HST Surveys of the ~~LMC~~ Planetary Nebulae

Dick Shaw

National Optical Astronomy Observatory

With thanks to the MCPN Research Team:

Letizia Stanghellini	Chris Blades	Diane Karlaka
Eva Villaver	Stacy Palen	Stacy Palen
Bruce Balick	Max Mutchler	Mike Dopita

Objective

- Observe large sample of PNe that minimizes:
  - Distance uncertainties
  - Selection bias (from I.S. extinction)
- Understand broad nebular morphological types
- Understand connections of morphology to:
  - Formation & state of nebular evolution
  - Evolution of CS & connection to nebular evolution
  - Population type of progenitor
  - Nebular chemical enrichment
- Gain insight into the role of the host galaxy on PN population
  - Chemical abundances
  - Star Formation History

Observing Program

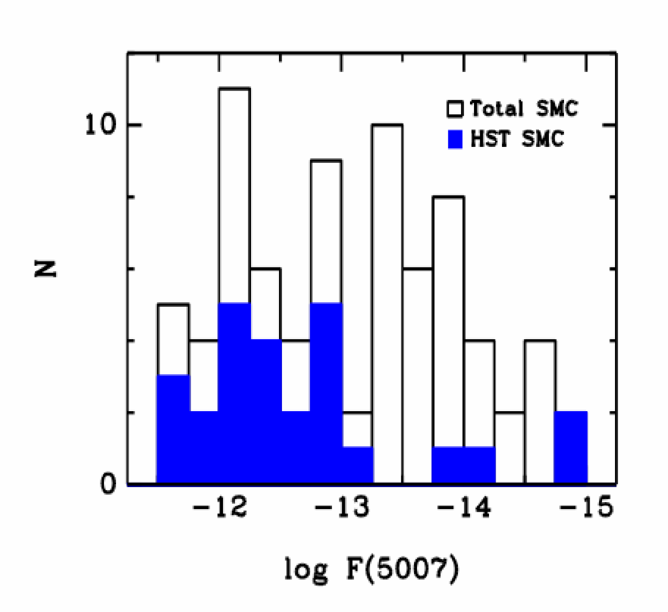
- Selected LMC & SMC
  - Population of hundreds of PNe, most spectroscopically confirmed
  - Nearby
- Obtained images & spectra using STIS on HST
  - Angular resolution of ~0.1” yields physical resolution of ~0.03 pc
  - SNAPSHOT mode means many targets and short exposures
- Broad-band images:
  - Nebular morphology (Flux > $\sim 10^{-15}$ erg/cm^2/s)
  - CS detected in ~60% of targets (V>25)
- Medium-dispersion slit-less spectroscopy:
  - Simultaneous morphology in: Hβ, Hα, He I, [O III], [O I], [N II], [S II]
  - Interstellar extinction & excitation class

LMC-SMP16 / G750M

MCPN Imaging Surveys with HST

Program	Investigators	Description	Targets
Various/LMC & SMC	Blades, et al.	GTO: FOC Narrow-band imaging: [O III] & Hβ	16
6704/LMC	Dopita, et al.	GO: WFPC2 Narrow-band imaging: [O III] 5007 & Hα	13
8271/LMC	Stanghellini, Shaw, Balick, Blades	SNAP: STIS Broad-band imaging & med. resolution slitless spectroscopy	29
8702/LMC	Shaw, Stanghellini, Balick, Blades	SNAP: WFPC2 Stromgren-*y* imaging	13
8663/SMC	Stanghellini, Shaw, Balick, Blades, Jacoby, De Marco	SNAP: STIS Broad-band imaging & med. Resolution slitless spectroscopy	27
9077/LMC	Shaw, Stanghellini, Balick, Blades	SNAP: STIS Broad-band imaging & med. Resolution slitless spectroscopy	51
9120	Stanghellini, Shaw, Balick, Blades	GO: UV slitless spectroscopy	12
10251/SMC	Shaw, Stanghellini, Villaver	SNAP: STIS Broad-band imaging & med. Resolution slitless spectroscopy	TBD (53)
10259/SMC	Stanghellini, Shaw, Villaver, Balick	GO: UV slitless spectroscopy	13

