Prosposal for X-ray astronomy from the lunar surface

Steven Sembay
Department of Physics and Astronomy
Leicester University, UK

Co-I and Calibration Manager of the EPIC-MOS X-ray camera on XMM-Newton

University of Leicester

“High Throughput X-ray Telescope on a Lunar Base”

Paul Gorenstein, 1990, in “Astrophysics from the Moon”, AIP

Phase 1: Late 1990’s 1 m^2

ESA XMM-Newton

0.43 m^2 @ 1.5 keV

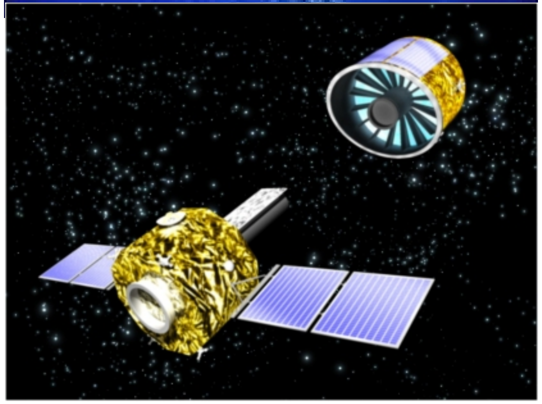
Launched: Dec 1999

Phase 2: 2010 10 m^2

ESA/JAXA Xeus

5 m^2 @ 1.0 keV

Likely Launch: 2020’s?



Phase 3: 2040 100 m^2

~400 ton facility,

Eff. Area ~ Optical regime

??

Speculative 21st Century High Throughput (>100 m^2) Lunar X-ray Observatory

Science Goals include:

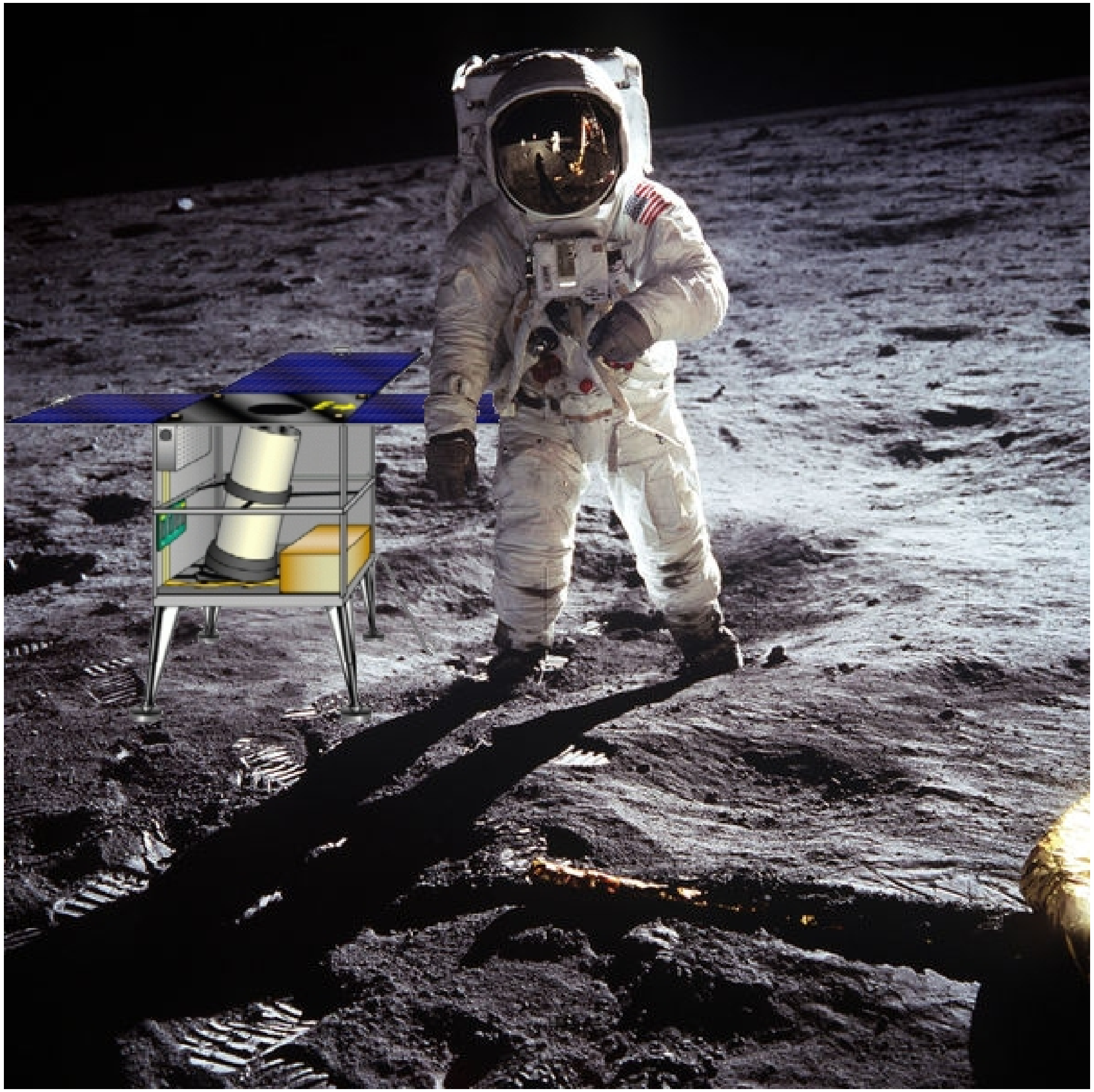
Large scale structure of the universe to z>=2 through survey of cluster Fe emission

Evolution of accretion disk in AGN to z>=2 through study of Fe fluoresence line

Steve Sembay (sfs5@star.le.ac.uk)

University of Leicester

Lunar X-ray Observatory on a more practical scale



Steve Sembay (sfs5@star.le.ac.uk)

University of Leicester

Program: Concept Studies for Lunar Sortie Science Opportunities

solicitation within NASA Research Announcement:

Research Opportunities in Space and Earth Sciences (ROSES) – 2006

Title of Investigation: Lunar-Based Soft X-ray Science

PI: Michael Collier

PI Institution: NASA/Goddard Space Flight Center

Collaborators: Univ. of Kansas, Univ. of Leicester UK, Acad. Sci. Czech Rep.

