'X-ray Processes in the Solar System (XRaySolSys)' Abstracts

Talks

Determining the Magnetopause Position from SXI Images

Authors

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Abstract

Soft X-rays produced by the charge exchange mechanism have been detected at most major bodies in the solar system. At Earth, these are produced by collisions between heavy ions in the solar wind and neutral hydrogen in the Earth's exosphere. This leads to the magnetosheath and cusps being regions of bright soft X-ray emission.
SMILE-SXI will launch this year to observe the X-ray emission from the Earth's magnetosheath. Its compact lobster-eye design, wide FOV and 51-hour orbit will allow us to observe the dynamics of the dayside magnetopause region on a timescale long enough to observe geomagnetic storms. Other future mission proposals to observe other solar system bodies are based on similar designs to SMILE-SXI.
This presentation will show how to infer the magnetopause position from SXI images using a forward modelling process. The magnetopause is an important boundary between the Earth's magnetosphere and solar wind that responds to changes in dynamic pressure and magnetic field orientation. We use physical models and an instrument simulator to fully generate model images that can be fitted to data, so that the magnetopause position can be extracted from the physical model. We show the robustness of this approach under a range of solar wind conditions.

Jupiter's X-ray Aurorae: A high signal spectral analysis of the 0.24 to 7.00 keV energy range

Authors

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Abstract

Jupiter provides a natural laboratory for the study of charge exchange (CX). The X-ray aurorae have been found to be dominated by ion CX spectral lines from energetic particle precipitations from the outer magnetosphere into the auroral regions of Jupiter (Branduardi-Raymont et al. 2007). Jupiter provides a unique opportunity to study the observed CX spectra and the ion population and conditions that produce them. For example, ion populations have been studied using the Juno Jupiter Energetic Particle Detector (JEDI) instrument (e.g. Haggerty et al. 2017; Clark et al. 2020), along with spectral analysis of the aurora in the X-ray waveband (e.g. Elsner et al. 2005). These CX spectra have rarely been directly compared with the ion populations that produce them.

The study investigates high signal X-ray spectra from the northern and southern auroral regions of Jupiter using the XMM-Newton X-ray telescope in the energy range 0.24 to 7.00 keV. The spectra are created from fourteen observations of Jupiter taken over a five-year period combined together, giving ~660 ks of good observation time.

The study used multiple ACX2 models, with ion species oxygen, neon, magnesium, silicon and sulfur, along with an APEC model to represent scattered solar coronal emission, a power law model of energetic non-thermal electrons and a velocity shift model. The results show that a good fit is obtained with the ion species and abundances observed by JEDI on the first perijove of the Jupiter mission.

The velocity shift when applied to the ACX2 models blue shifts the CX emission lines to improve the quality of the fit. The velocity shift in the northern auroral region of Jupiter agrees well with previous results obtained from the XMM-Newton Reflection Grating Spectrometer (RGS), suggesting that the ions collide with the atmosphere at velocities of ~5000 km/s.

The study also investigates potential CX emission lines in the high energy X-ray (1.60 keV – 7.00 keV) region confirming the detection of high charge states of sulfur (S XV and S XVI) with greater than 5 sigma significance for S XV and 3 sigma significance for S XVI. This result shows that sulfur ions are precipitating into Jupiter’s northern auroral region with energies up to 30 MeV which aligns well with the presence of MV potential drops previously reported. The study also considers other potential ion species candidates, silicon and calcium.

Spectral properties of Solar Wind Charge Exchange (SWCX) emission from the Earth's outer boundaries

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Abstract

The Solar Wind Charge Exchange (SWCX) mechanism, in which X-ray emissions are generated through interactions between heavy, highly charged solar wind ions and neutral atoms, offers new opportunities to observe planetary magnetospheres and cometary atmospheres in a more dynamic and spatially resolved manner. This has opened the door to observing variations in the fundamental states of Earth's magnetosphere, thereby improving our understanding of energy and momentum transfer processes within the Sun–Earth system, where previous observations have been limited by the restricted and often single-point nature of in situ satellite measurements and ground-based observations.

In the presentation, we showcase results that model and analyze SWCX signatures from Earth's magnetopause and cusp regions using global Magnetohydrodynamics (MHD) simulations enhanced to incorporate heavy ions and X-ray emissions. The SWCX mechanism is highly species dependent, governed by interaction cross sections and solar wind-ion abundances. Our simulations capture these species-specific properties, producing X-ray emission spectra with species-level resolution.

These emission profiles help us study solar wind drivers, their spatial and temporal evolution, and their ability to distinguish key magnetospheric regions. These findings are highly relevant for upcoming missions such as SMILE (Solar wind Magnetosphere-Ionosphere Link Explorer), the first mission dedicated to observing global X-ray emissions from Earth's magnetosphere. The model also enables investigation of kinetic particle effects such as Kelvin–Helmholtz waves and Flux Transfer Events (FTEs), which are discussed further.

State-of-the-art silicon detectors for soft X-ray imaging and spectroscopy

Authors

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Abstract

The Centre for Electronic Imaging (CEI) at the Open University has been collaborating with Teledyne e2v (T-e2v) for over 20 years on the development of silicon-based detectors for scientific and space applications. Charge-coupled devices (CCDs) have long been the technology of choice for X-ray imaging and spectroscopy, and despite rapid advances in alternative technologies, they remain highly competitive due to their excellent noise performance, spectral capability, and overall maturity.

The CEI is currently involved in a range of X-ray missions and instrument concepts across different stages of development, all of which use either state-of-the-art CCDs, or newer technology such as CMOS image sensors (CIS). These missions include the upcoming ESA SMILE telescope, the THESEUS mission concept, and future X-ray telescope concepts such as X-ray interferometry. For SMILE, bespoke large-format CCDs have been developed for the Soft X-ray Imager (SXI), which will observe emission from solar wind charge exchange around the Earth. The SXI focal plane consists of two 8 × 8 cm CCDs, incorporating design and manufacturing modifications to enhance radiation tolerance and extend operational lifetime in a challenging space environment.

In parallel to enhancement of already mature CCD technology, the CEI is advancing CMOS image sensor (CIS) technology to enable next-generation X-ray instruments. For the THESEUS mission concept, thermal constraints limited detector operating temperatures to approximately −40 °C, making CCDs unsuitable and motivating the development of alternative technologies. Since 2019, the CEI and Te2v have been developing CIS for X-ray imaging and spectroscopy, and has culminated in the development of the CIS221-X, a 2x2cm device with near-Fano limited energy resolution at a temperature of −40 °C, high framerate capabilities, and inherently low power consumption and high radiation tolerance. The technology is currently being scaled up in size, with the next-generation sensor, the CIS321 due for delivery in spring 2026. Although the 4.5x9cm sensor was designed to enable soft X-ray astronomy on THESEUS' SXI, the inherent benefits of CIS are highly attractive for many applications which need to operate in radiation-harsh environments or under high optical loading, of which many exist in the solar system.