International collaborations in space astronomy missions - past and future

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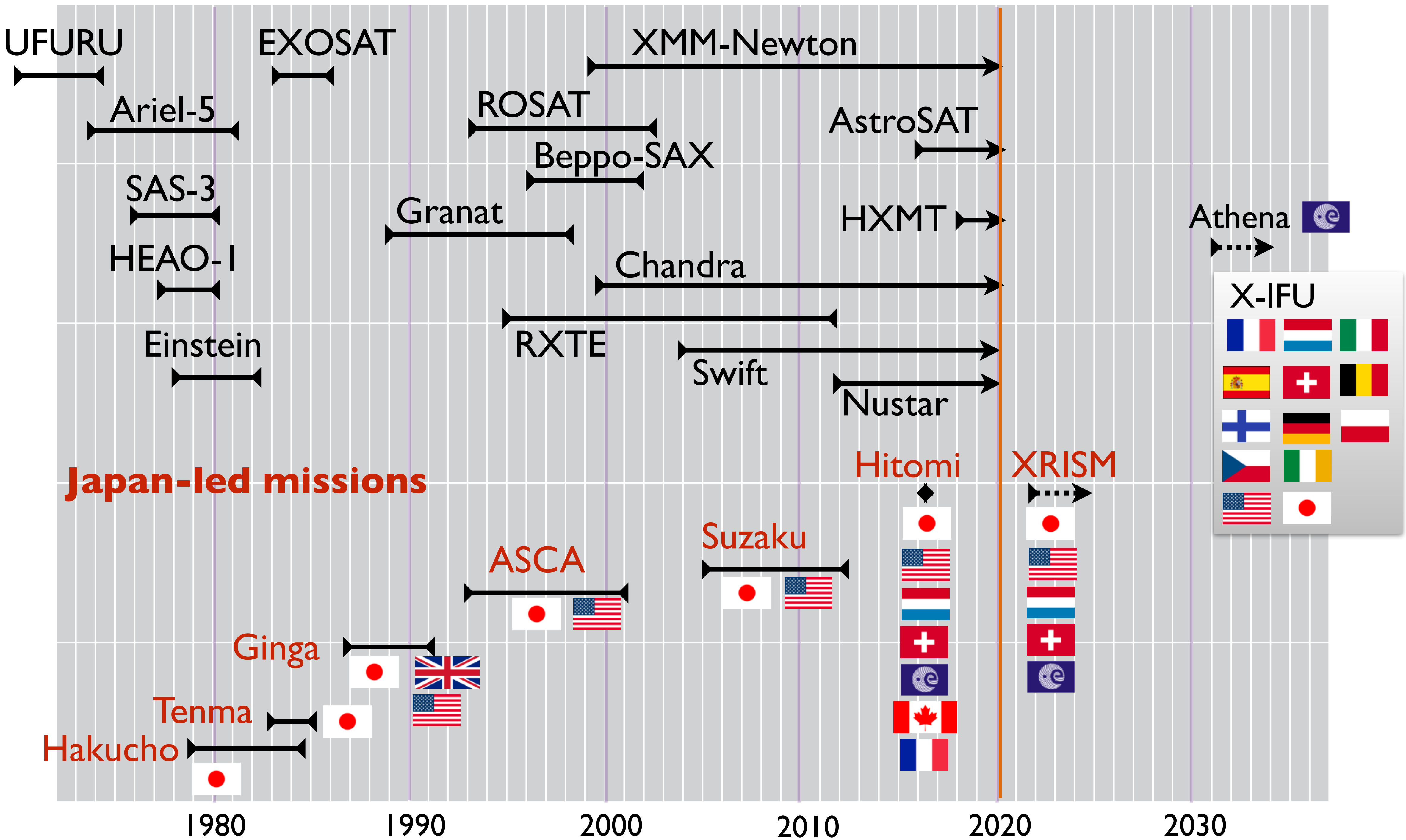
第39回 天文学に関する技術シンポジウム

