X-ray Emission from Planetary Nebulae

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X-ray emission from planetary nebulae (PNe) may originate from two sources: central stars which are 100,000–200,000 K will emit soft X-rays, and shocked fast stellar winds reaching $10^6 - 10^7$ K will emit harder X-rays. The former are point sources, while the shocked winds are expected to be extended sources emitting continuously out to the inner wall of the visible nebular shell (Weaver et al. 1977; Wrigge & Wendker 1996).

ROSAT observations of PNe have revealed diffuse emission and point sources with a variety of spectral properties (see Figure 1). Different types observed are:

D1 - diffuse emission with spectral characteristics of a thin plasma of 10^5 K, e.g., Abell 30 (Chu & Ho 1995);

D2 - diffuse emission with spectral characteristics of a thin plasma of 10^6 K, e.g., NGC 6543 (Kreysing et al. 1992);

P1 - point source with spectral characteristics of a 10^5 K blackbody, e.g., NGC 6853 (Chu et al. 1993), N67 in the SMC (Kahabka et al. 1994);

P2 - point source with spectral characteristics of a thin plasma of 10^6 K, e.g., BD+30°3639 (Arnaud et al. 1996);

P3 - point source with composite spectral characteristics of types P1 and P2, e.g., NGC 7293 (Leahy et al. 1994).

We have examined all archived ROSAT PSPC pointed observations centered on PNe. Out of the twenty-two objects studied, we find X-ray emission associated with eleven nebulae (see Table 1). NGC 3587 and Abell 36 do not have sufficient S/N ratios in their spectra for a reliable classification.

TABLE 1. ROSAT Observations of Planetary Nebulae

ROSAT Detections	Type	ROSAT Non-Detections
NGC 246	Type P1	NGC 1535
NGC 1360	Type P1	NGC 2371-2
NGC 3587	Type ?	NGC 6210
NGC 6543	Type D2	NGC 6572
NGC 6853	Type P1	NGC 6905
NGC 7293	Type P3	NGC 7009
LoTr5	Type P3	IC 418
BD+30°3639	Type P2	Abell 12
Abell 30	Type D1	Abell 33
Abell 36	Type ?	JN 1
N67 in the SMC	Type P1	YM-29

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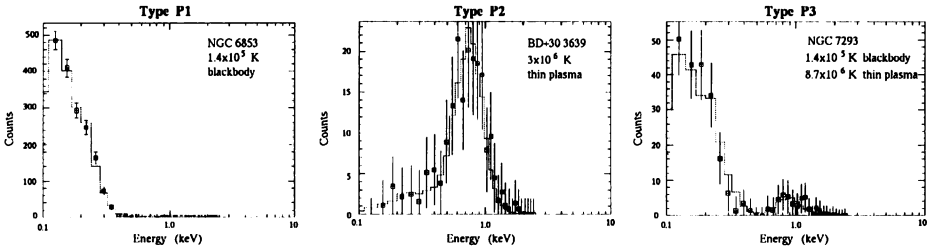

FIGURE 1: Examples of ROSAT PSPC X-ray Spectra

Types D1 and D2 diffuse emission must be associated with shocked fast stellar winds. However, the derived temperature of the X-ray-emitting plasma in A30 is much lower than expected (Chu & Ho 1995). Furthermore, the X-ray emission from A30, instead of extending to the visible shell as predicted, appears to originate from direct interaction between the fast stellar wind and circumstellar clumps (Chu, Chang, & Conway 1997).

Type P1 X-ray sources are probably true point sources. Some are consistent with stellar emission (e.g., NGC 6853) and another has been identified as a supersoft source in an X-ray binary (i.e., N67 in the SMC).

Type P2 source may be unresolved shocked stellar wind emission. The angular size of BD+30°3639 is much smaller than the ROSAT instrumental resolution, but the temperature derived from the spectral fit is consistent with the shocked wind model (Arnaud et al. 1996).

Type P3 sources show a low-temperature stellar component and a hotter component consistent with the shocked stellar wind (Leahy et al. 1994, 1996). However, as in the case of A30, the X-ray emission from NGC 7293 and LoTr5 is all concentrated within a central region much smaller than the PN shell.

High resolution X-ray images of PNe are needed to define more accurately the physical differences between the different types of X-ray spectra and to determine the nature of the X-ray emission. The forthcoming AXAF will provide the needed resolution for such a project.

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