

The planetary nebulae of PG 1159 stars – clues to their evolutionary history

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Abstract. It is shown that many planetary nebulae (PN) surrounding PG 1159 stars display a bipolar morphology. The frequency of these nebulae is higher than observed in other PN samples. Implications for the evolutionary history of the PG 1159 stars are discussed. Judged from our present day knowledge of PN formation it is likely that many PG 1159 stars are the result of some sort of binary evolution.

1. Introduction

The spectroscopic class of PG 1159 stars consists of very hot hydrogen-deficient stars just entering the white dwarf cooling sequence. Recent analysis yielded temperatures and gravities which are for most stars in agreement with a post-AGB status (see Dreizler et al. 1995 for a review). However, their virtually hydrogen-free surfaces cannot be explained by standard stellar evolution theory, which predicts that always a hydrogen-rich envelope remains. Two basic scenarios are discussed which can potentially explain the formation of PG 1159 stars. One is the so-called born again scenario in which a post-AGB star suffers from a late helium shell flash (Schönberner 1983). The star returns to the AGB and the hydrogen shell can eventually be removed (Iben 1984; Iben & MacDonald 1995). On the other hand the hydrogen might be stripped off by a binary interaction during the AGB phase of these stars. About half of the PG 1159 stars known today possess a PN. We will take a look at their morphologies and discuss which conclusions about the formation of PG 1159 stars can be drawn.

2. The planetary nebulae

PNe can be classified according to their morphological appearance. Two classes are relevant for our discussion here: the elliptical (including spherical nebulae)

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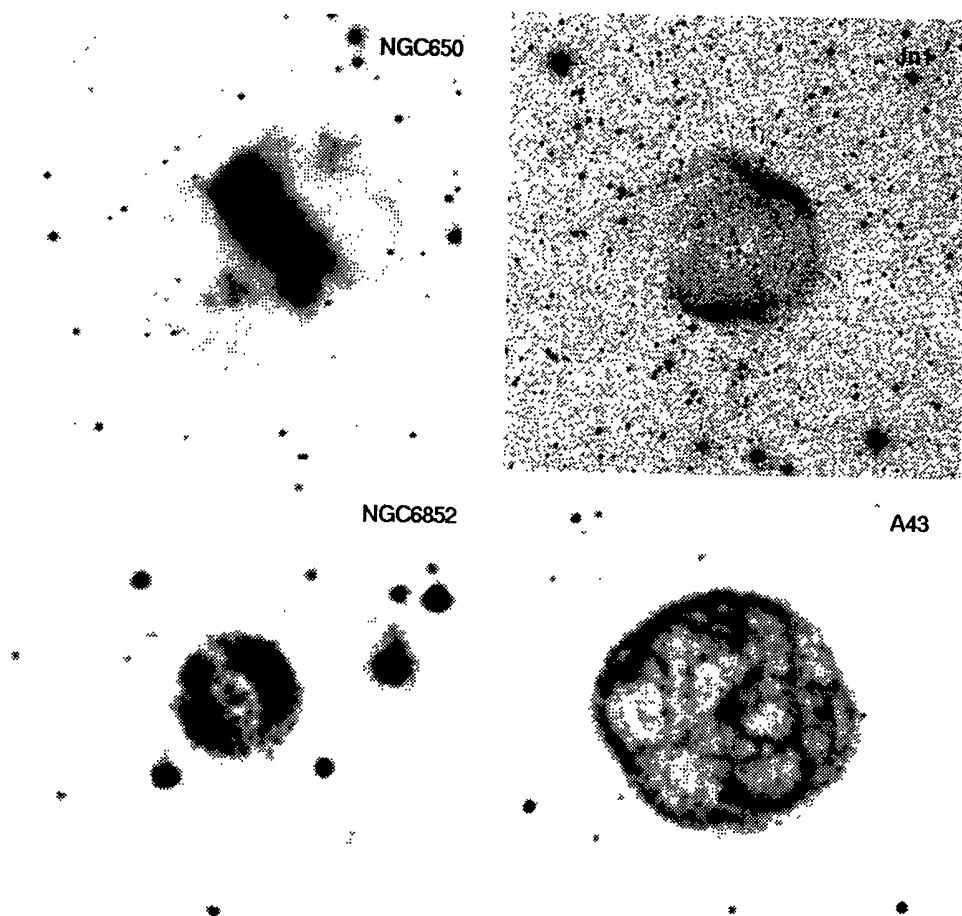


Figure 1. PNe with PG 1159 central stars: NGC 650 ($H_{\alpha}+NII$), Jn 1 (POSS E), NGC 6852 ($H_{\alpha}+NII$), A 43 (OIII). The CCD frames were obtained at the 1.23 m telescope of the Calar Alto observatory in Spain. The POSS E image was taken from the Digitized Sky Surveys

and the bipolar PNe (with an equatorial density enhancement and axissymmetrical shape). PNe of PG 1159 stars are displayed in Fig. 1. A very pronounced bipolar morphology is displayed by the PN NGC 650. An equator belt with strongly enhanced intensity/density is clearly visible. In the polar direction lobes and “ejecta” are present. Jn 1 (Fig. 1b) is a less pronounced (probably more evolved) example of a bipolar PN. At first glance NGC 6852 (Fig. 1c) looks like an elliptical PN, but there is still a strong density contrast present between equatorial and polar directions, indicating a bipolar nature. Further bipolar PNe of PG 1159 stars are NGC 6765, RXJ 2117.1+3412, Lo 3, K 1-16, VV 47, and Lo 4. Three PNe (NGC 246, A 43, and NGC 7094) can be classified elliptical. One example is A 43 displayed in Fig. 1d. Filamentary structures are present in this nebula as well as in the other two ellipticals. Some PNe of the PG 1159 sample are too faint or interacting with the interstellar medium (IsWe 1, Sh 2-78, PG 1520+525, A 21) preventing a reliable classification of the morphology.