January 17, 2020, at NAOJ, Mitaka

Major X-ray astronomy missions in 5 decades (not all)



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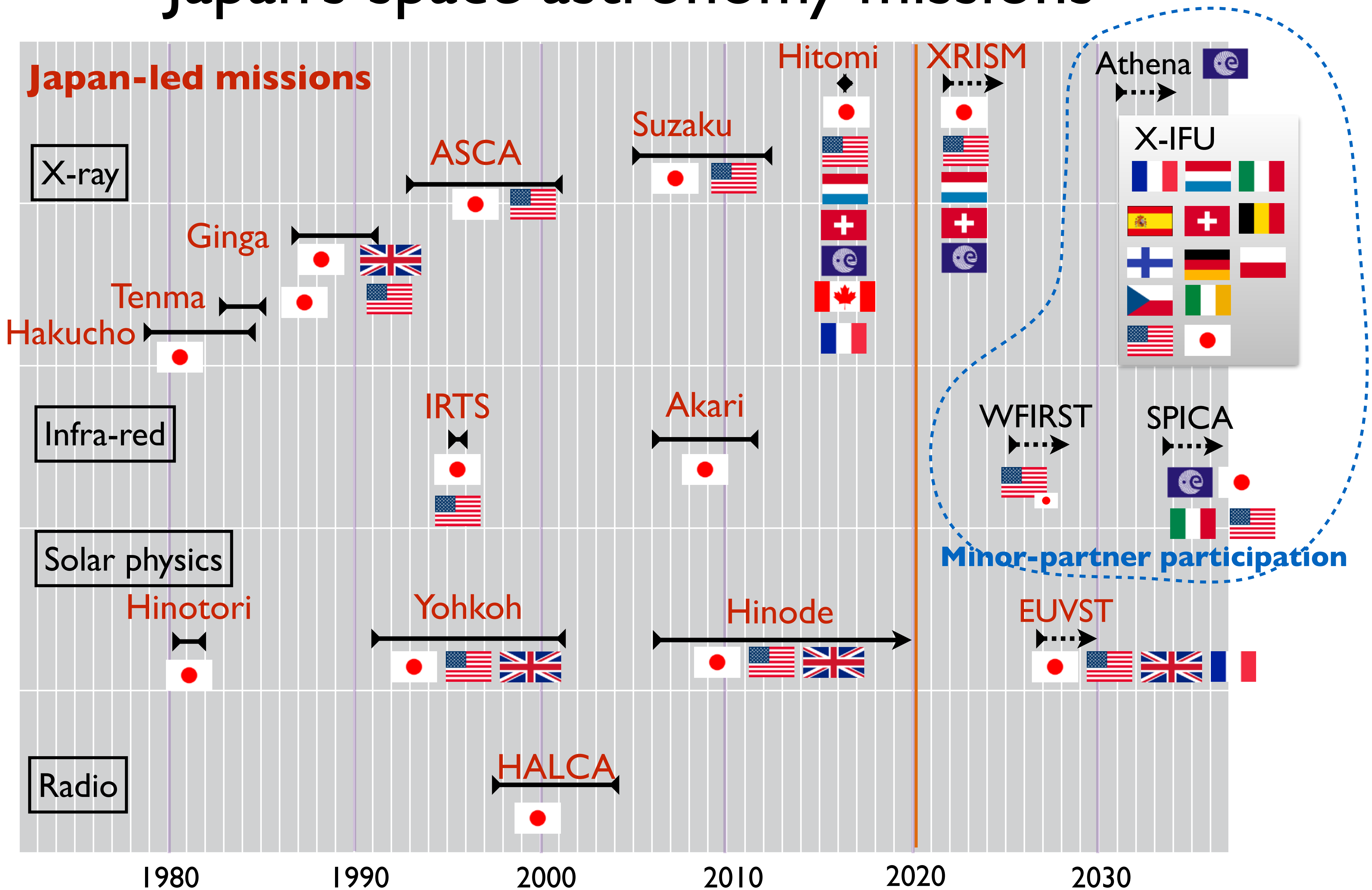
Major/minor partners

- All international space missions have a major parter and (a) minor partner(s). There is no mission with equal major partners.
  - A Japan-led mission = A mission in which Japan is the major partner
- A major partner must take final responsibility to solve any problems, using its own resources. It usually bears more than half of the total cost including launch and science operations.
- Japan built four X-ray astronomy missions with international collaborations. However, there is no participation as a minor partner so far.
  ESA's Athena will be the first.

