BeppoSAX and ROSAT Observations of the Supernova Remnant RCW86

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We present the first results of a BeppoSAX observation of RCW86, covering the south-west part of the remnant (**the knee**).

The spatial analysis of the LECS and MECS data confirms that strong variations of the emission hardness exist between the inner and the outer part of *the knee*. *ROSAT* data suggest that these variations are not due to absorption effects.

The Non Equilibrium of Ionization (NEI) spectral analysis of the LECS data shows that the emission is characterized by the presence of a temperature component at $kT \sim 2$ keV, which, if compared with recent ASCA results obtained with a similar analysis, is softer, more absorbed, and not heavily metal-depleted. The LECS data also do not exclude the presence of a second very soft component (VSC) with $kT \sim 0.4$ keV. The VSC, if real, is to be associated with interaction of main blast wave with interstellar medium (ISM) inhomogeneities.

The NEI spectral analysis of the ROSAT PSPC data confirms the presence of the VSC, and yields an estimate of the interstellar absorption and ionization parameters, but it does not exclude also higher temperature components.

1. Introduction

The supernova remnant RCW86 (also known as G315.4-2.3, MSH14-63) is one of the brightest objects in its category of all the X-ray sky. Recently, it has received renewed attention essentially because of the longstanding topic of the correlation with SN185, the first historical galactic supernova. We present the first SAX observation of the south west part of the remnant, which is expected to interact with an interstellar medium inhomogeneity (Figure 1).

2. SAX LECS Spectral Analysis

The LECS results, obtained with the NEI model in the SPEX software [1], are summarized in Table 1.

The **1T fit with variable abundances** provides a good χ^2 value and relatively low absorption. The free abundances for Mg, Si, S and Fe have been chosen among the expected severely depleted metals [4] which most affect the emissivity in the LECS bandwidth (Ca were excluded). In addition, O and Ne were included. However, the fitted abundances for Si, S and Fe are mostly consistent with unity, while O, Ne and Mg are slightly underabundant with respect to solar values. The spectrum and best-fit model with residuals are shown in Figure 2.

The **two temperature component (2T) fit with fixed solar abundances** provides worse χ^2 value than the 1T fit although slightly above the acceptance threshold for the appropriate number of d.o.f. (86 at the 95% level, and 92 at the 98% level with 66 d.o.f.). The fit results indicate the presence of a *very soft component* (hereafter we shall indicate with VSC a spectral component with $kT < 0.5$ keV). Evidence of VSC has been derived from Collisional Ionization Equilibrium (CIE) fits of EXOSAT data by [2], but not from the recent ASCA data [3].

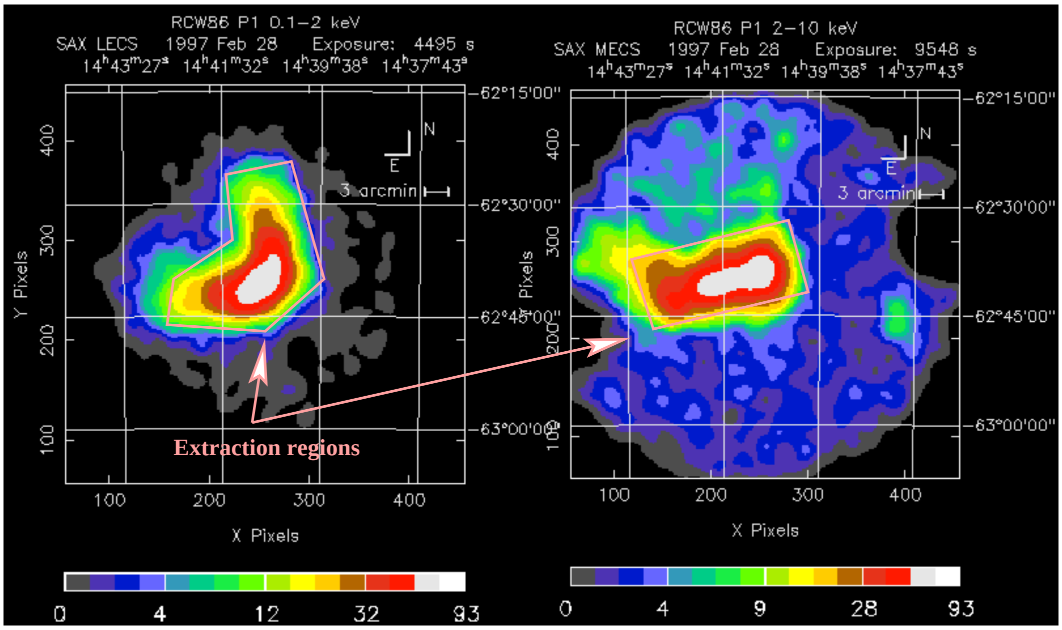

Figure 1. LECS (4.5 ksec) and MECS (9.5 ksec) observation of the RCW86 SNR. Regions used in spectra extractions are marked by polygons (4500 LECS and 12000 MECS counts).

