Astron. Astrophys. 318, 561–564 (1997)

ASTRONOMY AND ASTROPHYSICS

Two planetary nebulae with tori of different development⋆

F. Kerber[1] **and J.-F. Claeskens**[2,3]

[1] Institut für Astronomie der Leopold-Franzens-Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria
[2] Institut d'Astrophysique, 5, Avenue de Cointe, B-4000 Liege, Belgium
[3] European Southern Observatory, Casilla 19001, Santiago 19, Chile

Received 29 March 1996 / Accepted 7 June 1996

Abstract. In this paper we discuss the morphology of two bipolar planetary nebulae (PNe) based on broad-band (ESO/SERC) and narrow-band ([O III] and H_α) images. At first sight both objects are similar and show two pronounced bright knots – the usual signature of a torus seen edge-on. We demonstrate though that the two objects are not two of a kind at this point but are rather representing two different stages of evolution. The brightness distribution found in Wei 1–5 is well explained by a homogeneous torus with a ratio of radius to thickness of 2. KeWe 1 is a complicated object showing point symmetry. It can be understood in terms of an incomplete ring, probably a torus caught in the process of breaking up due to the action of a strong wind from the central star.

Key words: planetary nebulae: general – planetary nebulae: individual: Wei 1–5, KeWe 1

1. Introduction

The use of morphological criteria has been a popular approach to studying and classifying planetary nebulae (PNe) for decades (Curtis 1918; Perek & Kohoutek 1967). Only recently, narrow-band CCD imaging surveys (Balick 1987; Schwarz et al. 1992) with their unprecedented sensitivity and - more important - dynamical range have provided us with the amount of data necessary to investigate the morphology of a statistically relevant number of PNe. As a logical consequence new morphological classification schemes based on such surveys have been proposed (Balick 1987; Schwarz et al. 1993). The two objects presented here are bipolar PNe according to all these schemes. For a recent comparative study of bipolar PNe see Corradi & Schwarz (1995). Among bipolar PNe many peculiar, unique objects exist which cannot easily be fit into a unified scenario. Therefore every additional object of this class is of importance. Visual inspection of the POSS and ESO/SERC surveys continue to provide new discoveries of PNe (e.g. Kerber et al. 1996; Tamura & Weinberger 1995) despite the fact that this has been done for almost 40 years, now. Both objects discussed here are very recent additions to the sample of galactic PNe. Wei 1–5 ($\alpha = 19^h\,14^m\,11.5^s$, $\delta = -23°\,41'\,26''$, 2000.0) was recently reported as a possible new PN by Weinberger (1995). KeWe 1 ($\alpha = 10^h\,10^m\,33.7^s$, $\delta = -53°\,55'\,53''$, 2000.0) was classified as a "nebula of unknown nature" by Brand et al. (1986). It was recognized as a possible PN by Kerber & Weinberger (1995). New narrow-band images presented in this article enable us to confirm the nature of these objects as PNe and to discuss these nebulae and their morphology on a more solid basis.

2. Observations

The observations were made during two runs in December 1994 and July 1995 at La Silla with the Dutch 0.91 m and the 3.6 m telescope, respectively. At the Dutch 91 cm CCD # 33 with a TEK 512 chip (27 μm pixels) was used. The spatial resolution is $0\overset{''}{.}44$/pixel. Two H_α images of KeWe 1 each with an exposure of 10 min were obtained through filter #387 with a bandwidth of 81 Å and coadded. At the 3.6 m (back-up program) using the EFOSC 1 in imaging mode CCD # 26 with a TEK 512 chip with 27 μm pixels was employed. In this case the resolution was $0\overset{''}{.}61$/pixel. For Wei 1–5 15 min exposures were obtained in the light of H_α (filter #691, bandwidth 60 Å) and [O III] (filter #686, bandwidth 59 Å). For KeWe 1 a 15 min [O III] image was made.

3. Results and discussion

From a comparison between their appearance in the broad-band (ESO/SERC) images and the corresponding narrow-band images it becomes obvious that both objects are strong emitters in the light of (H_α + [N II]) and [O III]. As a first result the classification as PN can thus be confirmed. Following Acker et al. (1992), the designation for Wei 1–5 will be PN G013.7−15.3 and for KeWe 1 PN G280.5+01.8.

