New Faint Ring-Like Structures Found in Planetary Nebulae

G. Ramos-Larios[1], E. Santamaria[2], A. Marquez-Lugo[2], M.A. Guerrero[3], L. Sabin[1]

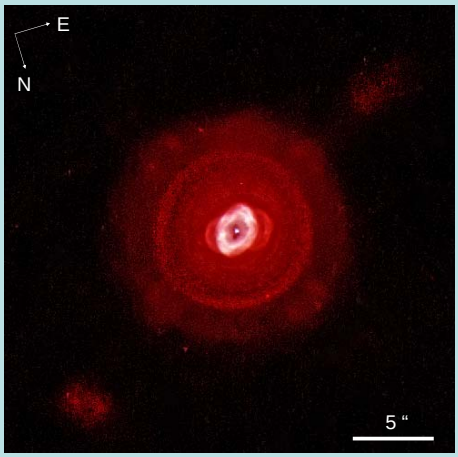
1. Instituto de Astronomía y Meteorología, Universidad de Guadalajara. Av. Vallarta 2602, Col. Arcos CP 44130. Jalisco, Mexico.
2. Centro Universitario de Ciencia Exactas e Ingenierías, Universidad de Guadalajara, Blvd. Marcelino Barragán 1421, CP 44430 Guadalajara, Jalisco, Mexico
3. Instituto de Astrofísica de Andalucía, Consejo Superior de Investigaciones Científicas. Glorieta de la Astronomía, s/n, 18008, Granada, Spain.

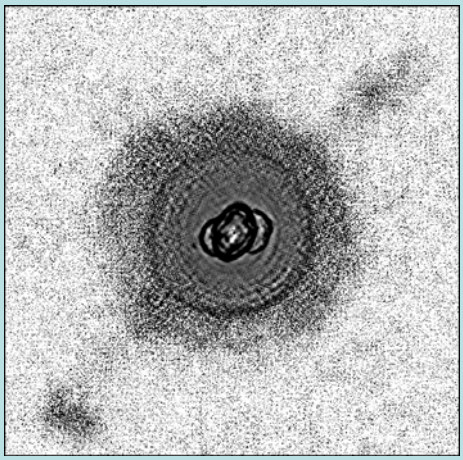
ABSTRACT

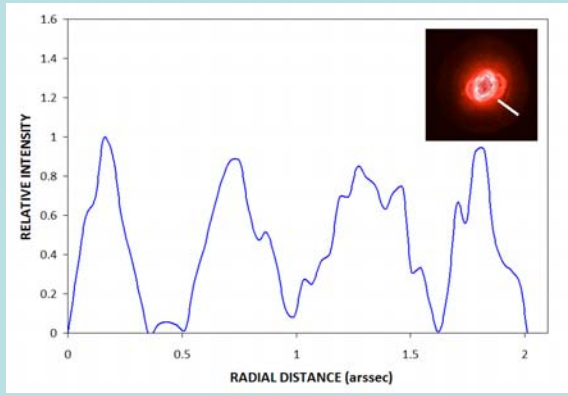
Many PNe show rings and shells related to the remnants of the circumstellar envelopes of the asymptotic giant branch phase (AGB). After an extensive search in the *HST* and *Spitzer* archives we found ring-like structures in several PNe. Following the image analysis described by Corradi et al. (2004), and unsharp masking techniques it was possible to effectively remove the underlying halo emission, enhancing the ring structures. We mention in the results some hypotheses about the origins of these rings.

IMAGING

The observations were obtained using the WFPC2 (Holtzman et al. 1995; see also the WFPC2 Instrument Handbook; Biretta 1996) and WFC3 (WFC3 Data Handbook; Rajan et al. 2010) over a variety of filters, exposure times and dates, ranging between 1996 and 2010, and different *HST* observing programmes. The images were downloaded from Mikulski Archive for Space Telescopes (MAST), the Hubble Legacy Archive (HLA) and the NASA/IPAC Infrared Science Archive.



