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Radio properties of Young Planetary Nebulae

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Abstract The formation of Planetary Nebulae (PN) is a poorly understood aspect of stellar evolution. In particular it is still not clear what mechanism can generate the complicated morphologies observed in these sources. In the last years we have started a systematic study of objects in transition from the post-AGB to the PN.

Introduction

Stars with main sequence mass in the range 1-8 $M_\odot$ go through the Asymptotic Giant Branch (AGB) phase, then into the Planetary Nebula phase (PN) to finish their evolution as a White Dwarf. The formation and early evolution of PN represent one of the most poorly understood phases of stellar evolution. In particular, it is quite challenging to understand how quite spherically symmetric AGB circumstellar shells transform themselves into the extremely asymmetric envelopes often observed in evolved PN. During the last few years many observational programs have been devoted to recognize new planetary and proto-planetary nebulae among unidentified IRAS sources with far infrared colours similar to those of known PN (Pottasch et al. 1988; Garcia-Segura 1997), with the final aim of understanding PN formation through the discovery and analysis of new transition objects. In these sources in fact the physical processes associated with PN formation, such as dynamical shaping, are still occurring and, as the number of known transition objects is extremely small, the individuation and study of new samples appears to be very important for further testing current models of stellar evolution. SAO 244567, for instance, is the youngest known PN, whose evolution appears to be quite rapid, since it has become ionized only within the past 20 years (Parthasarathy et al. 1993). Detailed studies of this object have raised several questions, since the obtained luminosity, core mass and observed rapid evolution are not in agreement with existent models. To detect new young PN we have selected a sample of post-AGB classified stars, then belonging to the phase preceding the PN, on the basis of their Far IR and optical properties. All of the selected targets have IR excess, B spectral type and show, in their optical spectra, nebular emission lines.

Observations and results

Flux measures

We observed our sample at 8.4 GHz with the Very Large Array[1] (VLA) in June 2001 and out of the 16 selected sources 10 were detected in

[1] The VLA of the National Radio Astronomy Observatory (NRAO) is operated by Associated

radio wavelengths. These observations allowed us to state that an ionized nebula is present in these stars, which are not to be considered as post-AGB anymore, but as recently formed PN (Umana et al. 2004). The study of the detected PN can offer a unique possibility for better understanding the very early evolution of these objects.

Both infrared and radio properties of the detected sample have been compared to another sample taken in the literature and made up of presumably young PN (Aaquist & Kwok 1991). Such comparing has led us to think our sample is constituted by particularly young PN.

This is confirmed by the optical spectrum of one of our sources, which we observed in 2002 at the Anglo Australian Telescope. Comparing this spectrum with literature ones (McCausland et al. 1992), a very rapid evolution of the star is evident, with recent (last decade) appearance of nebular lines indicating this star has evolved into a PN in the last 10-20 years.

On the basis of this result, we have planned systematical observations of our sample at the Nordic Optical Telescope (NOT): one source was observed last December and the others will be next July. Both radio detected and non radio detected sources will be observed at NOT, thus allowing us to further study the evolutionary status of the sample.

In February and March 2003, we also performed VLA array D observations at several wavelengths (20, 6, 3.6, 2 and 1.3 cm), to accurately measure our sources' flux densities and then building up their radio spectra. It is usually considered that young PN should be optically thick even above 5 GHz, because of their compactness. Yet, this is not what we observed: our sources seem to be optically thin below 5 GHz (as an example, see Fig.2.

Since we had previously performed multifrequency observations, with the Australia Telescope Compact Array[2], of SAO 244567 (Trigilio et al. 2004), we could compare this star's spectrum with our sources' ones. Figures 1 and 2 show that the tendency of younger PN not to be optically thick at higher frequencies may be intrinsic to the nature of these sources.

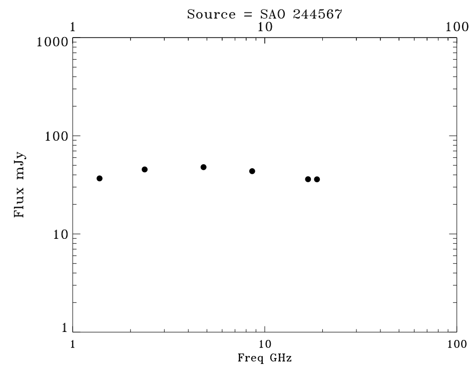

Figure 1. Radio spectrum of SAO 244567

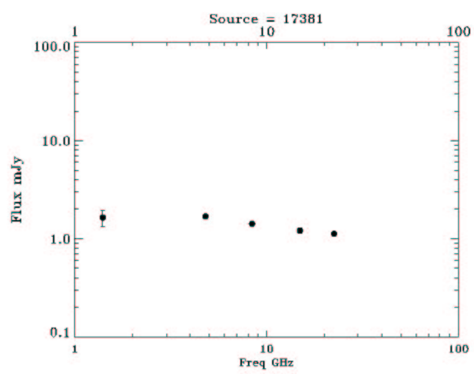

Figure 2. Radio spectrum of IRAS 17381-1616

Morphology

One of the major concerns about PN evolution is the way aspherical symmetries usually ob-

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[2] Australia Telescope Compact Array is funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO

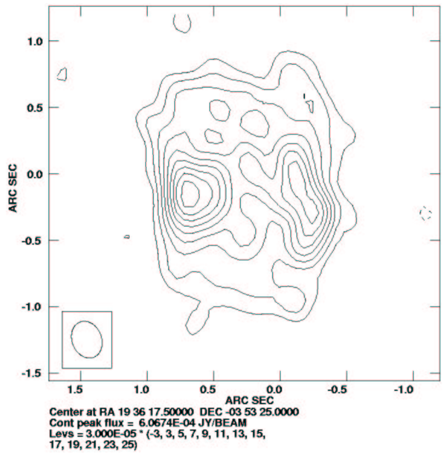

Figure 3. IRAS 19336 observed at 8.4 GHz with the VLA (resolution ~ 0.2″)

served in most (~ 80%) of these stars develope from the spherically symmetric AGB envelopes.

Several models have been taken into account to reproduce such structures, all of them considering the shells as the product of the interaction between the residual, slowly expanding (~ 20 km s^{-1}), AGB envelope and a subsequent, rapid (~ 1000 km s^{-1}) shaping agent. Some authors have suggested that magnetic fields can play an important role in shaping PN (Garcia-Segura 1997) and recently evidences for the presence of a magnetic field in the central star of a PN have been found (Jordan et al. 2005). Sahai & Trauger (1998) argue that PN could be primarily shaped by collimated high velocity outflows, which should already be active in such stars' very early evolution: right after the AGB.

To test if a bipolar morphology is present in our stars, in July and August 2003 we observed the brighter ones with the VLA in A array at 8.4 GHz, thus reaching an angular resolution about 0.2″. An example of the results is shown in Fig.3. It is evident that a bipolarity is present, thus confirming the hypothesis of the shaping to start well before the onset of ionization in the nebula.

Conclusions

We have detected a sample of newly ionized PN having some characteristics that differ from what expected for these sources.

We are still working on a multi-wavelength study of the selected sample and are confident that the data collected so far, together with future planned ones, will enable us to fully characterize our sample and contribute to understand PN evolution.

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