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A preliminary Chandra X-ray spectroscopy of the supernova remnant N132D

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Abstract

We present the preliminary results of a Chandra X-ray study of N132D, a young shell-like supernova remnant (SNR) in the Large Magellanic Cloud. The equivalent width maps of emissions from O, Ne, Mg, Si, and S are provided. Spatially resolved spectral analysis for the small-scale regions were tentatively performed. X-ray spectra of the interior can be described with a single-thermal model. The faint interior regions have lower density, higher temperature above 1 keV than that of bright interior regions. The X-ray spectra along the shell can be phenomenally fitted with either a double-*vpshock* model or a *vpshock* + *powerlaw* model. If the non-thermal component is true, N132D would be listed as another X-ray synchrotron SNR.

Keywords: ISM; Supernova remnants; N132D; X-rays; Large Magellanic Cloud

1. Introduction

N132D, one of the prototype O-rich supernova remnants (SNRs) of a massive progenitor, is located in the bar of the Large Magellanic Cloud (LMC) (Danziger and Dennefeld, 1976; Lasker, 1978). In X-ray morphology, N132D is an irregular shell of radius about 50″ with a break-out in the northeast (Mathewson et al., 1983). N132D is a good object to test the stellar evolution and nucleosynthesis models of massive stars since the interior fragments are exposed to direct investigation (Blair et al., 2000). N132D has two advantages for observation. First, because it is located in the LMC, the distance is well determined (50 kpc) and the extinction is low. Second, N132D is one of the brightest soft X-ray sources in the LMC (Favata et al., 1997). Multi-band observations have been performed on it.

In X-rays, Hwang et al. (1993) obtained relatively high resolution spectrum of N132D with the Einstein Solid State Spectrometer. Emission lines of O^{6+}, O^{7+}, Ne^{9+}, and Fe^{16+} were detected. In their work, the best-fit element abundances derived with a single-temperature non-equilibrium ionization (NEI) model are lower than the LMC mean abundances. With the data obtained by the concentrator spectrometer on board the X-ray satellite BeppoSAX, Favata et al. (1997, 1998) found that there should be two components with temperatures of 3.3 and 0.79 keV, respectively. The element abundances derived with the two thermal components model are similar to the normal LMC abundances. Hughes et al. (1998) first reported the CCD data of N132D obtained by the Solid State Imaging Spectrometer on board the Advanced Satellite for Cosmology and Astrophysics (ASCA). They fitted the ASCA data of high resolution with a single Sedov model and found that the temperature is around 0.7 keV and the element abundances are all around the LMC mean, too. Based on the ASCA observation, Chen et al. (2003) modeled the remnant evolution as the blast wave hitting the pre-existing cavity wall. With the extremely high spectral resolution of the Reflection Grating Spectrometers on board the XMM-Newton X-ray observatory, Behar et al. (2001) detected lines of C, N, O, Ne, Mg, Si, S, Ar, Ca, and Fe

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in the spectrum of N132D. Images in the narrow wavelength bands show that, with the exception of O, the dominant part of the soft X-ray emission originates from shocked interstellar medium (ISM). Using High Energy Transmission Grating (HETG) on board Chandra, Canizares et al. (2001) got dispersed high resolution X-ray images of N132D in which some regions of oxygen-rich material were clearly identified despite the spatial/spectral overlap.

In the optical and UV bands, with IUE data, Blair et al. (1994) noted that the X-ray peaks near the center were generally associated with low-velocity, normal composition, optical filaments, rather than with high-velocity, oxygen-rich ones. Morse et al. (1996) obtained high spatial resolution images of N132D with Hubble Space Telescope (HST). They distinguished oxygen-rich filaments from shocked clouds. Comparing with the ROSAT images, they confirmed that the O-rich ejecta emit little X-rays. Blair et al. (2000) performed detailed spectral analysis on the data from HST. The abundance they derived from the shocked ISM cloud in N132D is consistent with the LMC mean. From the spectra of the O-rich ejecta they clearly detected O, C, Ne, and Mg lines, but found no evidence of O-burning elements. They suggested that N132D is the remnant of a Type Ib supernova explosion of a W/O progenitor star with extensive O-rich mantle.

In radio, Dickel and Milne (1995) found that the 6 cm radio emission from N132D largely coincide with the X-ray shell, in other words the shell of N132D seems to be the source of both X-ray and synchrotron radio emission.

