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New evolved planetary nebulae in the southern hemisphere

F. Kerber[1], M. Roth[2], A. Manchado[3], and H. Gröbner[1]

[1]Institut für Astronomie der Leopold-Franzens-Universität Innsbruck, Technikerstraße 25, A–6020 Innsbruck, Austria
[2]Las Campanas Observatory, Carnegie Institution of Washington, Casilla 601, Chile
[3]Instituto de Astrofisica de Canarias, E-38200, La Laguna (Tenerife), Spain

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Abstract. The major purpose of this paper is to investigate the nature of planetary nebulae (PNe) candidates in the southern hemisphere, taken from an internal list. We present spectroscopic observations and imaging of six PNe identified for the first time. Another candidate turned out to be a galaxy. All observed PNe represent evolved stages, their angular diameter ranging from 15″ to 120″, and exhibit very low surface brightnesses. For three PNe indications of interaction with the interstellar medium (ISM) has been discovered.

Key words: surveys — planetary nebulae: general

1. Introduction

With this work we present six new planetary nebulae (PNe) in the southern hemisphere. The candidates have been taken from an internal list and complement 12 PNe from the northern hemisphere published recently (Kerber et al. 1996, hereafter Paper I). The objects were discovered by scanning the ESO/SERC survey plates for extended nebulae of low surface brightness, see e.g. Melmer & Weinberger (1990) for details of the search method; the area covered by the search represents about 40% of the southern sky.

The importance of the late stages of PN evolution and the interesting finds made over recent years have been described in Paper I; we will not repeat this here. Instead we will concentrate on one aspect, briefly mentioned in Paper I that seems to be highly relevant for some of the objects presented here. The process in point is the interaction of old evolved PNe with the surrounding ambient interstellar medium (ISM). Although first studied 20 years ago (Smith 1976) it remained somewhat of a curiosity, seemingly applicable only to a few peculiar objects like e.g. A 35 (Jacoby 1981; Hollis et al. 1996). Only with the work of Borkowski et al. (1990) it became obvious that such an interaction is of importance for many old, evolved objects. Since then a number of examples ranging from the mild e.g. A 34 (Tweedy & Kwitter 1994) to the extreme of Sh 2-174 (Tweedy & Napiwotzki 1994) have been identified. Most recently Xilouris et al. (1996) have considerably enlarged the sample of known examples.

The objects presented in this paper nicely demonstrate first that many more galactic PNe can be discovered and second that, as a consequence of the high degree of individuality that is inherent to PNe, every single object is of interest and well worth studying.

The objects discussed here are newly discovered PNe. They are included in the first supplement to the Strasbourg-ESO-Catalogue, by Acker et al. (1996), as private communication. With the spectra and images presented in this article we are able to discuss these nebulae on a more solid basis.

2. Observations

The spectra have been obtained in April 1996 with the 2.5-m duPont Telescope at Las Campanas Observatory, Chile. Operating the modular spectrograph we covered the spectral range from 4800 Å to 6800 Å for all objects. Using the TEK 1 CCD detector we obtained a spectral resolution of 2 Å/pixel. The exposure time ranged from 600 to 1800 s. The raw data were calibrated using the standard stars LTT 3218 and 3864 from the lists of Hamuy et al. (1992 and 1994). The resulting spectra are presented in Figs. 1 to 6. Additionally, narrow band images have been obtained for KeWe 5 at ESO's 1.54 m telescope and for KeWe 2 and NeVe 3-2 with LCO's 2.5-m duPont. The bandwidths were 62 Å for (H_α+[N II]), 35 Å for [N II] and 57 Å for [O III].

The objects observed have all been discovered on ESO/SERC film copies during dedicated searches for PNe by visual inspection, for details of this method see Paper I.