Wei 1–5 shows two pronounced knots with fainter extensions to the NW, Fig. 1. The morphology in both lines is very

Send offprint requests to: F. Kerber, florian.kerber@uibk.ac.at
⋆ Based on observations collected at the European Southern Observatory, La Silla, Chile

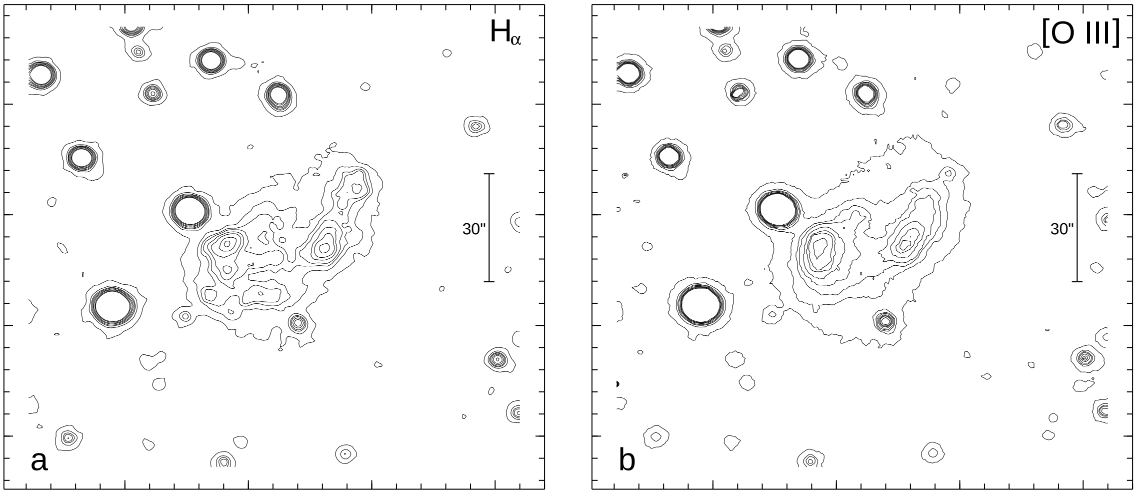

Fig. 1 a and b. H_α and [O III] images of Wei 1–5, North is to the top and East to the left.

similar. At low intensity levels the object has an elliptical outline. The extension of the western knot ends in a second intensity maximum that is seen in H_α only. The intensity distribution can best be understood in terms of a ring or torus seen edge-on. A cut through the plane common to both knots reveals the well-known doubly-peaked signature with a central trough. Fig. 2 also shows that the intensity distribution is virtually identical in [O III] and H_α; both have been scaled to the same peak value for comparison of shape. The distance between the knots is smaller in [O III] by about 15% as can be expected from ionisation stratification. Based on simple geometric considerations a homogeneous torus with a ratio of radius vs. thickness (R/d) of 2 is in good agreement with the observed distribution. More sophisticated models yield generally the same results (e.g. Pascoli 1990 and Figs. 9 – 11 in Mellema 1994). It is quite common for elliptical PNe to have brightness enhancements at the ends of the short axis and for most objects the long axis is perpendicular to the short one. In this case it is tilted by about 45°. The tilted extension of the knots can not be accounted for by the simple torus model. The shaping of these structures may be due to asymmetric expansion caused by the density distribution in the shell or in the surrounding ISM. Spectroscopic investigation is warranted, here.

KeWe 1 is of overall asymmetric appearance at first sight, but closer inspection reveals a number of symmetries (Fig. 3). Comparison of the ESO R film and the H_α image shows almost perfect agreement of the morphology even to small details; in [O III] comparison is limited by the low S/N ratio of the object on the SERC J. This comparison also helps to distinguish between nebular structure and the possible contribution from faint stars in this rather dense stellar field. For the following discussion we will concentrate on the H_α image (Fig. 3a) because of its high S/N ratio.

KeWe 1 is dominated by two bright cone shaped knots that give it its bipolar appearance, axis (A). In an axis (C) almost perpendicular to axis (A) two fainter knots can be found. This can be interpreted as the signature of an equatorial torus and two

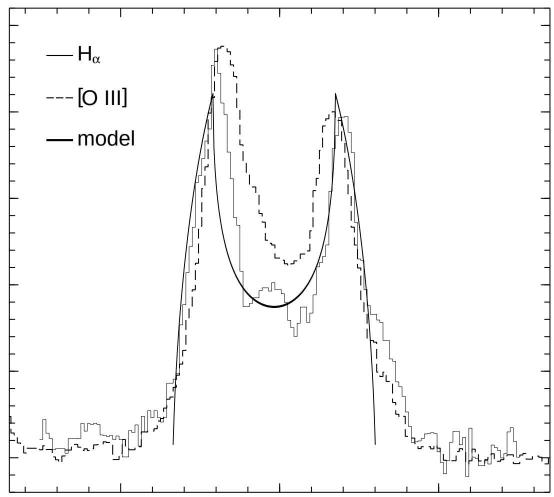

Fig. 2. Cut through the equatorial plane of Wei 1–5

polar knots. Examples for such a configuration are He 2–36 and He 2–123. A cut through the equatorial plane (A) shows again the doubly peaked distribution but an extremely deep central trough (Fig. 4). In H_α the intensity in the trough is essentially at the level of the background outside of the object, the central part is practically devoid of emission.

