JUXTA : A New Probe of X-ray Emission from Jupiter and the Solar System

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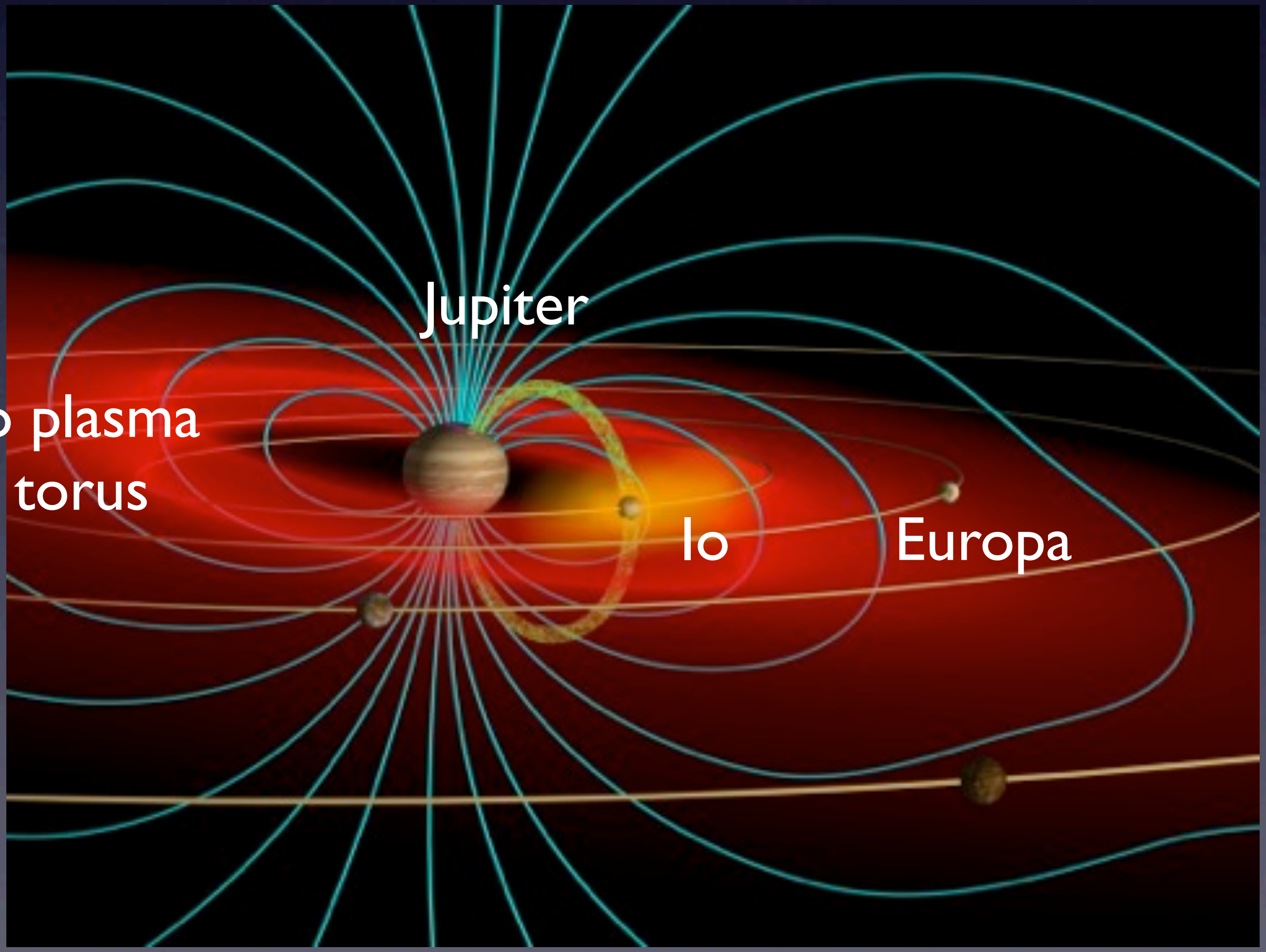
Outline

- Introduction
  - Past X-ray studies of the Jupiter system
- JUXTA instrument
  - In-situ X-ray imaging spectroscopy of the Jupiter system
- Summary

The Jupiter system

- Archetype for giant planets (x320 M_E, x11 R_E)
- Strong magnetic field (surface ~4 G, x500~1000 R_E)
- Ejecta from a volcanic Moon Io's volcanoes
- Internal oceans in Europa, Ganymede, Callisto
- *Planetary phys. Astrophysics Exoplanet phys.*



