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Suzaku observations of solar wind charge exchange and future Japanese missions

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Abstract

We review observational studies of solar wind charge exchange emission occurring in the Earth's magnetosphere with the Japanese X-ray astronomy satellite Suzaku. We also show how future Japanese missions offer the capability of characterizing the solar wind interaction with the magnetosphere using this soft X-ray emission.

1. Introduction

Soft X-ray studies of the solar system have revealed that the Solar Wind Charge eXchange (SWCX) process occurs in planetary atmospheres, comets, and interplanetary space [1]. The SWCX emission associated with the Earth's magnetosphere was discovered unexpectedly as strong and variable soft X-ray background. The solar wind ions interact with neutrals in the Earth's magnetosphere. The ion strips an electron(s) from the atom and releases X-ray or UV photon(s) as the electrons relax into the ground state. Since the motion of the solar wind ions is influenced by the Earth's magnetic field, this soft X-ray emission will offer a new tool for characterizing dynamic plasma structures in the Earth's magnetosphere (e.g., [2]).

To date, the X-ray studies of the SWCX emission associated with the Earth's magnetosphere have been conducted with Earth-orbiting X-ray astronomy satellites (ROSAT, Chandra, XMM-Newton, and Suzaku) (e.g., [3-4]). In this paper, we review X-ray observations of this emission with Suzaku.

2. Suzaku Observations

Suzaku is the 5^{th} Japanese X-ray astronomy satellite launched in 2005 [5]. The instrumental background of X-ray CCDs onboard Suzaku is lowest among all CCDs in currently available X-ray observatories. The Furthermore, near Earth region can be observed with Suzaku in Low Earth orbit, while constraints on Earth limb avoidance angle of other X-ray astronomy satellites in elliptical orbit limits the observable region. Suzaku is thus ideal for observing the diffuse SWCX X-ray emission in the Earth's magnetosphere.

Soon after the launch in 2005, X-ray enhancements due to the SWCX emission in the Earth's magnetosphere have been detected when Suzaku pointed in the direction of the north ecliptic pole [6] and also toward the sub-solar side of the magnetosheath [7]. Figure 1 shows an example of the X-ray light curve in comparison with the solar wind.

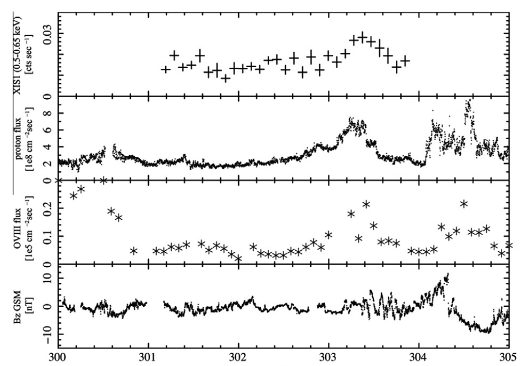

Figure 1. Suzaku light curve in the OVII line band (0.5-0.65 keV) compared to WIND solar wind proton flux, ACE OVIII flux and interplanetary magnetic field Bz component (from top to bottom) [7].

The line of sight direction of the north ecliptic pole observation goes through the north magnetic pole region where the distance to the point where the magnetic field is open to space can be down to 2-8 Earth radii. On the other hand, the line of sight direction in the latter case, i.e., toward the magnetosheath direction, the distance is almost constant and large ~12 Earth radii. These detections many places in the Earth's magnetosphere, although the observed intensity sometimes exceeds the empirical model prediction by a factor of ~10.

Motivated by these detections, Ezoe et al. (2011) established a method to extract the SWCX emission from the Suzaku data, using the temporal variation of the X-ray light curve and solar wind obtained at the L1 point [8]. Applying this method to Suzaku's 6 yrs archival data, Ishikawa (2013) has conducted the first systematic search of the Suzaku data for the SWCX emission in the Earth's magnetosphere [9]. Line of sight directions cover most of the accessible sky, apart from constraint of the Suzaku's Sun angle. From ~2000 data sets, ~40 data show correlations between the X-ray light curve and solar wind flux.

3. Future Japanese Missions

The X-ray studies of the SWCX emission associated with the Earth's magnetosphere are now giving us deeper insights in the dynamic plasma structures and neutrals in the Earth's magnetosphere. However, short of X-ray observatories with high energy resolution nor global imaging capability prevent us from fully utilizing this phenomenon for astrophysics and also geophysics.

The 6th Japanese X-ray observatory ASTRO-H [10] will advance our understanding on the SWCX emission. It will be launched around 2014 and carries an X-ray microcalorimeter, which has more than 10 times better energy resolution than X-ray CCDs and is especially effective for the diffuse objects including the SWCX emission. This will enable us to directly study dynamics of solar wind ions and chemical composition of neutrals.

The advent of a wide field of view X-ray imager will offer another capability, i.e., global imaging of the Earth's magnetosphere. We are proposing such an instrument, which is originally designed for in-situ observation of Jupiter [11], for small technology satellites SDS4 and DESTINY.

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