
Symmetry and Asymmetry in "born again" Planetary Nebulae

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Summary. While in the past spheroidicity was assumed, and still is used in modeling of most nebulae, we know now that only a small number of planetary nebulae (PNe) are really spherical or at least nearly round. Round planetary nebulae are the minority of objects. In case of those objects that underwent a very late helium flash (called VLTP or "born-again" PNe) it seems to be different. The first, hydrogen rich PN, is more or less round. The ejecta from the VLTP event is extremely asymmetrically. Angular momentum is mostly assumed to be the main reason for the asymmetry in PNe. Thus we have to find processes either changing their behavior within a few hundred to a few thousands of years or change their properties dramatically due to the variation of the abundance. They most likely have a strong link or dependency with the abundance of the ejecta.

Key words: ISM: planetary nebulae, late helium flash

1 The "Family"

Up to now it is under discussion, which objects are member of the "family". Hydrogen poor ejecta and knots are known in several PNe. Only a few of those have a clear signature of a VLTP event like it is described for the first time in [10]. Hot PG 1159 white dwarfs (so called after the prototype PG 1159-035 who has no surrounding PN) are also thought to be "remnants" of this kind of event. But less than half of them has a PN - although most of them are hot and luminous enough to be still in the evolutionary stage predicting one. Most of those having a PN ([6] list 65 hydrogen poor central stars of PNe) do not show (prominent) hydrogen poor ejecta (e.g. the hottest known star of that class - RXJ2117.1+3412 [4]). Thus, selecting only those having a hydrogen rich "normal" PN and prominent hydrogen poor ejecta in the core - and if it is observable - a hydrogen poor central star (CSPN), the family

contains the following objects (galactic positions according to [14]) . They are sorted by the age of the VLTP event.

1.1 A30 (GPN G208.55+33.28)

This object is most likely the oldest and best studied member of the family. After [11] and [12] discovered the unusual abundance of the central knots, a wide variety of wavelengths were used to derive physical properties. It shows all features of a "born-again" PNe

- A hydrogen poor central star with prominent C and O wind emission lines and unusual wind properties ([13], [24]).
- Fast moving hydrogen poor knots in a normal old PN ([12], [20]).
- Unusual hot small carbonous dust grains near the core in a ring/belt like structure ([2], [3])

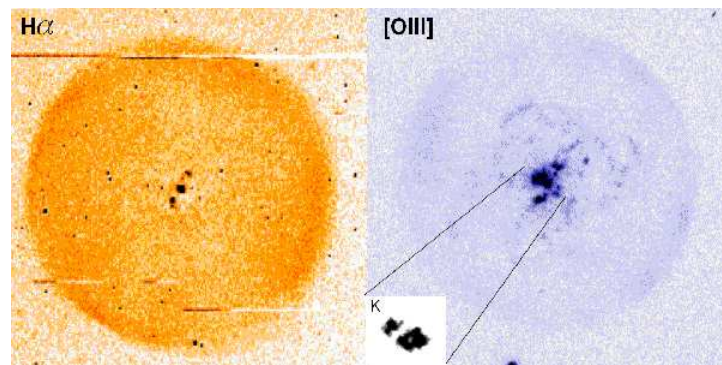


Fig. 1. Abell 30: The $H\alpha$ image from [1] and the [OIII] image from the ING archive show the perfect shape of the hydrogen rich old PN and the clumpy ejecta. The insert shows the K band image from [15]. It pronounces a "belt" of hot dusty material perpendicular to the main axis defined by the VLTP ejecta.

It is more or less the "prototype" for the class. The old nebula is the "perfect" example of a round PN. As A30 is high above the galactic plane, shaping by pressure equilibrium with the ISM can't be the prominent mechanism for the perfect geometry here.

1.2 A78 (GPN G081.29-14.91)

This old nebula seems to be shaped like a barrel, inclined to the line of sight. But this view is enhanced by an excitation effect. [OIII] is more prominent at the poles - there more UV radiation leaks through the ringlike structure of the inner VLTP material. As [16] show in their ISO study it has, similar to A30, a "belt" of dusty material perpendicular to the main direction of the fast ejecta. Outside an inner knotty bipolar ejecta a wide clumpy ring nearly leaving the area of the old PN is obvious. Thus also here the old nebula is by far more spherical than the newly formed VLTP material.

