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X-RAY ANALYSIS OF GALACTIC SNR G27.4+0.0

A. SEZER[1], E. N. ERCAN[1], M. HUDAVERDI[1,2], F. GÖK[3] and E. AKTEKIN[3]

[1]*Boğaziçi University, Physics Department, 34342 Istanbul, Turkey*
E–mail: aytap.sezer@boun.edu.tr

[2]*TUBITAK Space Technologies Research Institute, ODTU, 06531 Ankara, Turkey*

[3]*Akdeniz University, Physics Department, Dumlupinar Blvd, 07058 Antalya, Turkey*

Abstract. In this work, we present X-ray analysis result of SNR G27.4+0.0 observed by XMM-*Newton* satellite. Three EPIC detectors are studied comparatively. The spatial and spectral analysis are performed, 0.3-10 keV (all band). In order to define possible distribution of interested abundances soft, medium and hard X-ray images are constructed. NEI (Non-equilibrium ionization) plasma model is used for spectral modelling. Electron temperature (kT), neutral hydrogen column density and ionization time are estimated in the physical range. Flux and luminosity values are calculated for hard (2-10 keV) band. Intrinsic absorption is calculated to be higher than the expected galactic value, due to thick opaque remnant. Based on the analysis results we try to understand the undergoing physical mechanisms in the SNR G27.4+0.0.

1. INTRODUCTION

A supernova remnant (SNR) is the structure resulting from the gigantic explosion of a star in a supernova. The supernova remnant is bounded by an expanding shock wave and consists of ejected material expanding from the explosion and the interstellar material swaped up and shock heated along the way. In either case, the resulting supernova explosion expels much or all of the stellar material with velocities nearly 20000 km/s. The explosion is a result of either (i) a collapse massive star which is running out of fuel, ceasing to generate fusion energy in its core and collapsing inward under the force of its own gravity to form a neutron star or a black hole, or (ii) white dwarf, which is accreting material from a companion star until it reaches a critical mass and undergoes a thermonuclear explosion. When this material collides with the surrounding circumstellar or interstellar gas, it forms a shock wave that can heat the gas up to temperatures as high as 10 million K, forming a plasma.

SNRs are well known to be sources of radio synchrotron emission from GeV electrons. During the last 15 years, X-ray synchrotron emission from TeV relativistic electrons has been discovered in several shell-type SNRs. The X-ray spectrum of the SNR gives information about the temperature, the density and the luminosity of the shocked material, while imaging data provides information about the size and morphology of the region.

The galactic supernova remnant G27.4+0.0 (α = 19:41:19, δ = - 04:56:00) was discovered in radio band by Velusamy and Kundu (1974). First observation in X-ray is performed by *Einstein Observatory* in 1979. Fig. 1 shows 2.0-4.5 keV HRI X-ray image and VLA radio map (Kriss et al. 1985). They define a central point source AXP 1E1841-045 (Green's catalog 2006) with a nonthermal spectral index α=0.68 and angular size θ=9 arcmin and a shell morphology. The shell type radio emission is not related to the point source. Guseinov et al. (2003) adopted distance of 7 kpc to this remnant. There is no optical observation of G27.4+0.0. In this study we focus on the remnant by using XMM-*Newton* data. The quoted uncertainties for the best fit parameters of spectral fittings are given for 90% confidence range, unless otherwise stated.

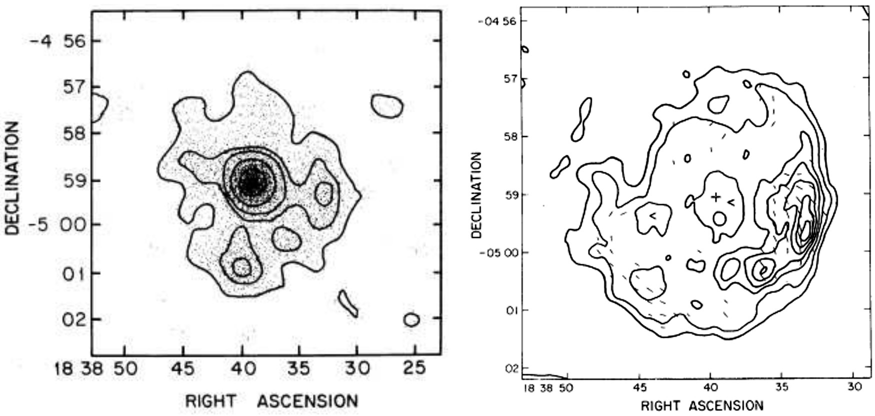

Figure 1: (a) HRI 2-4.5 keV X-ray image, (b) VLA radio map. (Kriss et al. 1985).

