The FORCE mission:

focusing
on
relativistic universe and
cosmic
evolution

Koji Mori
(University of Miyazaki, Japan)
on behalf of the FORCE collaboration

The FORCE mission:

A broadband X-ray imaging spectroscopy in 1-79 keV with high-angular resolution of < 15 arcsec

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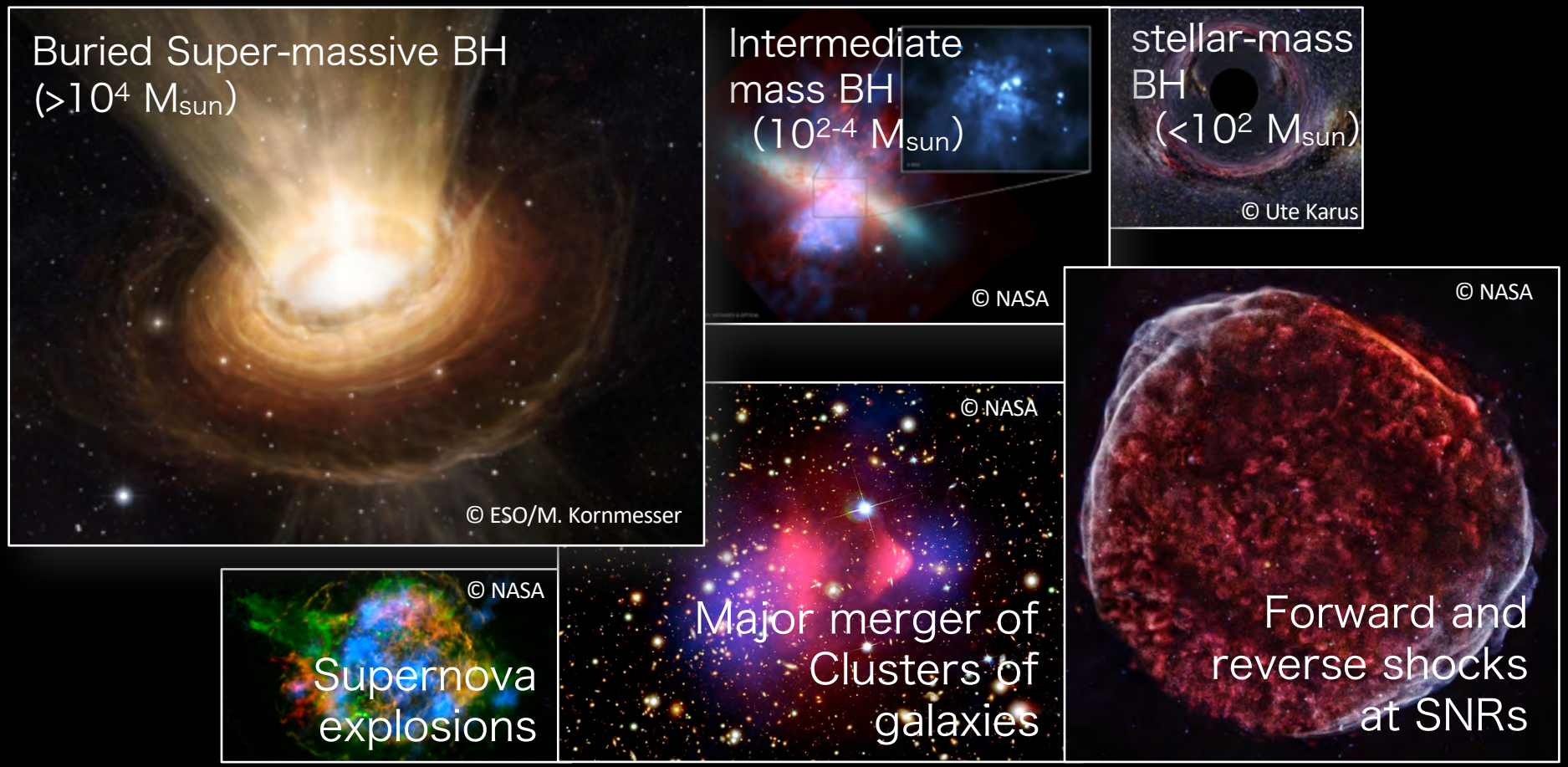
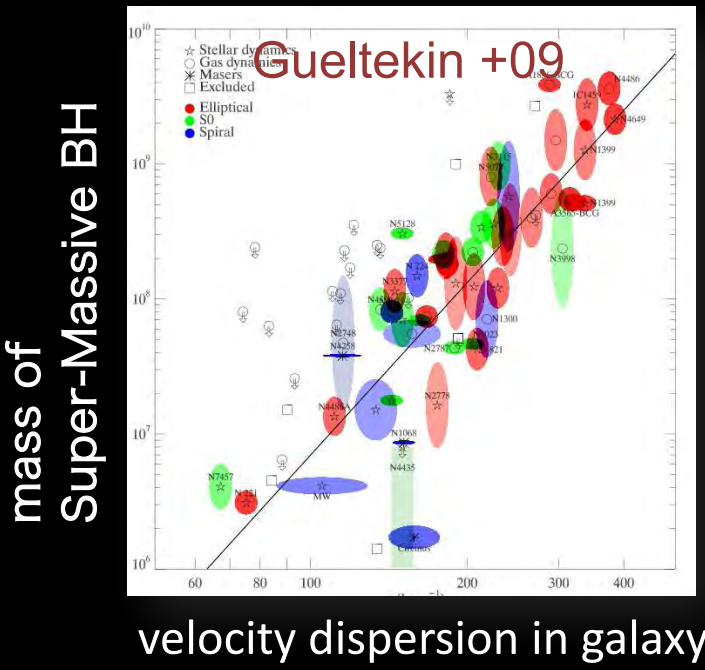
48 members