Send offprint requests to: F. Kerber, florian.kerber@uibk.ac.at

Table 1. Basic data for the PNe investigated

Name	Designation	RA (2000.0)	DEC (2000.0)	⌀[″]	Plate	x [mm]	y [mm]	Remarks
KeWe 2	PN G228.5−11.4	$06^h\ 37^m\ 39.3^s$	$-18°\ 57'\ 30''$	30	ESO 557	193	206	
KeWe 3	PN G238.4−01.8	$07^h\ 33^m\ 25.9^s$	$-23°\ 26'\ 08''$	120	POSS 656	95	220	also on ESO 492
KeWe 4	PN G257.8−05.4	$08^h\ 05^m\ 33.7^s$	$-41°\ 56'\ 31''$	45	ESO 312	273	76	CS $m_b \approx 21$
NeVe 3-1	PN G275.9−01.0	$09^h\ 34^m\ 04.6^s$	$-53°\ 12'\ 24''$	40	ESO 166	51	245	NeVe GN09.32.3
NeVe 3-2	PN G326.4+07.0	$15^h\ 19^m\ 43.3^s$	$-48°\ 59'\ 51''$	30	ESO 224	269	196	NeVe GN15.16.2
KeWe 5	PN G348.9+04.6	$16^h\ 57^m\ 57.0^s$	$-35°\ 24'\ 52''$	15	ESO 391	71	126	CS $m_b \approx 19.5$
	G272.6−05.3	$08^h\ 57^m\ 54.4^s$	$-53°\ 52'\ 18''$	35	ESO 165	78	213	ESO G165−08

Table 1 summarizes some basic data of the PNe. In the first column we give the common name (NeVe 3 stands for Neckel & Vehrenberg 1990), in the second the designation following the IAU recommendations outlined in the Strasbourg-ESO Catalogue of Planetary Nebulae (Acker et al. 1992). Columns 3 and 4 give equatorial coordinates, measured from the ESO/SERC films given in Col. 6, accurate to about 6 arcsec. The coordinates have been measured using a high resolution digitizer and software developed at the institute. In Col. 5 a diameter is given as measured on the ESO-R film. Columns 7 and 8 give x and y positions on the ESO/SERC films or POSS prints measured from the lower left corner in mm of the field. G272.6−05.3 showed no emission lines but a continuum, therefore it probably is a galaxy.

3. Results and discussion

For three objects narrow band images have been obtained, the remaining images are reproductions from ESO/SERC films. In all images north is up and east to the left. A summary of the identified emission lines and some derived properties, like electron density, extinction coefficient, radial velocity is given in Table 2; for NeVe 3-1 values for both the eastern crescent and the inner part are listed. The excitation class is derived from the ratio of the [O III] lines at 4959 and 5007 Å and H_β, follwing Aller's (1956) scheme.

KeWe 2 appeared as an elliptical ring of nebulosity on the ESO/SERC. In contrast to most elliptical PNe it shows brightness enhancements at the ends of the *major* axis. The new narrow-band image ([N II]) reveals faint outer extensions that indicate that this object is not really an elliptical but rather a bipolar PN with a pronounced equatorial density enhancement and very faint lobes; on the survey only the ring forming the waist of the butterfly according to the classification schemes of Balick (1987) and Schwarz et al. (1993) can be seen. The equatorial ring is seen almost face on. The spectrum shows a low excitation nebula with strong [N II] emission. H_β and [O III] are very faint but from comparison with H_α it is obvious that reddening must be rather small, while the ratio of H_β and [O III] indicates an excitation class < 4.