Current Status: NASA has budgeted ~$750K for 5-10 concept studies which are expected to take 6-9 months duration. Proposal has been submitted. Expect result spring 2007.

LSSO concept similar to….

ALSEP: Apollo Lunar Surface Experiment Package

Jim Lovell (CMDR Apollo 13) practising

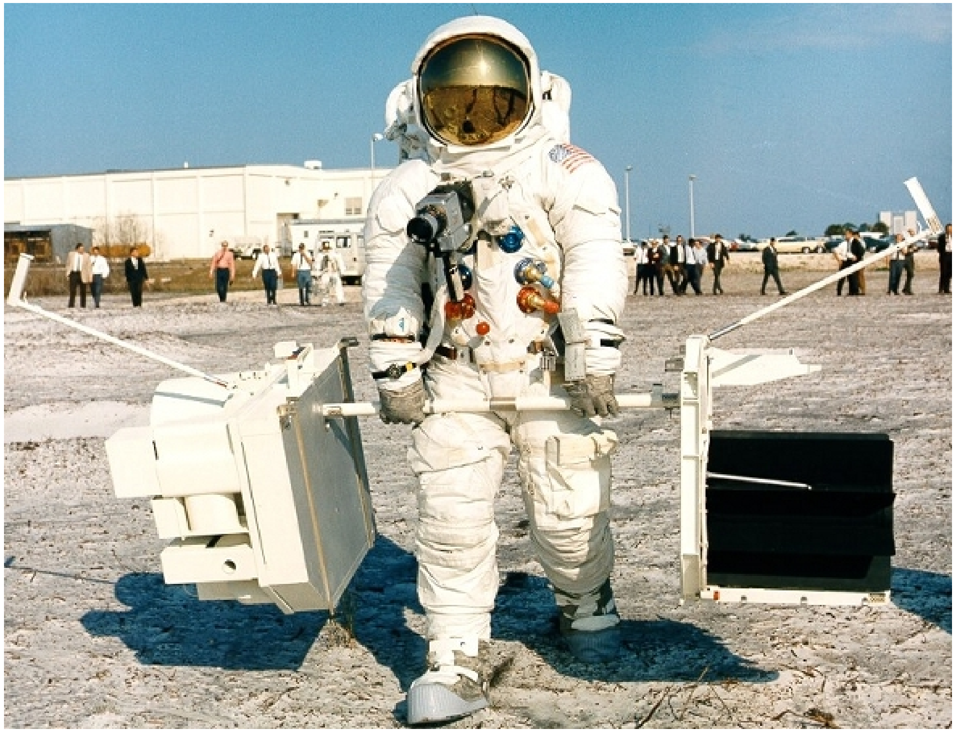


Image: www.myspacemuseum.com

Apollo 16 experiments

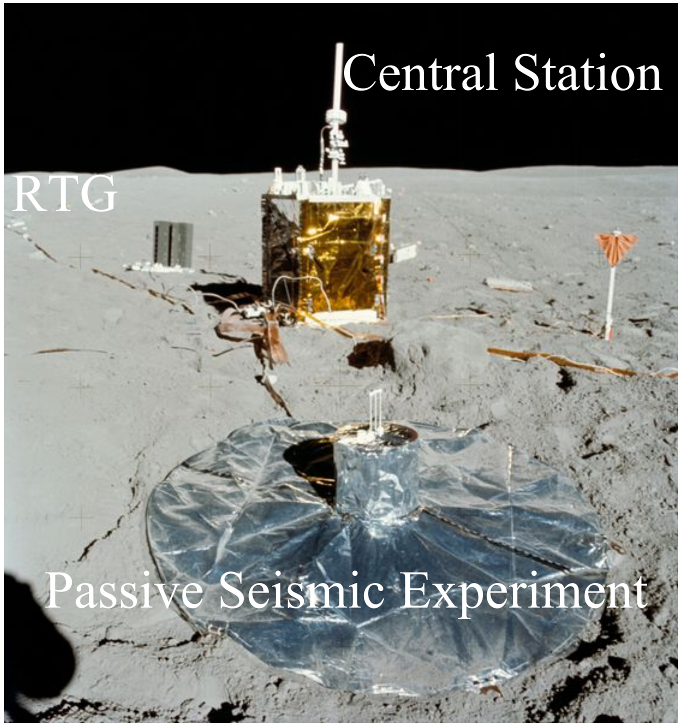
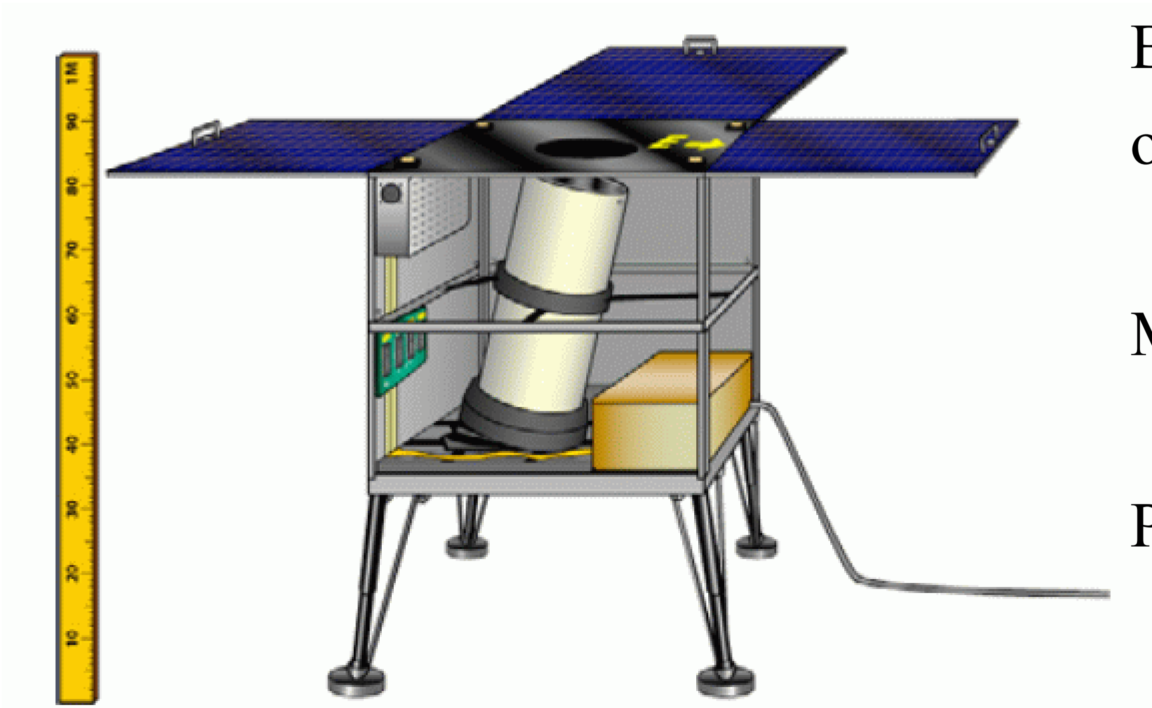