Japan's space astronomy missions



Similar situation in IR astronomy missions.

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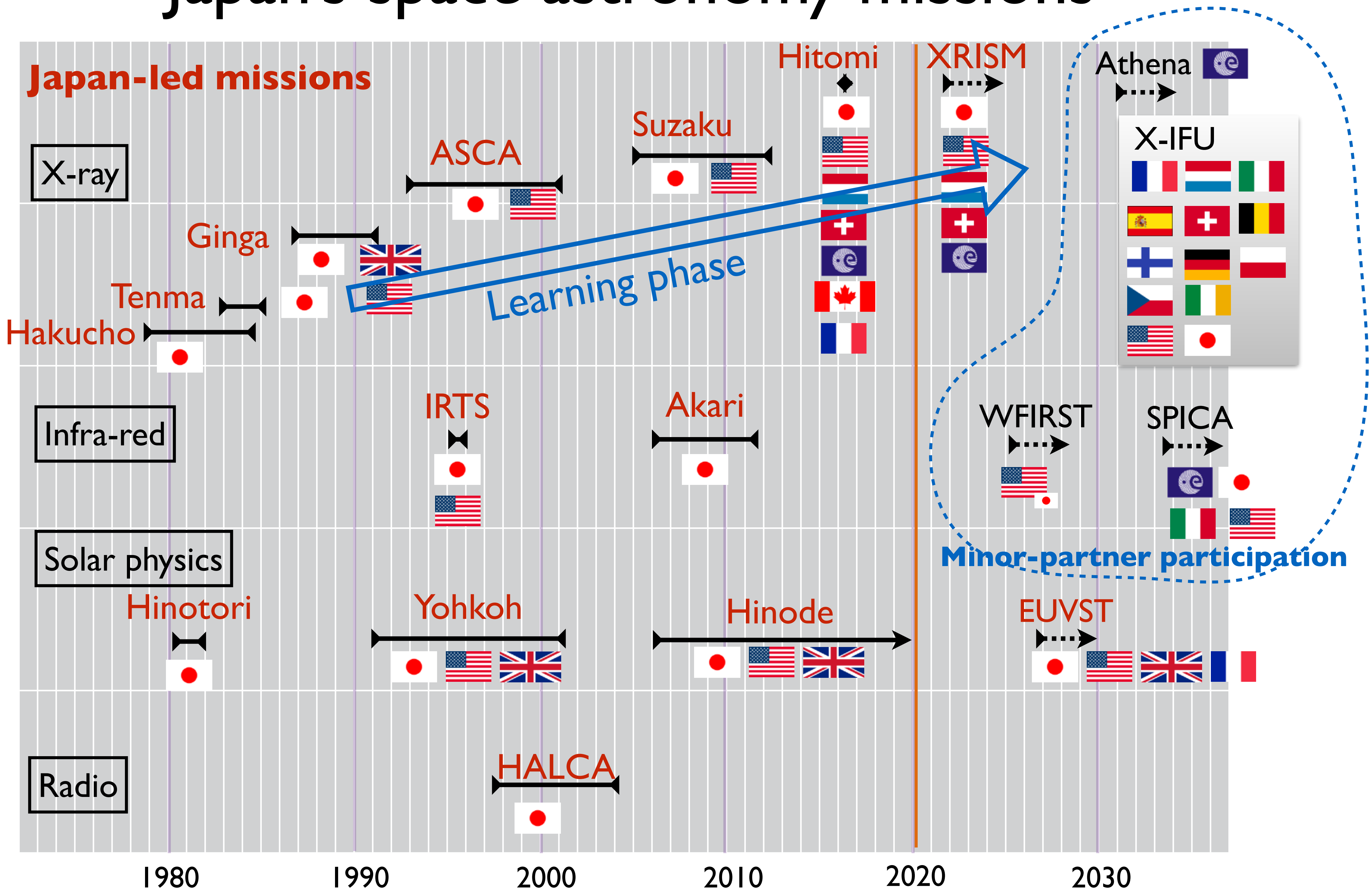
International collaborations: why do we need?