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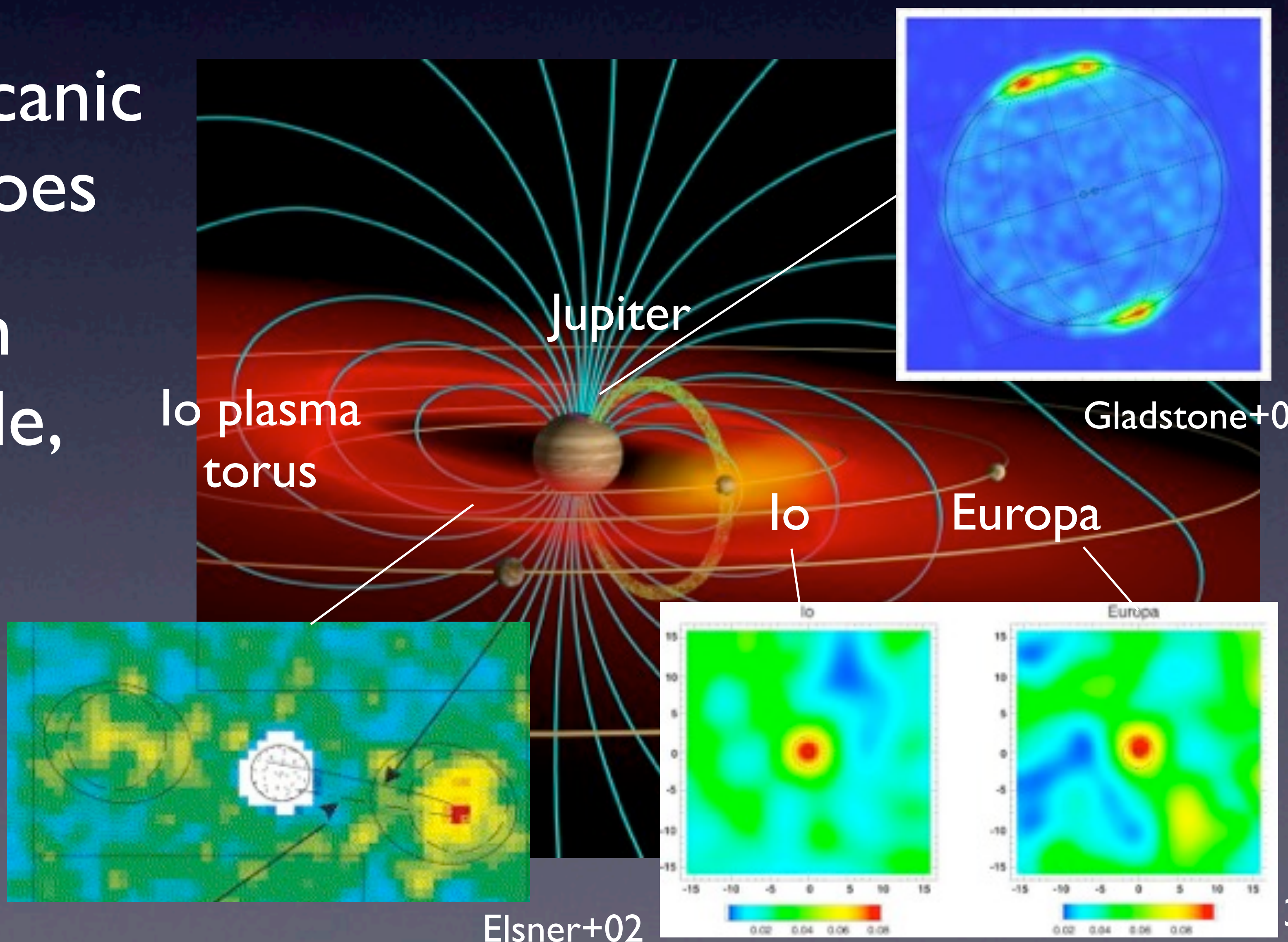
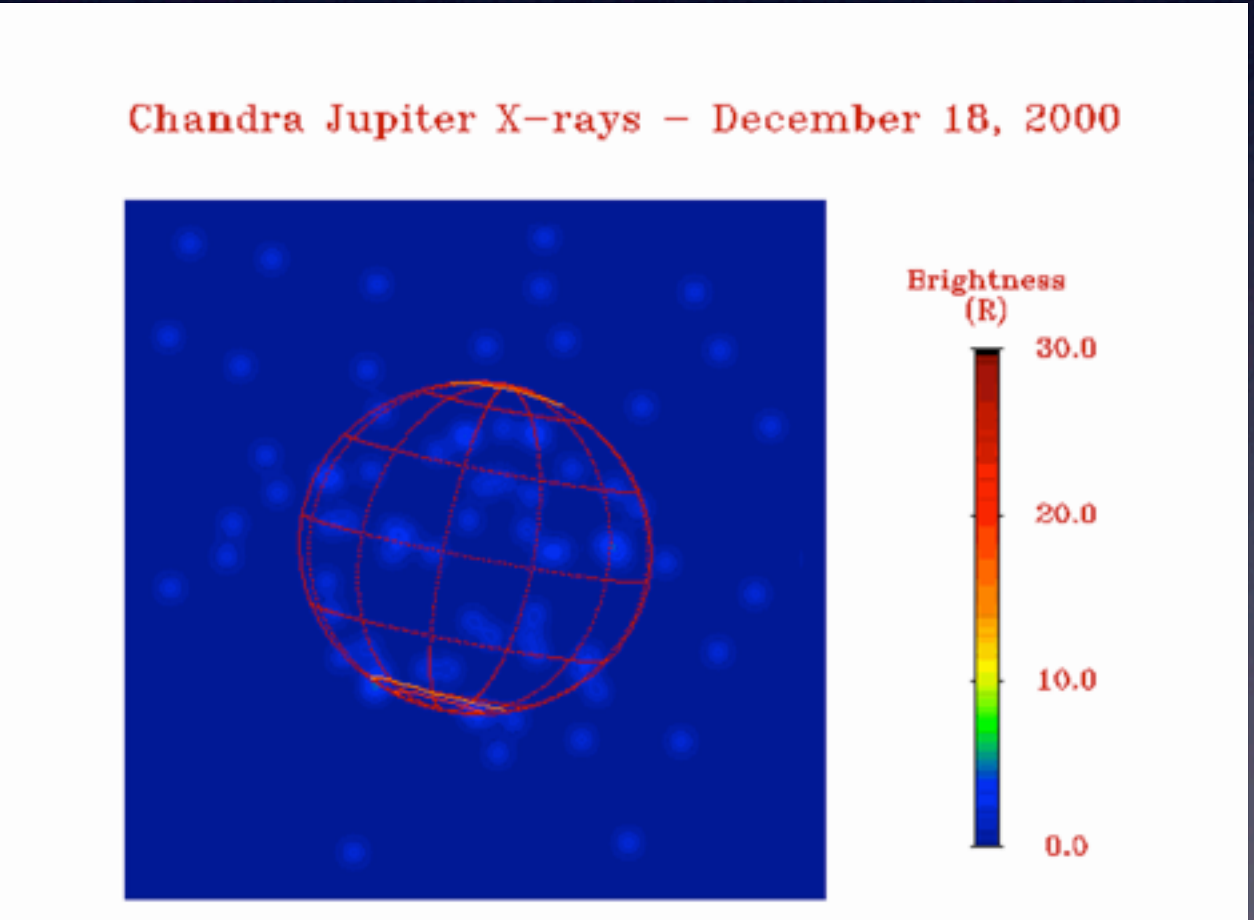


In the past decade or so

- X-ray studies of the Jupiter system have greatly advanced thanks to *Chandra*, *XMM*, and *Suzaku*
- Energetic particles in magnetosphere
  - tens eV~MeV e^-
  - MeV/amu ion
- Reprocessing of solar radiation
  - solar X-rays
  - solar winds

