Hitomi Observations of Supernova Remnants N132D and G21.5-0.9

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Abstract

We present preliminary results from Hitomi observations of supernova remnants (SNRs) N132D and G21.5-0.9 which were selected for the performance verification as well as initial calibration of the Hitomi satellite.

N132D is the X-ray brightest SNR in the Large Magellanic Cloud (LMC). It is a member of a rare class of oxygen-rich young SNRs, characterized by the presence of fast-moving oxygen-rich optical knots thought to result from He-burning nucleosynthesis in the cores of massive stars. In the early phase of the Hitomi observation of N132D, the satellite attitude control was unfortunately lost due to problems in the star tracker system (STT). Therefore, the exposure time of the soft-X-ray spectrometer (SXS) observation was unexpectedly short (less than an hour). Nevertheless, the SXS successfully detected some K-shell lines from highly-ionized sulfur and iron, thanks to its excellent spectral resolution and gain accuracy. On the other hand, the soft X-ray imager (SXI) was able to catch N132D even after the STT anomaly, thanks to its large field of view. Therefore, we obtained a statistically-rich SXI spectrum. We also investigated X-ray spectra taken by the Suzaku XIS and the NuSTAR FPM, and found clear signatures of Fe Lyα and Fe Heβ (Bamba et al. 2017 in preparation). Based on our modeling of the combined SXI+XIS+FPM spectra, we revealed that the Fe-K emitting plasma is recombining, and that the SXS-detected Fe-K lines complex, namely the strongest Fe-K feature in the X-ray spectrum, is likely to be Fe Heα lines. Using the SXS spectrum, we found these Fe Heα lines to be redshifted by $\sim$30 eV or $\sim$1500 km s^{-1}. This velocity is much larger than the LMC's systemic velocity along the line of sight (278 km s^{-1}: Mateo 1998, ARA&A, 36, 43), which can be naturally explained by an asymmetric supernova explosion. In addition, we were able to measure a line of sight velocity of the S Heα lines to be $\sim$5 eV or $\sim$600 km s^{-1}, roughly consistent with the LMC's systemic velocity. It should be noted, however, that the SXS energy-scale uncertainty in the low-energy band is larger than that around Fe Heα, and may be equivalent to the shift measured for S Heα. Cautious investigations of the SXS energy scale are now in progress to better constrain the S Heα lines' centroid.

G21.5-0.9 is a plerionic SNR with a bright Crab-like pulsar wind nebula (PWN) in our Galaxy, having a filled synchrotron nebula centered on the $\sim$62 ms pulsar, PSR J1833-1034. Hitomi observed G21.5-0.9 with the SXS, SXI, and the hard X-ray imager (HXI), providing a high-statistics wide-band ($\sim$1–60 keV) spectrum. The wide-band spectrum can be statistically better fitted with a broken power-law model than a simple power-law model, consistent with the previous NuSTAR result. This indicates either a break in the injected electron energy spectrum or energy losses due to particle transport in the PWN (Nynka et al. 2014, ApJ, 789, 72). The pulsation period and the period derivative of PSR J1833-1034 were measured in radio and GeV gamma-rays to be $P = 61.86$ ms and $\dot{P} = 2.0 \times 10^{-13}$ s s^{-1} (Camilo et al. 2006, ApJ, 637, 456; Abdo et al. 2013, ApJS, 208, 17), but have not yet been detected in the X-ray band. So far, our timing analysis using both the HXI and the SXS does not show any significant pulsations partly due to the much brighter PWN. However, given that the pulsed fraction (if any) would be fairly small in X-rays, we need further careful analyses of systematic uncertainties to find possible pulsations or give a stringent constraint on a pulsed fraction. In addition to these studies, a survey of emission and absorption lines in the SXS spectrum is ongoing, which will be presented in a forthcoming paper.

Key words: ISM: individual objects (N132D, G21.5-0.9) — ISM: supernova remnants — X-rays: ISM