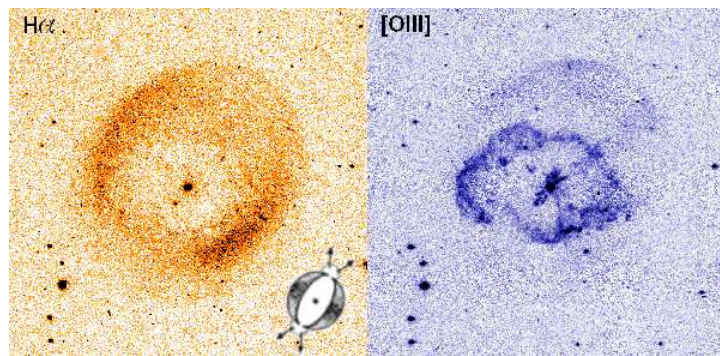


Fig. 2. Abell 78: The $H\alpha$ image at left (Calar Alto) show a barrel type structure (like that shown in the sketch by [1]). The $[OIII]$ image at right shows the clumpy ejecta.

1.3 IRAS 15154-5258 (GPN G324.08+03.53)

Both the old nebula (diameter $32''$) as well as the newly formed ejecta ($7''$) are perfectly circular (using only the outer boundary for classification). But the inner

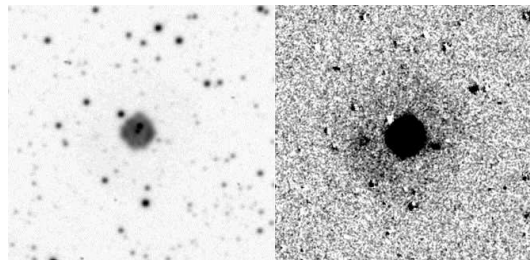


Fig. 3. IRAS 15154-5258: The 1991 $[OIII]$ image from the ESO archive show the hydrogen poor nebula ($7''$) and the very faint older smooth round nebula ($32''$).

nebula shows many radial structures. Additionally in the HST image taken with filter F656N it has a well pronounced bipolarity with two, possibly jet like, extensions along the axis. Although this filter is centered at $H\alpha$ the spectrum by [17] (it was integrated over $27''$ thus both nebulae and still $[NII]$ is more prominent than $H\alpha$) shows that a major fraction of the radiation most likely originates from the $[NII]$ lines (still waiting for verification). An expansion velocity is not known for this object. Nearly perpendicular to the optical "symmetry" axis the MSX C, D & E Band sources are extended and thus mark a possible dust belt. But the detections are near the limit.

1.4 CK Vul (NOVA Vul 1670)

CK Vul is discussed controversially. The images by [18] and [7] show the unusual structure of this object. While the light curve of the 1670 eruption and the recent

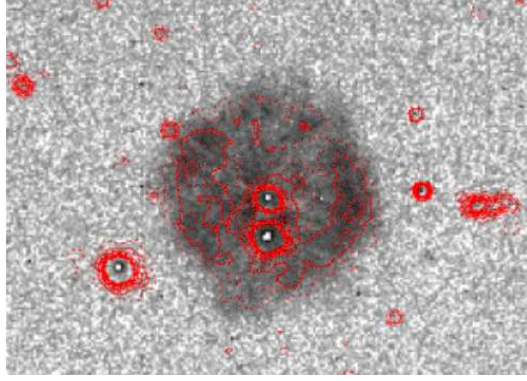


Fig. 4. IRAS 15154-5258: The HST images (lower: grey scale = [OIII], contours = [NII]+H α) show clumpy ejecta and even a jet like structure in the same direction like the main "symmetry" of the inner contours.

studies of the knots 4 and 5 in the ejecta by [7] fit well to a VLTP scenario, the low luminosity of the re-ionized core found in their radio observations does not match at all. The object consists of a large nebula shaped like an eight and fast moving hydrogen poor knots. The proper motion (derived from narrow band images taken 1991 and 2004) show no change at the main structure (slow moving ?) while the knots clearly originate from the 1670 event and point exactly towards the newly found obscured radio source. If it belongs to the "family" of VLTP objects it is clearly that one nearest to the galactic plane and with a highly asymmetric first PN. It is also outstanding with respect to the fact, that the hydrogen poor knots already are at the boundary of the other nebulosity. This would imply a very small, and thus very young, first PN - but then a VLTP should not occur ([9]).

1.5 A58 (GPN G037.60-05.16) & its central star V605 Aql

A 58 was discovered, after it was related to a thermal pulse scenario already by [23], to have a hydrogen poor central knot by [21]. [19] obtained high resolution spectra of the central region. As we know now from HST imaging the "standard" slit position E-W wasn't perfect to disemblem the asymmetry. On the other hand they had a very wide slit (2"). They derived, without knowing the orientation of the central knots, spectra from K1 (see figure 6).