2. OBSERVATIONS AND DATA REDUCTION

SNR G27.4+0.0 was observed with the XMM-*Newton* (obs ID 0101001334) for total 6016 s, on 2002. The observatory contains three X-ray detectors. Behind all of them are CCD detectors, collectively called the European Photon Imaging Camera (EPIC). Two of them are MOS type CCD detectors called MOS1 and MOS2 (Turner et al. 2001), the other is of the pn-CCD type (Strüder et al. 2001). The cameras were operated in the Prime Full Window mode with medium filters. The Science Analysis System software (SAS, version 6.1) was used for data reduction. Spectral analysis was performed with xspec v.11.1 (Arnaud 1996). The event lists were generated from the Observation Data Files (ODF) by the tasks EMCHAIN and EPCHAIN. We then selected the events with PATTERN 0-12 for MOS and PATTERN 0-4 for PN. In order to clean the contamination by soft proton flares, the extracted light curves for MOS (10-12 keV) and PN (12-14 keV) were clipped above and below 2.7 σ of the average count rate. Finally, the resulting Good Time Intervals (GTI) selections were applied to the event lists to produce filtered event files. The raw 0.3-10 keV X-ray image of MOS and PN are displayed in Fig. 2.

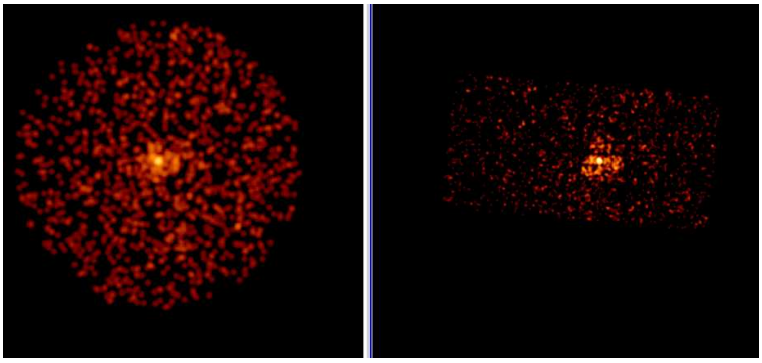

Figure 2: MOS and PN 0.3-10 keV images.

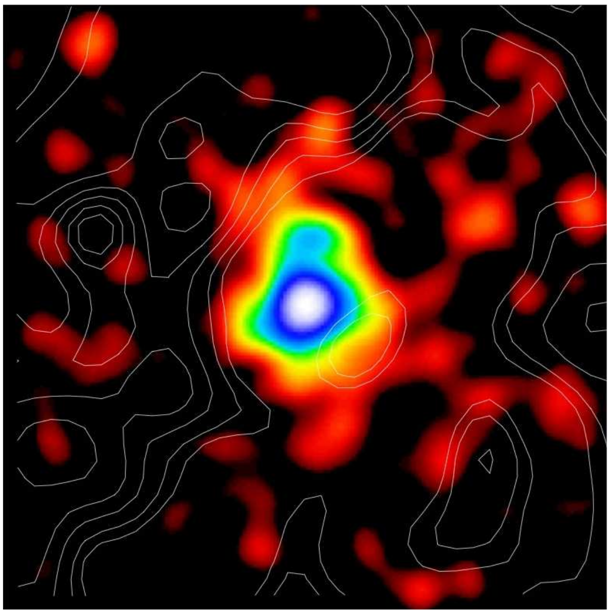

Figure 3: G27.4+0.0 in 0.4-0.7 keV X-ray, overlaid by VLA radio contours.

3. ANALYSIS

3. 1. IMAGE ANALYSIS

The X-ray image of G27.4+0.0 which is obtained in the range 0.4-0.7 keV soft energy band is shown in Fig. 3. The white contours are derived from VLA radio map. The radio emission is shell type, and no central radio source observed as reported in previous works (Kriss et al. 1985).