Image: en.wikipedia.com

Lunar X-ray Observatory (LXO): Strawman configuration



Basic Constraints based on ALSEP experience:

Mass < 40 kg

Power < 75W

- Mass < 40 kg (self-contained power system, i.e. solar cells + battery)
- Mass < 20 kg (external PSU common to multiple experiments)
- Power < 70W if actively cooled with Thermal Electric Cooler (TEC)
- Power < 20-30W if passively cooled and operated during lunar night.

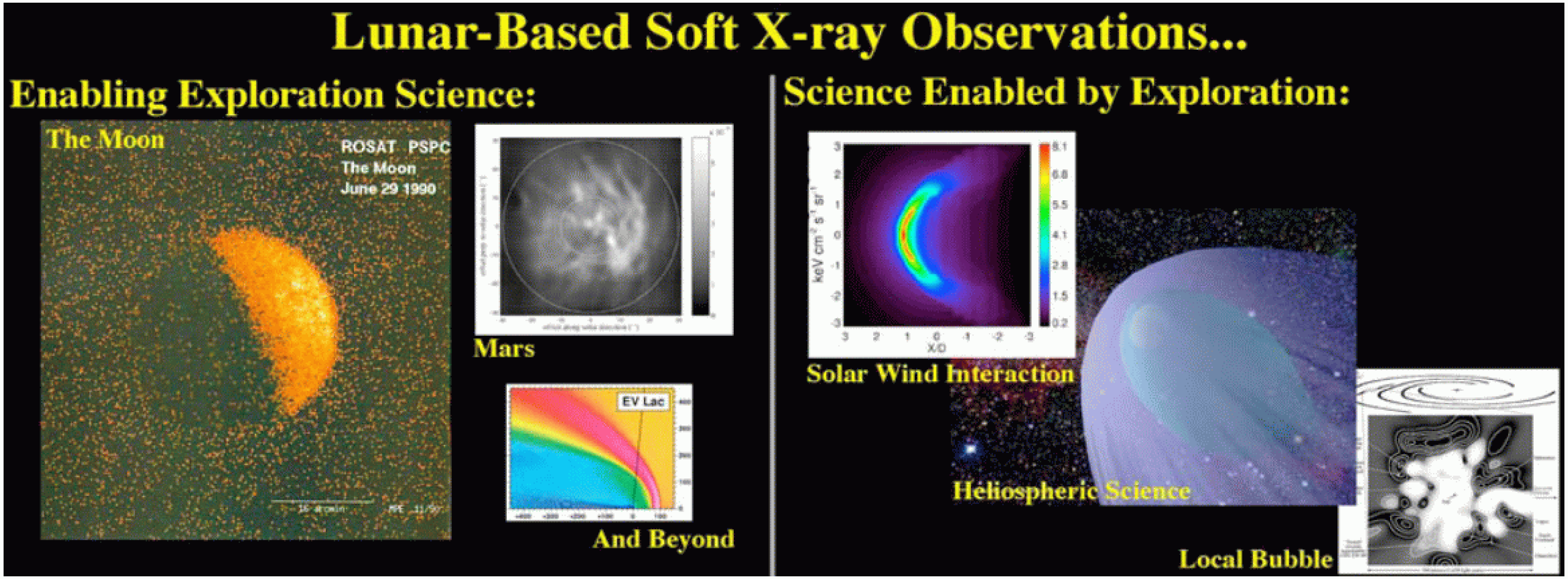
Competing Technologies for LXO Detector

Table 1. Candidate detector technologies for the LXO (Lunar X-ray Observatory)

X-ray detector technology	Advantages	Disadvantages	Heritage and potential partnering Institutions
Charge Coupled Devices (CCDs)	• Good resolution (able to differentiate OVII from OVIII) • Mature technology/TRL9 (ASCA, XMM/Newton, Chandra, Suzaku, Swift) • Could be passively cooled during lunar night	• limited collecting area (<40 cm^2) • cost • Needs to be cooled <~ -40C	• UK Leicester • Max Planck • MIT
Thin Window Proportional Counters	• large area • cost • Collecting area scales well • simple electronics • Does not need cooling • Mature/TRL9 (DXS, ROSAT)	• high pressure gas storage • short lifetime – expendables (days to weeks) • poor spectral resolution • Small unit very heavy but scales well • High voltage	• GSFC • University of Wisconsin
Large Area Solid State Detectors (Si(Li))	• large area/pixel • simple electronics • Large dynamic range • Good spectral resolution, equivalent to CCDs at higher energies (~90-160 eV ~ independent of energy • Mature/TRL9 (SSS, BBXRT)	• Separate amplifier chain per pixel or hybrid ASIC • Energy resolution degrades with increasing pixel area • Needs to be cooled to ~100K ➔ Requires cryogens or cryocooler	• GSFC

Steve Sembay (sfs5@star.le.ac.uk)
Towards a European Infrastructure for Lunar Observatories II

University *of* Leicester



1) Measure the solar wind's interaction with the Moon (including the lunar wake).
2) Measure the solar wind/magnetosphere interaction and heliospheric structure.
3) Perform the first high sensitivity measurements of the soft diffuse X-ray background free of the uncharacterised magnetosheath contamination.

"Background" to the soft X-ray sky

Soft X-ray background ($0.1<E<1.5$ keV) has substantial structure from contributions from beyond Solar System sources, namely…

1) Unresolved background from AGN
2) Extended Galactic Halo at $10^{6.5}$ K
3) Irregular distribution from 10^{6} K plasma in lower Galactic Halo
4) The Local Hot Bubble, a 10^{6} K plasma filling a cavity in the Galactic disk surrounding the Sun.