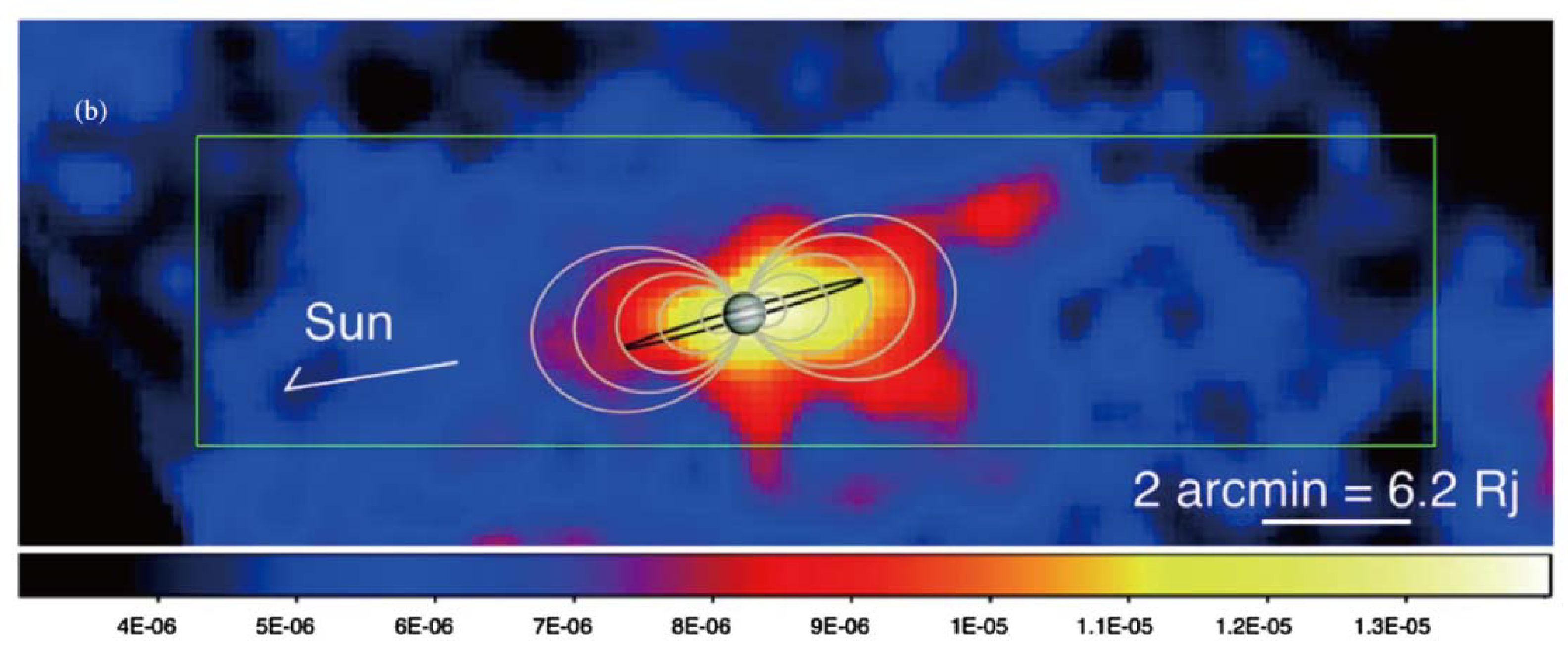


sidereal rotation period ~10 hr

Gladstone+02

Suzaku observation

- Japanese X-ray astronomy satellite (2005-)
  - CCDs with highest sensitivity for diffuse X-ray sources
- *Discovery of diffuse X-rays from inner rad. belts*
- Inverse Compton scattering by tens MeV electrons



Ezoe+10

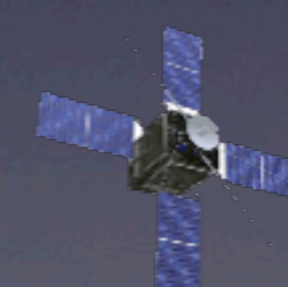
The way forward

- X-ray astronomy satellites orbit around Earth : limited photon statistics & spatial resolution
- No in-situ X-ray instrument so far
- *The first ever in-situ X-ray observation in future Japanese exploration !*

JUNO
Launch 2011
Arrival 2016

JUICE
Launch 2022
Arrival 2029

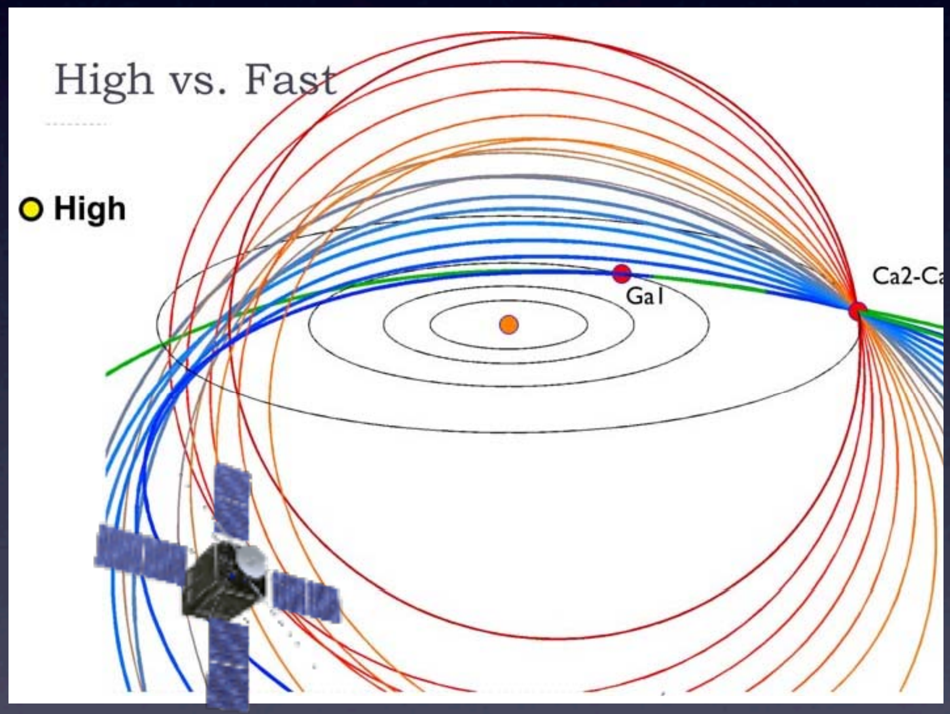
Japanese mission
“Solar sail, JMO”
proposed to be launched
in ~2020’s