Table 2. Line fluxes for the new PNe

Line (λ [Å])	KeWe 2	KeWe 3	KeWe 4
H_β 4861	100::		100
[O III] 4959		34	
[O III] 5007	170:	100	1070
He I 5875			100
[O I] 6300			
[O I] 6363			
[N II] 6548	600	380	50
H_α 6563	420	110	470
[N II] 6584	1740	1150	135
[S II] 6717		80:	35
[S II] 6731		90:	20
v_{rad}[km s^{-1}]	110	90	40
EC	< 4		6 – 7
c	< 0.5		0.7
n_e	–	–	< 100
log$F$(H_β)	–	–	−13.6
Line (λ [Å])	**NeVe 3-1**	**NeVe 3-2**	**KeWe 5**
H_β 4861		100	100
[O III] 4959	40	175	280
[O III] 5007	100	540	785
He I 5875		30	
[O I] 6300	55		
[O I] 6363	30		
[N II] 6548	260/69		575
H_α 6563	340/100	525	665
[N II] 6584	780/140	11	1680
[S II] 6717	170/60		345
[S II] 6731	140/56		255
v_{rad}[km s^{-1}]	0	– 80	– 10
EC	4 – 5	5	5
c	1.1	0.8	1.1
n_e	150/450	1000	< 100
log$F$(H_β)	–	−12.5	−14.4