- To perform the best investigations by most cutting-edge instruments.
  - Some of such instruments can be provided by partners.
- It is becoming difficult to develop an instrument by one country because of increasing complexity and cost of not only the whole mission but also even of an instrument, e.g. Athena X-IFU

International collaborations:
major and minor partners

- As a major partner,
  - you can invite minor partners, who have technologies you do not have.
  - you have to optimize whole the system and decide interfaces.
  - you can use your own mission/product-assurance and quality-assurance requirements in your parts.
- As a minor partner,
  - you can access high-quality data with relatively low cost,
  - you have to compete with other countries/agencies for your participation, (also, politics always applies)
  - interface may be given from the major partner,
  - you need to show your mission/product/quality-assurance requirements very clearly to the major-parter, or you will asked to follow their requirements.
  - you may be asked to show your technical details to the major parter.

Japan’s space astronomy missions



Participating as a minor seems more difficult than as a major partner.

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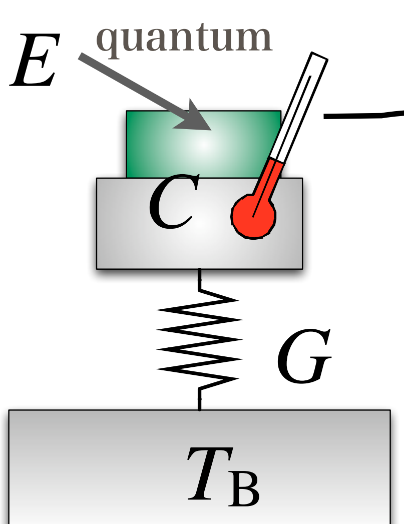
Athena X-IFU

A focal-plane instrument onboard ESA's Athena mission

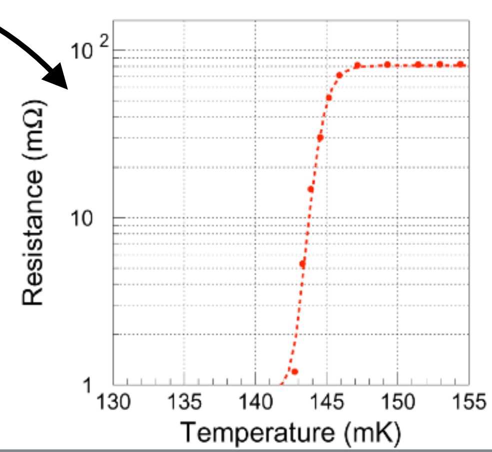
- Key technologies:
  - A ~3000-pixel TES microcalorimeter array operated at 50 mK.
  - ~40-pixel signal multiplexing at a cryogenic temperature of 2 K.