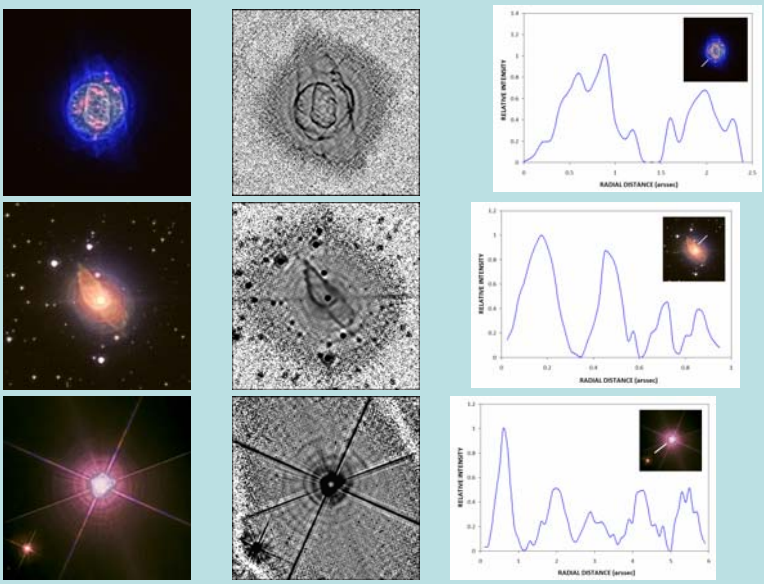




HST/WFC3 colour-composite picture (left) in the light of [OIII], F200LP and F350LP filters and unsharp mask [O III] image (center) of PNG 053.3+24.0. Note the new morphological features (blobs, halo, and system of outer rings) revealed for the first time in these pictures. The system of ring-like features is highlighted in the radial profile across the halo shown in the right panel (see inset for the precise location of the profile). The underlying halo emission has been fit and removed using a fourth-order least-squares polynomial fit. The unsharp mask image reveals an appreciable degree of circularity for the rings. The width and distance between these rings seem to be rather uniform. These results show new evidences for the annular features described by Corradi et al. (2004), as well as possible internal shock rims in many PNe.

ANALYSIS

Using the SDA processing (Corradi et al. 2004) and unsharp masking it was possible to emphasize finer details of the nebular structure. We have also obtained profiles through the rings by taking radial profiles across the rings, fitting the underlying (and smoother) component of emission using a least-squares polynomial fit and removing this from the total surface-brightness fall-off. This allows us to investigate variations in emission due to the ring structures alone.



RESULTS

We have found many PNe with new ring-like structures that will represent periods of enhanced mass loss, almost duplicating the total number of these kind of objects. It is clear that they are relatively faint, and have surface brightnesses which are no more than ~15 per cent of those of the underlying haloes. The origins of such rings are far from clear, although hypotheses will include:

1. Viscous momentum coupling between outflowing gas and dust (Simis, Icke & Dominik (2001); Meijerink, Mellema & Simis (2003)).
2. Changes in the polarity of the progenitor magnetic field (Garcia-Segura, Lopez & Franco 2001); but dynamo period too short (Meijerink et al. 2003).
3. Spiral shocks in mass-loss from binary systems (Mastrodemos & Morris 1999).
4. Relaxation oscillations within the progenitor (Van horn et al. 2003).
5. Solar-type cycles in magnetic activity (Soker 2000).
6. Variations in the periods of variability in the AGB progenitors (Zijlstra, Bedding & Mattei 2002).
7. Oscillatory pumping in the interior layers of an AGB star, leading to multi-periodicity or chaotic motion in the surface layers (Icke, Frank & Heske 1992), although it's not clear whether this can really account for the observed periodicity of the rings (Soker 2000).
8. Periastron passage of a stellar companion (Harpaz, Rappaport & Soker 1997), although this is inconsistent with circularity of the rings (Sahai et al. 1998).

This work is funded by grant 177864 of CONACyT.