JUXTA

(JUpiter X-ray Telescope Array)

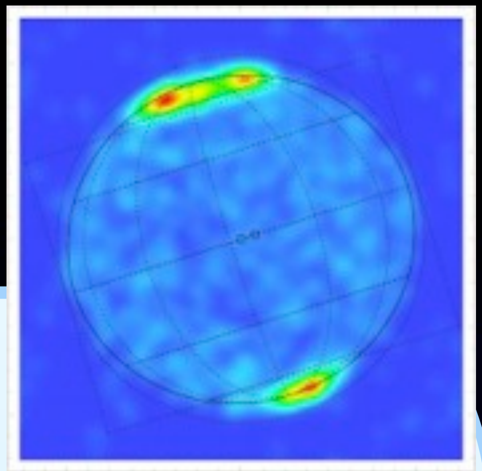
- *High photon stat.* & *high reso.* data unattainable otherwise
  - Area : *3 cm²* @ 30 R_J
    → 24 m² @ Earth orbit
  - Reso. : *5 arcmin* @ 30 R_J
    → 1 arcsec @ Earth orbit
- *Better than the gigantic X-ray astronomy satellite Athena+ (2 m², 5 arcsec, S/C ~5 tons, **2028**) as for the Jupiter system*



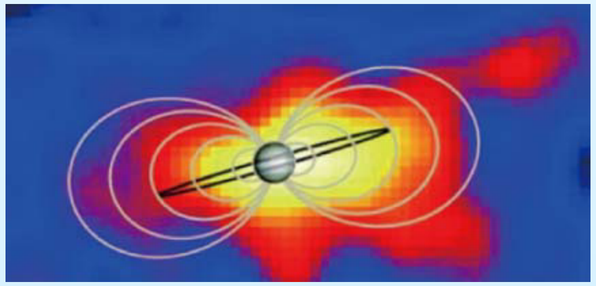
JMO : high inclination
periapsis 30 R_J, apoapsis 100 R_J

Ezoe+13

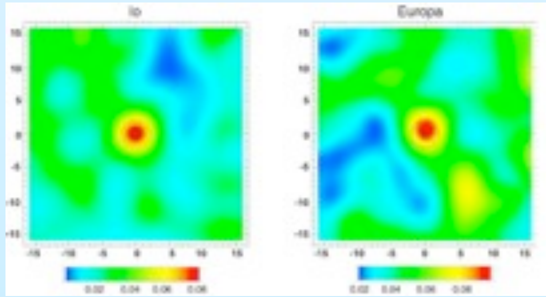
Science themes



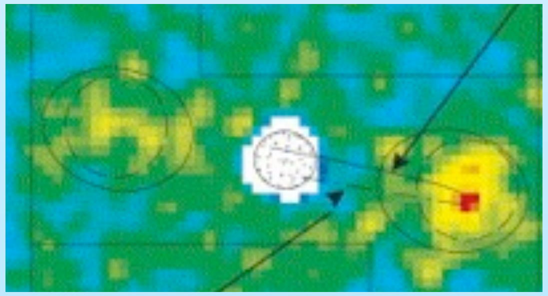
- *<u>1. Strong particle accelerations</u>*
  - aurora : keV e^-, MeV/amu ion
  - radiation belts : tens MeV e^-



- *<u>2. Jupiter-satellite binary system</u>*
  - Io, Europa, Ganymede ?, Callisto ?: ion
  - Io plasma torus : tens eV e^-, ion



- *<u>3. Rotational driven activities</u>*
  - auroral pulsation : keV e^-, MeV/amu ion