In the last decade or a so a much closer component (10^{-3} pc) has been identified: strong/variable emission due to solar wind charge exchange (SWCX) with neutral material in the Earth's magnetosheath, the Interplanetary medium and the heliospheric termination shock.

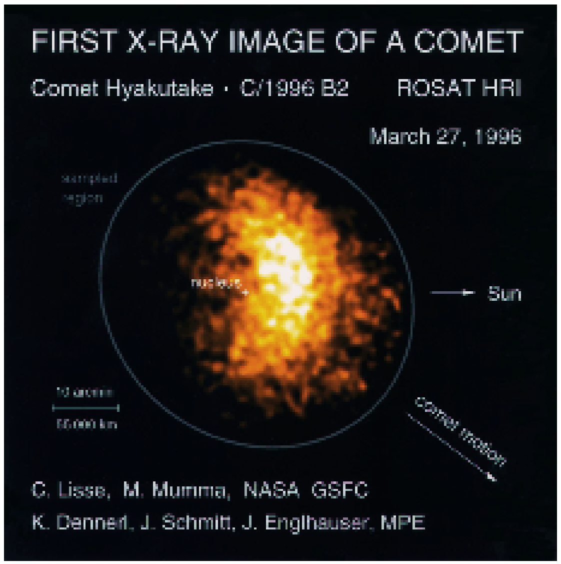
SWCX Mechanism:

Heavy solar wind ion in collision with neutral target atom or molecule

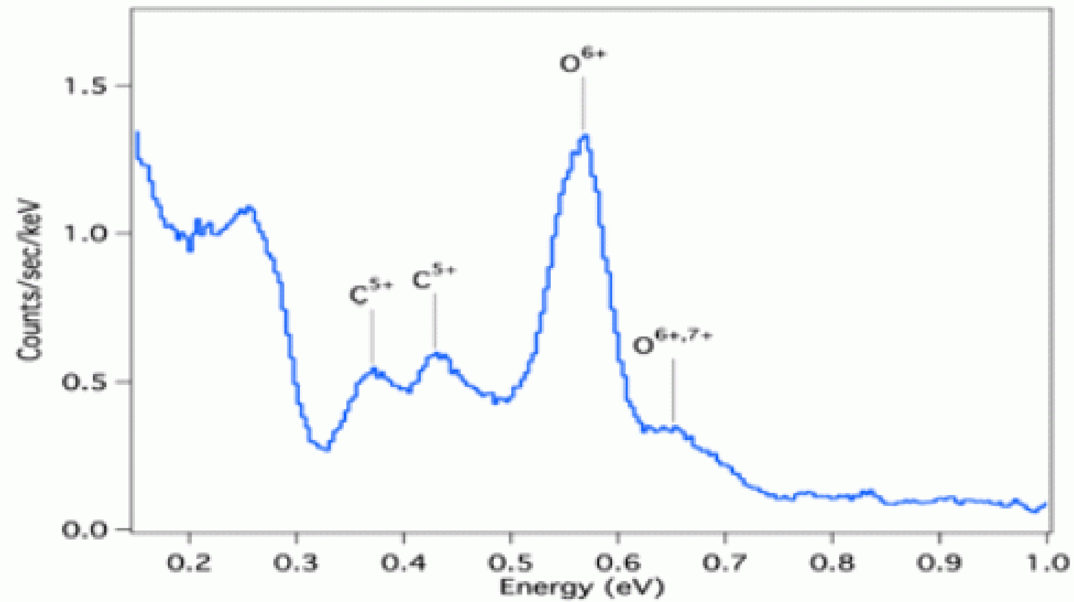
$$A^{q+} + B \rightarrow A^{(q-1)+*} + B^{+}$$

$$A^{(q-1)+*} \rightarrow A^{(q-1)} + h\nu$$

Process first detected in X-ray emission from comets:



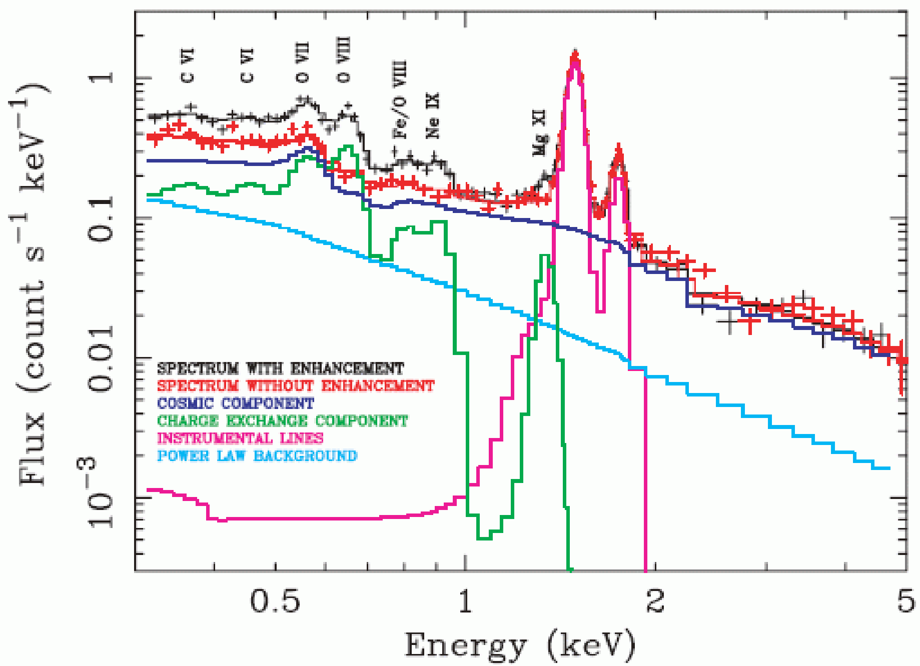
Rosat/HRI Image
GSFC/MPE



A soft X-ray spectrum of the SWCX spectrum from a comet taken with *Suzaku* demonstrates the need for spectral resolution to distinguish the different constituents of the (variable) solar wind.

