effect that PN have on the chemical evolution of galaxies are those by Tinsley (1978), Serrano (1983), Serrano and Peimbert (1983), Peimbert (1984) and Renzini (1984). The main interstellar medium abundances affected by PN enrichment are those of He, C and N. We will just briefly review two very strong constraints for galactic chemical evolution models provided by observations of H II regions: the C/O abundance ratio in the Small Magellanic Cloud, SMC, and the N/O versus O/H diagram made from galactic and extragalactic H II regions.

In the solar vicinity, SV, $C/O \sim 0.6 \pm 0.1$ (e.g., Peimbert 1984, and references therein). Dufour *et al.* (1982) have found that for H II regions in the SMC C/O = 0.13±0.03. Under the assumption that the initial mass function, IMF, is the same in the SV and in the SMC, the C/O difference can only be explained as an age effect in the sense that the stellar population in the SMC is younger on the average than that of the SV and that most of the C enrichment is due to stars with $M_i < 2\ M_\odot$. If the IMF for the SMC and the SV is the same then stars of the SV with $M_i > 10\ M_\odot$ produce at most a C/O value of 0.13 and consequently most of the C production in the SV is due to intermediate mass stars.

Serrano and Peimbert (1981) from chemical evolution models of the SV, where O is produced only by stars with $M_i \geq 10\ M_\odot$, obtain that the C produced by stars with $M_i \geq 10\ M_\odot$ amounts to a C/O value of 0.25, while the C produced by stars with $1 \leq M_i/M_\odot \leq 8$ amounts to a C/O value of 0.28. To reduce the C production by IMS and obtain agreement with the SV value Serrano and Peimbert (1981) find that models with $\eta = 1/3$ and $\alpha \geq 2$ are needed.

Renzini (1984) argues that the same result can be obtained by increasing η and reducing α. The O/H versus N/O anticorrelation can only be explained by increasing α since the O depletion is not sensitive to η. Therefore from the previous argument we still conclude that $\alpha \geq 2$. We also note that the mass loss rate increases with luminosity and that for $M_i > 2\ M_\odot$, η could very well be larger than 1/3 (e.g., Kwok 1983); moreover to explain the N/O versus He/H diagram in Type I PN η has to increase also with M_i (see §III).

Type I PN in the Magellanic Clouds also show O depletions (Peimbert 1984), this fact, coupled with the very low C/O ratios for H II regions in the Magellanic Clouds, also indicates that $\alpha \geqq 2$ for stars in these galaxies.

Serrano and Peimbert (1983) were able to explain the N/O versus O/H diagram for galactic and extragalactic H II regions with galactic chemical evolution models that included the following ingredients: i) a yield increasing with metallicity, ii) a different value for each object of γ, the ratio of accretion rate to star formation rate, with $0 \leqq \gamma \leqq 1$ for each object, iii) a N production by IMS mostly of secondary nature. Several authors have considered the possibility that in O-poor galaxies most of the N is of primary nature and that, as the O/H ratio increases, the ratio of secondary to primary N also increases; thus that in O rich galaxies most of the N is of secondary nature (Dufour *et al.* 1982; Dufour 1984; Renzini 1984). The very low C/O value in the SMC seems to support this idea; nevertheless, if the O depletion in Type I PN of our galaxy and of the Magellanic Clouds is real, most of the N could be of secondary origin but produced by O instead of C.

