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AXIOM: Advanced X-ray Imaging Of the Magnetosphere

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Abstract

AXIOM is a concept mission which has been proposed in response to the European Space Agency's 2010 Cosmic Vision M3 Mission call, in view of a 2022 launch. AXIOM aims to explain how the Earth's magnetosphere responds to the changing impact of the solar wind in a global way never attempted before, by performing wide-field soft X-ray imaging and spectroscopy of the magnetosheath, magnetopause and bow shock, at high spatial and temporal resolution.

1. Introduction

Plasma and magnetic field environments can be studied in two ways – by in situ measurement, or by remote sensing. These two techniques are complementary. In situ measurements provide precise information about plasma composition, instabilities and dynamics, but cannot provide the global view which is necessary to understand the overall behaviour of the plasma. Remote imaging provides excellent information about global configurations and overall evolution, but cannot provide the same level of local information that is required to fully understand the local plasma physics. Whilst some parts of the magnetosphere have been remotely sensed (e.g. by the IMAGE mission), the majority remains unexplored using remote measurements.

2. A new approach: remote X-ray imaging

We propose a new approach: to use remote X-ray imaging techniques, which are now possible thanks to the relatively recent discovery of solar wind charge-exchange (SWCX) X-ray emission; this was first observed at comet Hyakutake [3], and subsequently found by *XMM-Newton* to occur in the vicinity of the Earth's magnetosphere [4] and to peak in the sub-solar magnetosheath, a region where both solar wind and neutral exospheric densities are high [2] (see Figure 1 depicting the dayside magnetosphere).

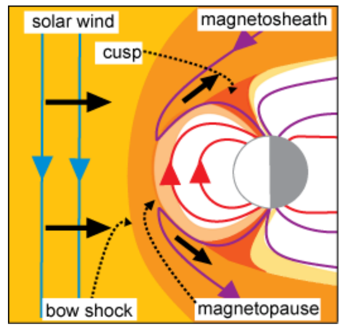

Figure 1. The dayside magnetosphere: The magnetopause represents the outer boundary of the magnetosphere, and is compressed on the dayside. The solar wind is deflected and decelerated at the bow shock, so that it may flow around the magnetopause.

The key science questions that AXIOM will address concern:
1) The magnetosphere: How do upstream conditions control magnetopause position and shape, and magnetosheath thickness? How does the location of the magnetopause change in response to prolonged periods of sub-solar reconnection? Under what conditions do transient boundary layers, such as the plasma depletion layer, arise?
2) Cusp physics: Cusp morphology – what are the size and shape of the cusps? How do the cusps move in response to changes in the solar wind? How does cusp density depend on magnetospheric coupling?
3) Shock physics: What controls where the bow shock forms upstream of a planetary magnetosphere? How does the steady-state thickness of a collisionless shock depend on the upstream conditions?
4) How does the magnetosphere respond to the arrival of shocks driven by a coronal mass ejection?

3. AXIOM

In this presentation we describe how an appropriately designed and located X-ray telescope, supported by simultaneous in situ measurements of the solar wind, can be used to image the dayside magnetosphere, magnetosheath and bow shock, with a temporal and spatial resolution sufficient to address several key outstanding questions concerning how the solar wind interacts with planetary magnetospheres on a global level. The relatively small, low-resource AXIOM model payload incorporates a wide-field soft X-ray telescope, using MCP optics and CCD detectors, for imaging and spectroscopy of the Earth's magnetosphere, a proton and alpha particle sensor designed to measure the bulk properties of the solar wind, an ion composition analyser which aims to characterise the populations of minor ions in the solar wind that cause SWCX emission, and a magnetometer for accurate measurements of the strength and direction of the solar wind magnetic field [1]. Figures 2 and 3 show the AXIOM configuration after fairing jettison, and the deployed spacecraft, respectively. Details of the mission profile will also be presented, as well as simulations of the expected performance (e.g. see Figure 4).

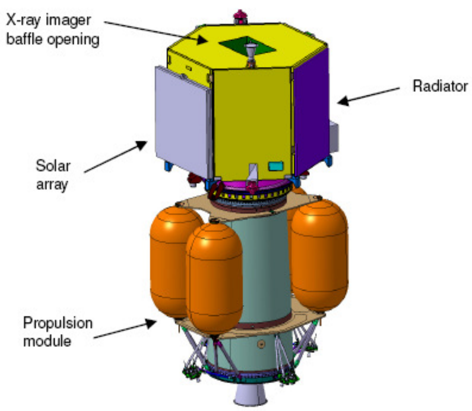

Figure 2. AXIOM configuration after fairing jettison.

4. Summary and Conclusions

The interaction of the solar wind with the Earth's magnetosphere involves a complex series of poorly understood inter-relationships. By visualising the previously unseen dayside interaction regions, through which all the solar wind mass, energy and momentum flow to power magnetospheric storms and sub-storms, AXIOM will make an essential contribution to understanding the nature of space weather and the solar wind-magnetosphere interaction.

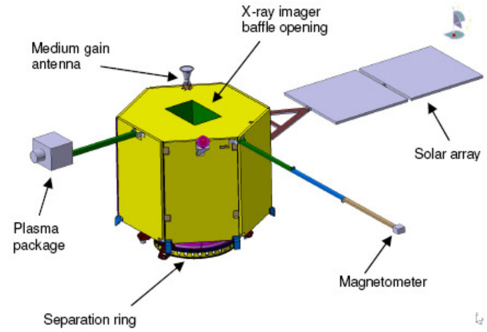

Figure 3. Deployed AXIOM spacecraft.

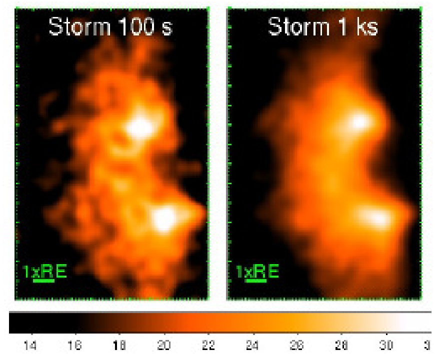

Figure 4. Simulated images from the wide field soft X-ray telescope, for solar storm conditions. The solar wind flows in from the left and the magneto-sheath and cusps, bounded by the bow shock (left) and magnetopause (right), emit brightly via SWCX.

References

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