XMM-EPIC detection of SWCX during observation of Hubble Deep Field North

1186 SNOWDEN, COLLIER, & KUNTZ Vol. 610



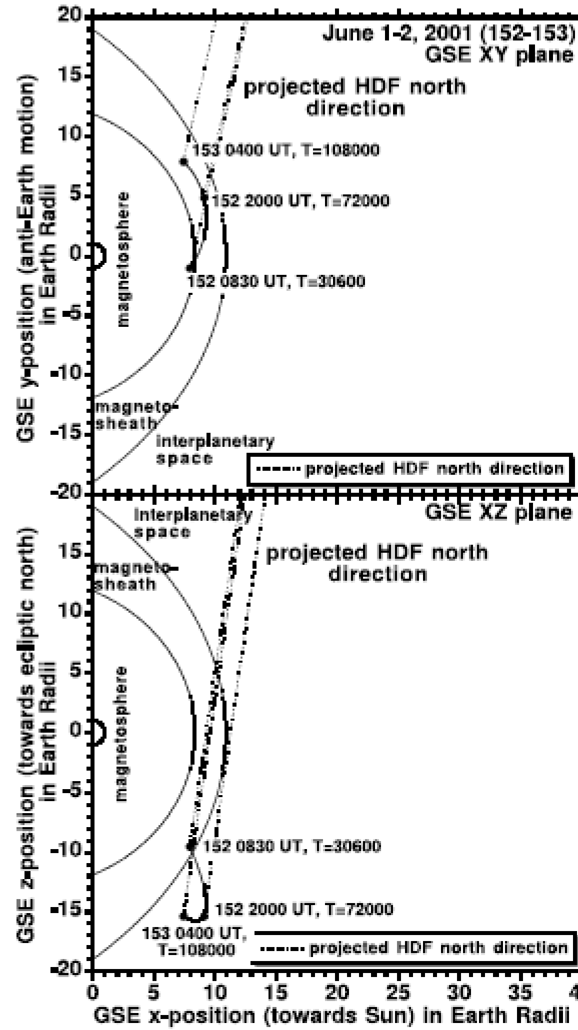
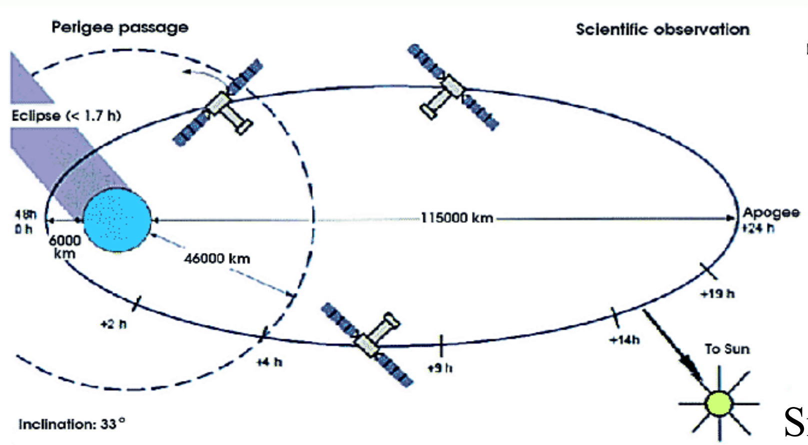


FIG. 3.—Model comp... emission period of HDF... components.

...and from the SW... proton) backgro...

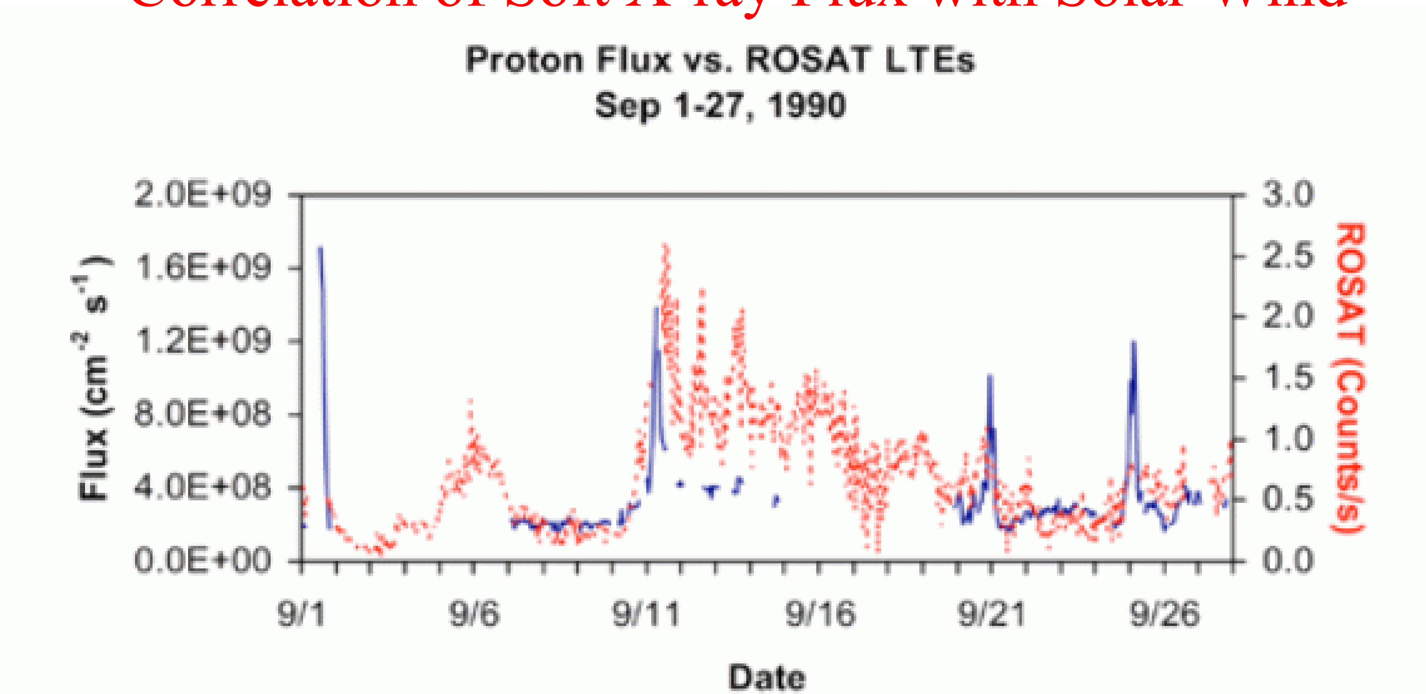


Snowden, Collier and Kuntz, 2004, ApJ, 610, 1182

Steve Sembay (sfs5@star.le.ac.uk)
Towards a European Infrastructure
for Lunar Observatories II