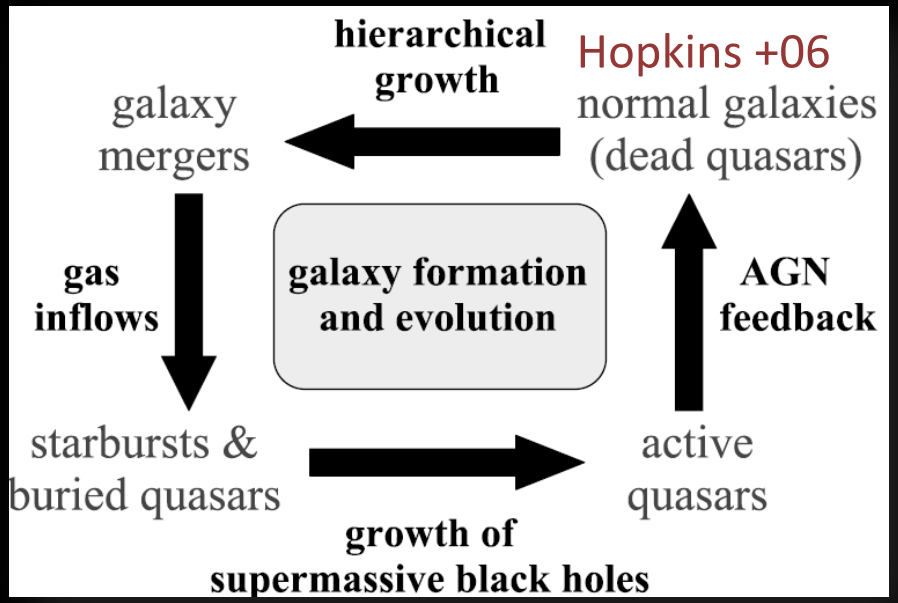
Scientific Goals



- Our scientific goals are
  - to complete a census of black holes across cosmic time and mass scale,
  - to measure the energetic content of relativistic particles in the universe, and
  - to understand the explosion mechanism and nucleosynthesis in supernovae

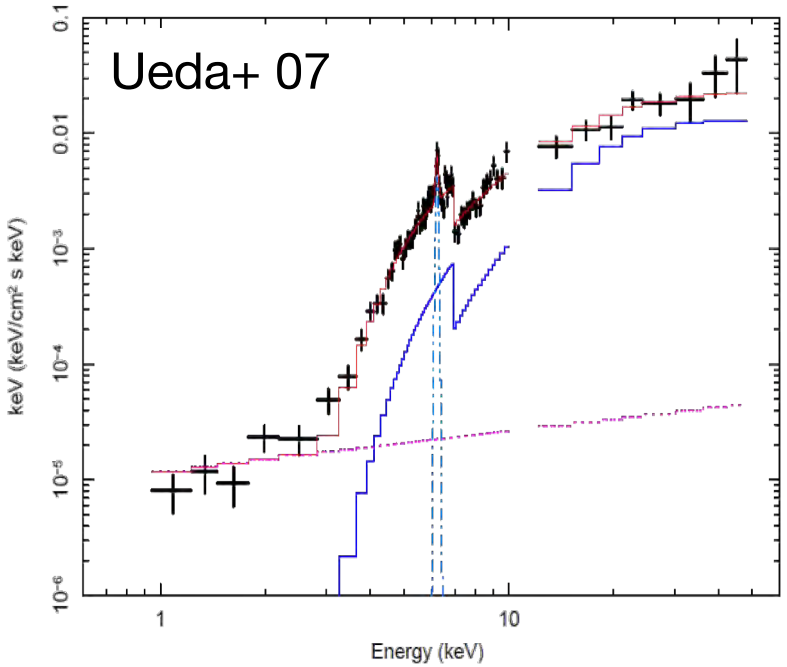
Probing Co-evolution of galaxies and their SMBH by buried AGN