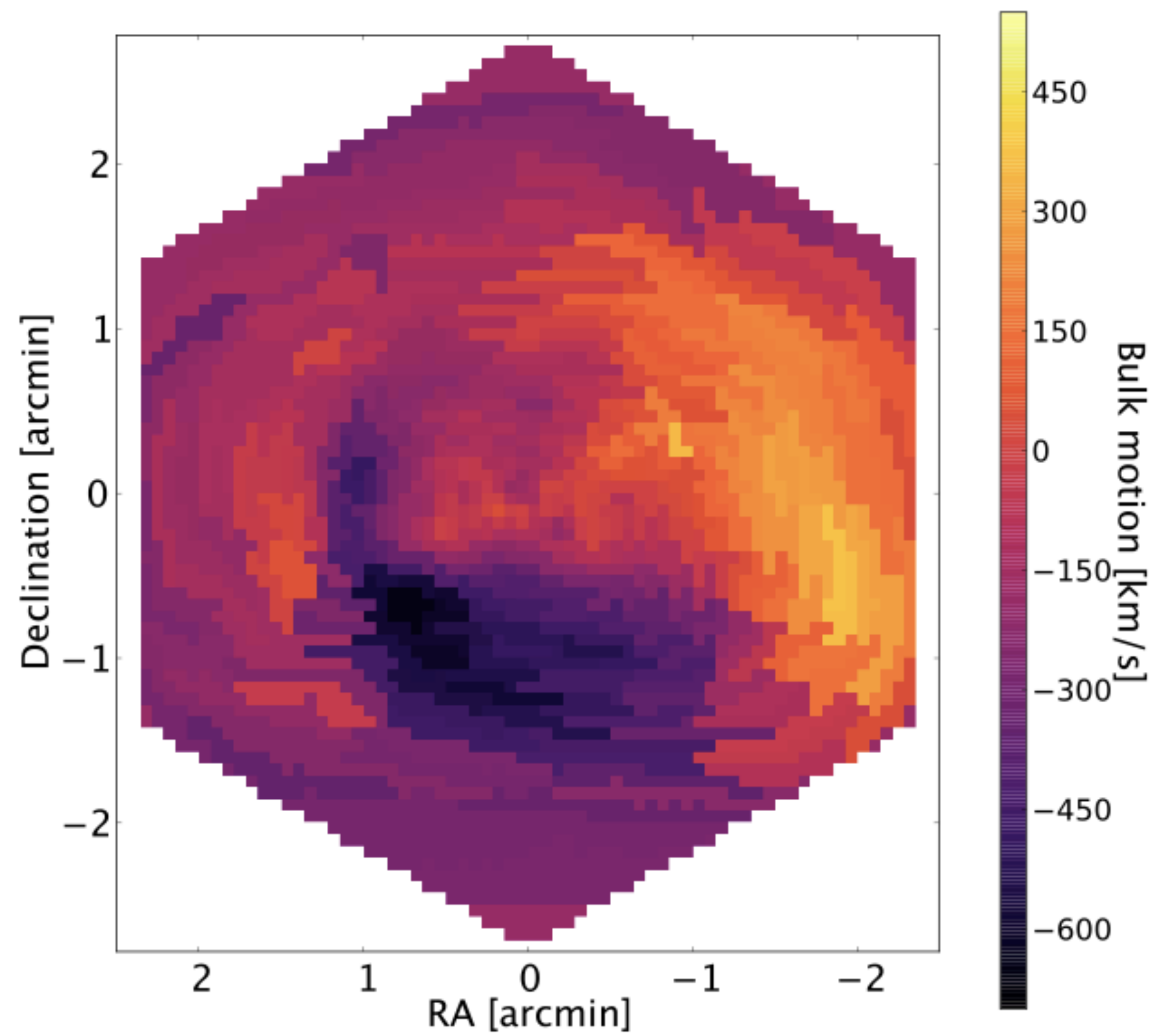
The microcalorimeter onboard Hitomi/XRISM has only 36 pixels.

A microcalorimeter detects a single X-ray photon as a heat pulse.



Superconducting transition edge as a thermometer.





Simulated velocity map of bulk motions of hot plasma in cluster

Peille et al. — Cucchetti et al.

