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The Wide Field Imager of the International X-ray Observatory

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ABSTRACT

The International X-ray Observatory (IXO) will be a joint X-ray observatory mission by ESA, NASA and JAXA. It will have a large effective area ($3\,m^2$ at 1.25 keV) grazing incidence mirror system with good angular resolution (5 arcsec at 0.1–10 keV) and will feature a comprehensive suite of scientific instruments: an X-ray Microcalorimeter Spectrometer, a High Time Resolution Spectrometer, an X-ray Polarimeter, an X-ray Grating Spectrometer, a Hard X-ray Imager and a Wide-Field Imager.

The Wide Field Imager (WFI) has a field-of-view of 18 ft × 18 ft. It will be sensitive between 0.1 and 15 keV, offer the full angular resolution of the mirrors and good energy resolution. The WFI will be implemented as a 6 in. wafer-scale monolithic array of 1024 × 1024 pixels of $100 \times 100\,\mu m^2$ size. The DEpleted P-channel Field-Effect Transistors (DEPFET) forming the individual pixels are devices combining the functionalities of both detector and amplifier. Signal electrons are collected in a potential well below the transistor's gate, modulating the transistor current. Even when the device is powered off, the signal charge is collected and kept in the potential well below the gate until it is explicitly cleared. This makes flexible and fast readout modes possible.

1. The IXO mission

The International X-ray Observatory (IXO) is a joint effort by NASA, ESA and JAXA to build the next-generation observatory-class X-ray mission.

Fig. 1 shows a conceptual view of the IXO spacecraft and instrument platform as proposed in a NASA study. Its key component is a grazing incidence angle X-ray mirror system with more than $A_{eff}=3\,m^2$ (at 1.25 keV) effective area, $f=20\,m$ focal length and 5 in. angular resolution.

As observatory facility, IXO will provide new insights into a broad range of astrophysical questions. For the Astro2010 Decadal Survey, a large number of white-papers were submitted that showcase the diverse science IXO is going to perform. Three overarching topics can be highlighted: *matter under extreme conditions* (e.g. Refs. [1–3]), *formation of structure* (e.g. Refs. [4–6])

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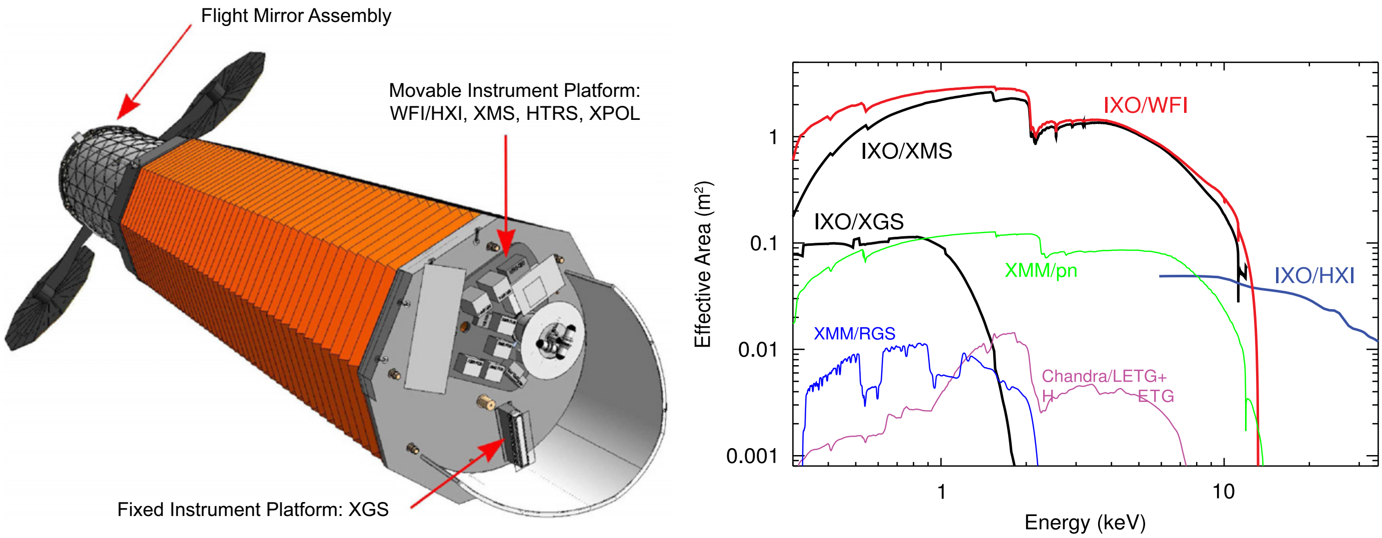