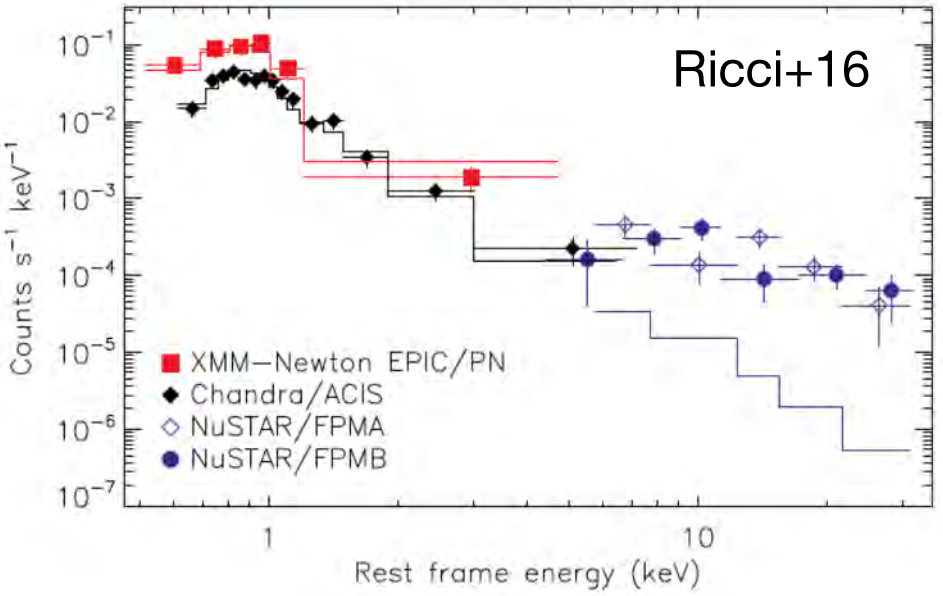




- "Co-evolution" of galaxies and their SMBH
- Buried, Compton-thick AGNs may be in rapidly growing phase of SMBHs and play a key role to understand the galaxy-SMBH evolution

