Constraining long-term variability of solar-wind charge exchange induced X-ray emission observed with Suzaku

Hiroshi Yoshitake, Kazuhisa Mitsuda, Noriko Y. Yamasaki., & Yoh Takei

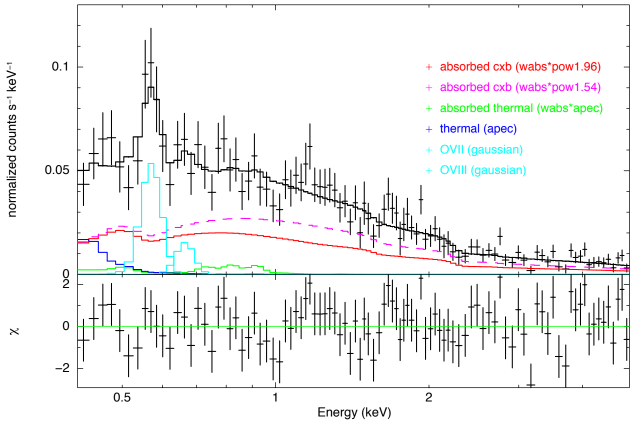
Institute of Space and Astronautical Science (ISAS) /
Japan Aerospace Exploration Agency (JAXA)
3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan

Abstract

From the first recognition of solar-wind charge exchange (SWCX) induced emission from comet Hyakutake by ROSAT satellite in 1996, possibility of SWCX emission in interplanetary space was pointed out. At present, Soft X–ray Diffuse Background (SXDB) under 1 keV is considered as the superposition of emission from 0.1 – 0.2 keV hot plasma bounded in our Galaxy (Local Hot Bubble; LHB or Galactic Halo; GH) and SWCX induced emission (Snowden, 2009). From some simulation results (Koutroumpa *et al.* 2006, 2007), OVII line intensity (0.56 keV) of SWCX emission reacted with interstellar neutrals in the heliosphere $\sim$ 100 AU from the Sun (helisopheric SWCX; HSWCX) is expected about 0.5 – 2.0 LU (Line Unit = photons $\mathrm{s^{-1}cm^{-2}str^{-1}}$), depending on line of sight and observation period. This amount shares 30 – 100 % of the total OVII intensity from various blank sky fields, so contribution from HSWCX has considerable amount of SXDB emission. In addition, SWCX emission reacted with geocorona (geocoronal SWCX; GSWCX) was also suggested. Though there are some observational evidences of GSWCX emission from X–ray light curve (e.g. Fujimoto *et al.* 2008), sufficient evidence of HSWCX has not been shown yet, because it is difficult to separate it from LHB and GH emission. Time scale of variation of GSWCX emission is shorter than 1 day. On the other hand, HSWCX emission should vary about 1 year longer than GWCX one, depending on annual modulation and 11–year solar activity.

In this paper, we show our current strategy how to know long term variability of HSWCX emission, and to get the true picture of X–ray emission from our Galaxy by using Suzaku satellite data. Suzaku has annually observed blank field region in almost same sky coordinate through 5 years. We tried to establish a limit to the long term variation of HSWCX induced OVII line intensity from these data. In addition, we also provide ideas to get an evidence of heliospheric SWCX emission via high energy resolution spectroscopy for a next Japanese X–ray satellite mission Astro–H.

We analyzed annual observations toward Lockman Hole where is used for the calibration target of Suzaku from 2006 to present. During this interval, solar activity passed the minimum of Cycle 23th, and the contribution from SWCX induced line emission is predicted to give minimum quantity to SXDB in high ecliptic latitude area from simulations. To see the universal emission from the interstellar space in our Galaxy, we need to reduce short time variation from X–ray data as possible. Suzaku goes around near-Earth orbit $\sim$ 550 km height that is closer to the Earth than XMM–Newton and Chandra, so the contribution of GSWCX is more influential to energy spectra. We checked correlations between energy spectrum and solar activity; solar wind proton/ion flux and solar X-ray intensity, or parameters related to the Earth; interplanetary magnetic field and density of neutral atmosphere. After screening X–ray events related to the GSWCX and solar X–ray emission carefully, we estimated the OVII line intensities from the spectrum fitting using a Trans–Absorption model (Fig. 1). The OVII intensity fluctuates $\sim$ 1.2 LU as an upper limit from a minimum intensity $\sim$ 2.7 LU at 2006 (Fig. 2).



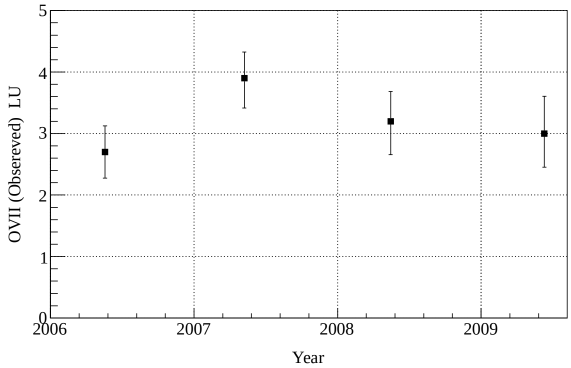


Figure 1: (Left) 0.4 – 5.0 keV CCD spectrum and emission models of the blank field toward Lockman hole in 2006 (top panel) and residual of the fit (bottom panel). The spectrum is convolved with Suzaku CCD response. Black crosses show the spectra with vertical 1σ statistical error bars. Step lines show the models with best fit values; total (black), Galactic Halo (green), LHB+SWCX (blue) with their oxygen abundances set to 0, CXB with $\Gamma = 1.52$ (magenta), and CXB with $\Gamma = 1.96$ (red) respectively. Both OVII and OVIII lines are estimated as single lines (aqua).

Figure 2: (Right) OVII line intensity toward Lockman Hole estimated from spectrum fitting.

Though it is difficult to separate fine structures of emission lines with CCD energy resolution under 1 keV, high resolution spectroscopy via microcalorimeter Soft Xray Spectrometer(SXS) onboard Astro–H (launched in 2014) will make us possible to undertake fine structure diagnostics of He-like triplet lines. We focused on the OVII triplet lines, and calculated if it is possible to identify the strong forbidden line feature of SWCX from spectra of various blank sky fields blended with hot gas emission of LHB and GH. The emission model of the each component was used from Koutroumpa *et al.* 2006, Kharchenko et al. 2003, and Yoshino *et al.* 2009. The field of view of a telescope on SXS is small ($\sim 3 \times 3$ arcmin^2), but we can confirm the contribution of HSWCX emission to the SXDB if more than 500 ksec exposure accumulation of blank field observations toward various line of sight avoiding low galactic latitude region $< |30°|$ is required for the detection of resonance/forbidden ratio anomaly with respected to CIE plasma with 3σ confidence level.

References

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