During an 2003 ESO NTT run KS obtained medium resolution spectra positioned along and perpendicular to the directions known now. This shows that the knots K1 and K2 are most likely not symmetrically around the central source. As both are blueshifted they are coming towards us and only K3 is a wing of straylight material coming from the redshifted side around a highly obscured dusty central region. Assuming such a geometry, a suspected center is $0''.8$ ($\Delta\alpha = -0''.72$; $\Delta\delta = -0''.34$) from the gaussian center defined by the emission of the (bright) knots.

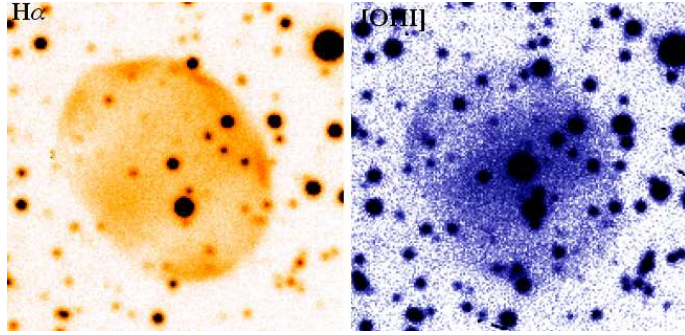


Fig. 5. A58: The old nebula again is very roundish with some weak ISM interaction at one side. The slightly enhanced elongated inner [OIII] part is orientated along the axis through K1, K2 and the suspected center (see figure below).

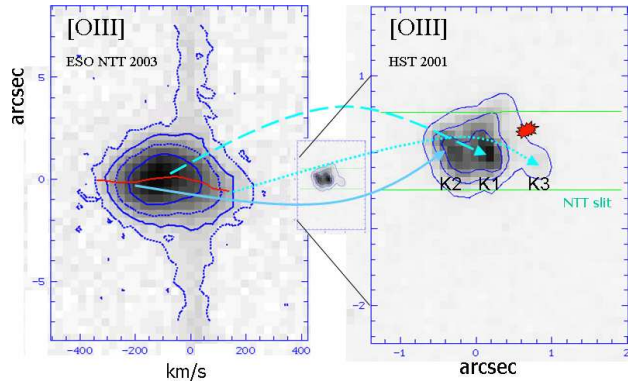


Fig. 6. V605 Aql: The NTT spectrum (left) and the HST image right. The small insert gives the HST image at the same spatial scale like the spectrum for comparison. The suspected center lies just above K3.

The coordinates of the Gaussian (dominated by the flux of K1 & K2) centered on the knots on the HST images, re-calibrated with UCAC2 sources, and those of the expected real center are:

[NII] & [OIII] knots	suspected center
$\alpha_{\text{ICRS2000}} = 19^{\text{h}}18^{\text{m}}20^{\text{s}}.55$	$\alpha_{\text{ICRS2000}} = 19^{\text{h}}18^{\text{m}}20^{\text{s}}.50$
$\delta_{\text{ICRS2000}} = +1^{\circ}46'59''.25$	$\delta_{\text{ICRS2000}} = +1^{\circ}46'58''.92$

1.6 GPN G010.47+04.41 & its central star V4334 Sgr (\equiv Sakurai)

The old PN around V4334 Sgr is clearly a round PN with a halo. Its morphology shows striking similarities to classical halo PNe like NGC 2438. Such PNe are typically near the turnaround of the evolution in the T vs. L diagram at maximum temperature and near maximum luminosity. This is a little bit too early in the evolutionary tracks for VLTP events.

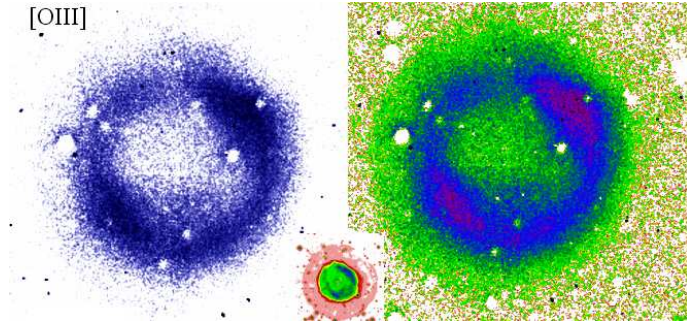


Fig. 7. Sakurai: The old round nebula is a halo PN like NGC 2438 (small insert).