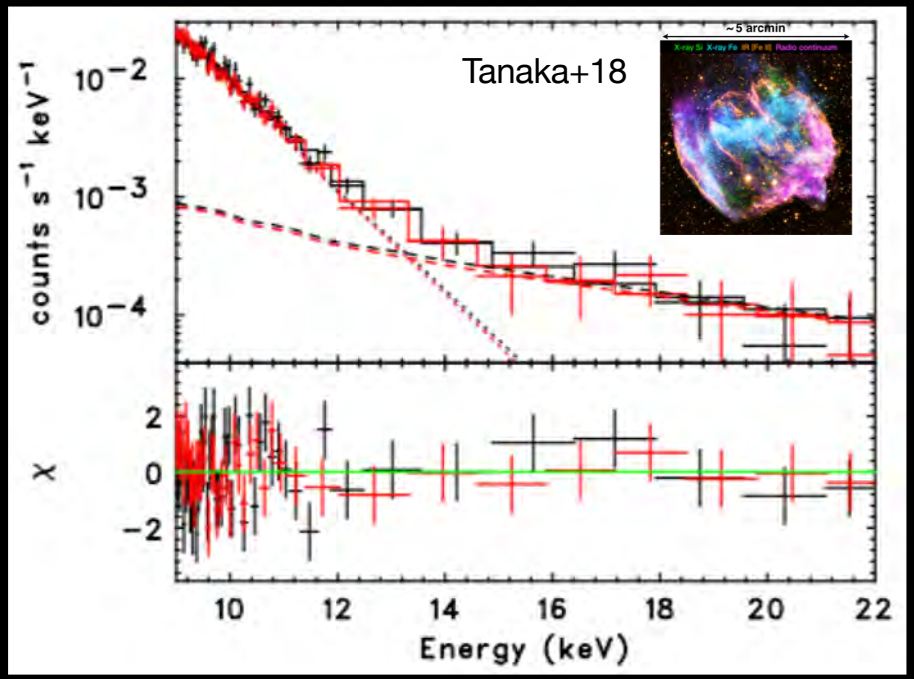
Hard X-ray census of Compton-thick AGNs

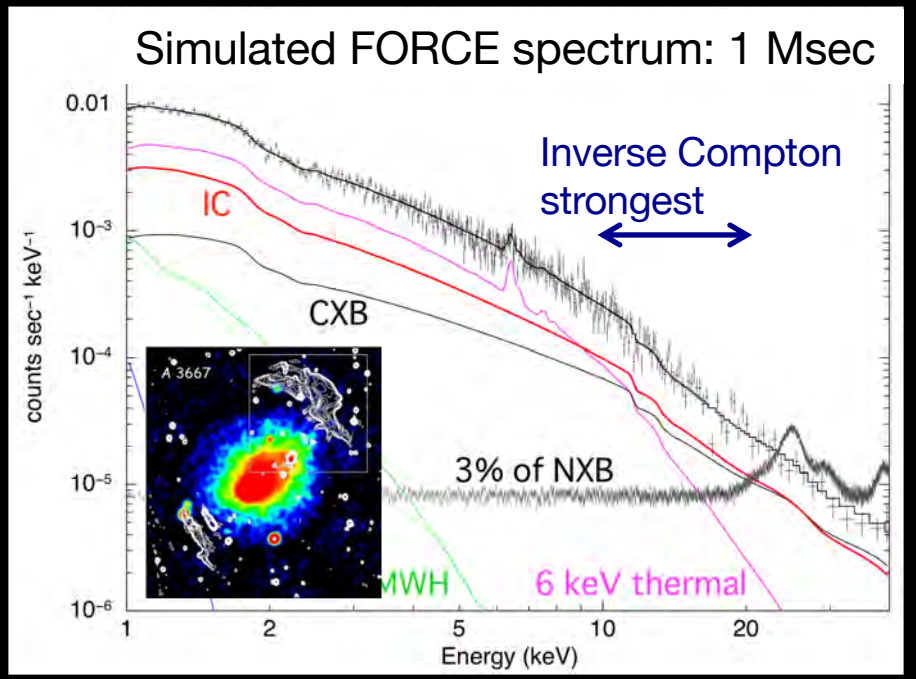




- The brighter CTAGNs have been studied with Suzaku non-imaging hard X-ray detector
- The NuSTAR's hard X-ray imaging is discovering a fainter population
- One-order magnitude deeper hard X-ray sensitivity to point sources is required to reveal how the CTAGN fraction evolve in cosmic time

Particle acceleration in Supernova Remnants / Clusters of galaxies





- Supernova remnants
  - What is the total energy of cosmic rays that each SNR can produce is an unresolved question
  - Nonthermal bremsstrahlung, recently discovered in the SNR W49B in the hard X-ray band (left figure), is a new window to study sub-relativistic particles accelerated in SNRs