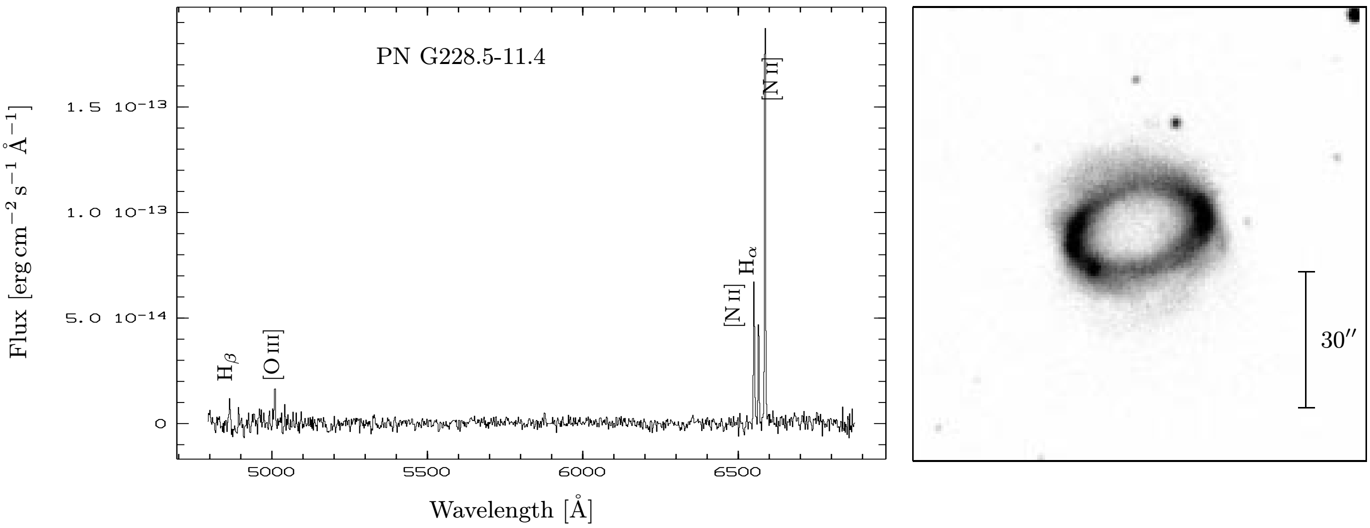

Fig. 1. Spectrum and [N II]-image for object KeWe 2, PN G228.5−11.4

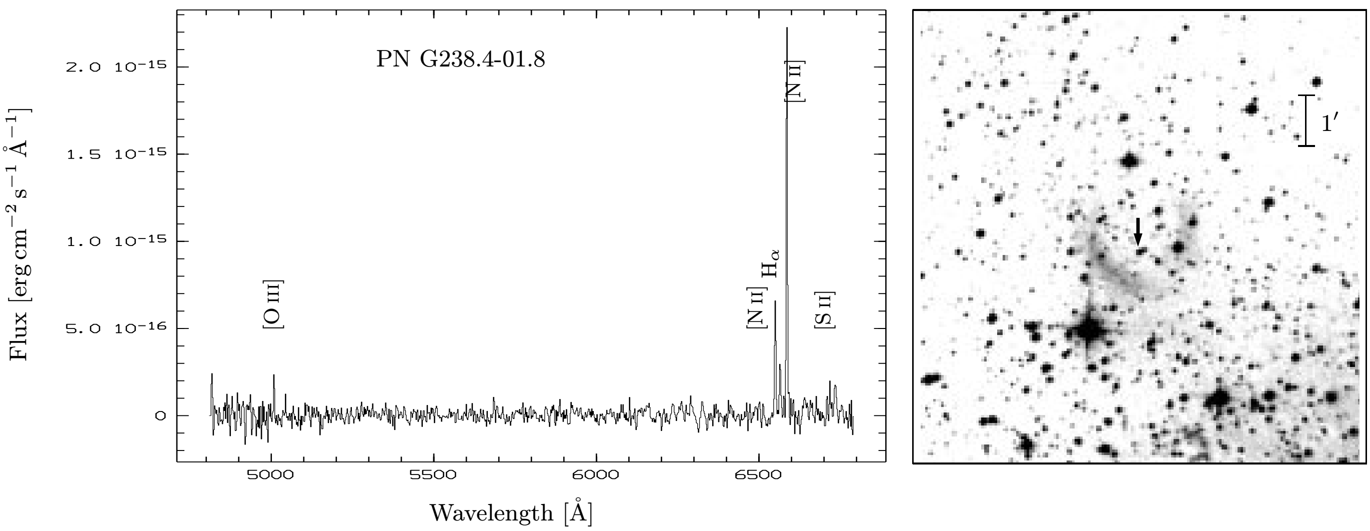

Fig. 2. Spectrum and ESO-R-image for KeWe 3, PN G238.4−01.8

