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

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Abstract

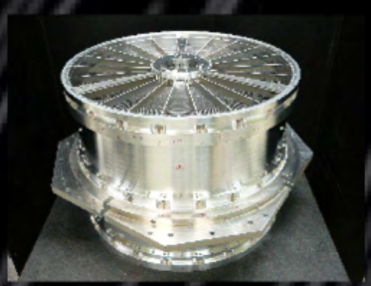
We present the concept and recent progress of future Japan-lead small-class mission, FORCE (Focusing On Relativistic universe and Cosmic Evolution), to be launched in the late 2020s. FORCE is a successor of Hitomi, focusing on the broadband X-ray imaging spectroscopy in 1-80 keV with a significantly higher angular resolution of < 15" in half-power diameter. The sensitivity above 10 keV will be 10 times higher than that of any previous hard X-ray missions. The soft X-ray band is simultaneously covered. The primary scientific objective of the FORCE mission is to trace the cosmic formation history by searching for ``missing black holes'' in the entire range of the mass spectrum of BHs. Also, investigation of the nature of relativistic particles at various astrophysical shocks is in our scope, with high-angular-resolution X-ray observations with the broadband coverage. FORCE will open 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

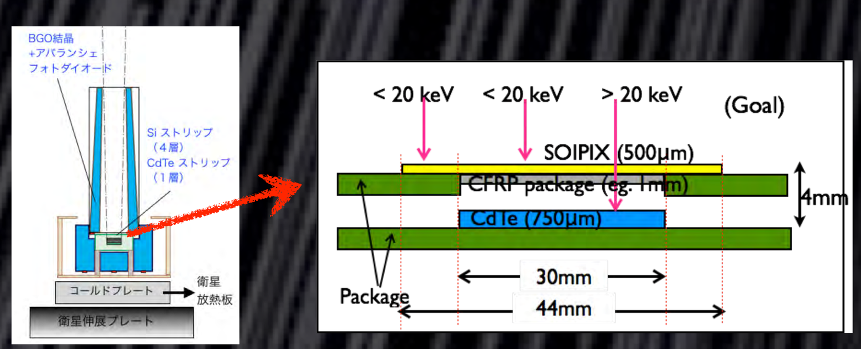
Parameter	FORCE	NuSTAR	ASTRO-H (HXT & HXI)
angular resolution (HPD)	<15″	58″	1.7′
bandpass (keV)	1–80	3–79	5–80
effective area (cm^2@30 keV)	>350	comarable with HXI	338
fov (50% resp. @30 keV)	>7′×7′	~10′×10′	~6′×6′
timing resolution	several × 10 μs	2 μs	several × 10 μs
energy resolution (FWHM)	<300 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

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



Scientific Objectives

• Our primary scientific objective is to trace the cosmic formation history by searching for ``missing black holes'' in the entire range of the mass spectrum of black holes (Fig. 1): ``buried supermassive black holes (SMBHs)", which reside in centers of galaxies in a cosmological distance, ``intermediate-mass BHs", which are possible seeds from which SMBHs grow, and ``orphan stellar-mass black holes'', which have no companion, in our Galaxy.

• Investigation of the nature of relativistic particles at various astrophysical shocks is also in our scope. Non-thermal X-ray emission from relativistic particles provide us with essential information their nature and origin.