- Clusters of galaxies
  - Origin of the cosmic magnetic field and the total content non-thermal energy in the Universe are not understood, and the measurements of particle energy and magnetic field over the cluster scale are demanded
  - Combination with synchrotron radio data, the detection of the inverse Compton emission in the hard X-ray band gives the energy spectrum of relativistic electrons and the magnetic field (right figure)
- Unprecedented Hard X-ray sensitivity to diffuse sources is also required to achieve these goals

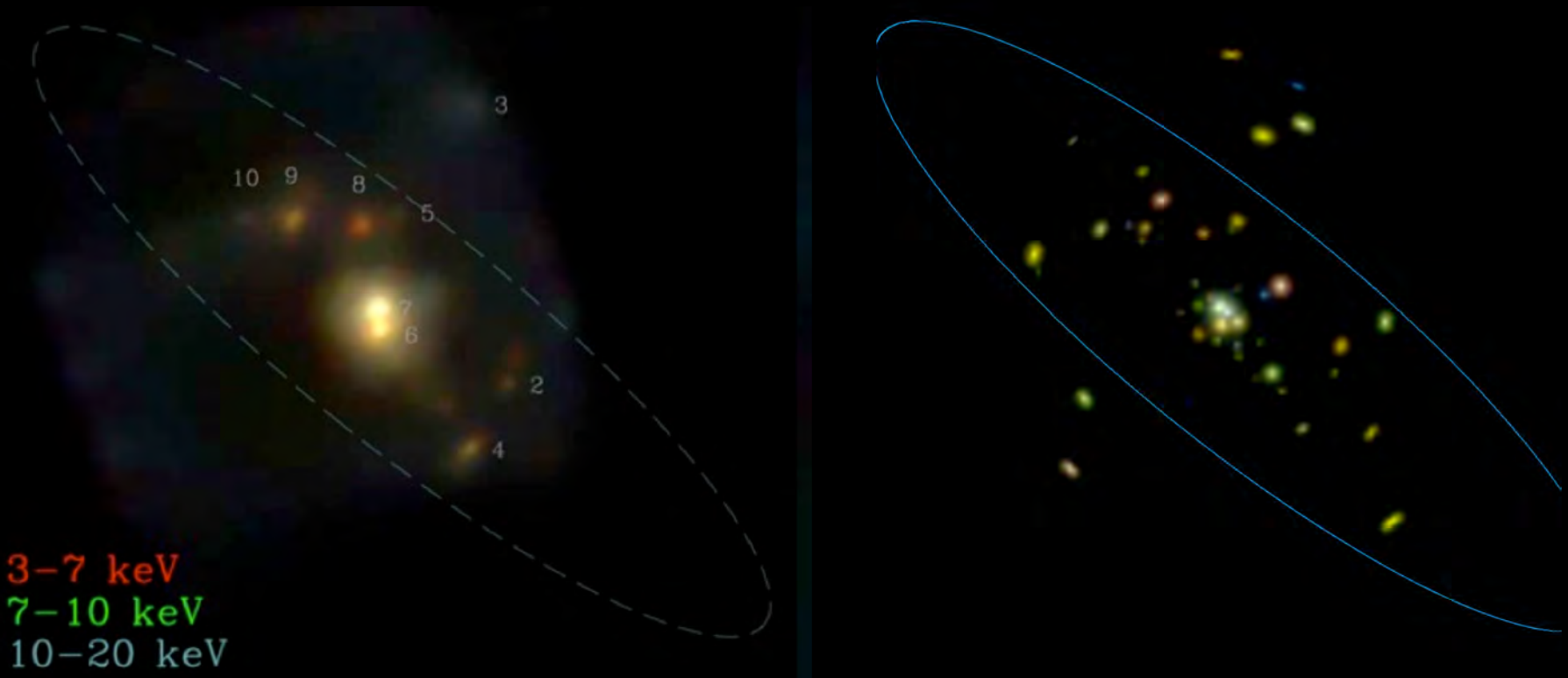
Mission requirements and design parameters

