THE LUNAR X-RAY OBSERVATORY (LXO)/MAGNETOSHEATH EXPLORER IN X-RAYS (MAGEX).

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Introduction: X-ray observations of solar wind charge exchange (SWCX) emission will dramatically enhance our ability to determine the structure and variability of the lunar space plasma environment, a critical measurement for exploration-enabling science. Furthermore, the observations will provide extraordinary imaging of key space plasma systems, including the Earth's magnetosphere and the heliosphere, and will quantify X-ray background levels for critical astrophysical measurements. The surface of the Moon is the perfect location for these measurements which will provide exciting and unique contributions to lunar science.

SWCX: The German ROSAT (Röntgensatellit) mission was launched on June 1, 1990 and had two scientific objectives: the first all-sky survey with imaging X-ray and EUV telescopes and the detailed study of selected X-ray and EUV sources. During ROSAT's collection of data for the all-sky survey, a significant variation in count rate was observed for similar look directions [1]. At the time, the origin of these time-dependent contaminations was unknown, and they were referred to as Long Term Enhancements (LTE).

Then, in 1996, a ROSAT observation of comet Hyakutake revealed unexpected X-ray emission originating from the vicinity of the comet [2]. Following similar observations from other comets, Cravens [3] explained these observations as solar wind charge exchange emission in which high charge state solar wind ions exchange electrons with cometary neutral atoms.

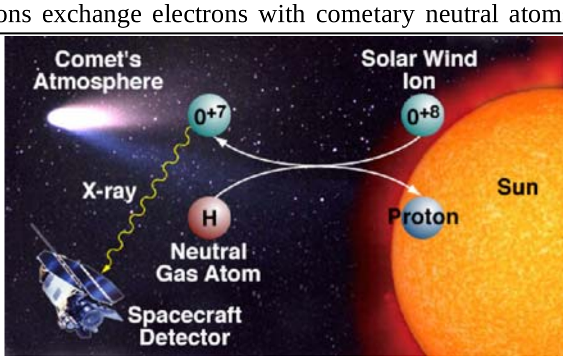

Fig. 1. Cometary soft X-ray emission results when high charge state heavy solar wind ions exchange charge with cometary neutral atoms and end up in an excited state. When the excited state relaxes, soft X-rays (<1 keV) are emitted.

The solar wind ions end up in excited states which relax, causing the emission of soft X-rays, as illustrated by Fig. 1. Cox and others [4, 5] suggested that SWCX between heavy solar wind ions and interstellar neutrals, as well as geocoronal neutrals, could account for the LTE. Cravens et al. [6] then found that the solar wind flux and the LTE were strongly correlated showing that indeed the origin of the observed LTE was SWCX with interstellar helium and geocoronal hydrogen. Fig. 2 shows the LTE rate with the solar wind flux observed over about a month.

Magnetosheath Imaging: Fig. 3 shows one of the major sources of SWCX, the magnetosheath formed by the interaction of the solar wind with the Earth's magnetic field. This interaction creates an upstream bowshock at about 13 R_E and the magnetopause which separates the region controlled by the Earth's magnetic field from the solar wind at about 11 R_E. The magnetosheath falls between the two boundaries. Fig. 4 shows an image of the solar wind-magnetosphere interaction in soft X-rays as observed from the surface of the Moon. The magnetosheath emission contributes significantly to the soft X-ray sky and can, at times, contribute more than all the other components put together [7].

Imaging the Solar Wind-Lunar Interaction: The Moon has a tenuous atmosphere with a density at the lunar surface of about 10^5 cm^{-3} and an exponential scale height of about 40 km [8]. However, the Moon lacks an intrinsic large-scale dipolar magnetic field like the Earth's. Consequently, the solar wind impacts the lunar surface and creates soft X-ray emission through

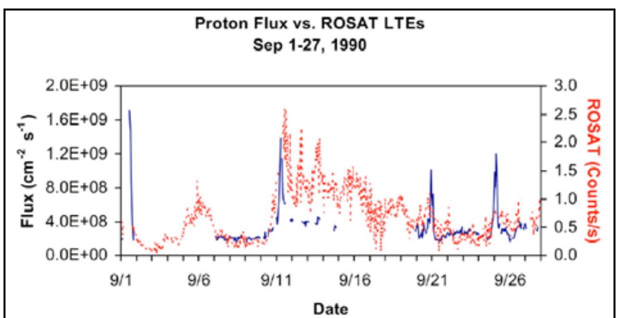

Fig.2. The correlation between the solar wind flux (blue solid) and the strength of the soft X-ray emission (red dashed).