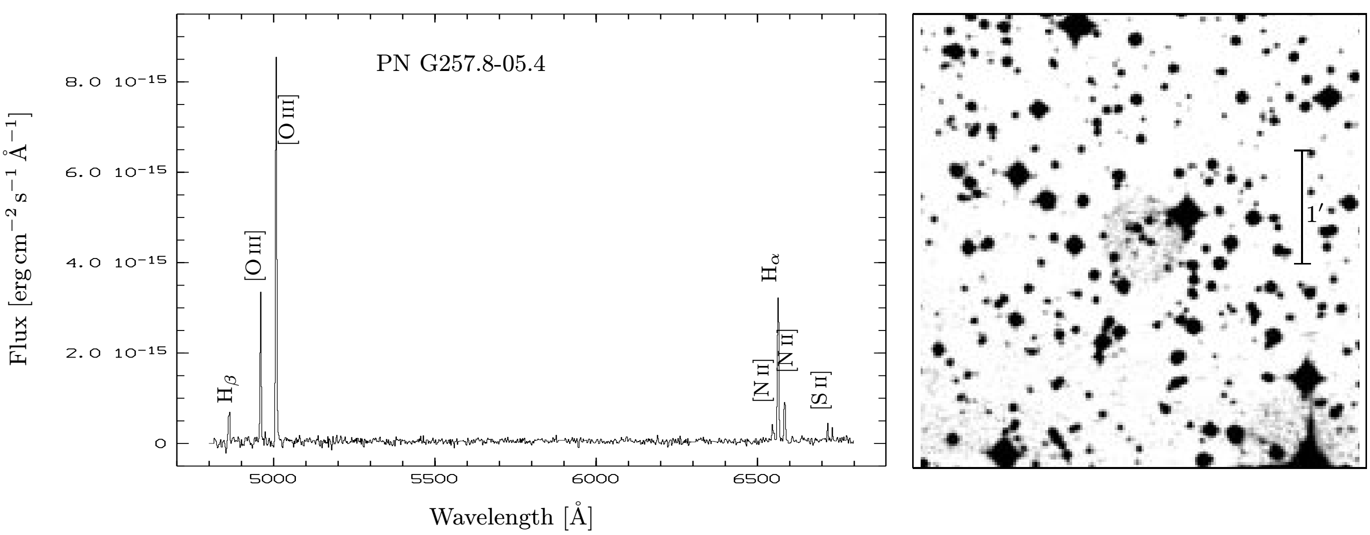

Fig. 3. Spectrum and ESO-R-image for KeWe 4, PN G257.8−05.4

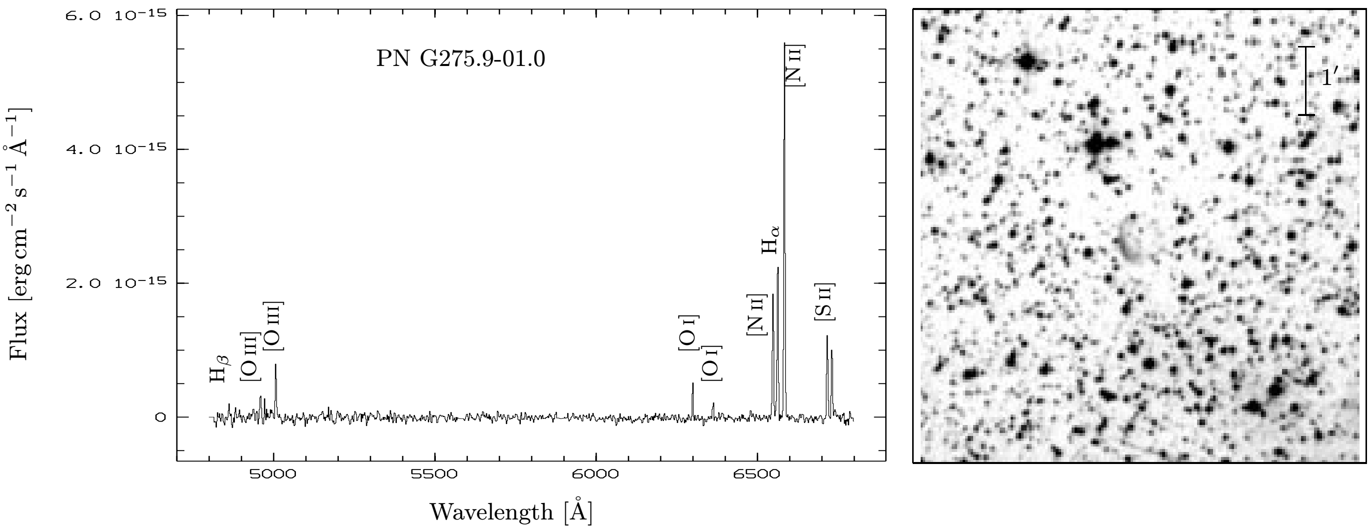

Fig. 4. Spectrum of eastern crescent and ESO-R-image for NeVe 3-1, PN G275.9−01.0