The recent observations of onset of photo-ionization is presented in detail in the contribution by P+H in this issue. The newly formed core is too young to be resolved yet. The asymmetry of the radio core stated by [8] was not confirmed by recent VLTI observations ([22]). We know from optical observations that the central star is highly obscured by dust (see Fig. 8). But ratio of the forward and backward clumps in the [NII] lines of the newly formed core do not show such an extreme ratio. This can be caused by clumps along an inclined axis only - similar to the situation in V605 Aql.

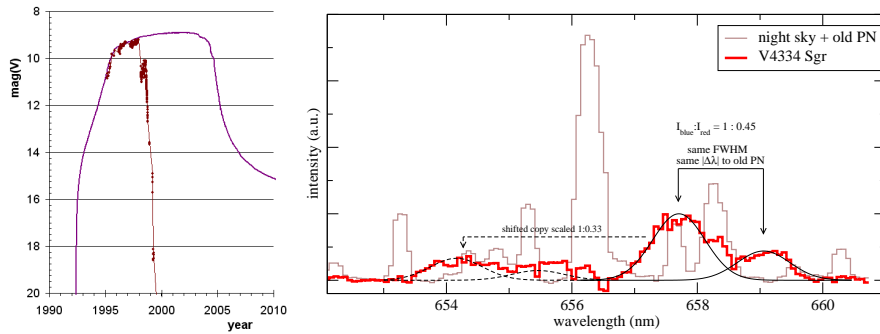


Fig. 8. V4334 Sgr: The photometry (left) of the born-again core. The data points superimposed to the prediction by the evolutionary track my [9] shows an obscuration by a factor of $\gg 10^4$ when the re-ionization started. The spectrum of the core (ESO VLT FORS) shows an obscuration of the knots on the far (red) side by only a factor of 2. The subtracted sky+old PN is indicated to show the problem of identification of a (possible) Hydrogen or Helium component in these spectra.

2 The Imagination

Commonly it is believed that asymmetry has its origin in transfer of angular momentum. The two events - the first regular PN and the VLTP ejecta are following each other in a few thousand to ten thousand years only. A binary system or even

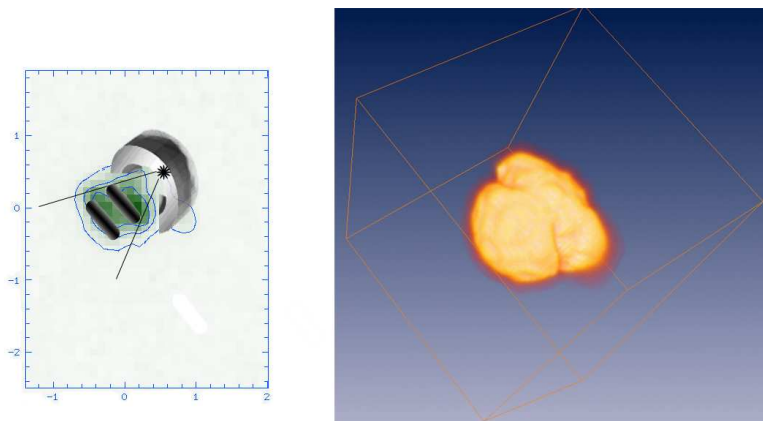


Fig. 9. A sketch of the born again core superimposed on the A58/V605 Aql image (left) and the result of a hydrodynamic simulation with a massive thick wind from a slowly rotating star.

orbits of massive planets do not change significantly during these phases. We are searching for a mechanism that **increases** its efficiency significantly from the one to the other event. As there is no obvious mechanism changing orbits, we have to think about mechanisms related to abundances. The efficiency forming dust and thus a dusty torus increases dramatically due to the carbon rich nature after the VLTP. We believe, that there lies the key difference. It has to happen near or at the surface of the central star. As shown by [5], the change of effective gravity as given by

$$\alpha = 1 - \frac{\omega^2 R_*^3}{GM_*}$$

changes the mass loss around the equator. In case of a carbonous chemistry the dust formation grows extraordinarily and builds a waist belt - especially during the AGB like phase just after the VLTP event. As shown by Icke (this volume) such a dusty belt leads to colliding counter-shocks of the later incipient thin hot wind forming a jet-like structure. The first model calculations look promising - a slowly rotating star builds such a structure in case of this special kind of wind.

On the other hand we do not see an obvious reason, why the number of round PNe (for the original first mass loss) dominates in case of the VLTP objects. One only can speculate; VLTP events, like those observed here, occur only in slow or non rotating stars ?

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