GEO-X : Geospace X-ray imager

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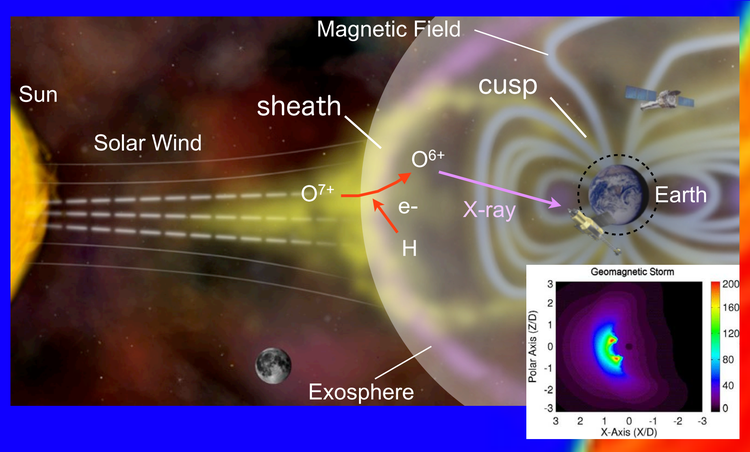
1. GEO-X

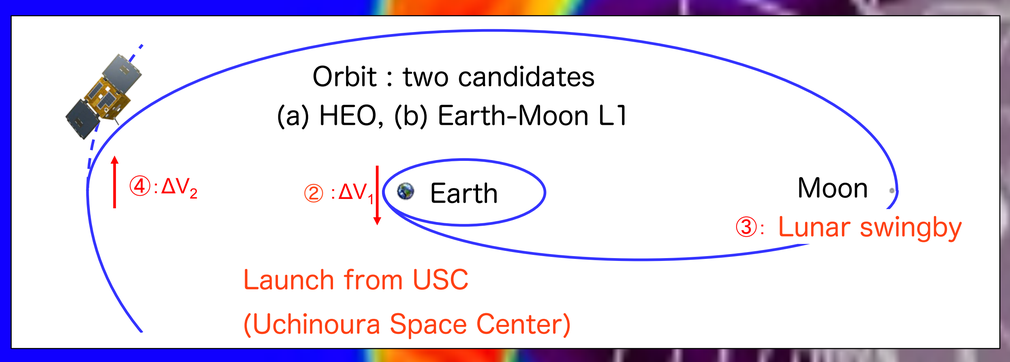
Recent observations with Earth-orbiting X-ray astronomy satellites revealed time-variable X-ray emission from Earth's magnetosphere (m-sphere) via Charge eXchange (CX) between solar wind and exospheric neutrals.



The X-ray intensity is "expected" to be strong at m-spheric boundaries such as magnetosheath and cusps.

Expected X-rays as seen at GSE Y = 60 R_E (Robertson+06)

We have begun concept study of a new mission GEO-X, aiming at "imaging" of Earth's m-sphere in X-rays for the first time. Our initial study confirms that such a mission is achievable in JAXA's small scientific satellite program.



Launch : JAXA's Epsilon rocket
Spacecraft : 330 kg (wet), 235 kg (dry)
Science payload : 40 kg, 40 W
Attitude : 3-axis stabilized (accuracy 1 arcmin/min)
Data rate : ~30 kbps (mainly science data)

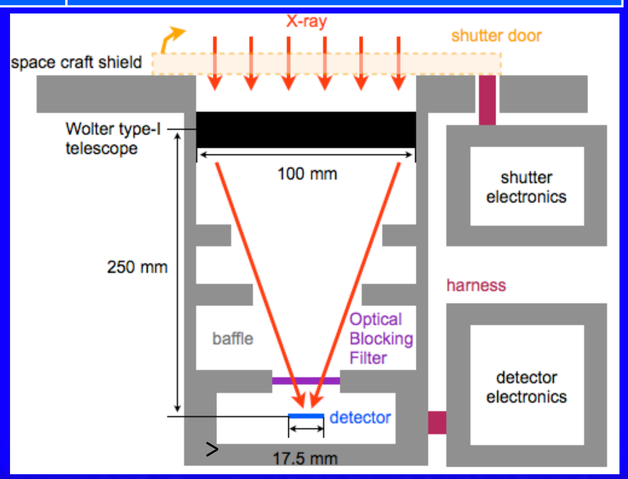
2. Science goals & requirements

Our science goal is visualization of m-spheric boundaries (cusp, sheath, LLBL etc..) in soft X-rays (<~1.5 keV). Requirements to meet this science goal are defined as follows.

Item	Requirements (at 60 R_E)	Comment
Energy band	0.3 - 2 keV	・C, N, O, Fe, Ne, Mg emission lines (<~ 1.5 keV) ・Estimate NXB by impacts of ions using X-ray photons above 1 keV
Spatial reso.	<0.1 R_E (<6 arcmin)	・Resolve fine structures of cusp and sheath
Energy reso.	<100 eV @ OVII K_α 0.6 keV	・Resolve C, N, O, Fe, Ne Mg emission lines
Time cadence	<1 hr (>~ 20 cm^2 deg^2 @ OVII K_α 0.6 keV)	・Detect changes of m-sphere in size and shape ・Expected X-ray flux for a large magnetic storm event ~0.1 cps @ OVII K_α
FOV	> 5 R_E x 5 R_E (5° x 5°)	・Grasp cusp and sheath at the same time

To this end, we plan to have a 2x2 array of compact X-ray telescope units (XTUs).

