Astrophysical Sciences & Technology
Ph.D. Dissertation Defense

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Multiwavelength Imaging of Planetary Nebulae: Resolving & Disentangling PN Structure

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Abstract:

Planetary nebulae (PNe) represent the late stages of low-mass stellar evolution. The formation of the myriad of PNe morphologies involves processes that are present in many other astrophysical systems such as wind-blown bubbles. In this dissertation we present the results of an X-ray study of PNe, and two modeling projects that incorporate the resulting data with the goal of furthering our understanding of their X-ray properties and morphologies, and the 3D multiwavelength structure of PNe.

CHANPLANS was designed to investigate X-ray emission from PNe. The results from Cycle 14 *Chandra* observations of 24 PNe brought the overall CHANPLANS diffuse X-ray detection rate to ~27% and the point source detection rate to ~36%. The detection of diffuse X-ray emission is unmistakably associated with young ($\lesssim$5000 yr), compact ($R \lesssim 0.15$ pc) PNe that exhibit closed elliptical structures and high electron densities ($n_e \gtrsim 1000$ cm^{-3}).

Utilizing the CHANPLANS data for 14 PNe that exhibit diffuse X-ray emission, we constructed simple, spherically symmetric two-phase models using the astrophysical modeling tool, *SHAPE*. Our models consisted of a hot bubble and swept-up shell with the intent of investigating the X-ray morphology of these objects and the extinction caused by the swept-up shell. We compared simulated and observed radial profiles and we draw the conclusion that while most (~79%) PNe exhibit a limb-darkened X-ray morphology, this is due to nebular extinction of an intrinsic limb-brightened hot bubble structure.

Expanding upon our two-phase model, we generated a 3D model of the brightest diffuse X-ray PN, BD+30°3639, using *SHAPE* and previously published multiwavelength data. Our aim was to investigate the multiwavelength 3D morphology of this well-studied nebula and draw connections with other PNe. We interpreted kinematic and observational data to best fit our model with observations and found that the inherent structure shares similarities with several other PNe, suggesting a common evolutionary path.