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DISCUSION

Pastoriza: ¿El mecanismo de producción de N a partir del O explicaría los gradientes de O y N observados en galaxias espirales?
Peimbert: Los modelos de Serrano y Peimbert (1983) explican los gradientes de O y N bajo la hipótesis de que la mayor parte del N es de origen secundario (ya sea a partir de C o de O); los modelos no consideran la destrucción del O por mecanismos secundarios, sin embargo este efecto sería importante únicamente en aquellas regiones del medio interestelar donde N/O ≧ 1/3.
Bruzual: ¿Coincide el número observado de NP de Tipo I con el número esperado de acuerdo a la función inicial de masa?
Peimbert: Es muy difícil comparar estos dos números debido a las incertidumbres en los factores que intervienen en su derivación. El tiempo que permanecevisible una NP depende del tiempo de evolución de la estrella central por la parte relevante del diagrama HR (a mayor masa más rápida es su evolución) y del tiempo característico de recombinación de los átomos de la nebulosa, en ausencia de la estrella ionizante, que es del orden de $10^5/N_e$ años. Para las NP de Tipo I el tiempo de recombinación es más largo que el de evolución y permite que la nebulosa sea visible aunque la estrella central ya no sea capaz de mantenerla ionizada. Tylenda (pretiro 1983) estima que en las partes externas de NGC 2440, NGC 6445 y otras NP de Tipo I los fotones ionizantes provienen de la nebulosa y ya no de la estrella central. Por otro lado el porcentaje observado de NP de Tipo I en la vecindad solar y en las nubes de Magallanes está comprendido entre el 10 y el 20%. Tomando en cuenta estos y otros factores yo diría que no hay contradicccción entre ambos números pero que podrían diferir hasta por un factor de tres.
Niemela: ¿Qué tipo de planetarias son las que tienen estrellas WR como estrellas centrales?
Peimbert: Las WC tempranas corresponden a NP de Tipo I y las WC tardías a NP de Tipo II. También hay algunas WN como estrellas centrales y corresponden a NP de Tipo II.
Niemela: ¿Hay un límite muy preciso entre nebulosas planetarias y nebulosas de anillo?
Peimbert: Considero que hay dos diferencias muy marcadas entre ambos tipos: a) la luminosidad de las estrellas centrales de las nebulosas de anillo es de diez a cien veces mayor que la de las estrellas centrales más brillantes de las NP, b) la masa de la envolvente ionizada es como un orden de magnitud mayor en el caso de las nebulosas de anillo que en el de las NP.
Blanco: ¿Cree usted que exista una masa mínima para la producción de NP?
Peimbert: Las cuatro NP de halo tuvieron progenitoras en el intervalo de masas entre 0.8 y 0.9 $M_\odot$, sin embargo aparentemente muy pocas estrellas con masas menores a una masa solar pasaron por la etapa de NP, tal vez las cuatro NP de halo cumplan ciertas condiciones especiales que no cumplen otras estrellas y consecuentemente la masa mínima sea del orden de una masa solar.
Blanco: ¿Ve usted alguna conexión entre las estrellas que producen NP y las estrellas de carbono?
Peimbert: Veo una conexión y un problema. Las 4 NP de Tipo IV presentan un exceso en C/O lo cual aparentemente concuerda con el alto cociente de estrellas de carbono a estrellas gigantes M encontrado por usted y sus colaboradores en la nube menor de Magallanes y tal vez indican que el tercer dragado ocurre en estrellas de baja masa si la metalicidad es muy baja. El problema que veo es que el cociente de C/O en el medio interestelar de la nube menor de Magallanes es mucho menor que en nuestra galaxia o sea que las estrellas de carbono de la nube menor de Magallanes no están enriqueciendo apreciablemente el medio interestelar con carbono.
Méndez: ¿Hay alguna estimación de la densidad de polvo en el disco de

NGC 6302?
Rodríguez: Resultados preliminares, obtenidos en San Pedro Mártir Baja California, indican que el lóbulo occidental muestra una absorción en el visual, A_V, aproximadamente 0.7 mag mayor que la del lóbulo oriental, si se supone que la diferencia de absorción se debe al disco se podría hacer una estimación de la densidad de polvo.
Pöppel: ¿Qué se sabe sobre la presencia de moléculas en NGC 6302?
Rodríguez: La línea S(1) $\nu = 1 \rightarrow 0$ de H_2 ha sido observada en emisión por Phillips, Reay y White (1983, *M.N.R.A.S.*, 203, 977), e indica la presencia de ondas de choque en material neutro cercano al centro de NGC 6302.

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