Magellanic Cloud Planetary Nebulae: A Fresh Look at the Relations between Nebular and Stellar Evolution

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Abstract. Studies of the relationship between planetary nebula morphology and the evolution of the central stars has long suffered from uncertainties in distance determinations, and from the bias of interstellar absorption, that are typical for Galactic PNe. We will be able to eliminate the distance errors and be assured of the sample homogeneity by studying Large Magellanic Cloud (LMC) PNe with images from the Hubble Space Telescope. In this talk we present the first observations in our new sample. The data consist of broad-band images and medium dispersion, slit-less spectra obtained with STIS, and are of excellent quality. Indeed, these data show great promise for subsequent analysis, which will centered on the relationship between nebular morphology and stellar and nebular evolution. While the most intensive analysis of the sample must await the completion of the survey, the data obtained so far show that we will learn a lot along the way.

1. Why study Magellanic Cloud Planetary Nebulae?

Planetary Nebulae (PNe) and their central stars (CSs) have been used for decades as probes to the final phases of low- and intermediate-mass stars. The nebular gas expelled at the end of the Asymptotic Giant Branch (AGB), and sculpted by radiation and a CS fast wind, acquires a shape that depends upon the combination of the distribution of gas and dust in the circumstellar shell, and upon the local ISM environment. It it thus important to study nebulae and stars together to obtain a more complete understanding of the final phases of stellar evolution.

Since the pioneering work by Greig (1972), PN morphology has been associated to stellar population and, by inference, to the CS mass (see Stanghellini 1995 for a review); the latest finding on the correlations between nebular morphology and stellar evolution/population (e.g., Manchado, this volume) certainly show that there is a strong trend that connects large masses stars and asymmetric PNe. Nonetheless, to date the (sometime very) convincing trends that link the evolution of stars and nebulae have been criticized for the biases and
uncertainties inherent in the distance scale for Galactic PNe. On these grounds, we decided to pursue the investigation in the Large Magellanic Cloud, where uncertain distances are not an issue. A study of this type is presently only possible with the capability of the Hubble Space Telescope. In this short communication we present the aims of our project, some limited analysis of SMP-27, and a roadmap to future developments.

2. The LMC Strategy

The Large Magellanic Cloud (LMC) PNe have a typical size of ∼half an arcsecond. For this reason, their morphology (and size) make them suitable targets for the HST. As of this writing, the only published HST data on Magellanic Cloud PNe are monochromatic images obtained by Dopita (Dopita et al. 1996) using WFPC-1, and Blades et al. (1992) using FOC (see also Stanghellini et al. 1999), on a grand total of 30 PNe. Both sets suffer from spherical aberration of the HST primary mirror prior to the first servicing mission. A third set of LMC PNe is available in the HST Data Archive (PI = Dopita), which includes 14 objects observed in monochromatic lines with WFPC2. Clearly, to perform an LMC PN study of the type of that reported by Stanghellini et al. (1993) for Galactic PNe, there is the need for a larger database. For this reason we pursued our slit-less spectroscopic study of 50 LMC PNe. We chose to obtain slitless spectra in order to determine the PN shapes in a range of different ionization levels. In particular, we aim at obtaining monochromatic images in the major nebular lines such Hβ, [O III], Hα, [N II], [O I], He I and [S II].

3. STIS slitless observation of SMP-27

Our program was approved as a HST Cycle 8 snapshot. When deciding on our target list, we choose PNe within a large span in the Hβ and [O III] fluxes. Images of the PNe were obtained with the Space Telescope Imaging Spectrograph (STIS) in white (50CCD) light, and with the medium-dispersion gratings G430M and G750M, which allowed us to obtain the morphologies in the traditional lines ([O III], Hα, and [N II], as well as the others mentioned above. The Hα image of SMP-27 is shown in Figure 1. The slitless spectrograms provide both the spectral and spatial information, thus in this image we see the emission nebula and the material surrounding it. The planetary nebula SMP-27 is very clearly quadrupolar, and shows this type of morphology in all prominent spectral lines. The ring segment and the blob of outer material that we were able to observe around this nebula are suggestive of a previous ejection event from the PN progenitor, or, possibly, a remnant of the prior AGB fast wind. The absence of an obvious, nearby source of ionizing radiation, and the decline in the ionization level (as measured by the ratio of the [O III] and Hα images) makes the association of the distant arc and blob with the CS fairly secure.

A quick analysis shows that SMP-27 is a high excitation PN of approximately 0.85 arcsec of diameter (encircling 95% of the nebular light), corresponding to 0.106 pc. The separation between the main nebular body and the north-west arc is about 1.53 pc, while the arc itself is 2 pc long. There is also a fainter blob of material 14.6 deg east of north. The nebula is also detected in
Figure 1. Hα image of LMC SMP-27 (North up, East left). Note the quadrupolar shape, and the outer material possibly ejected at previous stellar stages.
the following lines: $\lambda$ 6678 He I, $\lambda$ 6584 [N II], $\lambda$ 6548 [N II], $\lambda$ 4959 [O III]. The calculated reddening for this PN is zero. The star has a hot spectrum, more prominent in the blue than in the red, which is consistent with the relatively high nebular ionization. The estimated magnitude of the CS is $V \approx 19.6$. A preliminary estimate of the luminosity and temperature yields log $L = 2.7$ and log $T_{\text{eff}} = 4.5$ by using the hydrogen line intensities. As this PN appears to be optically thin, the derived $L$ & $T$ are probably lower limits to the actual luminosity and temperature.

4. Future work

At the time of writing, this project just getting underway. But the exceptional data quality prompted us to present a preview of the results. The overall analysis of the morphological sample will be done once the bulk of the observations are complete. Morphology, size, expansion age, and central star physics will be studied for the homogeneous dataset. Ground based spectroscopy will be used, together with the available data in the literature, to probe the relationship between morphology and stellar evolution, including the yield of the PN progenitors.

References

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