International X-ray Observatory (IXO)

Planetary Science Advances with the International X-ray Observatory

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Introduction

Planets and their formation sites are far too cold to produce thermal X-rays. Nonetheless, they emit X-rays by unusual processes which provide astrophysical insights inaccessible at other wavelengths. Since 1983, X-rays been detected from Jupiter, Saturn, Venus, Mars and many comets[1,2]. The principal emission mechanism is charge-exchange between solar wind ions and neutral atmospheric molecules. X-rays from magnetic flares have been seen in hundreds of pre-main sequence stars hosting protoplanetary disks[3,4,5]. X-ray irradiation and ionization of disks may play significant roles in planet formation processes[6]. X-ray diagnostics can provide unique inputs into conditions for planet habitability.

IXO's combination of broad energy coverage, high sensitivity and spectral resolution will make qualitatively new advances in planetary science.

Jupiter and Mars

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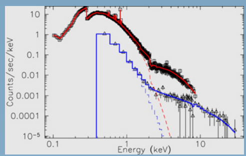


Jupiter's atmosphere shows spatially distinct, rapidly varying X-ray components from charge exchange of heavy solar wind ions, electron bremsstrahlung continuum, scattering and fluorescence of solar X-ray emission. The images above map two line tracers from XMM[9]. IXO will produce superb spectra (including dozens of charge-exchange lines) and movies of each component during the planet's 10-hr rotation and response to solar flare/CME events.

Mars shows fluorescent solar X-rays from the upper atmosphere and a halo of charge-exchange X-rays from a previously unknown exosphere out extending to ~8 Mars radii. The image here, derived from XMM observations, shows charge-exchange O^{+6}-O^{+7} in blue, C^{+4}-C^{+5} in green, and fluorescent lines in yellow[10].

QuickTime™ and a decompressor are needed to see this picture.

Study of the Martian exosphere with IXO may give crucial clues to the processes of atmospheric evaporation by stellar ultraviolet emission and winds, which may be a critical determinant of the habitability of terrestrial planets.

The IXO Planetary Key Projects

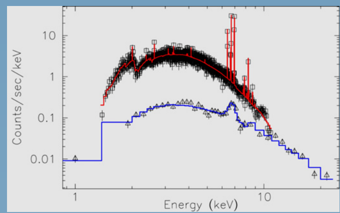
Probing protoplanetary disks with the fluorescent iron line
Elucidating the complex X-ray emission of Jupiter & Mars
Cometary charge exchange
Heliospheric charge exchange
Atmospheric evaporation of extrasolar planets

X-rays, protoplanetary disks and planet formation

All pre-main sequence stars produce magnetic flares far more powerful and frequent than older main sequence stars. A bright X-ray flare is shown above from a 1.2 day Chandra observation of protostar YLW 16A in the nearby Ophiuchus star forming cloud[7]. At peak emission, the flare shows $\log L_x$~32.1 erg/s and kT~10 keV plasma temperature.

Iron Kα emission lines are seen both from hydrogenic iron in the flare plasma at 6.7 keV and from neutral iron at 6.4 keV. This is interpreted as fluorescence off of the proto-planetary disk (diagram below). Evidence for efficient X-ray irradiation of disk outer layers includes the [NeII] 12.8 μm line[8] and excited molecular rovibrational transitions.

The spectrum below simulates an IXO observation of the YLW 16A flare. The fluorescent line is so strong in the TES detector (red line) that the disk structure can be mapped by light-travel delays during the flare decay. IXO can survey the 6.4 keV line in hundreds of disk-bearing stars to test predictions of X-ray effects on disk dynamics and chemistry.



The IXO Hard X-ray Telescope (blue line) can trace the emission out to 10-30 keV range where X-rays may penetrate into the disk midplane. This is critical for determining the extent of ionization-induced MHD turbulence (via the magneto-rotational instability) in the disk and the size of the `dead zone'. The diversity of planetary systems may depend in part on the early X-ray irradiation history of the disks.

1 Bhardwaj, Elsner et al. 2007, Plan. Space Sci.
2 Bhardvaj & Lisse 2007 in Encycl. of the Solar System
3 Feigelson & Montmerle, 1999, ARA&A
4 Guedel, 2004, A&A Rev.
5 Feigelson et al, 2007, in Protostars & Planets V
6 Glassgold et al. 2000, in Protostars & Planets IV
7 Imanishi et al. 2001, ApJ
8 Glassgold et al. 2007, ApJ
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10 Dennerl 2006, Space Sci. Rev.

This study is based on the report of the *Solar System, Planet Formation and Evolution* science panel for the Constellation-X mission, the predecessor of IXO. We thank Randall Smith (NASA-GSFC) for excellent support of the panel's work.