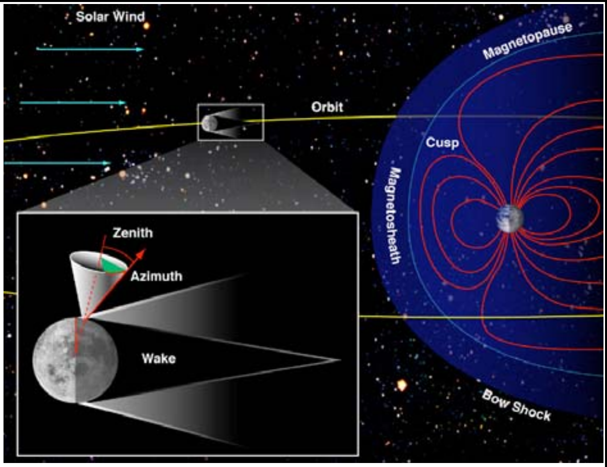

Fig. 3 – The geometry of the solar wind with respect to the Earth-Moon system.

its interaction with the lunar atmosphere.

The solar wind-Moon interaction shown in Fig. 3 creates the lunar plasma wake, a void downstream of the Moon where the solar wind plasma is blocked by the Moon. At the wake boundary, a significant density gradient forms, providing a wakeward electric field. Electrons move ahead of the less mobile protons to fill the cavity and form an ambipolar electric field which accelerates the ions and causes them to follow the electrons as indicated by the grey region at the flanks of the wake.

Fig. 5 shows a simulation of soft X-ray emission from the solar wind-lunar interaction and uses the coordinate system shown in Fig. 3. When the zenith angle is 90°, the positive azimuth angles look through the lunar wake, so the X-ray fluxes are suppressed, while the negative angles look back over the pole where the intensities are higher.


Fig. 4 – The solar wind-magnetosphere interaction in soft X-rays as observed from the lunar surface.

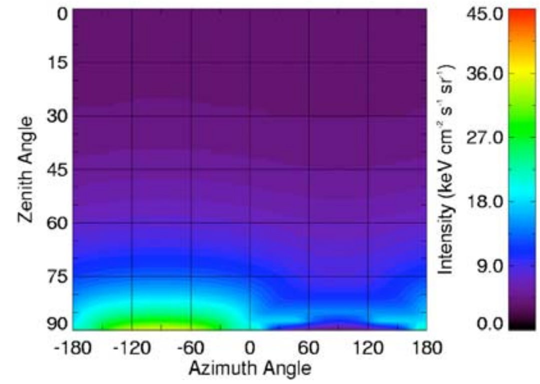

Fig. 5 – A simulation of the soft X-ray emission as a function of position in the lunar sky.

The Lunar X-ray Observatory (LXO)/Magnetosheath Explorer in X-rays (MagEX): a "Lunar X-ray Observatory" (LXO/MagEX) implemented by placing one or more small, light-weight, low power, wide field-of-view soft X-ray detectors on the lunar surface will: (1) Measure the solar wind/magnetosphere interaction and heliospheric structure. (2) Measure the solar wind's interaction with the Moon (including the lunar wake) which contributes to lunar hazards for astronauts. (3) Perform the first high sensitivity measurements of the soft diffuse X-ray background free of magnetosheath contamination. Fig. 6 shows an initial design for such an instrument. For more information, see http://www.src.le.ac.uk/projects/magex/index.html.

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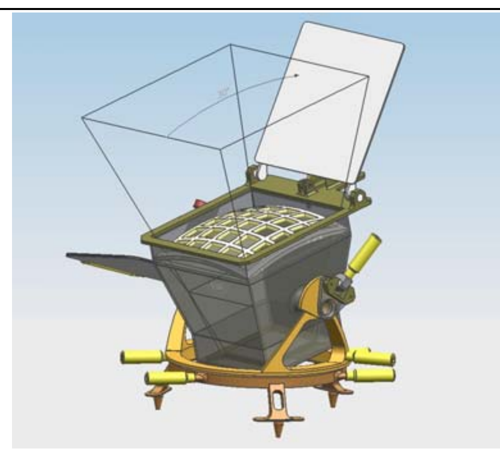
Fig. 6 – An initial design for a lunar-based soft X-ray instrument.