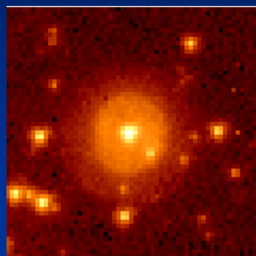
Completeness (or lack thereof…)

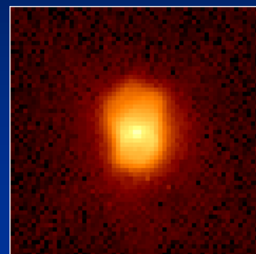


- Surveys of PNe in the MCs are notoriously incomplete (c.f. talk by Jacoby)
  - This will change as next-generation surveys are completed & published
- Expect faint PNe to vastly out-number bright targets
  - Even allowing for ionization & abundance effects
- Limits on HST/SNAP dwell time
  - The brighter targets were preferentially selected for HST programs
- New SNAP program could more than double this SMC sample

MCPN Gallery

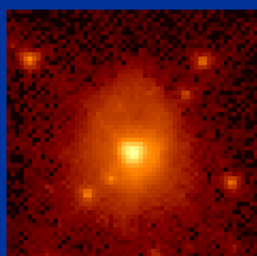
J33

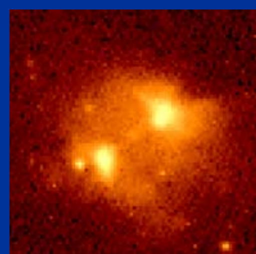




SMP67

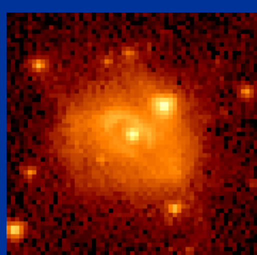
J05

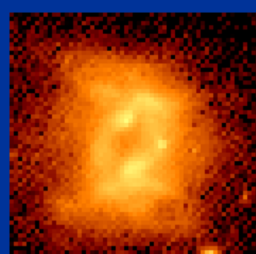




SMP14

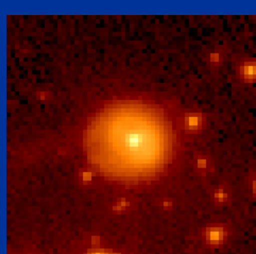
Sa107

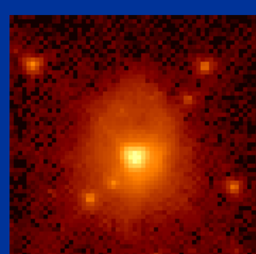




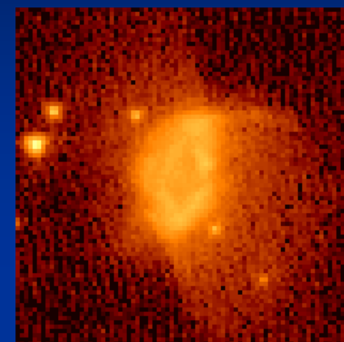
SMP69

SMP57

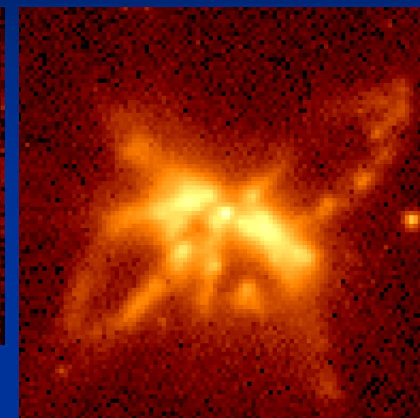




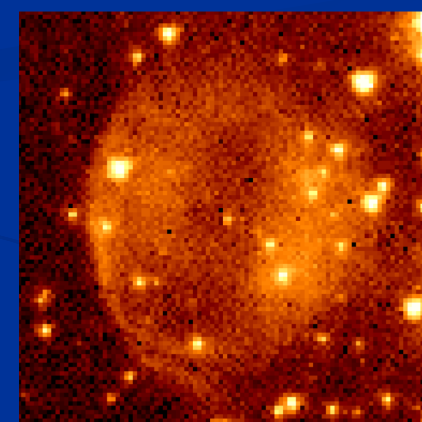
J05



SMP91



SMP83



Mo33

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