Such a distribution cannot be reconciled with a complete torus. Deep troughs result from large R/d ratios as in thin shells, but this is not compatible with the extension of the cones in this case. Therefore the existence of an incomplete torus or clouds has to be assumed. A more detailed inspection of the nebula gives us a clue of the processes that shape it. Both bright knots are cone shaped, resembling Mach cones with a rarefaction zone in their wake, forming the waist of the nebula. Both polar knots are elongated radially outward from the center of the nebula, the northern knot is particularly interesting because it shows a linear extension resembling a contrail, pointing to the north. This might be the result of wind erosion of a dense knot by a

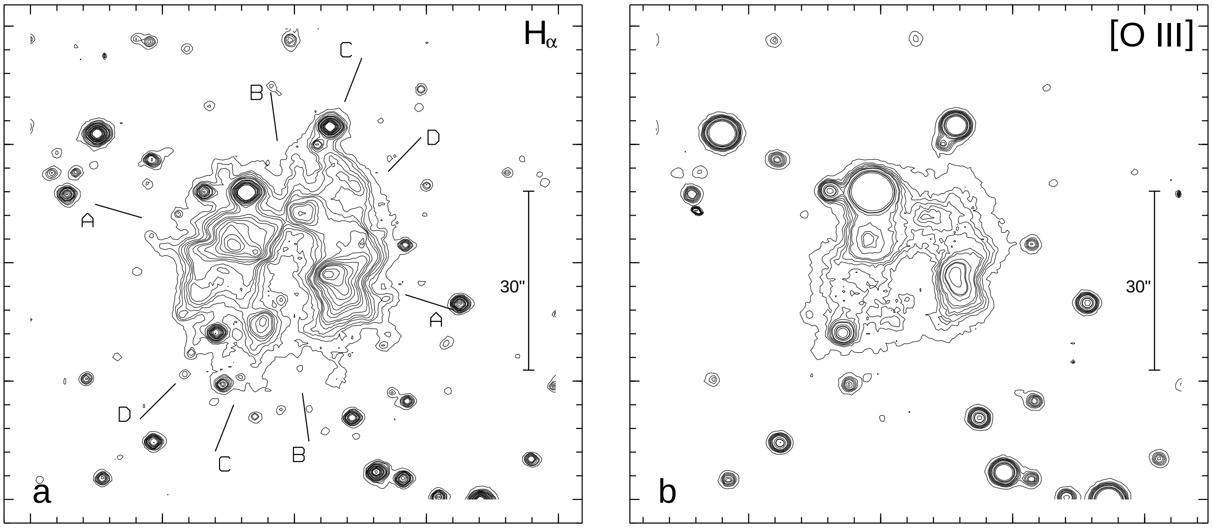

Fig. 3 a and b. H_α and [O III] images of KeWe 1, North is to the top and East to the left.

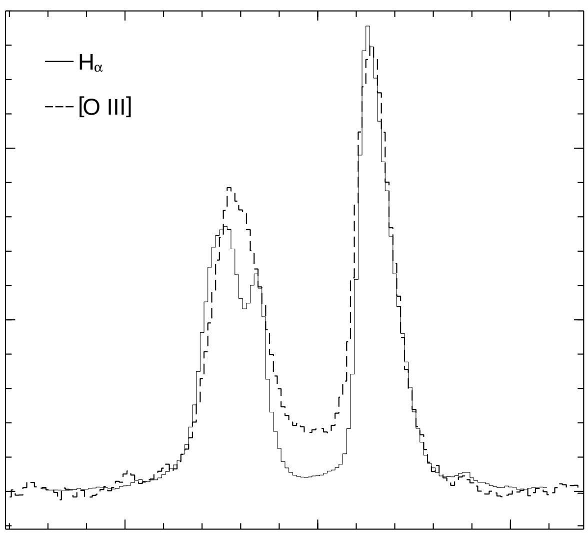

Fig. 4. Cuts through plane (A) in H_α and [O III] for KeWe 1

strong stellar wind. Such winds are not uncommon among PNe, velocities ranging from 1000 to 4000 km/s have been reported (Pauldrach et al. 1988; Patriarchi & Perinotto 1991). A dramatic example for such wind erosion can be seen in HST images of the inner part of A 30, see Borkowski et al. (1995).

Other indications for wind action in KeWe 1 can be found. At low intensity levels the object takes on an elliptical contour but the brighter parts form a broken shell. Along a plane orientated almost N-S very little emission can be found forming an empty channel or chimney (B). A similar but less obvious channel exists in the NW-SE direction (D). Both are inclined to the polar axis (C) by 25 to 30°. Axes (A) to (D) intersect each other very close to the center of the nebula. This indicates that the forces shaping these structures have a common origin there, at the central star. Looking at the radial distances to this center it becomes apparent that a high degree of point symmetry can be discerned including not only knots of matter but also regions of very low density.

