

Ablation and Wind Mass-Loading in the Born-Again Planetary Nebula A 30

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Abstract. We present *XMM-Newton* and *Chandra* observations of the born-again planetary nebula A 30. These X-ray observations reveal a bright unresolved source at the position of the central star whose X-ray luminosity exceeds by far the model expectations for photospheric emission and for shocks within the stellar wind. We suggest that a “born-again hot bubble” may be responsible for this X-ray emission. Diffuse X-ray emission associated with the petal-like features and one of the H-poor knots seen in the optical is also found. The weakened emission of carbon lines in the spectrum of the diffuse emission can be interpreted as the dilution of stellar wind by mass-loading or as the detection of material ejected during a very late thermal pulse.

Keywords. planetary nebulae: individual (A 30), X-rays: ISM

The planetary nebula (PN) A 30 is one of the few born-again PNe, where thermonuclear burning of H in the remnant stellar envelope built up He until it ignited its fusion into C and O during a late thermal pulse. At optical wavelengths (e.g., Borkowski *et al.* 1995; Chu *et al.* 1997), A 30 consists of (a) an old, round shell with 2' in size, (b) an intricate system of arcs or petal-like features, best seen in [O III], (c) a disk and two bipolar outflows of H-poor knots, and (d) a H-deficient [WC]-PG1159 type central star (CSPN).

ROSAT PSPC observations of A 30 revealed a source of soft X-ray emission from a plasma at a temperature $\sim 3 \times 10^5$ K (Chu & Ho 1995). Follow-up HRI observations showed a central point source and hints of diffuse emission (Chu *et al.* 1997). We have obtained new X-ray observations of A 30 using *XMM-Newton* (PI: Hamann) and *Chandra* (PI: Chu) with net exposure times ~ 31 ks for *XMM-Newton* EPIC-MOS and RGS, ~ 25 ks for *XMM-Newton* EPIC-pn, and 96.1 ks for *Chandra* ACIS-S.

XMM-Newton detects a bright, soft (< 0.6 keV) source at the CSPN with an EPIC-pn count rate in the 0.22–0.6 keV energy band of 39.6 ± 1.3 counts ks^{-1} . *Chandra* also detects this point source with a count rate of 1.80 ± 0.14 counts ks^{-1} in the same energy band. In addition, *XMM-Newton* confirms the presence of faint extended emission at distances $\geq 13''$ that fills the [O III] petal-like features, while *Chandra* suggests tantalizing evidence of emission associated with the southwest cometary knots.

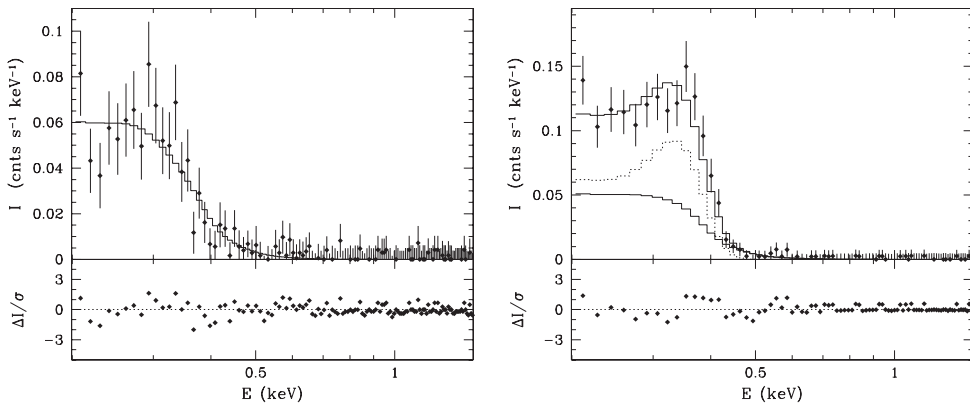


Figure 1. *XMM-Newton* background-subtracted spectra overplotted with best-fit models of the diffuse (*left*) and stellar (*right*) emissions. The latter shows the C VI emission line (dotted histogram) added to the thermal component with Leuvenhagen *et al.*'s (1993) chemical abundances (thin histogram) that suggests higher carbon abundances than the diffuse emission.

The spectrum of the diffuse emission (Figure 1-*left*) has been modeled using an absorbed optically thin plasma emission model, adopting Leuvenhagen *et al.*'s (1993) chemical abundances and a foreground hydrogen column density (N_{H}) of $5 \times 10^{20} \text{ cm}^{-2}$ (Chu & Ho 1995) with best-fit parameters $T_{\text{X}} \approx 7.9 \times 10^5 \text{ K}$ and $L_{\text{X}} \approx 6.0 \times 10^{31} \text{ erg s}^{-1}$ ($d = 2.4 \text{ kpc}$). This model, however, does not provide a good fit to the spectrum of the CSPN (Figure 1-*right*) that shows emission excess at $\sim 0.36 \text{ keV}$. The addition of an emission line, suggested by the RGS spectra to be the C VI L_{α} line at 33.7 \AA , matches better the CSPN spectrum with best-fit parameters $T_{\text{X}} \approx 9.4 \times 10^5 \text{ K}$ and $L_{\text{X}} \approx 1.2 \times 10^{32} \text{ erg s}^{-1}$.

The higher C abundances of the CSPN with respect to the diffuse emission may imply in the latter the dilution of the stellar wind by mass-loading, or the detection of emission from material ejected during a late thermal pulse. As for the CSPN, we may consider:

- **Photospheric emission of the hot CSPN:** The expected X-ray flux is 10^{10} times lower than observed, as radiation is blocked by CNO bound-free and K-shell opacities.

- **Shocks within the stellar winds:** Shocks embedded in the radiation driven winds of hot stars can produce X-ray emission (e.g., Feldmeier *et al.* 1997). For the canonical $L_{\text{X}}/L_{\text{bol}} \approx 10^{-7}$ relationship of O stars (Berghoefter *et al.* 1997), A 30 CSPN would be 100 times fainter than observed. Moreover, this [WC]-PG1159 CSPN is expected to be X-ray fainter than O stars, because the winds of WC stars are very opaque to the X-rays produced in zones of strong wind acceleration at few stellar radii (Oskinova *et al.* 2003).

- **“Born-again” hot bubble:** The CSPN wind mechanical luminosity, $\sim 10^{35} \text{ erg s}^{-1}$, is ~ 800 times larger than the observed L_{X} , and its spectrum is consistent with thermal emission. Thus, our favored interpretation is that X-rays originate from hot plasma generated by the present fast stellar wind ramming into previously ejected slow material.

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