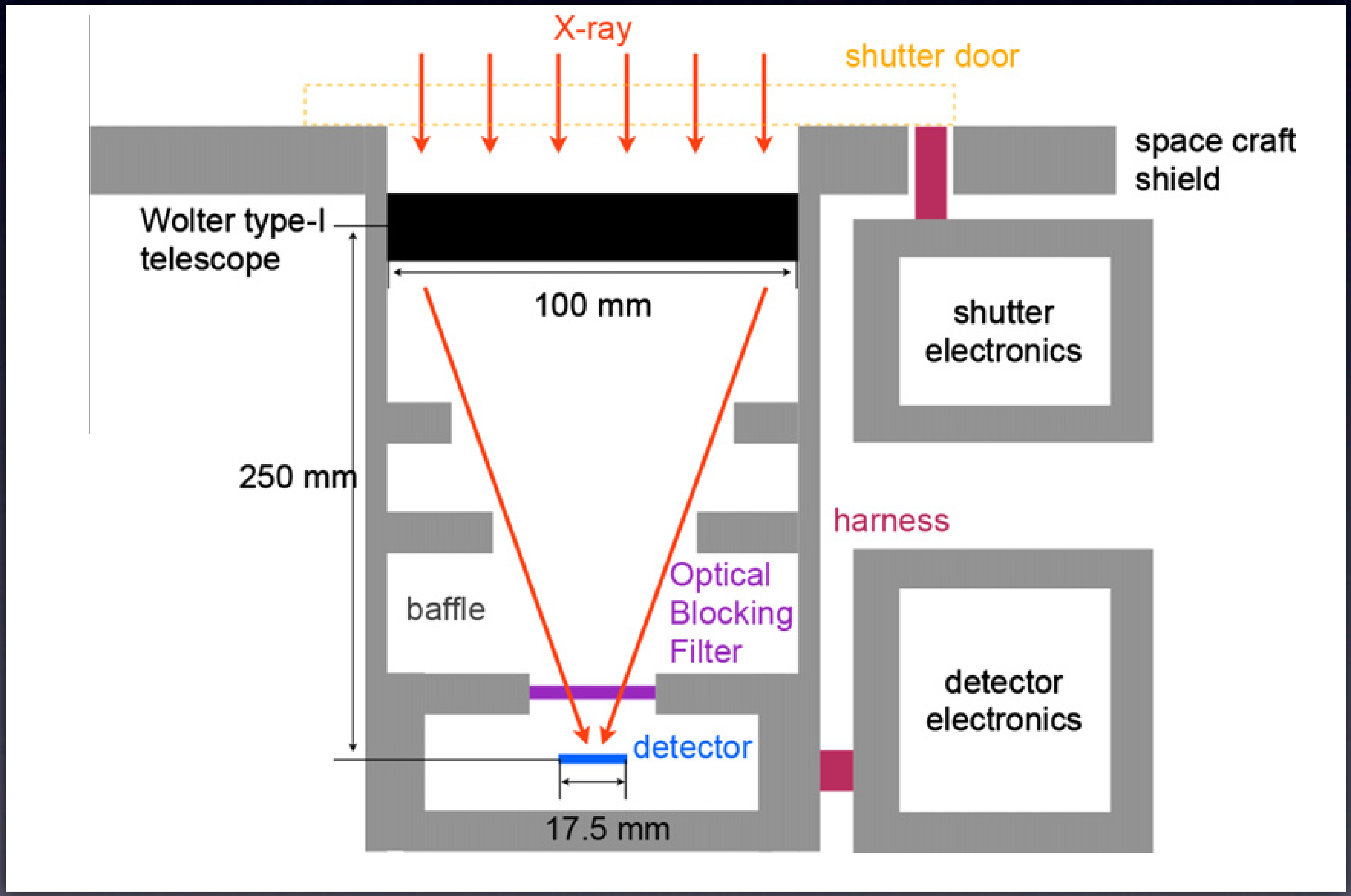


Instrument requirements

item	requirement	reason
Energy band	0.3 - 2 keV	• Ion : emission lines at <1 keV • Electron : bremss >1 keV
Spatial resolution	<5 arcmin	• Angular size of auroral hot spot ($\sim 10^4$ km @ 30 R_j)
Energy resolution	<100 eV at 0.6 keV	• Separate ion emission lines
Time resolution	<1 min → >3 cm^2	• Detect periodic X-ray pulsation of aurora
Field of view	>4 deg dia.	• Size of Jupiter at 30 R_j

JUXTA : baseline design

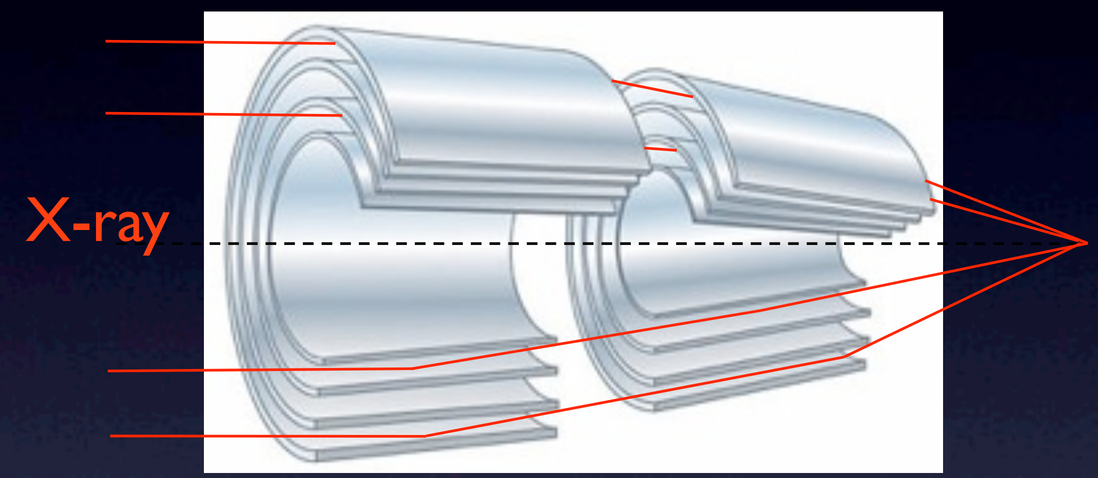
- A new light weight telescope & a radhard detector
- Size : ~25 cm cubic
- Mass : ~10 kg
- Power : ~10 W
- Count rate :
  - Jupiter : ~40 cps
  - rad. belts : ~2 cps



JUXTA : optics

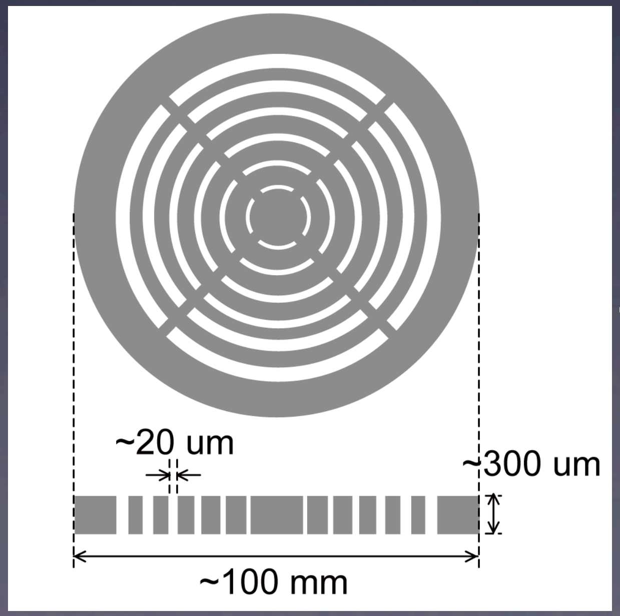
- The optics are the key to achieving the challenging science requirements under limited resources
- Breakthrough technology Micromachined optics