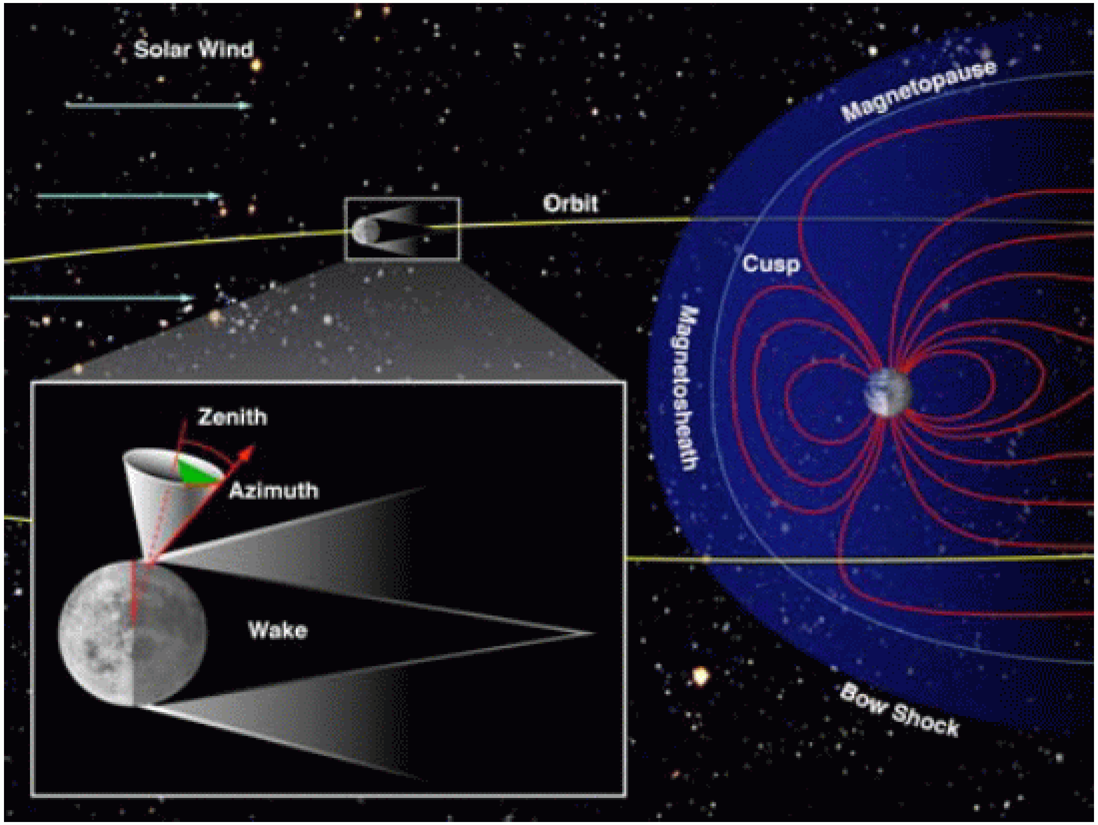
University of Leicester

Correlation of Soft X-ray Flux with Solar Wind

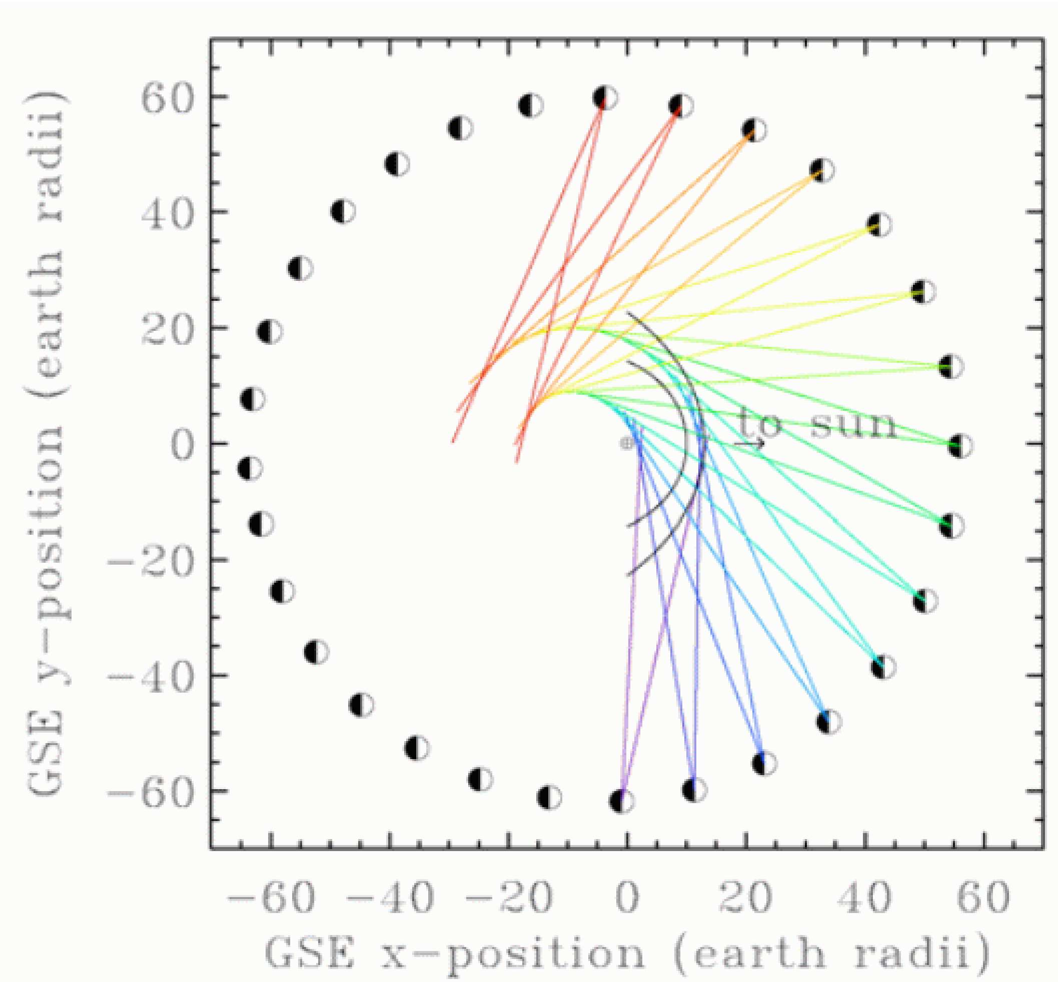


Correlation of the strength of the solar wind and the strength of the soft X-ray emission as seen by ROSAT in low Earth orbit. ROSAT Long Term Enhancements (LTE) in background attributed to SWCX with interstellar hydrogen and geocoronal hydrogen.