So while it may not be the only way to explain the variety of features observed, a strong wind from the central star (CS) can be considered a likely mechanism. Unfortunately no CS has been found in KeWe 1 to date, but this is not really surprising. Bipolar nebulae seem to result from relatively massive ($> 1.5\,M_\odot$) stars (Peimbert 1978, Corradi & Schwarz 1993, 1995). The resulting CSs have high temperatures. This is consistent with a strong wind, see Pauldrach et al. (1988). Hot CSs are very faint in the optical and extinction towards KeWe 1 is rather substantial, so its CS may well be beyond the limiting magnitude of the SERC. Objects with similar morphology – including point symmetry – exist, for example K 1–10, NGC 2899 or He 2–36. Most of these objects show high velocity features and/or high expansion velocities (Corradi & Schwarz 1995). For very few of them binary CSs have been identified, for others no CS is known, e.g. NGC 2899. A binary star is the most natural explanation for the morphologies observed, see e.g. Livio 1993, Soker & Harpaz 1992. KeWe 1 may be an object developing into a butterfly nebula, its rapid evolution being manifested in the wind shaped features. Spectroscopy to determine the physical properties of the nebula and the velocity field in it, will be performed in the near future.

4. Conclusion

We have presented narrow-band imaging for Wei 1–5 and the newly discovered KeWe 1 confirming their nature as PNe. Both objects are morphologically similar at first sight, but a detailed inspection reveals that they are decidedly different or at least in different stages of their evolution. Wei 1–5 can be described in terms of a torus seen edge-on with a ratio of radius to thickness of 2. KeWe 1 is a more complicated case. Its central region seems to be devoid of emitting gas and a complete torus is not compatible with observations. We propose an incomplete torus and a broken shell both under destruction by a strong wind of the central star. A variety of shapes has been identified that can be interpreted as the result of erosion by this wind. KeWe 1 seems to be a rapidly evolving object, perhaps developing into a butterfly nebula, like K 1-10 or NGC 2899.

Acknowledgements. We thank H.E. Schwarz for providing the observing time at the Dutch 91 cm, thereby giving this project a good start. R. Weinberger is thanked for the observations at the 3.6 m and helpful discussions. The torus fitting procedure owes a lot to H. Gratl. We gratefully acknowledge the financial support by the "Fonds zur Förderung der wissenschaftlichen Forschung"; project P10279-AST and a travel grant from the Austrian "Bundesministerium für Wissenschaft, Forschung und Kunst". This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.

References

Acker A., Ochsenbein F., Stenholm B. et al., 1992, Strasbourg-ESO Catalogue of Galactic Planetary Nebulae
Balick B., 1987, AJ 94, 671
Borkowski K.J., Harrington P.J., Tsvetanov Z.I., 1995, ApJ 449, L 143
Brand J., Blitz L., Wouterloot J.G.A., A&AS 65, 537
Corradi R.L.M., Schwarz H.E., 1995, A&A 293, 871
Corradi R.L.M., Schwarz H.E., 1993, A&A 278, 247
Curtis H.D., 1918, Publ. Lick Obs., 13, 55
Heap S.R., 1993, in IAU Symp. 155: Planetary Nebulae, R. Weinberger, A. Acker eds. Kluwer, Dordrecht, p. 23
Kerber F., Weinberger R., 1995, Ann. of the Israel Phys. Soc. Vol. 11, 193
Kerber F., Lercher G., Weinberger R., 1996, A&AS 119, 423
Livio M., 1993, in IAU Symp. 155: Planetary Nebulae, R. Weinberger, A. Acker eds. Kluwer, Dordrecht, p. 279
Mellema G., 1994, A&A 290, 915
Pascoli G., 1990, A&A 232, 184
Patriarchi M., Perinotto M., 1991, A&AS 91, 325
Pauldrach A., Puls J., Kudritzki R.P., Mendez R.H., Heap S.R., 1988, A&A 207, 123
Peimbert M., 1978, in IAU Symp. 76: Planetary Nebulae, Y. Terzian ed. Kluwer, Dordrecht, p. 215
Perek L., Kohoutek L., 1967, Catalogue of Galactic Planetary Nebulae, Prague, Czechoslovakian Academy of Sciences
Schwarz H.E., Corradi R.L.M., Melnick J., 1992, A&AS 96, 23
Schwarz H.E., Corradi R.L.M., Stanghellini L., 1993, in IAU Symp. 155: Planetary Nebulae, R. Weinberger, A. Acker eds. Kluwer, Dordrecht, p. 214
Soker N., Harpaz A., 1992, PASP 104, 923
Tamura S., Weinberger R., 1995, A&A 298, 204
Weinberger R., 1995, PASP 107, 58

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.