A broadband X-ray imaging spectroscopy with high-angular resolution: The FORCE mission

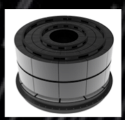
Koji Mori (University of Miyazaki, Japan),
T.G. Tsuru (Kyoto), K. Nakazawa (Nagoya), Y. Ueda (Kyoto), S. Watanabe (ISAS/JAXA), T. Tanaka (Kyoto),
M. Ishida (ISAS/JAXA), H. Matsumoto (Osaka), H. Awaki (Ehime), H. Murakami (Tohoku Gakuin), M. Nobukawa (Nara edu),
A. Takeda (U. of Miyazaki), Y. Fukazawa (Hiroshima), H. Tsunemi (Osaka), T. Takahashi (Kavli IPMU/U of Tokyo),
A.E. Hornschemeier, T. Okajima, W.W. Zhang, B.J.Williams (NASA/GSFC), and the FORCE WG

Abstract

We are proposing FORCE (Focusing On Relativistic universe and Cosmic Evolution) as a future Japan-lead X-ray mission in the late 2020s. FORCE is characterized by broadband X-ray imaging spectroscopy with high angular resolution. The current design of FORCE has an energy band pass of 1-79 keV, with an angular resolution of <15", achieving 10 times the sensitivity of previous missions above 10 keV. Our primary scientific goals are (1) to complete a census of the black holes across cosmic time and mass scale, (2) to measure the energetic content of relativistic particles in the Universe, and (3) to understand the explosion mechanism and nucleosynthesis in supernovae. FORCE will mark the beginning of a new era in these fields.

X-ray Super-mirror

- Light-weight Si mirror provided by NASA/GSFC [3]
- Multi-layer coating directly on the Si mirror surface
- Unprecedented angular resolution of < 15" in hard X-ray



Current design

- High angular resolution in hard X-ray is the key parameter to achieve high sensitivity in Hard X-ray, 2-3x10^{-15} erg/s in 10-40 keV, that is required from our science goals [1,2] (Tab. 1)
- Broadband response, not limited to hard X-ray, is also a characteristic feature of FORCE

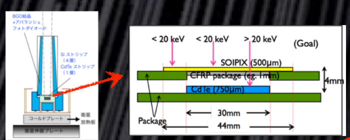
Tab. 1 FORCE design parameters in comparison with NuSTAR and ASTRO-H

Parameter	FORCE	NuSTAR	ASTRO-H (HXT & HXI)
angular resolution (HPD)	<15″	58″	1.7′
bandpass (keV)	1–80	3–79	5–80
effective area (cm^2@30 keV)	> 200	184*	198*
fov (50% resp. @30 keV)	>7′×7′	~10′×10′	~6′×6′
timing resolution	several × 10 μs	2 μs	several × 10 μs
energy resolution (FWHM)	<300 eV at 6 keV comparable with HXI	400 eV at 10 keV 900 eV at 68 keV	900 eV at 14 keV 1500 eV at 60 keV

* 4arcmin radius extraction region

Wideband Hybrid X-ray Imager

- New Si sensor (SOI-CMOS) + CdTe hybrid
- Low BG with active shield, the same concept as the ASTRO-H's HXI achieving the lowest BG in the hard X-ray[5]
- Wideband sensitivity of 1-80 keV



References

[1] Mori et al. 2016, SPIE, 9905, 99051O
[2] Nakazawa et al. 2018, SPIE, 10699, 106992D
[3] Zhang, W.W. et al. 2016, SPIE, 9905, 99051S
[4] Tsuru, T.G. et al. 2018, SPIE, 10709, 107090H
[5] Nakazawa et al. 2018, JATIS, 4, 021410

Scientific Objectives

- The concept of the FORCE mission is to focus on "the high energy processes that govern the structure and evolution of the Universe." Our primary scientific objectives are then (1) to complete a census of the black holes across cosmic time and mass scale, (2) to measure the energetic content of relativistic particles in the Universe, and (3) to understand the explosion mechanism and nucleosynthesis in supernovae (Fig.1).

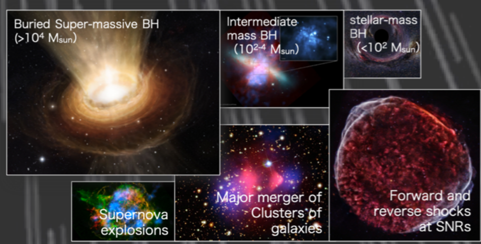


Fig. 1 The scientific targets of the FORCE mission, shown here, are high energy objects that play crucial roles in the formation and evolution of the Universe

Recent progress

- **Si-mirror**: The half-power diameter < 12" at 15 and 30 keV is demonstrated with a single pair of mirrors (Fig. 2)
- The alignment and bonding of multiple modules and the multi-layer coating are the key issues to the next stage

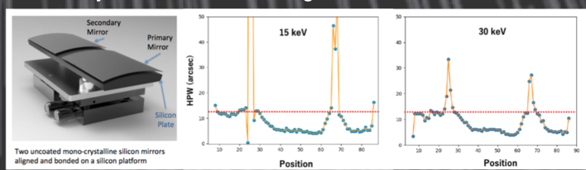
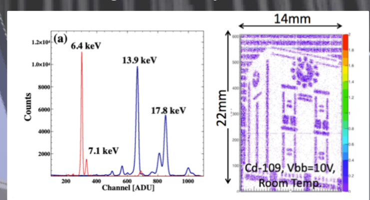


Fig. 2 X-ray testing of a single pair of Si-mirrors

- **SOI-CMOS**: In the event-readout mode, Fe-Kα and Fe-Kβ lines are clearly resolved and an imaging with the event rate of > 500 Hz is demonstrated [4] (Fig. 3)
- Development of the tray for the SOI-CMOS chips suitable for the current camera design is the key issue to the next stage



The movie demonstration of the right figure is available from the QR code below or directly accessing to http://www.soipix.jp/material.html

Fig. 3 X-ray testing of the SOI-CMOS sensor, XRPIX.
The Co-57 and Am-241 spectra (left) and the shadow imaging (right)

Japan-US collaboration

- The X-ray astrophysics laboratory at NASA/GSFC has been working closely with us and expresses a strong commitment to the FORCE mission