X-IFU major contributors

Major institution	Major responsibilities	# of Co-I
CNES, IRAP	Systems engineering, Project management, Sub-K cooler, Room temp. electronics	11
SRON	Detector assembly, signal multiplexing	7
INAF	Anti-co TES detector	7
NASA/GSFC	TES microcalorimeter array	4
JAXA	1K/4K coolers SQUID array amplifiers for multiplexing	4
Other 8 countries		12
total		45

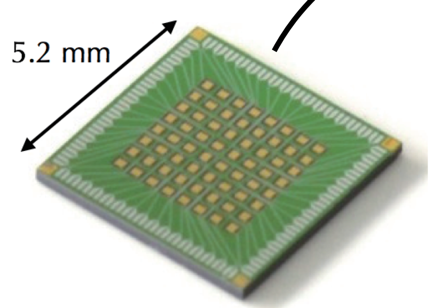
All 4 institutions developing TES X-ray micro calorimeters for space

SQUID= Superconducting Quantum Interference Device

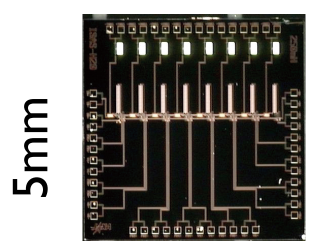
Can Japan build a microcalorimeter space instrument alone?