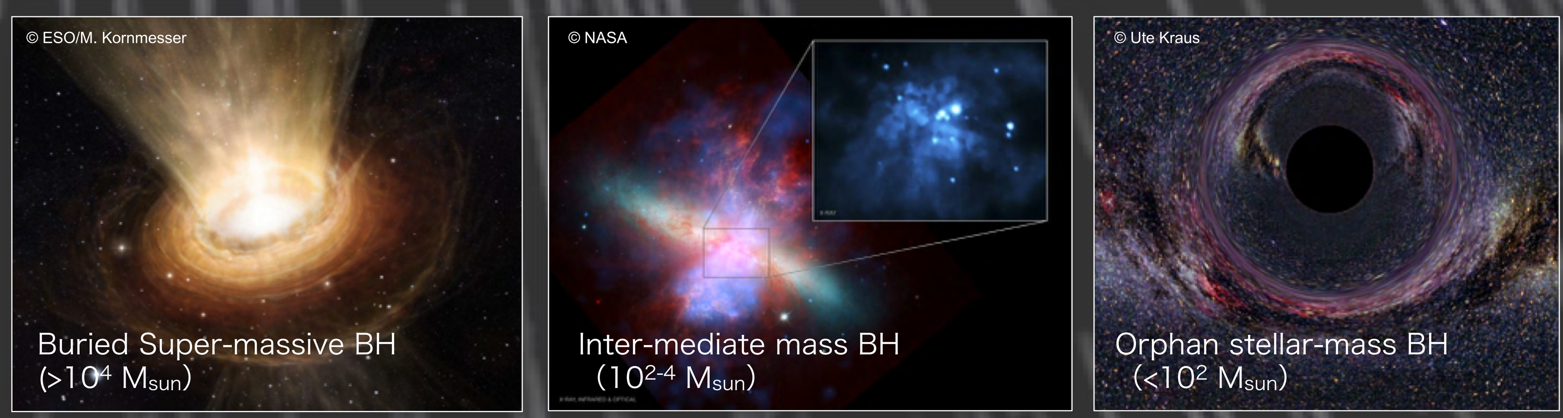


Fig. 1 "missing black holes" in various mass-scales

Recent progress

• **Si-mirror**: The half-power diameter of 3.4" at 4.5 keV (Ti-K) 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

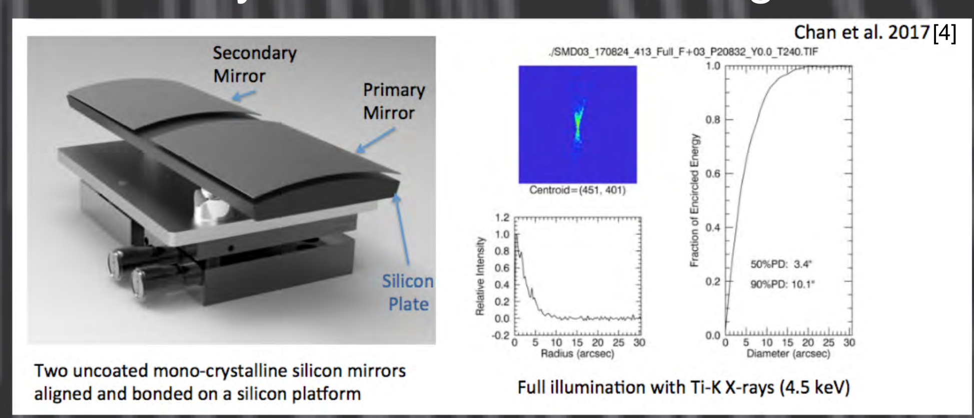


Fig. 2 X-ray testing of a single pair of Si-mirrors

• **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 (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

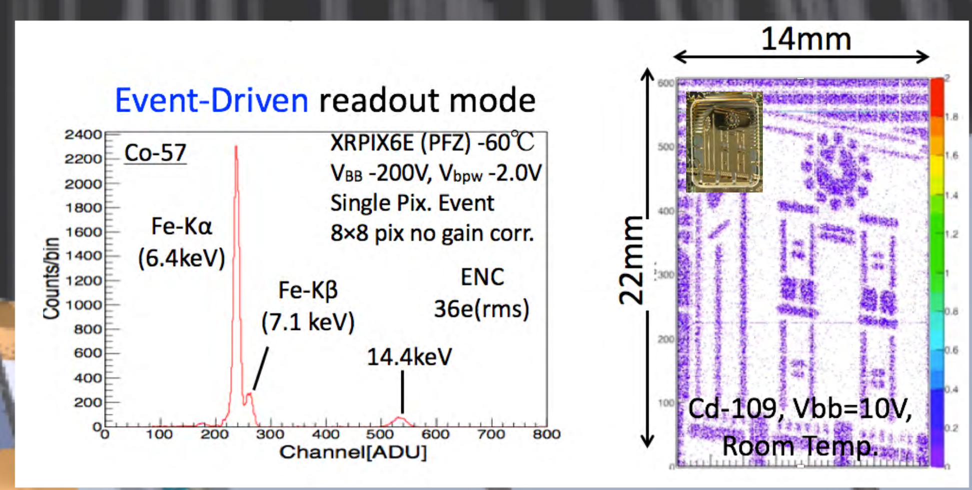


Fig. 3 X-ray testing of the SOI-CMOS sensor, XRPIX. The Co-57 spectrum (left) and the shadow imaging (right)

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

References

[1] http://www.cc.miyazaki-u.ac.jp/force/wp-content/uploads/force_proposal.pdf

[2] Mori et al. 2016, SPIE, 9905, 99051O

[3] Zhang, W.W. et al. 2016, SPIE, 9905, 99051S

[4] Chan, K-W. et al. 2017, SPIE, 10399, 103990U

[5] Nakazawa et al. 2017, JATIS, submitted