Recent *HST* Surveys of Planetary Nebulae in the Magellanic Clouds

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The MCPN Surveys with *HST*

The study of the formation and evolution of planetary nebulae (PNs) has been a subject of active investigation for several decades. In the past 15 years the relationship between nebular morphology and nebular/stellar evolution has been investigated in some detail. Although important insights have been gained, the connection between PN formation and even basic morphological features of the evolving nebula is far from clear. One of the most vexing problems to overcome is the difficulty of obtaining, at least for Galactic PNs where statistical distances must be adopted, reliable dimensions, ages, luminosities, and other physical quantities that are essential for understanding the evolutionary state of individual nebulae. Our work of late has been to obtain high-resolution images of a large sample of PNs in the Magellanic Clouds, where uncertainties in the distances are minimal and selection effects due to dust absorption in the Galactic plane do not apply.

We present broad-band images and slit-less spectrograms from our recent surveys of Magellanic Cloud planetary nebulae (MCPNs) using the Space Telescope Imaging Spectrograph on-board *HST*. These data were obtained during the past few years from *HST* GO programs 8271, 8663, and 9077. The spectrograms yield monochromatic images in up to 13 nebular emission lines (including Hβ, Hα, [N II], and [O III] plus other, fainter lines of varying ionization, such as [O I], He I, [S II], and [S III]) at a physical resolution of ~0.03 pc, which is comparable to observations of Galactic PNs from the ground. These data on 27 PNs in the SMC and 48 PNs in the LMC (at this writing) nearly double the number of HST observations of MCPN from prior-generation HST surveys that employed a limited set of narrow-band filters. (Many of the early observations were compromised by the aberrated beam of *HST* prior to the installation of corrective optics.) Our survey will continue during the next year, with up to 100 new observations of LMC PNs.

Science from Nebular Morphology

These data are very rich in scientific content. Our ability to observe PN morphology over a factor of 30 in physical size and in a number of emission lines has allowed us to explore the variation of nebular morphology with size, age, ionization, density, optical depth, and metallicity. We have confirmed in MCPNs many of the relationships reported for Galactic PNe, such as the correlation of asymmetric morphological types with chemical enrichments (or depletions), and progenitor star Population type (Stanghellini et al. 2000). The sample has also lead to refinements in the morphological classification scheme itself, including the recognition of the important bipolar-core type, which we have shown is a subclass of the bipolar type, rather than of the elliptical or round types (Stanghellini et al. 1999). We also found significant differences between LMC and SMC samples in the incidence of morphological types, which when combined with the difference in mean chemical abundance of the host galaxies, may yield important insights into environmental or chemical influences on PN formation (Shaw et al. 2001).

Morphology and Nebular Evolution

We classified the morphologies in our sample from the [O III] λ5007 images as described in Shaw et al. (2001). With this dataset, together with *HST* archival data (see Stanghellini et al. 1999) and new STIS spectral images, we revisit the question of temporal evolution of the nebular morphology by examining the distribution of nebular surface brightness as a function of nebular size. Figure 1 shows that the decline in surface brightness of the ensemble with radius can be characterized by a simple power-law relation. It is not yet clear whether the evolutionary "trajectory" of individual nebulae through this diagram also follows this relation, or whether the distribution relates to unappreciated factors that affect observability.

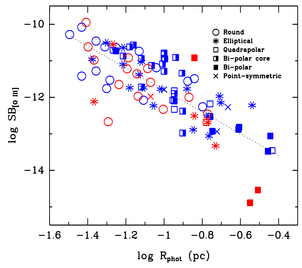

Figure 1: The decline of surface brightness (in the light of [O III] λ5007, corrected for extinction) with nebular radius is consistent with $SB \sim R^{-3}$ (*dotted line*). Morphological types are shown in the legend for LMC (*blue*) and SMC (*red*) PNs. The segregation of the B and BC morphological types may be a result of real evolution of morphological type.

Science Potential of Nebular Morphology

The relationship in Fig. 1 should place useful constraints on PN evolutionary models: The actual evolution of surface brightness must depend in some complex way on the initial distribution of mass within the PN; the subsequent expansion of the nebula; the ionization, temperature, density, and chemical composition of the gas; and upon the simultaneous and potentially very large change in the T_{eff} and L of the evolving central star. We plan to explore this complex relationship with the aid of photo-ionization and hydrodynamical models. Our plans also include:

1. exploration of the SB vs. R relationship as a useful distance indicator for Galactic PNs
2. comparison of the Galactic distance scale calibration as derived from the LMC and SMC, to search for dependencies on nebular morphology and on host galaxy metallicity
3. further refinements to the morphological classification scheme, including methods to disambiguate the effects of projection, ionization, and mass distribution
4. comparison of the [O III] luminosity function between the LMC and SMC to explore any dependency on metallicity of the host galaxy and upon the distribution of morphological types
5. a comparison of the evolutionary state of the central stars with nebular morphological type
6. a new comparison of evolutionary rates implied by stellar evolution theory vs. rates implied by the surrounding nebula.