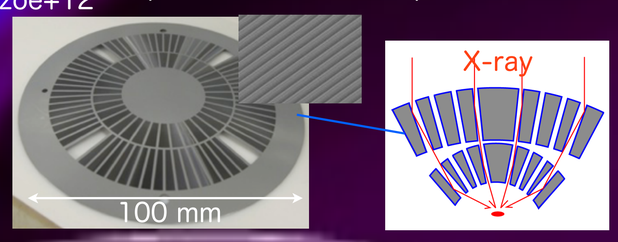
<Resources per XTU>
Mass : 10 kg
Power : 10 W
Size : 30 cm cubic
FOV : 4° x 4°



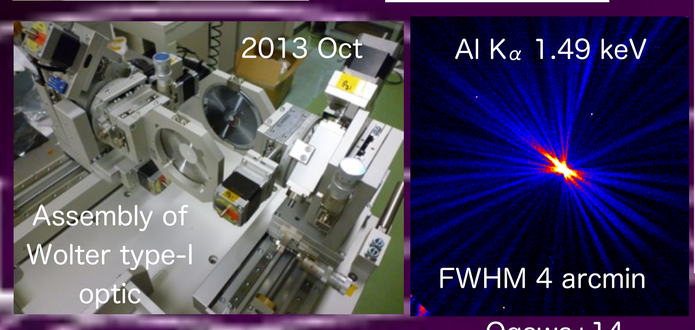
3. Science Payload

Each XTU is composed of an X-ray telescope and a detector. We are currently developing a new X-ray telescope, called MEMS X-ray optics for GEO-X as well as X-ray astronomy missions. We have constructed a Wolter type-I optic optimized for soft X-rays.

Ezoe+12 20 μm-width curvilinear pores



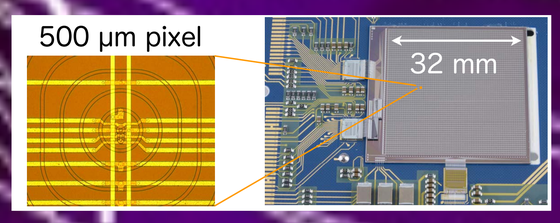
A MEMS X-ray optic is made from a few hundreds μm thick Si wafers with metal coating. It is ultra light in weight (x >40 lighter than past X-ray telescopes).

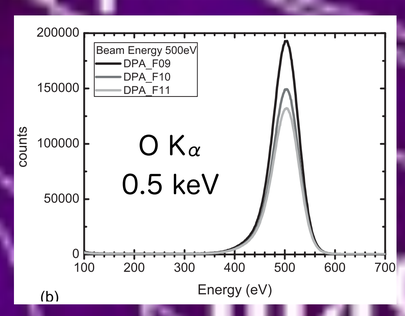


Ogawa+14

<Expected performances>
Diameter : 100 mm
Focal length : 250 mm
FOV : 4° in diameter
On-axis area : 4 cm^2 @ 0.6 keV
Grasp (SΩ) : 16 cm^2 deg^2 @ 0.6 keV
Weight : 5 kg (mirrors are only 4 g)

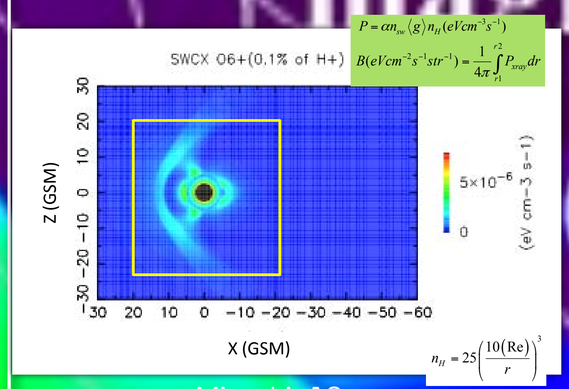
DepFET sensors developed by MPE are low noise, high frame rate, and extremely radiation hard, ideal for astronomy and planetary missions. We plan to use this detector for GEO-X.





Majewski+13

<Expected performances>
Pixel size : 300 μm square
Array : 64 x 64
Size : 1.92 cm x 1.92 cm
Frame time : 1 ms
Temperature : <~-40 deg C
E reso. : <100 eV @ 0.6 keV
Power & weight : 10 W & 3.5 kg
(incl. readout electronics)



Miyoshi+13

A typical X-ray flux in large CME and geomagnetic storm events (Dst < -100 nT) is ~30 and ~10 ph/cm2/s/str @ 0.6 keV for cusp and sheath. With one XTU, this promises S/N = 10 in ~1 ks and ~3 ks exposure times, satisfying the required time cadence (<1 hr). In early 2020's, we expect that such events will occur ~5-10 per year.

4. Future prospects

We plan to propose GEO-X for a future call of JAXA's small science satellites. The earliest opportunity will be early 2020's, corresponding to the next solar maximum phase. We envision that the XTU will be used in various future exploration missions.