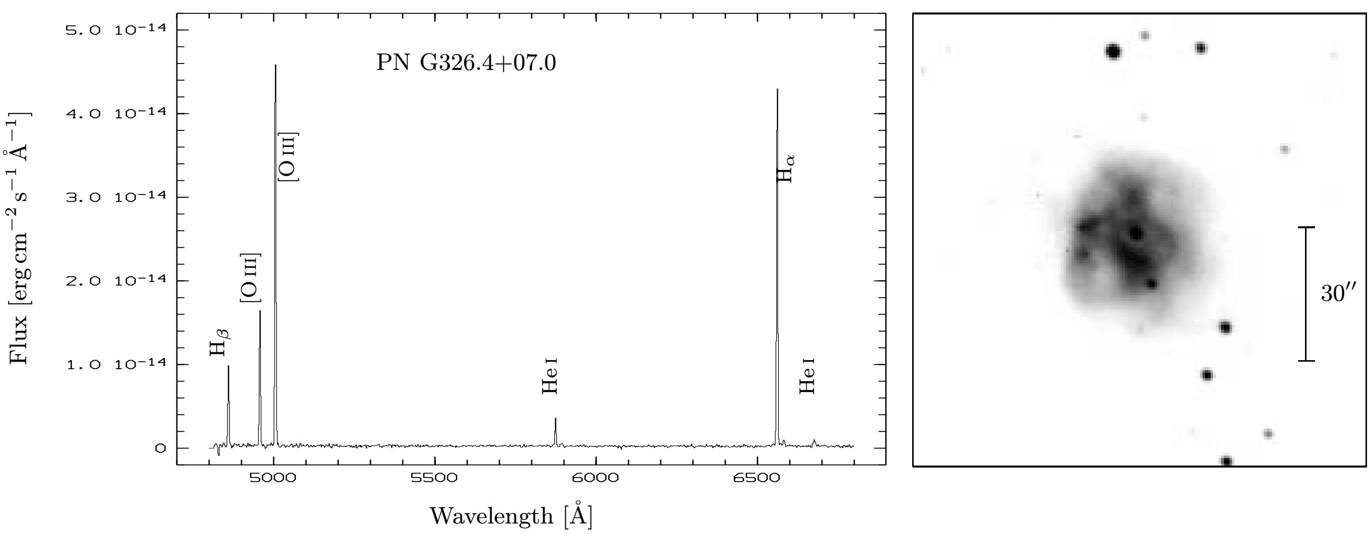

Fig. 5. Spectrum and (H_α + [N II])-image for NeVe 3-2, PN G326.4+07.0

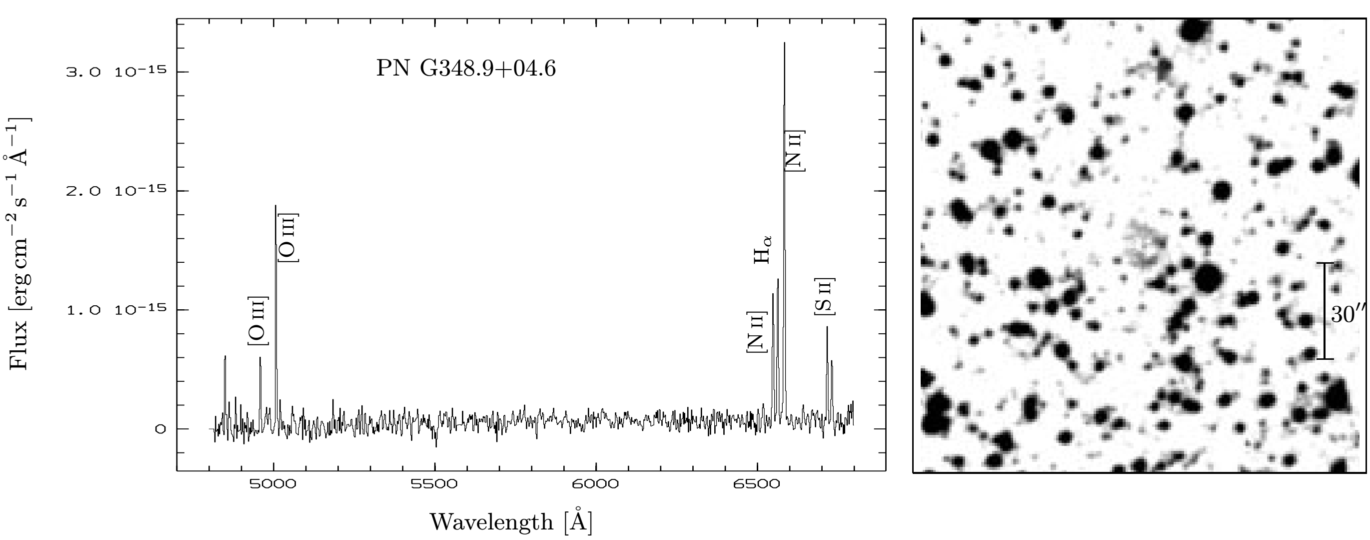

Fig. 6. Spectrum and ESO-R-image for KeWe 5, PN G348.9+04.6

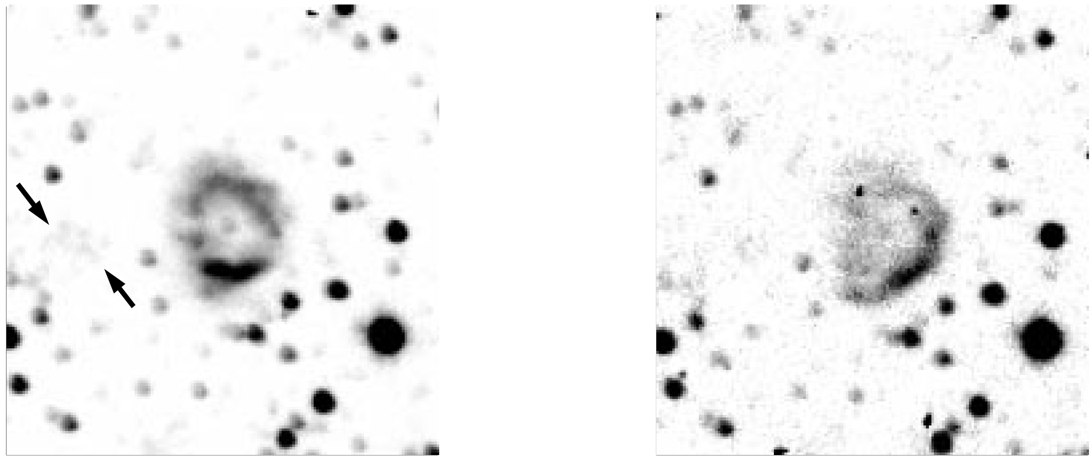

Fig. 7. (H_α + [NII]) and [O III] images for KeWe 5, PN G348.9+04.6

KeWe 3 is a rather large (2 arcmin) nebula consisting of two crescent shaped arcs forming a highly incomplete shell. The eastern crescent is brighter on the ESO/SERC. A possible central star is identified in Fig. 2 b. The spectrum is remarkable showing strong [N II] emission but very weak lines of H_α and [O III]. The strange nitrogen ring nebula PL 1547.3−5612 has a very similar spectrum (Ruiz 1983). Due to the lack of useable lines no reliable information on reddening or density of the object could be derived. Still the distinct morphology and the extreme H_α to [N II] ratio makes this object a likely candidate for an evolved PN in an advanced stage of interaction with the ISM. This is corroborated by the fact that no complete shell is visible, compared with A 34 and A 61 whose structure is still intact, see Tweedy & Kwitter (1994).

From a morphological point of view KeWe 4 is a typical old PN – interestingly enough it is the only such archetypical object in our sample – sporting a disklike structure of homogeneous but extremely low surface brightness and a central star (CS). Similarly the physical properties derived from the spectrum are quite ordinary for an evolved PN. A comparatively small reddening of $c = 0.7$ is obtained from the Balmer decrement, while the excitation class from H_β and [O III] is relatively high, EC $\approx 6{-}7$. The sulfur doublet gives an electron density of < 100 cm^{-3} making this a normal old PN at a statistical distance of 3.5 kpc (diameter ≈ 0.7 pc) that would certainly have been discovered and identified much earlier had it not been for its extremely low surface brightness.