Wolter type-I optics

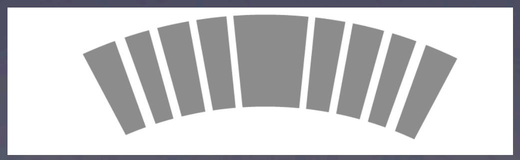


reflection angle < a few deg

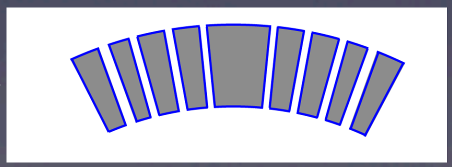
Si dry etching & smoothing



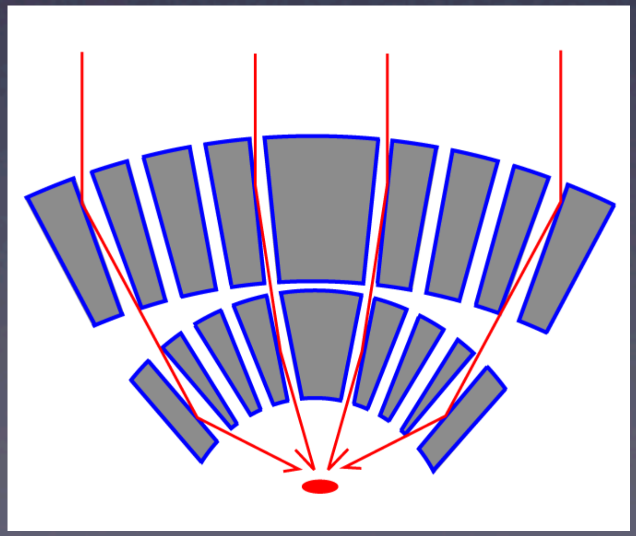
plastic deformation



Metal (Ir) coating

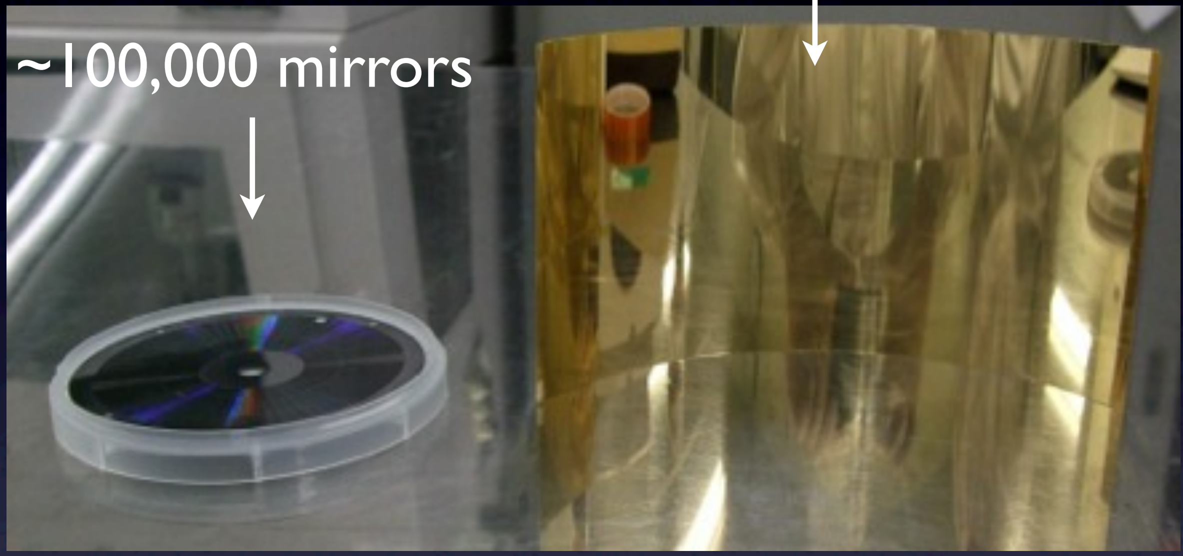


Assembly of two wafers



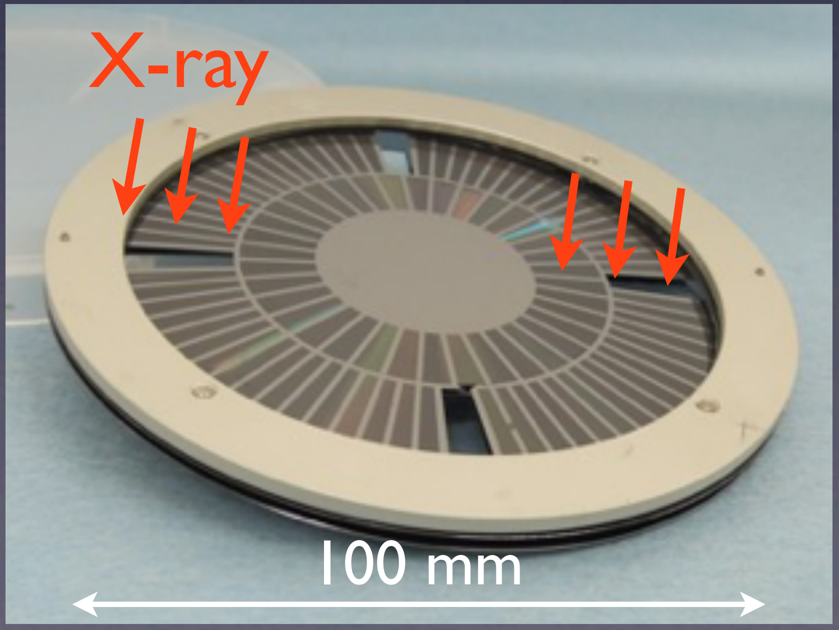
Ezoe+10, Ezoe+12, patent pending

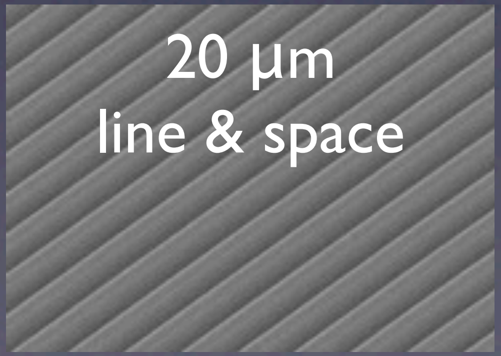
JUXTA : optics



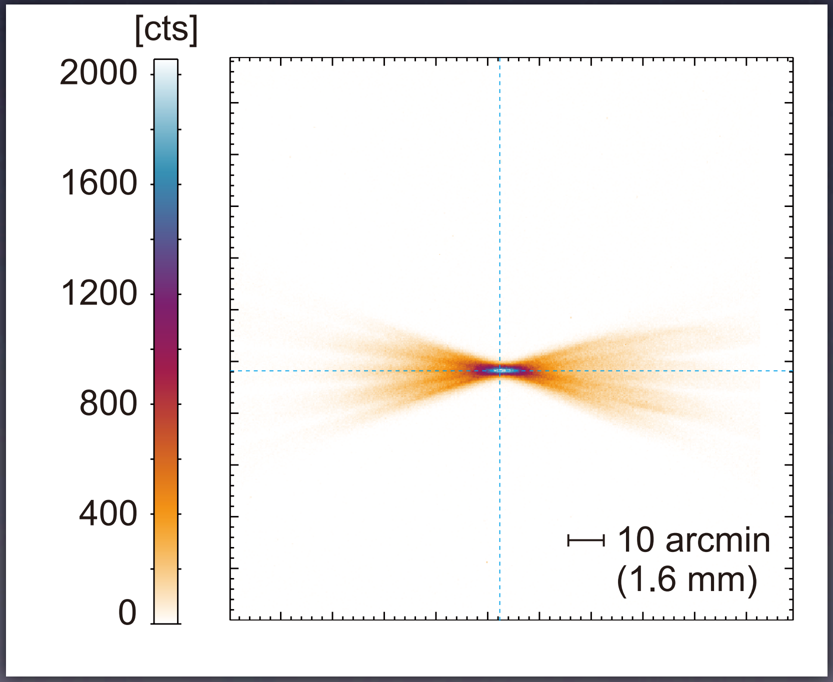
- Ultra light-weight
  - *area to mass : ~10 cm^2/g*
- High reso. & low cost
  - *FOV 5 degΦ, f 250 mm, >3 cm^2, <5 arcmin (FWHM)*