- High sensitivity in the hard X-ray band above 10 keV
  - 2-3x10^{-15} erg/s in 10-40 keV
- Broadband response
  - simultaneous coverage of the soft and hard X-ray bands is essential to study intrinsically time-variable AGNs
- Large effective area

Parameter	FORCE (requirement)	NuSTAR	ASTRO-H (HXT & HXI)
angular resolution (HPD)	$<15''$	$58''$	$1.7'$
bandpass (keV)	1–79	3–79	5–80
effective area (cm^2@30 keV)	>200	184*	198*
fov (50% resp. @30 keV)	>49 $arcmin^2$	~85 $arcmin^2$	~36 $arcmin^2$
timing resolution	several × 10 μs	2 μs	several × 10 μs
energy resolution	<300 eV at 6 keV	400 eV at 10 keV	900 eV at 14 keV
(FWHM)	comparable with HXI	900 eV at 68 keV	1500 eV at 60 keV

* 4 arcmin radius extraction region

X-ray image with HPD 15” in the hard X-ray band



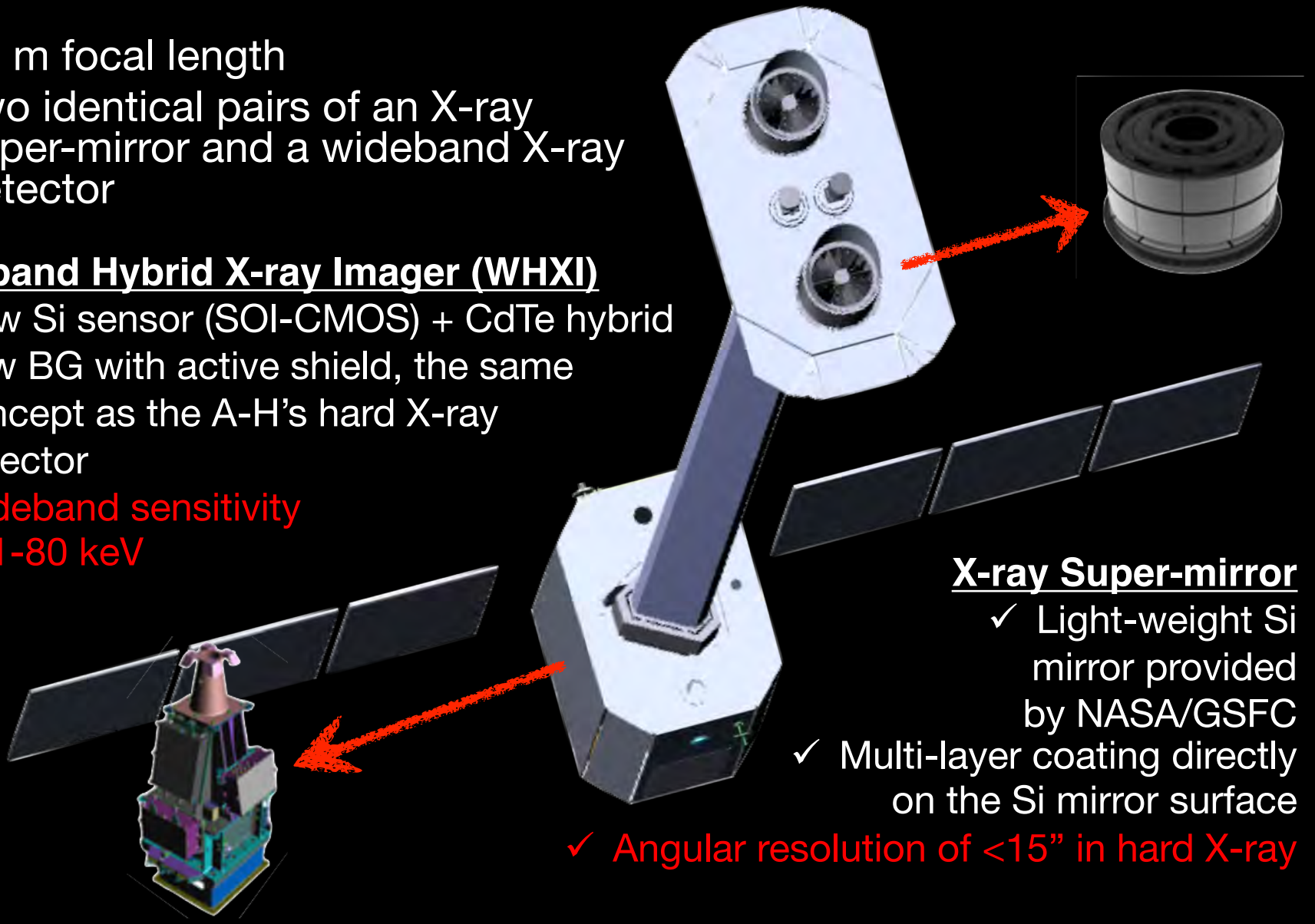
- NGC 253, bright, nearby, and one of the best-studied starburst galaxies
- Left image shows 495 ks NuSTAR image whereas right image shows ~400 ks FORCE image as expected from the current design

Overview of the FORCE satellite

- 12 m focal length
- Two identical pairs of an X-ray super-mirror and a wideband X-ray detector

Wideband Hybrid X-ray Imager (WHXI)

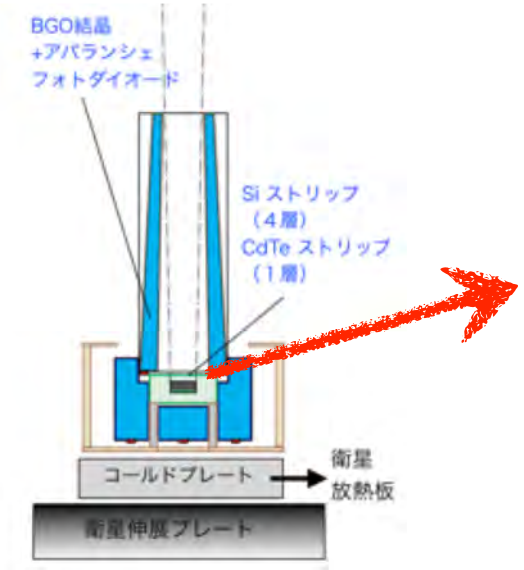
- ✓ New Si sensor (SOI-CMOS) + CdTe hybrid
- ✓ Low BG with active shield, the same concept as the A-H's hard X-ray detector
- ✓ Wideband sensitivity of 1-80 keV

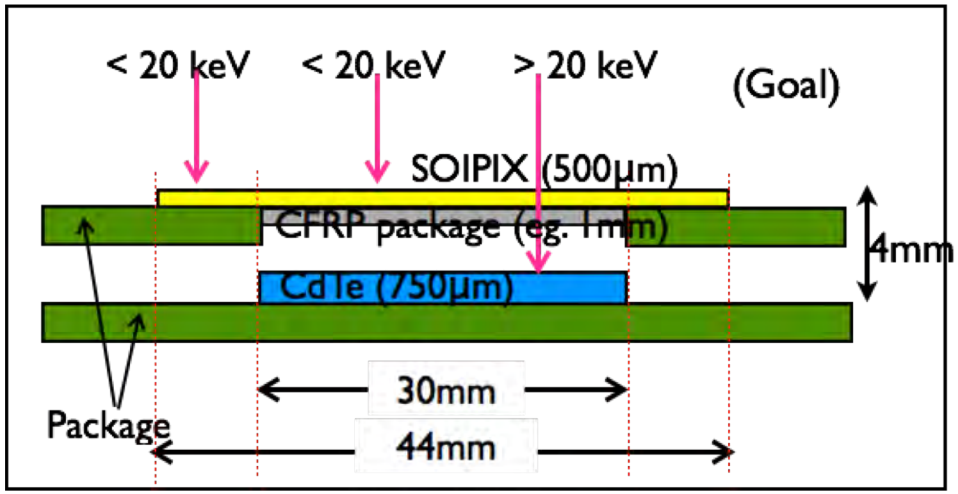


X-ray Super-mirror

- ✓ Light-weight Si mirror provided by NASA/GSFC
- ✓ Multi-layer coating directly on the Si mirror surface
- ✓ Angular resolution of <15" in hard X-ray

