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The Physical Structure of NGC 3242

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Abstract. The formation and evolution of planetary nebulae (PNe) is largely attributed to the interaction of the fast stellar wind with the wind of the Asymptotic Giant Branch (AGB), and to the dynamical effects of the photo-ionization of the nebular material. The physical structure of a PN can be used to assess the relative importance of fast stellar winds and photo-ionization in its shaping and evolution, but there is little information on the hot gas content of PNe. Using our recent *XMM-Newton* observations of NGC 3242, we have made a comprehensive analysis of the physical structure of this nebula, combining the physical conditions of the shocked fast stellar wind in its interior and the spatio-dynamical structure and physical conditions of the photo-ionized material.

Keywords. planetary nebulae: individual (NGC 3242)

1. A Complete Study of the Physical Structure of NGC 3242

NGC 3242 is a multiple-shell planetary nebula (PN) with a bright inner shell surrounded by a fainter envelope (Figure 1-*left*). Its morphology is suggestive of an interaction between its fast stellar wind (v_∞=2,400 km s^{-1}) with the slow Asymptotic Giant Branch (AGB) wind, in which the fast stellar wind has excavated a central cavity confined by a thin inner shell. This interaction is also expected to produce shock-heated gas inside the central cavity that should be detectable through its X-ray emission.

Indeed, *XMM-Newton* observations of NGC 3242 have detected diffuse X-ray emission with an X-ray luminosity of 2×10^{31} ergs s^{-1} in the 0.3–2.5 keV energy band (Figure 1-*right*). The X-ray emission is confined within the inner shell of NGC 3242, as predicted by the interacting-winds model. Furthermore, the X-ray spectrum of NGC 3242 implies thermal emission of hot gas at a temperature of 2.1×10^6 K and an rms density of $\sim$10 $\epsilon^{-1/2}$ cm^{-3}, where ϵ is the filling factor. The detailed morphology of the X-ray emission from NGC 3242, however, is more asymmetric than expected in the interacting-winds model, with a bright emission peak located towards one of the two extensions (the northwest one) protruding from the inner shell. The internal absorption in NGC 3242 is very low and cannot be responsible for the asymmetric X-ray morphology.

To investigate the physical structure of NGC 3242, we have combined these X-ray observations with narrow-band *HST* images and intermediate- and high-dispersion spectra. The high-dispersion spectra indicate that the inner shell can be described as a tilted ellipsoidal shell with an equatorial expansion velocity of 26 km s^{-1}. At a distance of $\sim$1.0 kpc, as derived from a study of the expansion of NGC 3242 using multi-epoch *HST*

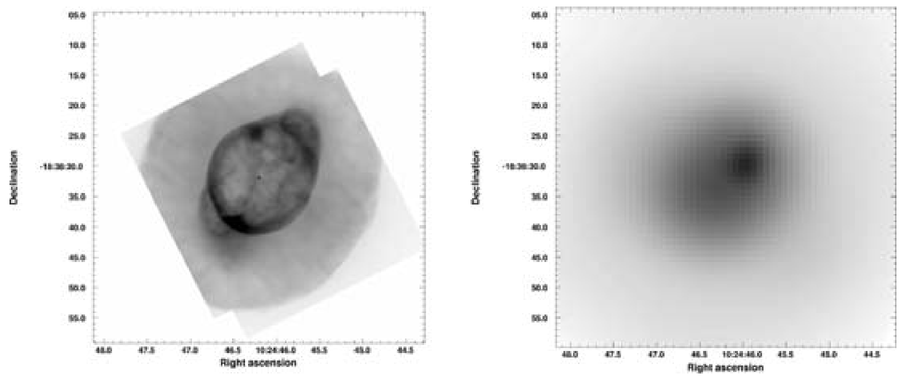

Figure 1. (*left*) *HST* WFPC2 [O III] image of NGC 3242. Several observations of NGC 3242 have been combined to produce this image. (*right*) *XMM-Newton* X-ray image of NGC 3242 in the 0.3-1.2 keV energy band.

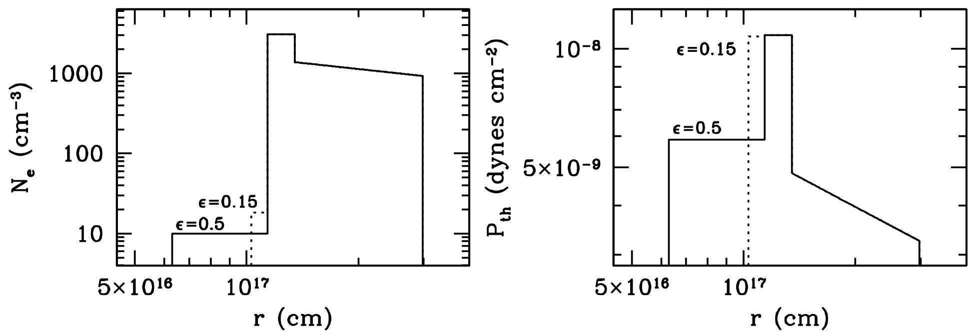

Figure 2. (*left*) Density and (*right*) thermal pressure radial profiles of the central cavity, inner shell and envelope of NGC 3242. The density and thermal pressure of the X-ray-emitting gas within the central cavity are shown for two different values of the filling factor, ϵ.

images, its kinematic age is ~1,700 yrs. The Hα surface brightness profile along the minor axis of NGC 3242 at PA 230° has been used to derive the electron densities of the inner shell and the envelope as a function of nebular radius. The inner shell can be described as a thin shell with a constant density of 3,100 cm^{-3} and a thickness 15% its radius, while the envelope is best described by a shell whose density declines $\propto$ r$^{-1/2}$ (Figure 2-*left*). These densities are consistent with the electron densities of the inner shell and envelope of 2,600 cm^{-3} and 800 cm^{-3}, respectively, computed from density diagnostic line ratios measured in the intermediate-dispersion spectra.

The thermal pressures of the hot bubble and inner shell and envelope have also been derived, using the electron temperature of 12,500 K for the inner shell and envelope derived from temperature sensitive optical line ratios. The hot bubble is in pressure equilibrium with the inner shell if its filling factor, ϵ, is 0.15 (Figure 2-*right*).

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