THE X-RAY PLANETARY NEBULAE DATABASE

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ABSTRACT

Planetary nebulae (PNe) are one of the latest additions to the zoo of X-ray sources. *XMM-Newton* and *Chandra* observations have finally detected diffuse X-ray emission from shocked fast winds in PN interiors and from bow-shocks of fast collimated outflows impinging on nebular envelopes. These X-ray observations have produced exquisite images and invaluable spectra of PNe that allow us to examine the spatial distribution and physical properties of hot gas in PN interiors. However, X-ray observations of PNe have not been optimally used, as papers reporting X-ray analysis of PN emission applied preliminary calibrations and methods which have since been significantly improved, and X-ray observations of PNe resulting in non-detections are often left in the archive without appearing in the literature. To present a homogeneous analysis of recent X-ray observations of PNe, we introduce the XPN Database webpage, http://www.iaa.csic.es/xpn, which highlights all *XMM-Newton* and *Chandra* observations of PNe that are available in the archives. We have processed these observations using the most up-to-date calibration files and we make the data at different processing levels available to the astronomical community through this webpage. These X-ray observations have been analyzed consistently using the most recent versions of SAS and CIAO. Statistical analyses of the X-ray and physical properties of PNe can yield crucial constraints on the formation and evolution of PNe.

Key words: Planetary Nebulae; X-rays.

1. INTRODUCTION

PNe are the descendants of low- and intermediate-mass stars. In addition to soft photospheric X-ray emission from their hot, >100,000 K, central stars, diffuse X-ray emission from PNe can also be expected. Two different mechanisms can produce hot gas in PNe:

- Shocked fast stellar wind
  In the standard interacting-stellar-winds model of PN formation, the fast stellar wind emanating from the central star sweeps up the slow AGB wind to form a sharp nebular shell. This central cavity is expected to be filled with shock-heated fast wind that emits X-rays with a limb-brightened morphology.
- Fast collimated outflows
  Fast collimated outflows that occur near the end of the AGB phase impinge on the AGB wind, producing bow-shock structures. When the shock velocity is >300 km s^{-1}, extended cavities filled with hot X-ray-emitting gas can be formed

The processes responsible of the production of hot gas in a PN are, thus, closely tied to the shaping of the PN itself. X-ray observations of PNe are the key to assessing the action of fast stellar winds and collimated outflows in the formation and evolution of PNe.

Diffuse X-ray emission from hot gas in PNe was hinted by *ROSAT* and *ASCA* (Kreysing et al. 1992; Arnaud et al. 1996; Guerrero, Chu, & Gruendl 2000), but only the improved sensitivity and spatial resolution of *XMM-Newton* and *Chandra* have allowed the unambiguous detection of hot gas from PNe. *XMM-Newton* and *Chandra* observations of PNe have produced exquisite X-ray images and low-resolution spectra that can be used to determine the spatial distribution and physical properties of the hot gas in PNe. Among the most important results are the detections of diffuse X-ray emission with limb-brightened morphology from shocked fast stellar wind: BD+30°3639 (Kastner et al. 2000), NGC 40 (Montez et al. 2005), NGC 2392 (Guerrero et al. 2005), NGC 3242 (Guerrero et al. 2006), NGC 6543 (Chu et al. 2001), NGC 7009 (Guerrero et al. 2002), NGC 7026 (Gruendl et al. 2005), and NGC 7027 (Kastner et al. 2001); and diffuse X-ray emission from the bow-shocks of the fast collimated outflows in Hen 3-1475 (Sahai et al. 2003) and Mz 3 (Kastner et al. 2003).

2. THE XPN DATABASE

These X-ray observations are helping us to better assess the relative importance of fast stellar winds and collimated outflows in the shaping and evolution of individual

Table 1. XMM-Newton *and* Chandra *Database of PNe*

PN	Obs.	Count Rate (cnts s^{-1})	Flux (erg cm^{-2} s^{-1})
BD+30°3639	CXO	0.242±0.004	6.8×10^{-13}
CRL 618	CXO	<0.00025	$<8.3\times10^{-16}$
CRL 2688	CXO	<0.0013	$<4.4\times10^{-16}$
Hen 2-90	CXO	<0.0010	$<3.4\times10^{-15}$
Hen 2-99	CXO	<0.00076	$<3.0\times10^{-15}$
Hen 2-104	CXO	<0.00058	$<2.0\times10^{-15}$
Hen 3-1475	CXO	0.0017±0.0003	5.1×10^{-15}
M 1-16	CXO	<0.0010	$<3.6\times10^{-15}$
M 2-9	CXO	<0.0017	$<5.9\times10^{-15}$
MyCn 18	CXO	<0.0004	$<1.4\times10^{-15}$
Mz 3	CXO	0.0022±0.0003	7.0×10^{-15}
NGC 40	CXO	0.0029±0.0008	1.7×10^{-14}
NGC 246	CXO	<0.011	$<6.4\times10^{-14}$
NGC 2346	XMM	<0.0045	$<5.0\times10^{-15}$
NGC 2392	XMM	0.0534±0.0026	6.0×10^{-14}
NGC 3242	XMM	0.0384±0.0021	6.7×10^{-14}
NGC 4361	CXO	<0.00009	$<4.2\times10^{-15}$
NGC 6543	CXO	0.0316±0.0009	1.0×10^{-13}
NGC 7009	XMM	0.0615±0.0017	7.2×10^{-14}
NGC 7026	XMM	0.0083±0.0011	8.8×10^{-15}
NGC 7027	CXO	0.015±0.001	3.1×10^{-14}
NGC 7293	CXO	<0.020	$<1.0\times10^{-13}$
OH 231.8+4.2	CXO	<0.00054	$<2.4\times10^{-15}$

PNe. A comprehensive picture, however, is lacking, because the comparison of observations among PNe is not possible as the X-ray analyses are not homogeneous. Furthermore, a significant number of X-ray observations of PNe that did not detect diffuse X-ray emission have not been reported in the literature.

We have undertaken a systematic study of all *XMM-Newton* and *Chandra* observations of PNe that will benefit from an homogeneous analysis using the recently released calibration files that have much greater accuracy for energies below 1.0 keV, where most of the X-ray emission from PNe is found. Systematic comparisons with observations at other wavelengths will help determine the physical structure of these PNe. All reprocessed event files, derived data products (X-ray images and spectra) and analysis results are forming a database, the *XPN Database*, that can be accessed at http://www.iaa.csic.es/xpn

The *XPN Database* webpage assembles all available *XMM-Newton* and *Chandra* observations of PNe. These are listed in different tables that present both the PNe with X-ray detections and those that are not detected. For the non-detections, the 3-σ upper limits of the count rate and flux are given (often for the first time). For the X-ray detections, the tables include the X-ray size, count rate and observed flux. The PNe included in the XPN Database are listed in Tab. 1.

The *XPN Database* webpage also offers links to webpages of individual PNe with detected X-ray emission. The webpages of individual PNe provide further information on these objects and link to data at different processing levels (event files, X-ray images and spectra). Count rates and fluxes in different energy bands are also given, along with further links to detailed spectral and imaging analyses.

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