NeVe 3-1 looks somewhat similar to KeWe 5 but the brightness distribution is even more lopsided with the E crescent being much brighter. In the central region that appears empty on the ESO/SERC the spectrum is of poor S/N and therefore it is not shown here, the only useful parameters derived are a density of ≈ 450 from the [S II] lines and a H_α to [N II] ratio of 0.7. The spectrum of the two crescents are very interesting: both show a nebula of medium excitation (EC 4−5) with strong [N II] lines and considerable reddening, $c = 1.1$. Comparison of the two spectra reveals a number of important differences, in particular some observed line ratios are not constant. While the ratio of H_α/[O III] is essentially constant the ratios of H_α/[N II] and [N II]/[O III] are not. [N II] is much stronger in the East, the brighter crescent. The electron density in both crescents is decidedly lower than in the central region (450); an upper limit of $<$100 is found for the fainter arc, compared to a value of $\approx$150 in the brighter one. These observational facts: onesided brightness enhancement, enhancement of density and lower ionisation stages are exactly what is predicted for an evolved PN interacting with the ISM (Soker et al. 1991). NeVe 3-1 might be an excellent object to study these processes in more detail.

NeVe 3-2 is a roundish nebula with a bright central object. The spectrum is dominated by the Balmer lines and [O III] emission, He I is present, while the low ionisation stages like [N II] and [O I] are very weak. In fact almost all [N II] seems to be concentrated in a small knot east of the CS, as seen on the raw data, that has a density of 1000 cm^{-3}. The reddening is determined as $c = 0.8$ from the Balmer decrement giving a diameter of 0.25 pc at a statistical distance of 1.8 kpc.

At first sight KeWe 5 looks like an ordinary PN on the ESO/SERC showing a circular shape and a CS. The spectrum reveals a nebula of medium excitation with strong [N II] emission that must be in a highly evolved state since the [S II] doublet is in its low density limit, indicating a density < 100 cm^{-3}. At a distance of some 15 arcseconds a faint nebular emission was identified in the spectrum; despite its poor S/N ratio it is obvious that the ratio of H_α to [N II] is higher in this patch (≈ 0.8) than in the nebula itself (0.4); the location of this faint nebular patch is marked in the (H_α + [NII])-image by two arrows. Note that this patch cannot be explained by diffuse galactic emission which has been found in [S II] by Kingsburgh & English (1992) around a number of objects. A statistical distance of 8 kpc is found but this can only be considered a very rough estimate due to the low H_β flux observed. The narrow band images taken in H_α and [O III] reveal a much more complicated structure than the ESO/SERC. In the (H_α + [NII]) image the PN looks like a broken elliptical ring with a very pronounced brightness enhancement in the North. In [O III] in contrast the object takes on an oddly deformed shape again showing a strong brightness enhancement but the position does not coincide with the brightness maximum in H_α. Concentrated asymmetric brightness enhancements and disrupted structure are suggestive of an interaction with the interstellar medium (ISM). This could also account for the strong [N II] emission, see Borkowski et al. (1990) and Tweedy & Kwitter (1994) for details. The low density observed is also consistent with this notion.

KeWe 2, KeWe 3, NeVe 3-1 and KeWe 5 all show very high [N II]/H_α and [S II]/H_α ratios. In fact the observed [N II]/H_α ratios are among the highest ever found in PNe (e.g. Guerrero et al. 1995). Unfortunately, due to the poor signal to noise ratio of the spectra, a proper analysis of the abundances of the ionized gas could not be carried out. However we have placed those values in a diagnostic diagram (Canto 1981), and they are located very close to the position of the supernova remants. This indicates that a strong contribution of the excitation in these nebulae is due to shock.

4. Conclusion

In conclusion we'd like to reiterate a point already made in Paper I: due to the extreme heterogeneity of the class each PN is, to a certain extent, unique. So every new addition is well worth studying in detail, despite the more than 1000 galactic PNe known. The new objects presented here vividly illustrate this. Of the six objects in our sample three show signs of interaction with the ISM. They rank among the smallest but also most promising examples yet identified. In fact their small angular size should make them very good targets for further study by spectroscopy and narrow-band CCD imaging despite their low surface brightness. A solid observational base combined with further theoretical study will definitely be able to help better understand this process that seems to be much more common and important in the late stages of PN evolution than once thought. Additionally it provides a unique opportunity to study the properties of the ISM.

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