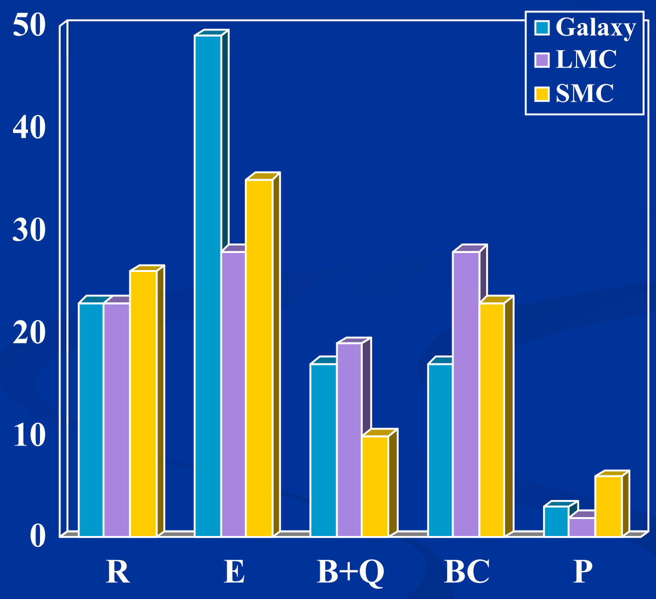
Morphology and Abundances

- Abundance indicators correlate strongly with nebular morphology, as in the Galaxy. Asymmetric PNe, relative to symmetric, tend to be:
  - Enriched in N/O, depleted in C/O, showing post-MS processing consistent with more massive progenitors
  - Enriched in Ne, Ar, S, which are not altered significantly during AGB evolution, showing progenitor population is chemically enriched
  - Greater fraction of asymmetric PNe found in LMC, relative to SMC
- [L. Stanghellini will discuss these results in more detail]
- Implications for PN formation mechanism(s)
  - Is asymmetry caused *primarily* by interaction of the CS with a close binary companion?
    - Dependence of duplicity on PN mass?
    - Dependence of duplicity on host galaxy?

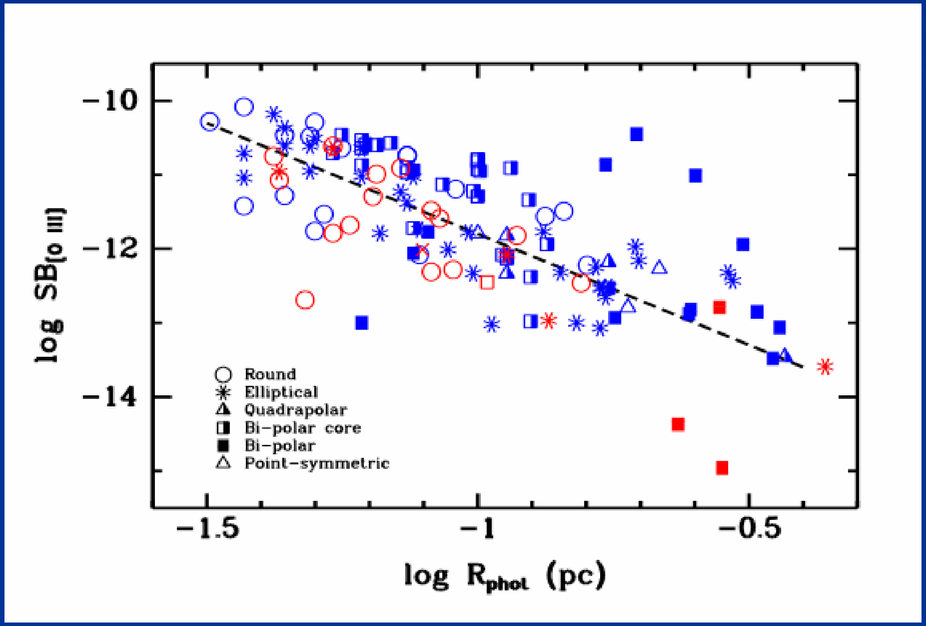
Morphology vs. Host Galaxy

- Broad morphological types are:
  - Round (R)
  - Elliptical (E)
  - Bi-polar (B)
  - Bi-polar core (BC), found within R or E types
  - Quadrupolar (Q)
  - Point-symmetric (P)
- Asymmetric distribution:

Galaxy	LMC	SMC
26%	47%	32%



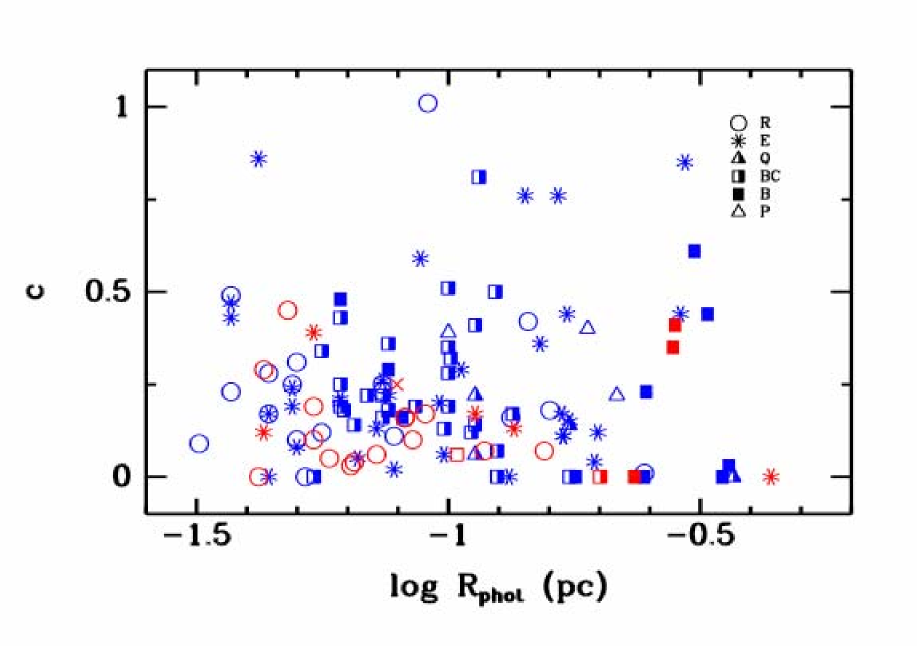
Emission-Line Surface Brightness



- Decline in SB ~ $R^{-1/3}$
- Similar power-law decline in Hα, [N II], [O I]
- Some segregation of morpho-logical types:
  - R more common at small radius
  - Fewer BC at large radius
  - E at all radii
- Trajectory of individual nebulae depends on co-evo-lution of CS + expanding nebula: see paper by Villaver

Extinction vs. Size & Morphology

- The amount of extinction appears *not* to depend upon
  - Nebular size
  - Morphological type
- Extinction appears uniform in selected high-*c* nebulae on spatial scales of ~0.05 pc
- Implications:
  - Extinction largely external
  - No obvious connection between *c* and CS mass



Morphology & CS Properties

- Although the available data are scarce, no obvious correlations of CS properties (mass, evolutionary state) with morphology of the host PN have emerged.
  - Small sample sizes: 16 LMC and 14 SMC with well determined masses
  - CS masses are typical of Galactic values, but distribution may be different?
  - More data pending analysis, which will increase CS sample by X2
- E. Villaver will discuss these results in much more detail

Summary

A major HST observing program to obtain images & slit-less spectroscopy of MCPNe has yielded major insights into the evolution of PNe and their central stars.

- There is some evidence of morphological evolution with age
- There is strong evidence that progenitor chemistry affects the ultimate PN morphology
- There is strong evidence that more massive CSPNs tend to produce asymmetric nebulae

Future Work:

- Obtain additional data on SMC PNe: luminosity-limited sample
- Compare the nebular & stellar “evolutionary clocks” to understand the AGB->PN transition time
- Use the PN population as a tool to understand the early epoch of star formation of the host galaxy