In order to study the distributions of possible metals in the vicinity, we divide the total energy band into three sections. Fig. 4 shows three band images of soft, medium and hard band. It is evident that soft emission is more patchy. The remnant is more dominant in hard X-rays. Fig. 5 XMM-*Newton* three-color image in the same area. Red, green, and blue represent 0.4-0.7 (for O lines), 0.7-1.2 (for Ne lines), and 1.2-5.0 (for hard band) keV, respectively. Red spots are locations of O, green regions are Ne.

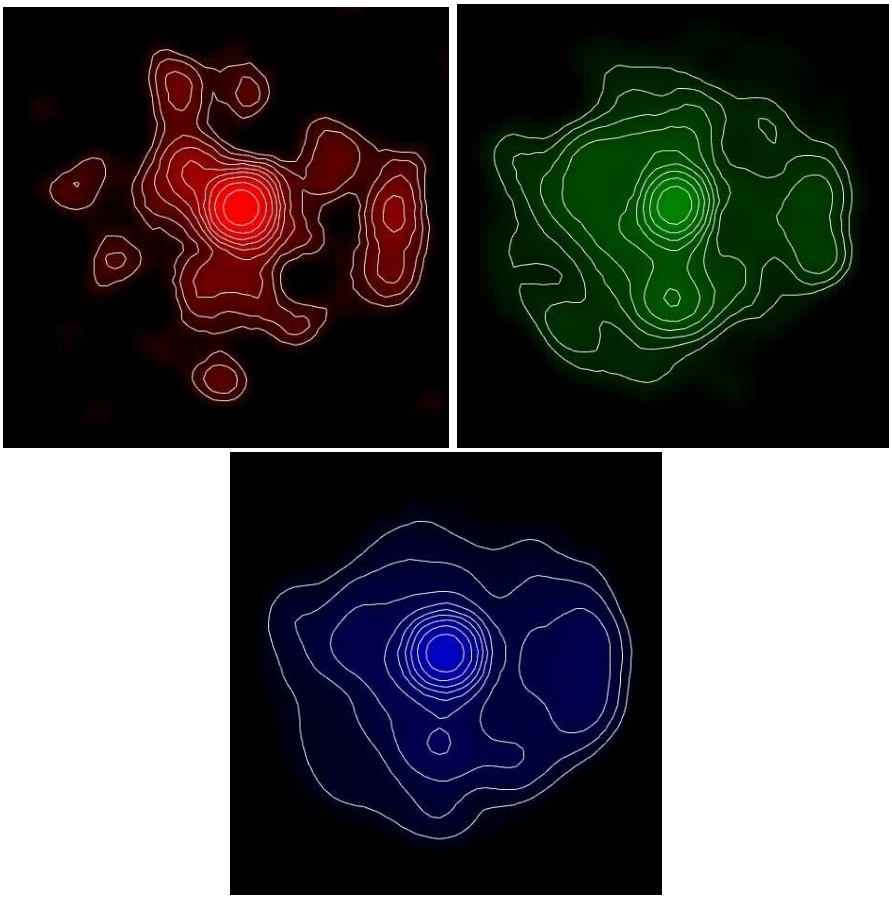

Figure 4: 0.4-0.7 (soft), 0.7-1.2 (medium), and 1.2-5.0 (hard) keV, respectively.

3. 2. SPECTRAL ANALYSIS

Since central point source is studied in previous works, we focus on spectral properties of the remnant. The southern remnant counts are extracted from a 0.5 arcmin radius circle. The background estimate was obtained from a same sized circle out off SNR region. Fig. 6 shows the region of interest and background extraction regions. The required response and auxiliary files for spectra were produced by rmfgen-1.53.5 and arfgen-1.66.4, respectively. We fitted the spectrum with a single Non-equilibrium ionization (NEI) model. Parameters of interest are neutral hydrogen column density