This correlation allows remote sensing of the strength of the solar wind using soft X-ray fluxes as a proxy.



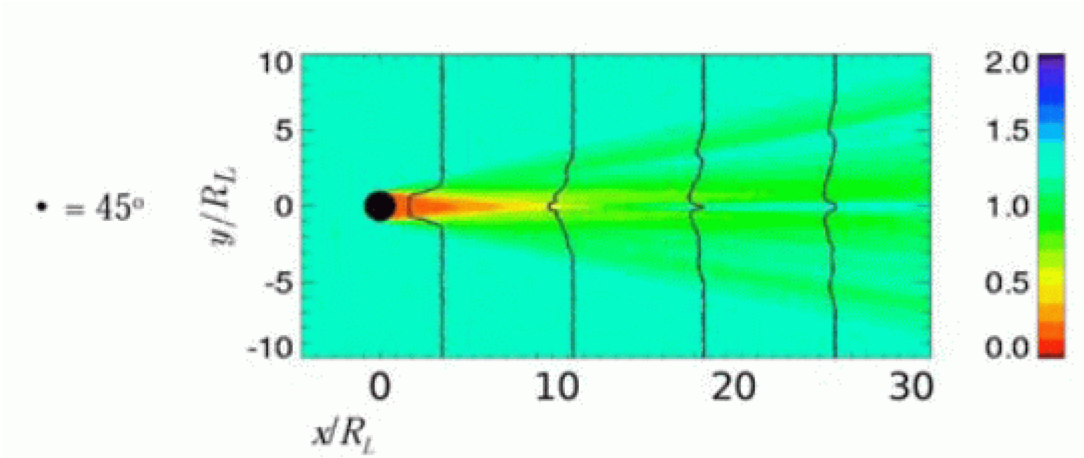
The geometry of the solar wind with respect to the Earth-Moon system. A Lunar X-ray Observatory properly placed on the Moon will be able to observe soft X-ray emission from the interaction of the solar wind with both the lunar atmosphere and the magnetosheath.



FOV of an observatory on the lunar surface with a fixed look angle will sweep past the densest part of the magnetosheath each month.

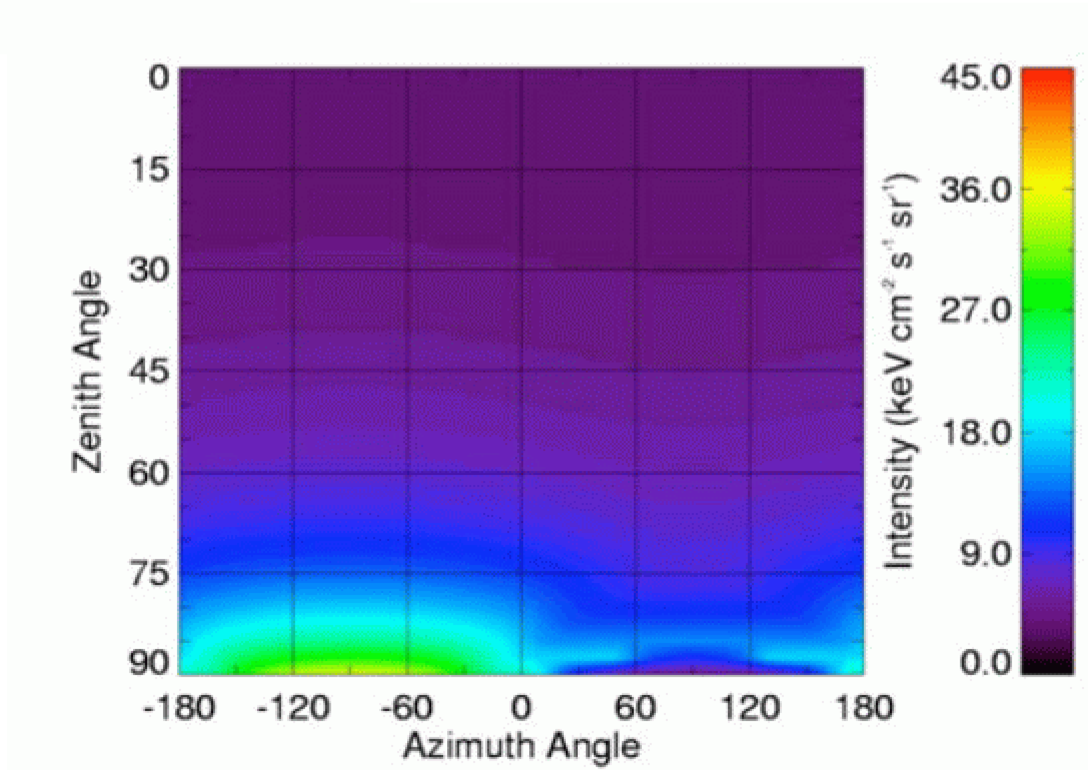
In addition to allowing observation of the lunar atmosphere-solar wind interaction, it is an ideal platform for studying the magnetosphere-solar wind interaction.

