Magnetopause Detection through Solar Wind Charge-exchange X-ray Imaging

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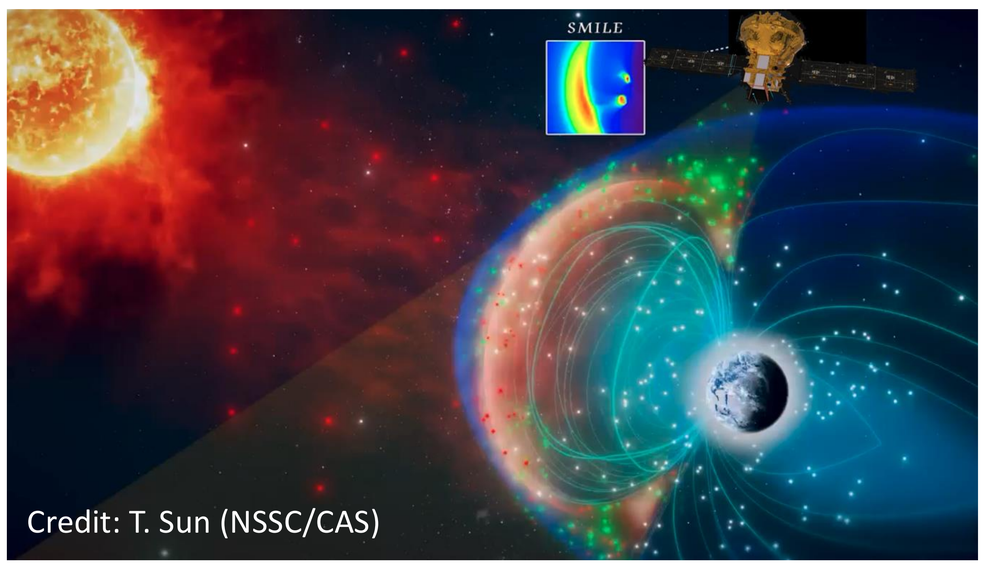
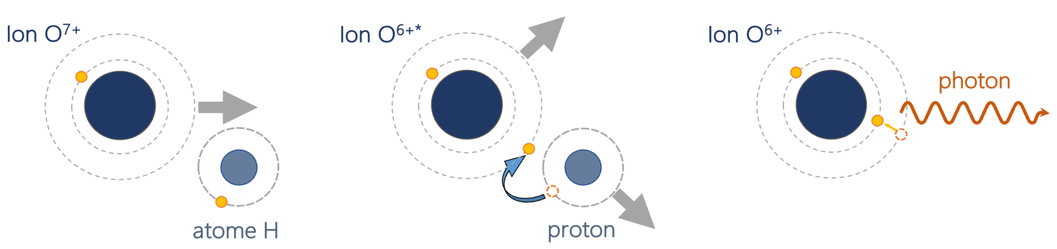
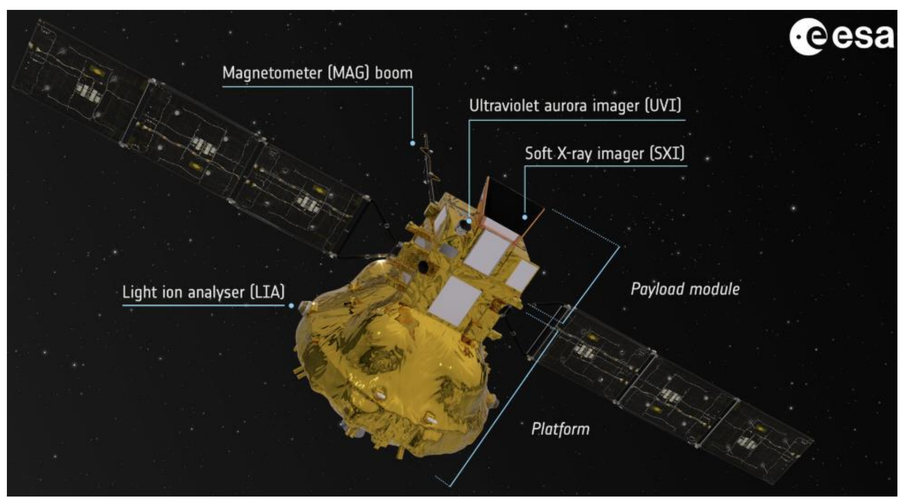
Solar wind Magnetosphere Ionosphere Link Explorer (SMILE): X-ray imaging of the magnetosphere

Solar Wind (SW) ions compressed in the magnetosheath, charge-exchange with planetary neutrals, illuminating the interface region and frontier surfaces (bow shock, **magnetopause-MP**, cusps) in X-rays.