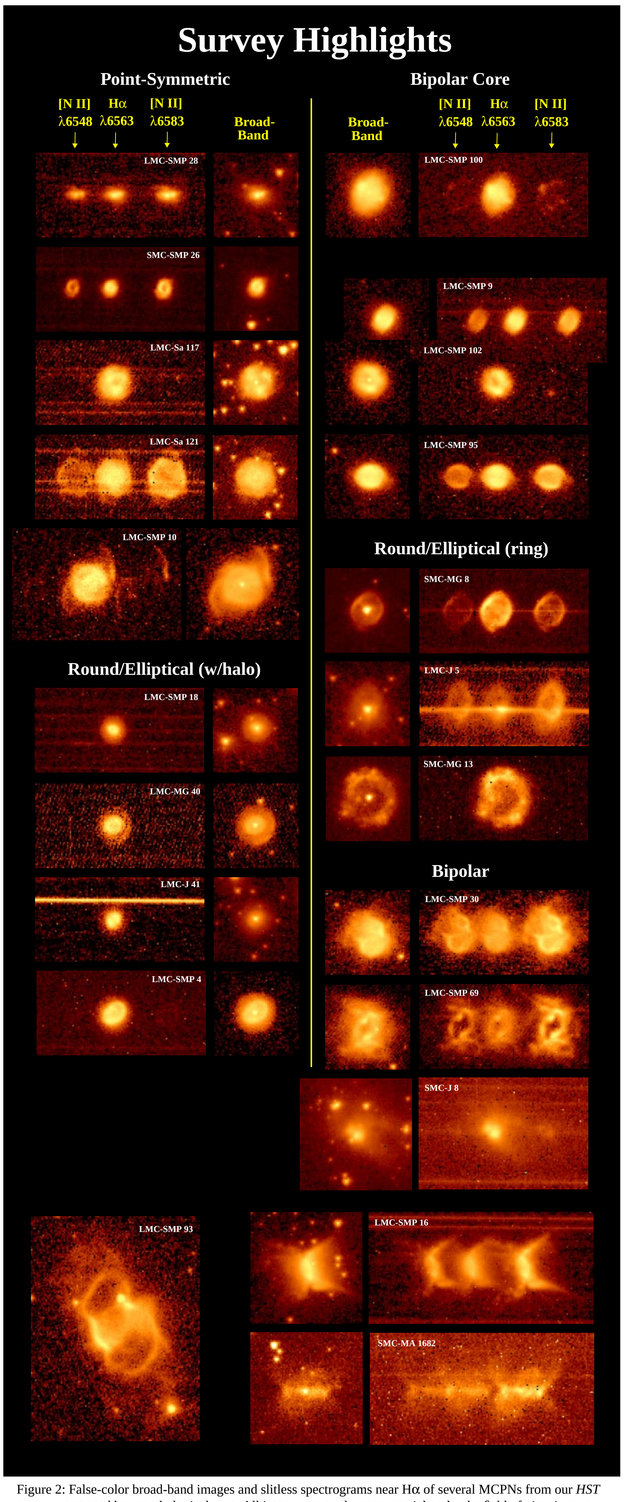

Figure 2: False-color broad-band images and slitless spectrograms near Hα of several MCPNs from our *HST* surveys, arranged by morphological type. All images are on the same spatial scale; the field of view in most images is 3 x 3 arcsec. The physical scale is ~0.25 pc/arcsec.

MCPN Public Archive and Web Services

Our *HST* surveys of MCPNs are of substantial archival value, and we are endeavoring to provide public access to scientifically useful products that will enable additional research and new observations of MCPNs. All of the survey data obtained so far are in the public domain; data from all future observations (which will extend into 2002) will also be placed in the public domain immediately after they are obtained. We have created a Web site, featuring various value-added data products relating to our published papers, including processed FITS images, extracted spectra, and catalogs of the object parameters such as coordinates, size, morphology, and emission line fluxes. Direct your browser to:

`http://archive.stsci.edu/hst/mcpn/`

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References

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