In summary nine of the classified twelve PNe of PG 1159 stars are of the bipolar type, i.e. a fraction of 3/4. This is drastically higher than the usual frequency of bipolars in PNe samples (<25%; Górný & Stasińska 1995). Thus this PN type is highly overabundant in our sample. Since the nebula is formed, when the star leaves the AGB the first time this preference for bipolarity cannot be explained by the born again scenario, which affects only the following evolution. Today it is believed that bipolar PNe are the result of a binary interaction on the AGB (see e.g. Livio 1993). One important scenario is the common envelope phase in which the secondary is embedded in the low density envelope of the AGB primary. Thus the presence of many bipolar PNe in our sample indicates that binarity is an important ingredient in forming a PG 1159 star.

Werner & Heber (1991) concluded from an intercomparison of surface abundances that the Wolf-Rayet central stars (spectral type [WC]) are precursors of the PG 1159 stars. In their recent paper Górný & Stasińska (1995) investigated the PNe of [WC] nuclei. Many properties of these nebulae are similar to that of a comparison sample. In contrast to our finding for the PG 1159 central stars, the frequency of bipolar nebulae within the [WC] sample is not significantly higher than for the non-[WC] PNe. (23% vs. 21%, resp.). What is the cause for these differing results? Since we had only twelve PNe of PG 1159 stars with good classifications at hand, we cannot completely rule out that the high frequency of bipolars is caused by small number statistics. However, while the classification criteria of Górný & Stasińska (1995) are similar to ours, their sample consists partly of very young, compact PNe. It might be difficult to recognize bipolarity in these PNe, especially if one has to rely on printed images from literature, as it was partly necessary for Górný & Stasińska. Moreover, Frank & Mellema (1994) concluded from their 2-D hydrodynamical simulations of PNe that bipolar features become more pronounced with age. This would cause a higher detection rate for the older PNe of PG 1159 stars.

An important step in our understanding should be provided by a homogeneous classification based on high quality data of representative samples of PNe of hydrogen-rich and [WC]/PG 1159 stars. To minimize the influence of evolutionary effects, as discussed above, it should be useful to look out for criteria which are closer related to the polar/equatorial density contrast than the morphological appearance is. Since PN imaging with CCD devices has become a standard technique today, it is relatively easy to apply more quantitative criteria. For instance, the angular intensity profile provides a relative direct measurement of the density contrast within the nebula. The intensity profile of the bipolar PN NGC 650 is plotted in Fig. 2, clearly showing the intensity enhancement at the equator ($\approx 120^\circ$ and 320°). The autocorrelation function (Fig. 2) has a strong peak at 180° , as expected from the axisymmetric morphology. A weaker but still pronounced correlation peak is derived for e.g. NGC 6852, too, but not for the ellipticals A 43, NGC 246, NGC 7094.

3. Discussion

The frequency of bipolar PNe in the sample of PG 1159 central stars (3/4) is higher than it is found in other samples of PNe (<25%). Since the formation of bipolar nebulae is likely caused by binary interaction during the AGB phase, this

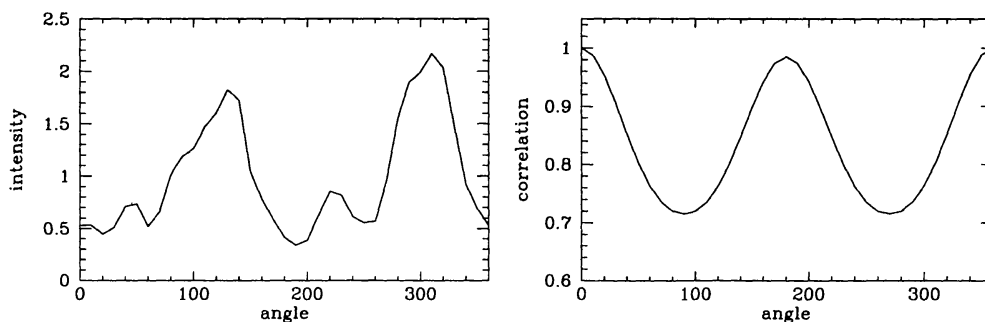


Figure 2. Intensity profile (left) and its autocorrelation function (right) for the bipolar PN NGC 650

finding implies that binarity is important for the production of a PG 1159 star. The competing born again scenario cannot explain the preference for bipolar PNe.

Our conclusion are somewhat contrasted by the finding of Górný & Stasińska (1995) that the frequency of bipolar nebula in their sample of PNe with [WC] central stars, the likely PG 1159 progenitors, is *not* significantly higher than in a comparison sample. A possible explanation is given by evolutionary effects, which make the contrast in the younger PNe weaker. In addition it is more difficult to detect bipolarity in the sometimes very compact nebula of young [WC] stars. A thorough investigation of representative samples of PNe with central stars of known spectral type might help to improve the situation. A homogeneous classification based on high quality images is highly wanted. We expect a further improvement from the development and use of new more quantitative classification criteria, e.g. that proposed above. If our finding for the nebula of PG 1159 stars can be confirmed, this will provide us with an important tool for our understanding of these stars.

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