Recently, Tappe et al. (2006) detected strong 24 μm infrared emission from swept-up, shock-heated dust grains in the N132D with Spitzer Space Telescope. The image of 24 μm emission follows the X-ray image well. Additionally, they detected PAH molecular bands from N132D.

Profited from the high spatial resolution of Chandra, we have performed a spatially resolved spectroscopic analysis of N132D and present a fresh look of the physical properties of the remnant.

2. Observation and data analysis

We combined two sets of data (ObsId 121 and 1821 observed by C.R. Canizares) released by Chandra X-ray center. Both of the data were dispersed by the HETG at first, then read out by the Advanced CCD Imaging Spectrometer (ACIS). The two observations were carried out on July 19, 2000 with exposure time of 22 ks and on July 20, 2000 with exposure time of 74 ks, respectively.

The tool we used to process the data is Chandra Interactive Analysis of Observations (CIAO) software package (ver. 3.2). Considering the effect of the spatial/spectral overlap after dispersion by the HETG, we only analyzed the zeroth order data. The two sets of data were reprocessed separately to generate level 2 event files following the threads for extended sources (the threads are available on http://cxc.harvard.edu/ciao/). During the course of the reprocessing, we corrected hot pixels and cosmic ray afterglows, filtered bad grades and applied good time intervals correction. Then we merged the two sets of cleaned data for subsequent analysis.

2.1. Spatial analysis

Fig. 1 shows diffuse emission from SNR N132D in the broad band 0.3–8.0 keV. Regions shown in the map are used for spectral analysis (see Section 2.2). This image displays a horseshoe morphology with a bright ridge south to the center, similar to that found in earlier X-ray observations (Mathewson et al., 1983; Hughes, 1987; Behar et al., 2001) as well as the recent IR observation (Tappe et al., 2006). It is easy to distinguish a bright shell with a break-out in the northeast. Noticeably, there are some bright knots and thin filaments along the shell.

The tricolor X-ray image is shown in Fig. 2. The 0.3–1.0 keV emission is coded in red, 1.0–2.0 keV in green, and 2.0–8.0 keV in blue. The images in the three bands were adaptively smoothed using CIAO tool *csmooth* with a signal-to-noise ratio of 3, respectively. In the tricolor image, soft emission (in red) is basically observed all over the image. Soft emission dominates the northeast region where the break-out locates. Southwestward, the proportion of hard emission (in blue) increases. Hard emission could be easily distinguished in the south part of the horseshoe-like shell.

From the overall spectrum of N132D (Fig. 3), we can distinguish emission lines of element species O, Ne, Mg, Si, S, Ar, Ca, and Fe, as are seen in the XMM spectrum (Behar et al., 2001). Considering the low signal-to-noise ratio in the high energy band, we only present the equivalent width (EW) maps of O, Ne, Mg, Si, and S. Here we have applied an adaptive mesh method to rebin the data so as to include at least 10 counts in each bin. EW map indicates regions of high line to continuum ratio, which

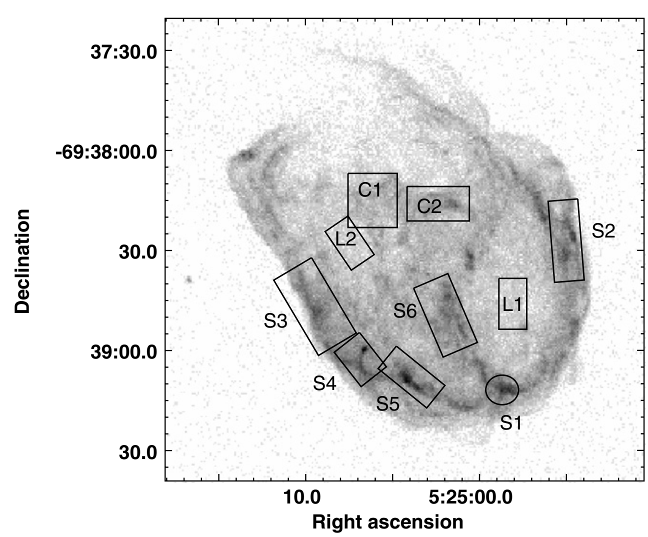

Fig. 1. Raw ACIS-S image of N132D in square-root brightness scales. The labeled regions are used for spectrum extraction.