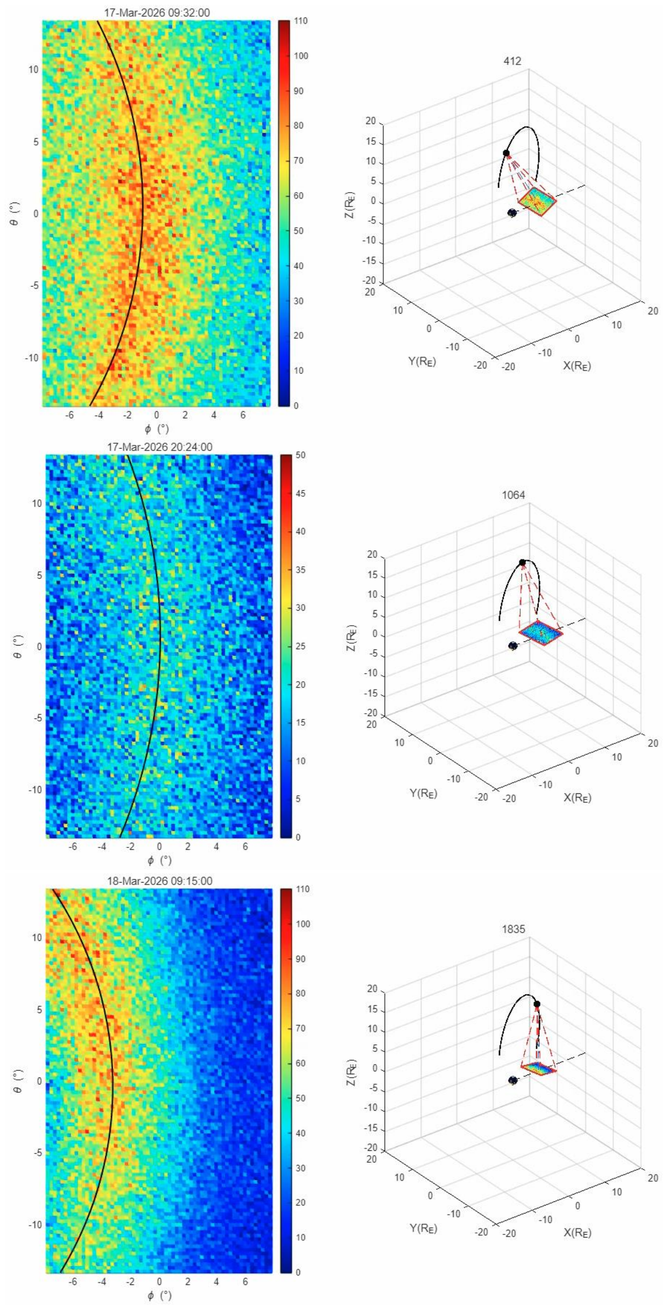




SMILE (Wang+) will be the first mission to investigate the solar-terrestrial interaction globally. The soft X-ray imager (SXI) will make the first-ever detailed and long-running X-ray observations of Earth's magnetic field, combined with simultaneous UV imaging (UVI) of the aurora borealis, and in-situ monitoring of the SW and magnetosheath plasma conditions (LIA, MAG).

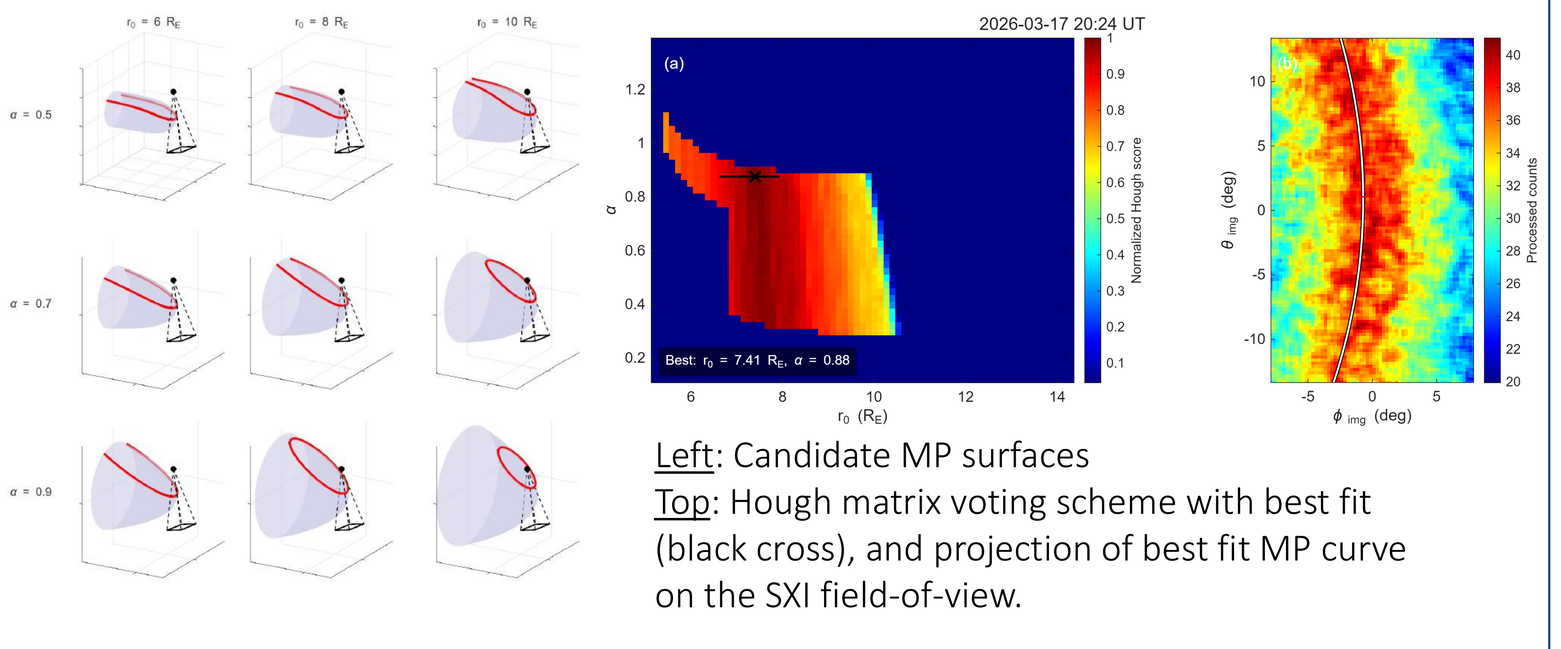
The SXI Grand Analysis Challenge (GAC)