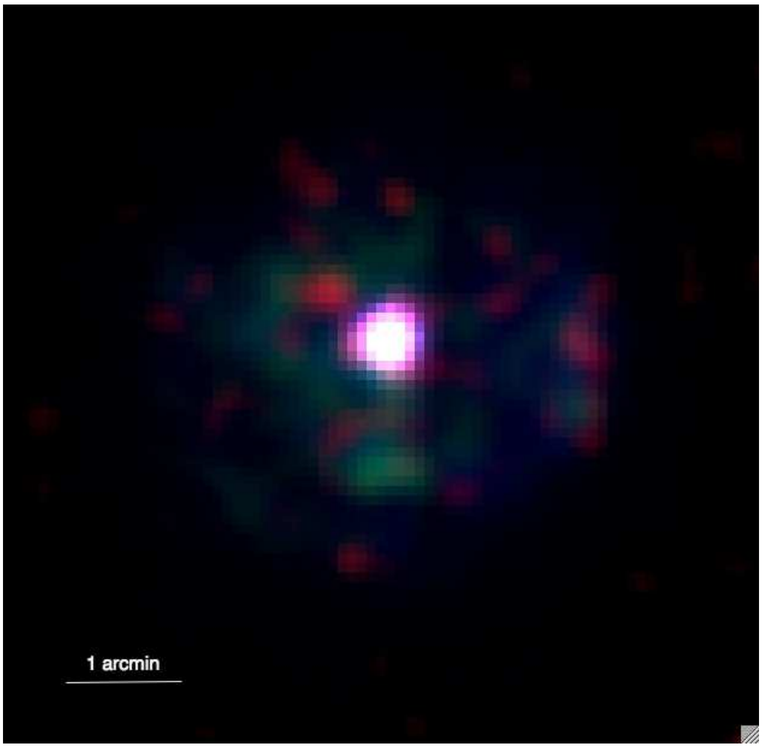

Figure 5: Red, green, and blue represent O, Ne, and hard energy distributions, respectively.

$N_{\rm H}$, electron temperature (kT), and ionization time ($n_{\rm e}t$). The $N_{\rm H}$ = 3.3 × 10^{22} cm^{-2} is significantly higher than the Galactic value. The electron temperature is kT= 0.49 keV. The flux is F_X = 5.7 × 10^{-13} erg cm^{-2} s^{-1}. The best fit parameters (Table 1) are calculated in the physical range.

Table 1: NEI model best fit spectral parameters.

Parameter	Value	Error
$N_{\rm H}$	3.3×10^{22} cm^{-2}	-0.5×10^{22} / $+0.6\times10^{22}$
$kT_{\rm e}$	0.49 keV	-0.10 / +0.12
$n_{\rm e}t$	3.1×10^{13} s cm^{-3}	-3.0×10^{13} / $+1.9 \times 10^{13}$
F_X	5.7×10^{-13} erg cm^{-2} s^{-1}	
L_X	0.13×10^{34} erg s^{-1}	

4. DISCUSSION

We analyzed X-ray emission of the supernova remnant G27.4+0.0, by using the data from a set of public archive XMM-Newton observations. It has a central compact X-ray source is clearly seen our image analysis (Fig. 3). The extend radio emission has shell-type morphology. There is no central counter part in radio wavelength. The

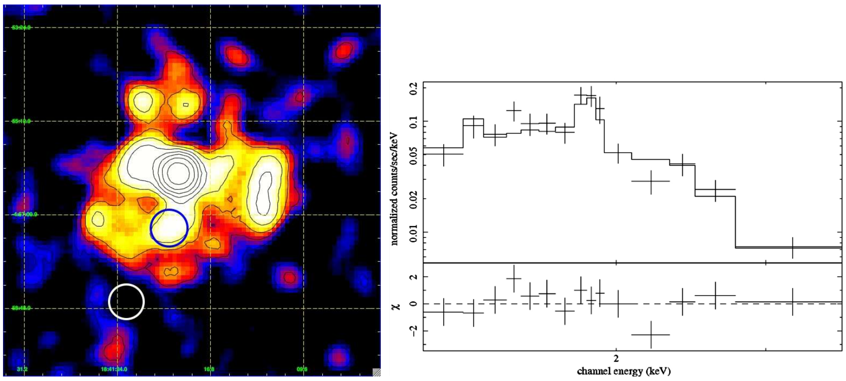

Figure 6: (a) Remnant with spectrum extraction regions, (b) MOS1 spectral fit.

spectral analysis of the southern part of the remnant revealed significant absorptions ($N_{\rm H} = 3.3 \times 10^{22}$ cm^{-2}) relative to Galactic value, which is due to absorption by the remnant itself. The point source has a luminosity of $L_X \sim 10^{35}$ erg s^{-1}, while the remnant is fainter as expected ($L_X = 0.13 \times 10^{34}$ erg s^{-1}). Based on the true-color image (Fig. 5) produced in this study, O and Ne enriched knotty ejecta are found which are known to be core-collapse SN debris (Thielemann et al. 1996). We aim to make optical observations of this sources which will give us opportunity of detailed analysis.

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