Fig. 1. Left: conceptual drawing of the IXO spacecraft and instrument platform (NASA study). To achieve the long focal length of 20 m in a way that is compatible with the launch vehicle fairing, the optical bench is mounted on an extensible instrument platform. The instrument platform consists of a Fixed Instrument Platform (FIP) on which the XGS is mounted as sole off-axis instrument, and a Moveable Instrument Platform (MIP), on which the complement of on-axis instruments (WFI/HXI, XMS, HTRS, XPOL) are mounted. The on-axis instruments are moved into focus individually as the science observations dictate. Right: effective area of various IXO instruments in comparison to XMM and Chandra heritage (NASA).

and *life cycles of matter and energy* (e.g. Refs. [7,8]). To address these questions, IXO's baseline instrumentation foresees suite of six instruments [9]:

- WFI/HXI The *Wide-Field Imager* and *High-energy X-ray Imager* are two independent instruments that are mounted behind each other in the same instrument slot of IXO's Movable Instrument Platform (MIP). As they share one position on the MIP, and thus always observe simultaneously, they can be considered as one instrument from the observatory standpoint. The WFI is an Active Pixel Sensor (APS) detector which covers a very large FoV of 18 ft × 18 ft with good spectral resolution (~ 125 eV at 5.9 keV), and good imaging resolution (fivefold oversampling of the mirror PSF) in the energy range of 0.1–15 keV. The HXI extends IXO's energy coverage to higher energies. It offers an 8 ft × 8 ft FoV with energy resolution of better than 1 keV (at 30 keV) in the energy band of 15–40 keV.
- XMS The *X-ray Microcalorimeter Spectrometer* is a non-dispersive imaging high-resolution spectrometer, using an array of superconductive Transition Edge Sensors (TES). It has a spectral resolution of 2.5 eV in a field of view (FoV) of 2 ft × 2 ft, and 10 eV in an extended FoV of 5 ft × 5 ft.
- HTRS The *High Time Resolution Spectrometer* is an array of 37 hexagonal Silicon Drift Diodes (SDD), placed out of focus so that the converging beam from the mirror assembly is distributed across the whole SDD array. This allows IXO to observe objects with fluxes of up to several tens of Crab without pile-up degradation with very high time resolution. The HTRS provides moderate (200 eV) energy resolution, but no imaging.
- XPOL The *X-ray Polarimeter* is an imaging polarimeter, sensitive roughly to a 1% level polarisation of a 1 mCrab source in a 100 ks observation. It has a FoV of 2.6 ft × 2.6 ft, and a moderate energy resolution of $E/\Delta E \sim 5$ at 6 keV.
- XGS The *X-ray Grating Spectrometer* is a non-imaging dispersive high resolution spectrograph. It is the only instrument that is operated constantly in parallel to the other instruments, as it diffracts light out of the main optical path onto its CCD detector array. The effective area used by the XGS is $A_{\mathrm{eff}} = 1000\,\mathrm{cm}^2$ (0.3–1.0 keV). It offers a very high spectral resolution of $\lambda/\Delta\lambda = 3000$.

The long focal length of the mirror system necessitates an extensible Deployment Module (DM). Retracted in its launch configuration, the DM allows IXO to fit into the fairing of either an Ariane 5 or an Atlas V launcher. Extended, it will move the instrument platform into position 20 m away from the mirror. Most of the instruments are on-axis instruments, therefore the optical bench will feature a Moveable Instrument Platform (MIP) that will move one on-axis instrument into focus at a time. The XGS is the only off-axis instrument and will therefore sit on the Fixed Instrument Platform (FIP) (see Fig. 1).

2. The IXO Wide Field Imager

One principal challenge encountered in the WFI is the need for very high readout rates. As can be seen in Fig. 1, the effective area of the IXO mirror system at 1 keV is more than a factor of 20 larger than previous X-ray missions, with correspondingly higher event rates. This necessitates very fast and flexible readout modes, in order to reduce event and pattern pile-up. Charge Coupled Device (CCD) sensors, which have been the predominant type of spectral imaging X-ray detector in recent decades, need to shift the signal charges across macroscopic distances, which inherently limits the speed with which signal charges can be accessed. Additionally, the Charge Transfer Efficiency (CTE), which is crucial for the performance of a CCD, depends on the quality of the bulk material and may deteriorate by radiation damage during the detector lifetime. This deterioration has for instance been observed in the Chandra ACIS and Suzaku XIS instruments [10].

For these reasons Active Pixel Sensors (APS), in which each pixel stores and amplifies the signal charge individually, have intrinsic advantages for the application in the IXO WFI. To achieve a field of view (FoV) of 18 ft, the WFI APS covers nearly the complete usable surface of a 6 in. wafer. Fig. 3 shows a mechanical prototype illustrating the physical and logical layout of the WFI APS.