-Blind-test of MP detection methods.
-2500 1-minute simulated SXI images using MHD codes for various solar wind conditions.
-SMILE orbit, attitude and SXI aim point provided.
-No prior information on input solar wind conditions.



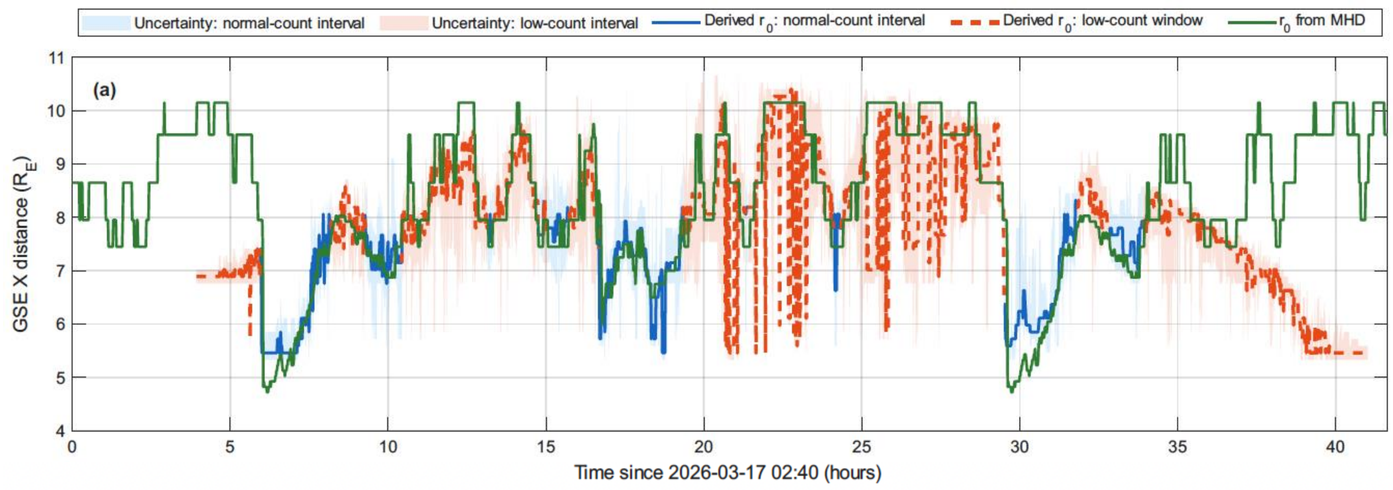
The Tangent Hypothesis – Hough Transform method

- X-ray emissivity peaks near the MP. → SXI 2D images will present a maximum along the tangent to the MP (longest line-of-sight path through the maximum emissivity region)
-We parametrize the MP surface using a simple axisymmetric Shue model (r0 = MP subsolar standoff distance, α = MP flaring).
-For each simulated SXI image, we extract the tangent curve in the SXI field of view (red curves), for various (r0, α) couples.
-We maximize the Hough score in the (r0, α) parameter space, and trace the best fit MP curve.



Left: Candidate MP surfaces
Top: Hough matrix voting scheme with best fit (black cross), and projection of best fit MP curve on the SXI field-of-view.

Conclusion:Comparison with the GAC Ground Truth (green) shows excellent agreement during normal/high count-rates (blue), and within errorbars in most of the low count-rate periods (red)



References: Hough, US Patent 3,069,654 (1962); Shue+, JGR: Space Physics, 102, 9497 (1997); Boskou+ SF2A (2025); Wang+, SSRv, 221, 9 (2025)

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