3. ROSAT Spectral Analysis

An archive PSPC data set (9500 sec, pointed to *the knee*) has been used to further investigate the possibility of a VSC, which, if present, should be detected in the ROSAT bandwidth. The PSPC image is shown in Figure 3.

In order to exploit the PSPC spatial resolution and to avoid superposition effects, we selected 5 extraction regions (Figure 3) in the SW Soft region defined in [3], following the suggestion of [5] about the minimum number of counts to perform NEI spectral analysis (> 5000).

For fitting purposes, we have used the single component XSPEC STNEI custom model of [6]. The results ($N_H = 4-8\times10^{21}$ cm^{-2}, $kT > 0.2$ keV, $U = 2-3$ in log yr cm^{-3}) indicate that the data are consistent with the presence of VSC. Moreover, there are no significant differences of the best-fit spectral parameters between the selected regions. The confidence regions show, however, that *an higher temperature* $kT \gtrsim 1.5$ *keV with a lower absorption* $N_H < 5\times10^{21}$ cm^{-2} cannot be excluded by the fitting.

4. SAX LECS Spectral Analysis with a ROSAT-constrained very soft component

The detection of a VSC in the LECS and ROSAT data is very interesting, because, if confirmed, it would give us the chance to study the shock-ISM interactions. Therefore, we have tried to understand if a VSC, as seen with ROSAT, which has a bandwidth better tailored to detect it, is compatible with the LECS data.

We have adopted a NEI model with two components: the *first one* has T and the ionization parameter U fixed to the ROSAT best-fit, the second one is a free NEI component. We have also set O and Fe abundances free in the first component, since their values largely affect the emission below 1 keV, and Mg and Si in the hot component, for a similar reasoning.

Table 1
Summary of SAX fit results. Errors are at the 99% confidence level for one interesting parameter.

Par	1T Var.Ab.	2T Fix.Ab.	2T ROSAT VSC
N_H $(10^{2}1\ \mathrm{cm}^{-2})$	3.6 (3.1-4.2)	5.3 (4.2-6.3)	4.8 (4.4-5.3)
kT_1 (keV)	2.06 (1.71-2.62)	0.18 (0.16-0.20)	0.4^a
U_1 (Log yr cm^{-3})	1.16 (1.06-1.30)	2.52 (2.00-3.21)	2.3^a
Norm$_1$ ($n_e n_H V$ 10^{53} cm^{-3})	5.6 (4.2-7.3)	94.4	1.8 (0.1-7.0)
kT_2 (keV)	-	7.4 (5.1-12.1)	2.04 (1.77-2.51)
U_2 (Log yr cm^{-3})	-	1.74 (1.61-1.85)	1.12 (1.01-1.16)
Norm$_2$ ($n_e n_H V$ 10^{53} cm^{-3})	-	1.8	5.6 (5.1-6.1)
O	0.37 (0.25-0.48)	-	0.03^b (0-2.2)
Ne	0.66 (0.54-0.83)	-	
Mg	0.49 (0.36-0.66)	-	0.61^c (0.45-0.81)
Si	0.79 (0.49-1.20)	-	1.00^c (0.71-1.45)
S	1.00 (0-2.44)	-	-
Fe	1.08 (0.44-3.06)	-	1.13^b (0-2.0)
χ^2 (d.o.f)	72 (63)	91 (66)	77 (62)

a - fixed values based on the ROSAT best-fits.
b - Fe and O are free parameters of the soft component.
c - Mg and Si are free parameters of the hard component.

The result, also reported in Table 1, yields a good χ^2 with the free component very similar to the LECS 1T fit, and confirms that a VSC as detected by ROSAT is not excluded by the LECS data.

5. Discussion

Here we discuss some of the main results about our analysis.

We found that **NEI fit of intermediate counting statistic LECS spectra with free abundances have chances to be trapped in local minima**, which may yield different abundance values. This effect is in principle present also in other detectors with similar spectral resolution. Longer SAX LECS exposure times may overcome this problem, though an extensive set of simulations should be done to quantitatively investigate it. *We have tried several fits with different starting parameters to be sure, as far as possible, that the best-fit converged to the global minimum.*

There is strong evidence for a NEI thermal component with $kT \sim 2$ keV in the knee of RCW86. This component is found in both 1T and 2T LECS fits, but it is not consistent with recent ASCA results. In fact, the thermal component derived with SAX LECS seems *softer* ($kT_{ASCA} > 2.2$), *more absorbed* ($N_{H(ASCA)} < 2.7 \times 10^{21}$ cm^{-2}), and *not heavily metal-depleted* (ASCA abundances are mostly < 0.3, except Si which is < 0.6).