JUXTA BBM



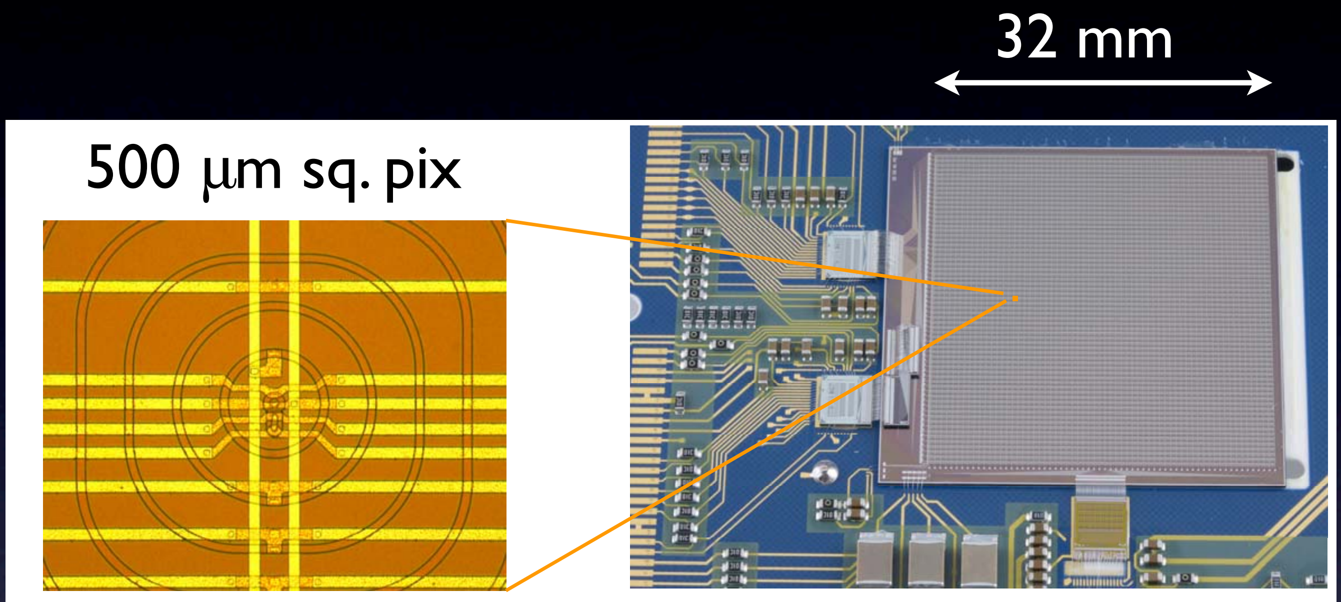


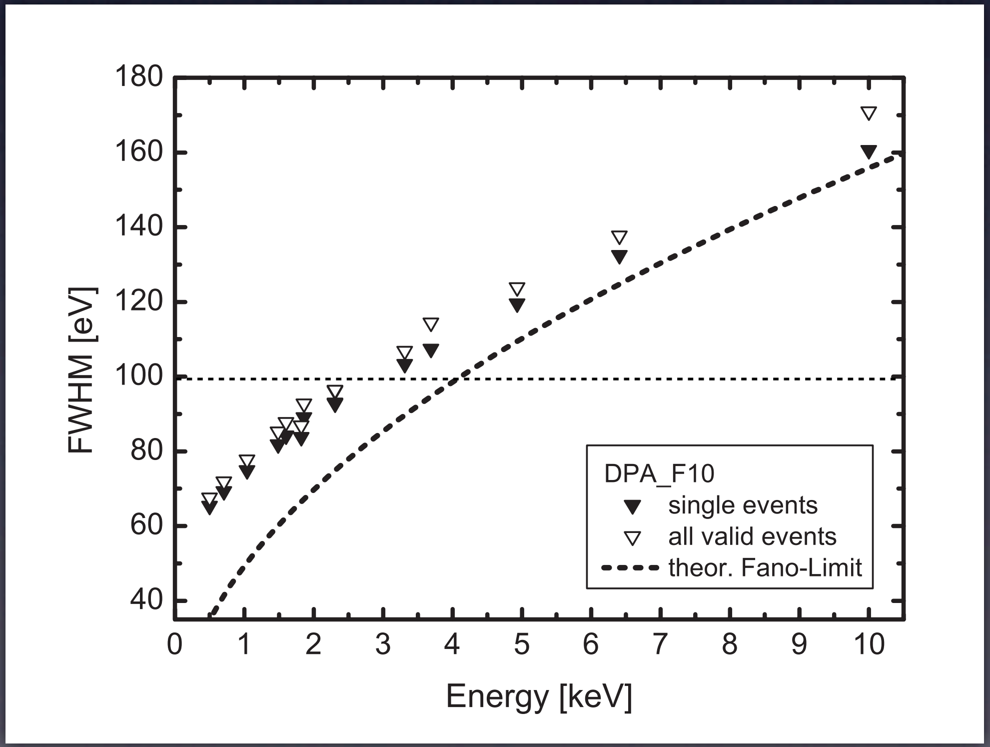
Ezoe+12



JUXTA : detector

- High spectroscopic resolution under harsh radiation environment Kasahara+13 (~20 krad/y @ 20 R_J)
  - DepFET (Depleted P-channel FET)
- *Pix 360 μm sq, 64 x 64, Array 17.5 mm sq, frame time 10 ms, <−40 deg C*





To be used in BepiColombo (2015) Strueder+13

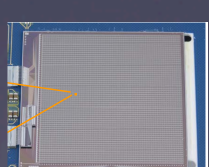
Toward JUXTA

- Light weight X-ray imaging spectrometer for micro/small sats, exploration missions, etc

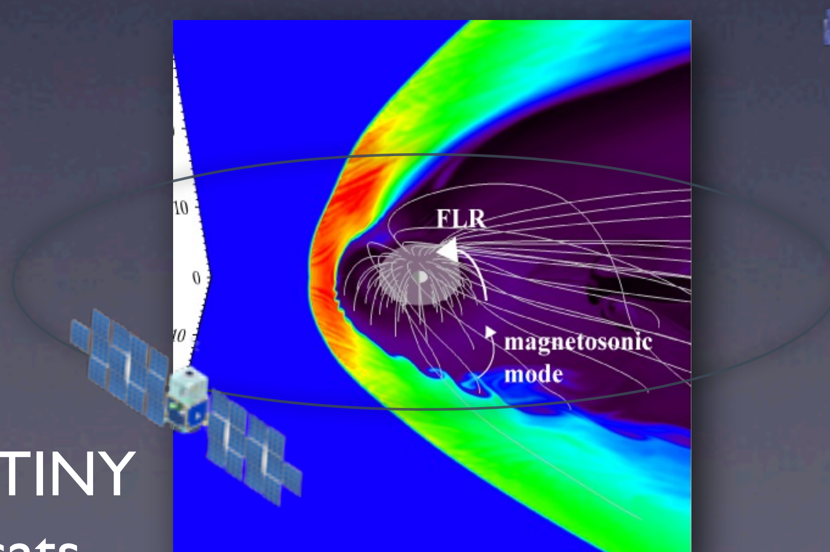
everywhere in the solar system

2014 | 2018 | early~mid 2020's

technology development → prototype fabrication & tests → FM fabrication & tests →

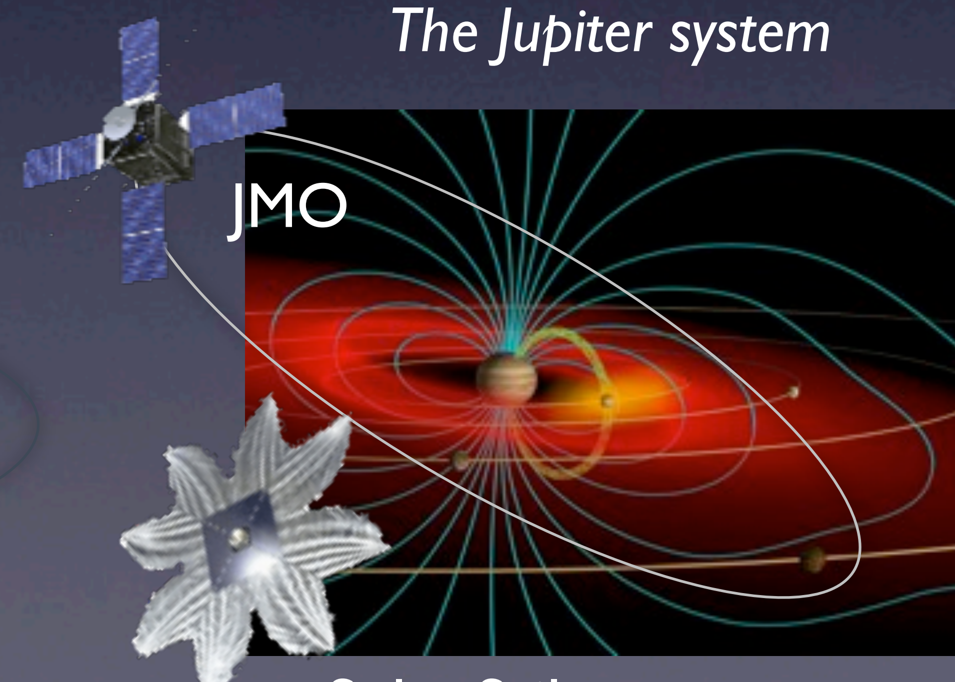


Earth's magnetosphere aurora



DESTINY
micro/small sats

The Jupiter system



JMO

Solar Sail

JUXTA Team

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- PI : Y. Ezoe (TMU)
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- A. Yamazaki (ISAS)
- K. Mitsuda (ISAS)
- M. Fujimoto (ISAS)

Science
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- K. Ishikawa (TMU)
- Y. Miyoshi (Nagoya Uni.)
- G. Branduardi-Raymont (UCL)

Telescope
- I. Mitsuishi (TMU)
- Y. Ezoe (TMU)
- K. Mitsuda (ISAS)

Detector
- L. Strueder (PNsensors)
- S. Kasahara (ISAS)
- A. Yamazaki (ISAS)

Summary

- X-ray emission from Jupiter, its Moons, Io torus and radiation belts has been discovered
- In-situ X-ray observations have a potential to revolutionarize solar system physics
  - particle accelerations
  - Jupiter-satellite binary system
  - rotational driven activities
- JUXTA aims at the first in-situ X-ray imaging spectroscopy of the Jupiter system