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Is Vela Jr. a young supernova remnant?

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Abstract

The supernova remnant RX J0852.0-4622 (or Vela Jr.) has been considered to be very young (∼680 yr) based mainly on the possible detection of a radioactive decay line of ^{44}Ti whose lifetime is only ∼90 yr. Here, we report on expansion measurements of the northwestern rim of this remnant, based on *XMM-Newton* observations separated by 6.5 yr. The expansion rate is derived to be $0.026 \pm 0.05 \pm 0.09\%\ \mathrm{yr}^{-1}$ (the first and second-term errors are responsible for statistical and systematic uncertainties, respectively). We estimate the age of this remnant to be ∼1000–3000 yr. Therefore, Vela Jr. turns out to be not so young as it was considered previously. The distance to this remnant is also derived to be at least ∼740 pc, assuming a high shock speed of 3000 km s^{-1}.

Keywords: ISM: individual (RX J0852.0-4622: Vela Jr.); Shock waves; Supernova remnants; X-rays ISM

1. Introduction

The supernova remnant (SNR) RX J0852.0-4622 (or Vela Jr.) was discovered in the southeastern corner of the Vela SNR in the high energy band (above 1.3 keV) image obtained by *ROSAT* all-sky survey (Aschenbach, 1998). The shape is a nearly perfect circle with a large angular radius of ∼60 arcmin. The discovery of this remnant was accompanied by a report of the *COMPTEL* detection of γ-ray line emission from ^{44}Ti (Iyudin et al., 1998), suggesting that this new remnant is young and nearby because of the very short ^{44}Ti lifetime (∼90 yr). Combining X-ray and γ-ray data, the age and the distance of this remnant are estimated to be ∼680 yr and ∼200 pc, respectively (Aschenbach et al., 1999). However, the detection of ^{44}Ti line itself has been debated; a separate reanalysis of the *COMPTEL* data finds that the detection of this remnant as a ^{44}Ti source is only significant at the 2–4 sigma level (Schönfelder et al., 2000). The age and the distance are quite interesting in the light of the other exceptional natures of this remnant, namely the predominance of non-thermal X-ray radiation (e.g., Tsunemi et al., 2000, Slane et al., 2001), the existence of an enigmatic central-compact object (CCO) (e.g., Aschenbach, 1998, Kargaltsev et al., 2002), and the detection of the TeV γ-ray emission (Aharonian et al., 2007).

If we take 680 yr as the best-estimated age of Vela Jr., the proper motion of the shock front is expected to be ∼5.3 arcsec yr^{-1}, assuming the free expansion of the shock. The expected motion is large enough to be measured with the current X-ray observatories. We report on measurements of the forward-shock expansion rates of the northwestern (NW) rim of Vela Jr. from *XMM-Newton* observations taken over 6.5 yr.

2. Observations

The NW rim of Vela Jr. has been observed several times with *XMM-Newton*. Among them, the first (2001) and the

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Table 1
XMM-Newton observations.

Obs. ID	Camera	Instrument mode	Obs. date	Good time interval (ks)
0112870301	MOS1/2	PrimeFullWindow	2001-04-25	31.3
0412990201	MOS1/2	PrimeFullWindow	2007-10-24	62.6

last (2007) observations, which yields the longest time difference of 6.5 yr, are analyzed here. The information on these observations is summarized in Table 1. All the raw data were processed with version 7.1.0 of the XMM Science Analysis Software (XMMSAS). We concentrate on the data taken by European Photon Imaging Camera (EPIC) MOS1 and MOS2 detectors, since the spatial resolution of the EPIC MOS is slightly better than that of the EPIC pn detector. We selected X-ray events corresponding to patterns 0–12. We further cleaned the data by rejecting high background (BG) intervals. After the filtering, the data were vignetting-corrected using the XMMSAS task `evigweight`. We further need to subtract the cosmic X-ray BG and the cosmic-ray induced BG at energies above typically 1.5 keV (Arnaud et al., 2001). To this end, we subtracted the data set accumulated from blank sky observations prepared by Read and Ponman (2003).