Wide-band Hybrid X-ray Imager

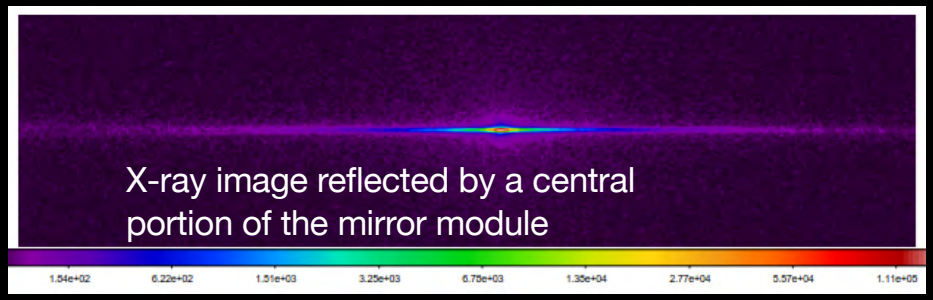


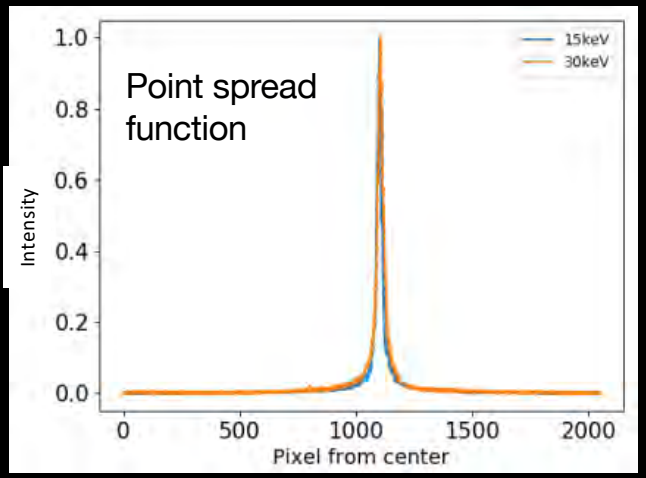


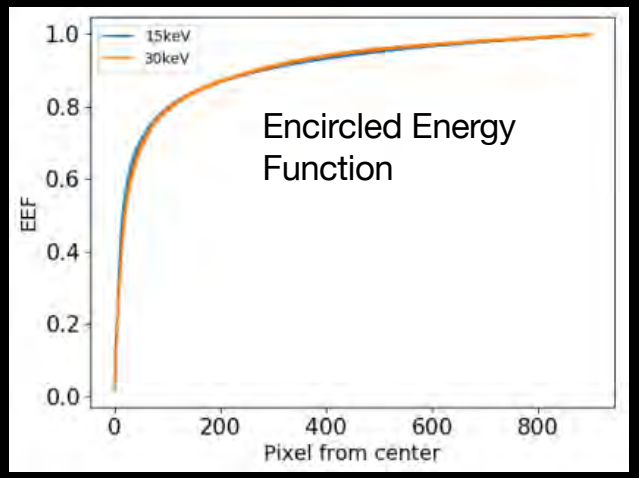
- Si + CdTe Hybrid detector with active shield
  - The same concept as the ASTRO-H Hard X-ray Imager, low cost and low risk
- Replacing Si top layer from strip to SOI-CMOS pixel detectors
  - Low readout noise is achievable, lowering the energy threshold down to 1 keV
  - similar working temperature to that of CdTe
  - anti-coincidence technique can be utilized thanks to good time resolution and self-trigger function

Hard X-ray performance of a pair of silicon mirror segments

a mirror module consisting of a pair of silicon mirror segments with Pt/C depth-graded multiplayer coating