In addition, a very soft component (VSC, $kT \sim 0.4$) could also be present, consistently with the *ROSAT* results, although the 2T SAX LECS fits provide a slightly higher χ^2 value than the 1T LECS fit ($kT \sim 2$ keV), and also the ROSAT data do not exclude the presence of a single hot component at $kT \sim 2$. However, the 2T emission model is more realistic because the *SAX extraction region likely includes different physical environments (clouds, reverse shocks)*, and this gives easily rise to multi-temperature X-ray emission [6].

6. To-be-done list

On going MECS data analysis will be used to shed more light on the detection of the hot thermal components and on the associated metal abundances.

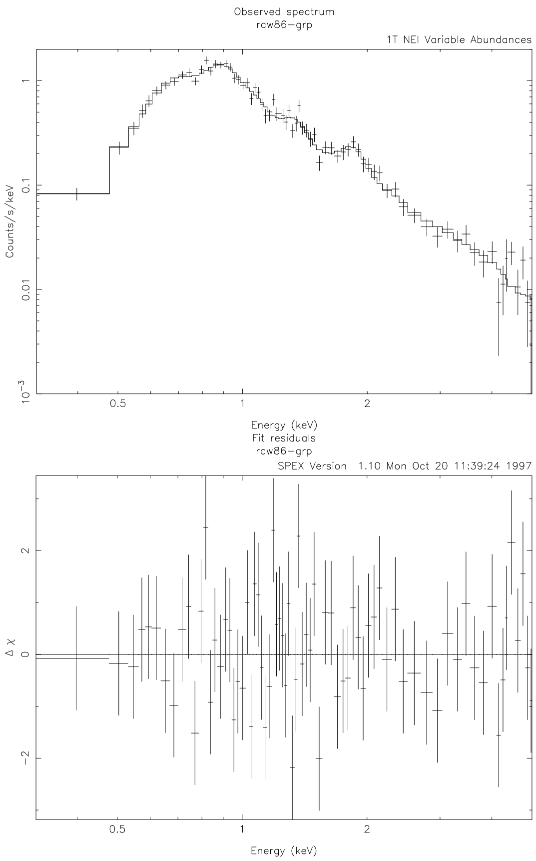

Figure 2. Spectrum, best-fit model and χ^2 residuals of a LECS fit to 1T NEI variable abundances model.

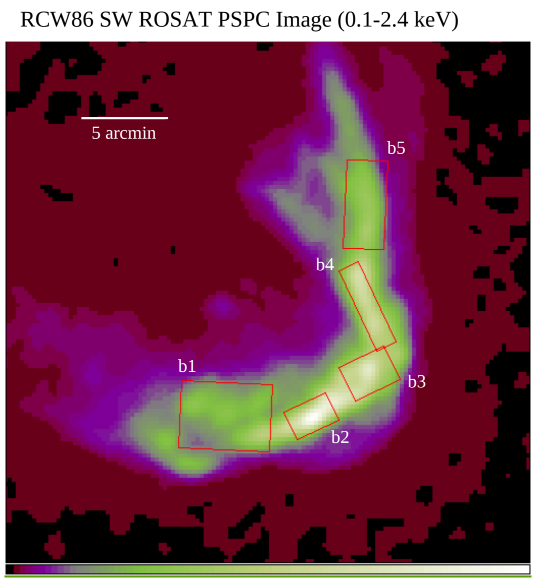

Figure 3. ROSAT PSPC image of the SW part of the RCW86 SNR. Boxes mark the extraction regions used in PSPC spectral fitting.

The hot $kT \sim 2$ keV component may be associated to inter-cloud Sedov expansion of the remnant. Characteristic parameters (E_0, age) could be derived with this assumption, to investigate on the RCW86-SN185 connection.

A more precise abundance determination with the parametric fit approach requires that spectral simulations are performed to better understand the instrumental capabilities vs. counting statistics for NEI emission models.

The SW of RCW86 is an interesting region because our preliminary results indicate interactions with ISM-inhomogeneities (especially if VSC is confirmed). Cloud evaporation models and/or bow shock models could be in principle tested against the data. The remnant also provides challenging observational tests for dusty shock models.

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