3. Analysis

Fig. 1(left) shows the BG-subtracted *XMM-Newton* hard band (1.5–8 keV) image of the NW rim of Vela Jr. We can clearly see sharp filamentary structures whose emission is dominated by non-thermal emission (Tsunemi et al., 2000; Slane et al., 2001). These structures mark the current locations of the shock fronts of the NW rim of Vela Jr. There is a significant X-ray contamination from Vela SNR along the line of sight. However, the emission is negligible in this hard energy band, since it is believed to be dominated by thermal emission with the electron temperature of below 0.3 keV (e.g., Iyudin et al., 2005).

According to an *XMM-Newton* calibration status report (Kirsch, 2007), the absolute astrometric accuracy is $\lesssim$2 arcsec. We determine positions of four point sources serendipitously detected in our FOV, by applying an XMMSAS tool `edetect_chain` which takes into consideration of a point spread function of *XMM-Newton*'s X-ray telescope. The rms residual calculated for the positions of the four point sources between 2001 and 2007 images was 1.8 arcsec. Then, we confirm that the astrometric accuracy of $\lesssim$2 arcsec is achieved in our observations. We take the error of 2 arcsec as a systematic uncertainty in the following proper-motion measurements.

The difference between the 2001 and 2007 images in 1.5–8 keV band is shown in Fig. 1right. We can clearly see a black (negative) narrow line running from the northeast (NE) to the southwest (SW) as a sign of the expansion of the shock front in 6.5 yr. Other black or white lines are due to artificial effects such as bad columns or gaps among the CCD chips.

Next, we measure the shift of the X-ray filament, based on one-dimensional profiles across the filament. We select two areas of the narrow filament as shown in Fig. 1. These areas are chosen so that they are perpendicular to the shock front and are not suffered from bad columns. We slice the areas into 2″-spaced regions parallel to the filament. The BG-subtracted radial profiles for the two epochs are plotted in Fig. 2. The x-axis is the distance from the X-ray SNR center of $\mathrm{RA} = 08^{h}52^{m}00^{s}$ [J2000], $\mathrm{DEC} = -46^{\circ}22'00''$ [J2000] (Aschenbach, 1998). In area-A, we clearly see that the peak position of the filament at around $R \sim 3295$ arcsec in 2001 is shifted to $R \sim 3300$

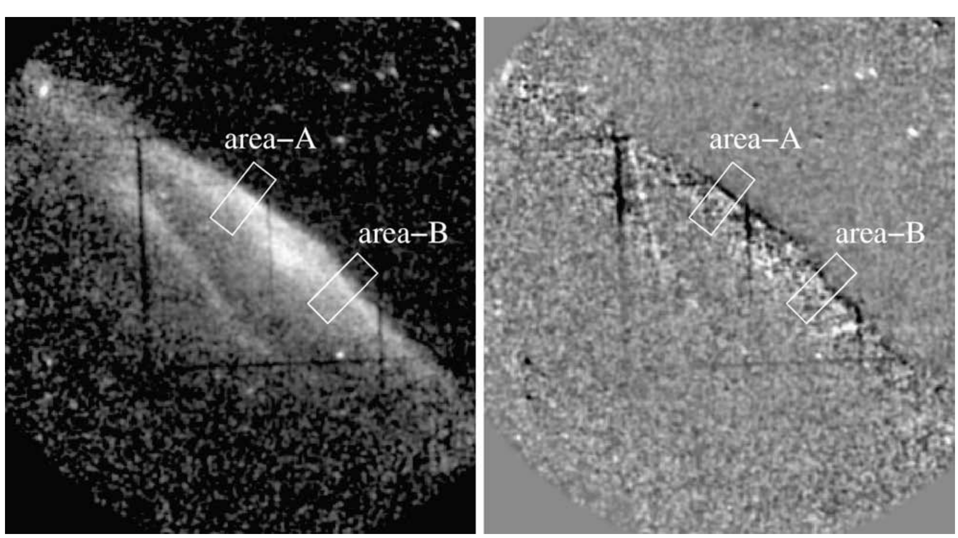

Fig. 1. Left: *XMM-Newton* 1.5–8 keV band image obtained in 2001. The image is binned by 5 arcsec and has been smoothed by Gaussian kernel of $\sigma = 10$ arcsec. The intensity scale is square root. We investigate the radial profile of the X-ray filament in the rectangular areas (area-A and B). *Right*: the difference map between images taken in 2001 and 2007 (i.e., the 2001 image has been subtracted from the 2001 image). The intensity is linearly scaled from -1.5×10^{-4} to $+1.5 \times 10^{-4}$ counts s^{-1} $pixel^{-1}$.