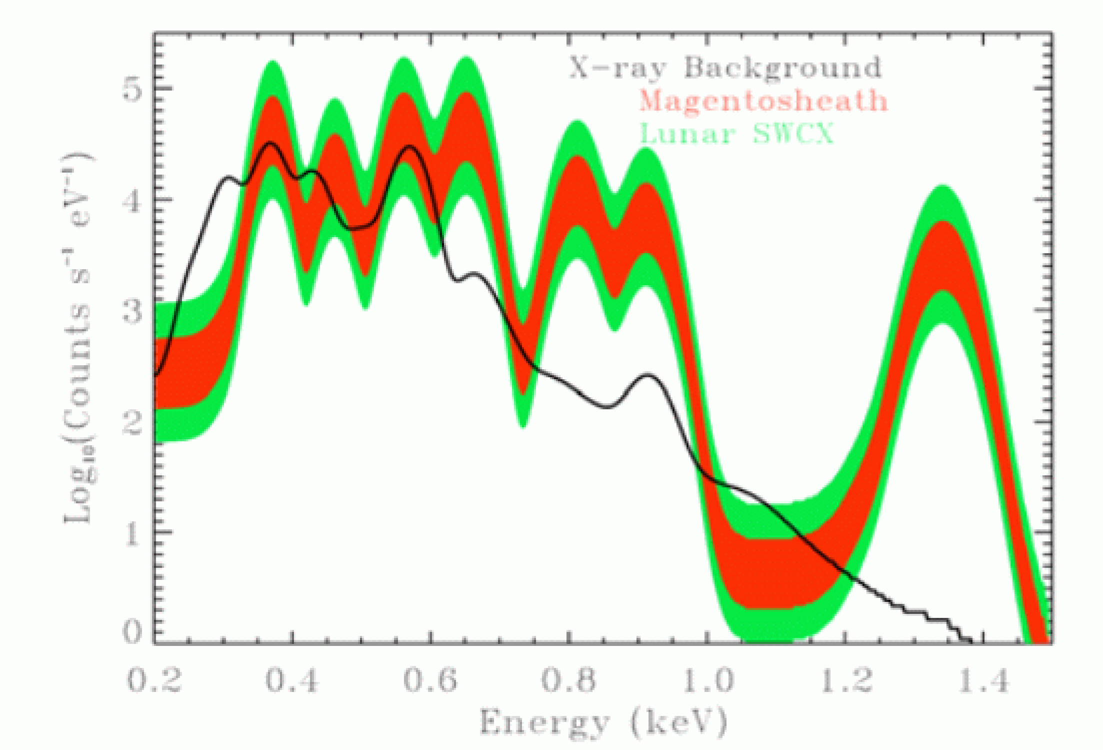
Configuration for observations during lunar night.



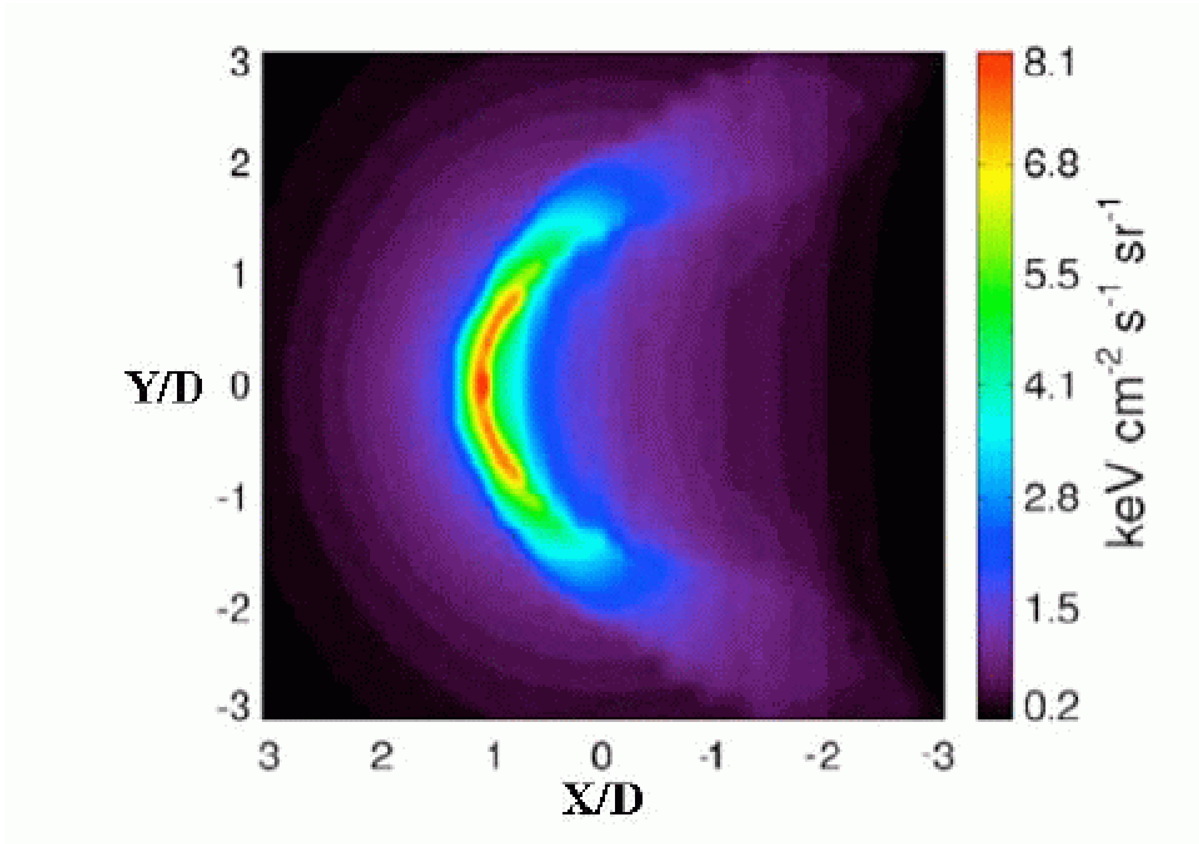
A simulation of the density of the solar wind near the Moon shows the lunar wake.

Simulation of the soft X-ray emission as a function of Position in the lunar sky.





A model of the X-ray background (black), the magnetosheath (SWCX) (red), and the SWCX emission from the lunar atmosphere (green). All have similar strengths and spectral shape. We will be able to separate the components only by looking at time variability of the components.



A model of the strength of the magnetospheric SWCX emission as a function of position around the Earth (at origin). Current observatories orbit within the magnetosheath and cannot clearly distinguish SWCX emission from background

Summary:

- The moon is an ideal location for soft X-ray astrophysics, both for studying Solar System SWCX processes directly and for helping to decouple this emission from Cosmic astrophysical sources.

- The LXO is practical (the technology is mature and well understood) and is relatively low cost because it is piggy-backing onto a larger program (NASA's Vision for Space Exploration).