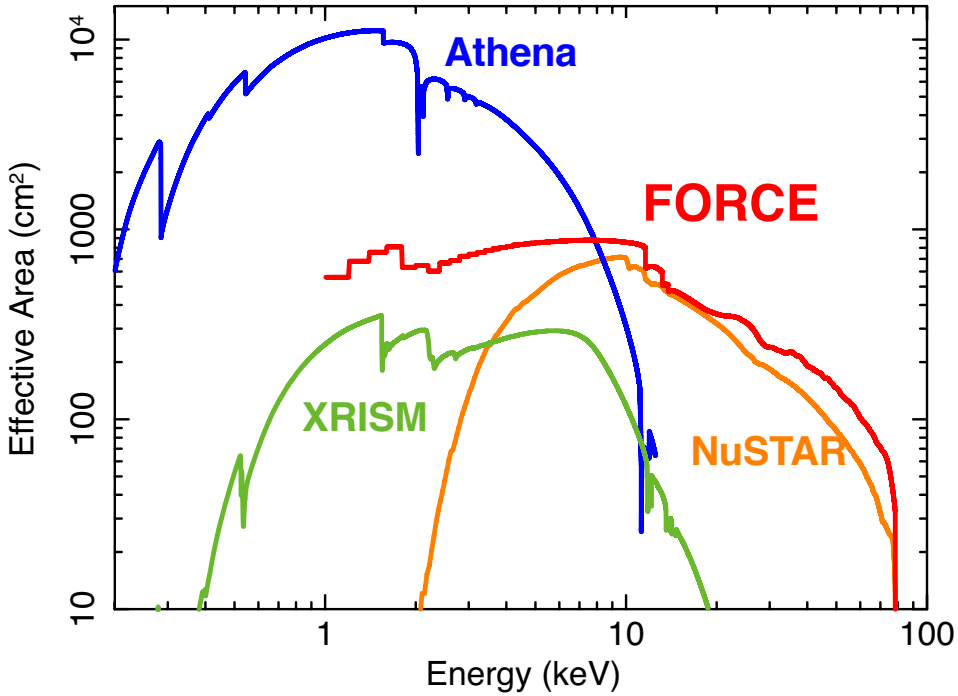


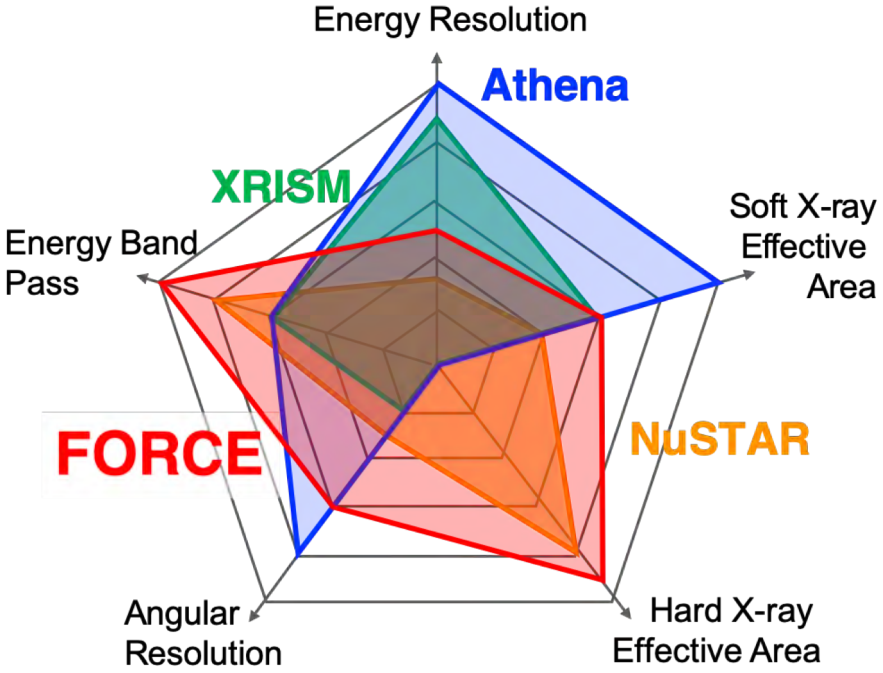




- The hard X-ray performance of a mirror module consisting of a pair of silicon mirror segments with Pt/C depth-graded multiplayer coating was measured at SPring-8
- The HPDs are 5 and 6 arcsec at 15 and 30 keV, respectively at the central portion of the mirror

Comparison with other X-ray missions





- FORCE encompasses NuSTAR in all the directions of the performance radar chart (right) and plays a complementary role to XRISM/Athena (both figures)

Summary

- FORCE (Focusing On Relativistic universe and Cosmic Evolution) is a concept of next Japanese medium-class mission, characterized by broadband (1-79 keV) X-ray imaging spectroscopy with high angular resolution (<15”)
- FORCE will trace the cosmic evolution of black holes in the entire range of the mass spectrum, reveal the nature of relativistic particles at various astrophysical shocks, and shed a new light on the explosion mechanism and nucleosynthesis in supernovae
- FORCE is an international collaborative mission between JAXA and NASA
- We are proposing this mission to be realized in late 2020s/early 2030s

May the force be with you