TES detector for material analysis developed at Mitsuda/Yamasaki group JAXA

8x8 TES array

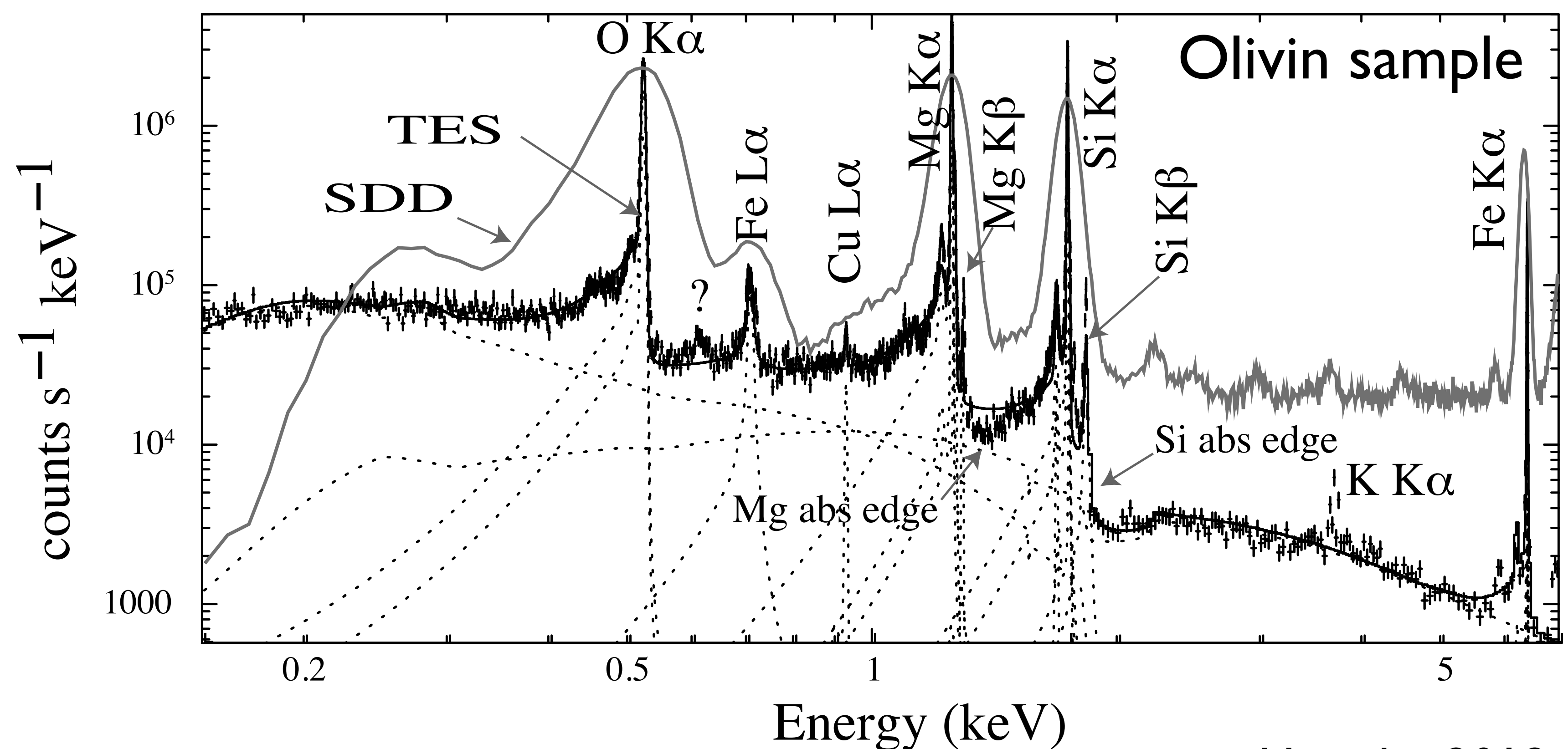


SQUID array amp.



Detector head@100mK

Mounted on the STEM at NIMS in Tsukuba



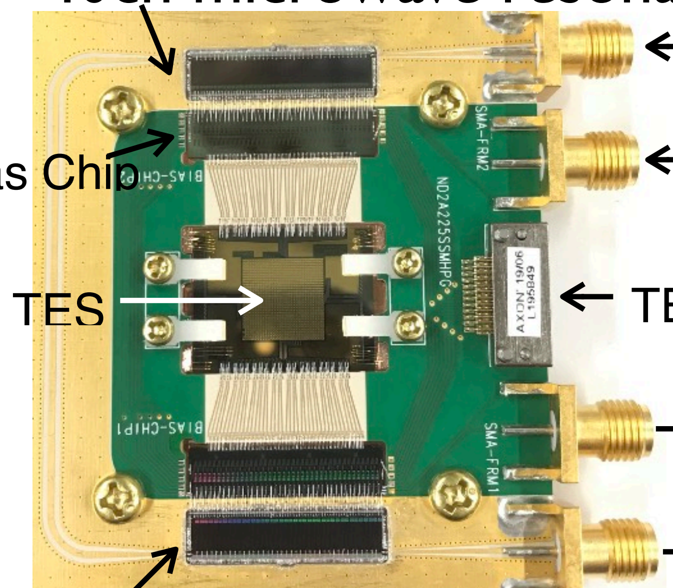
Hayashi+2018

8x8 array, 4.8 eV FWHM energy resolution
(c.f. Hitomi/XRISM= 6x6 array, 5 eV FWHM)

Can Japan build a microcalorimeter space instrument alone?

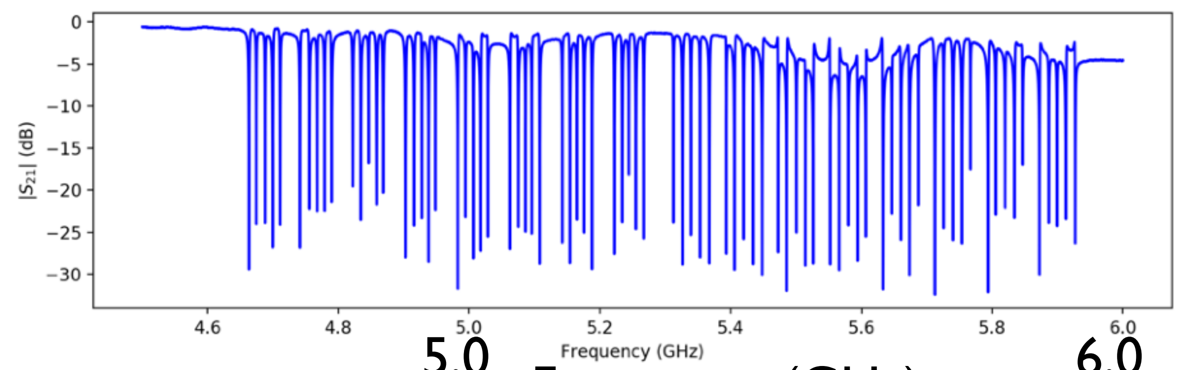
80-ch microwave rf-SQUID multiplexer for X-ray TES
(AIST and JAXA mitsuda/yamasaki group)

40ch microwave resonators



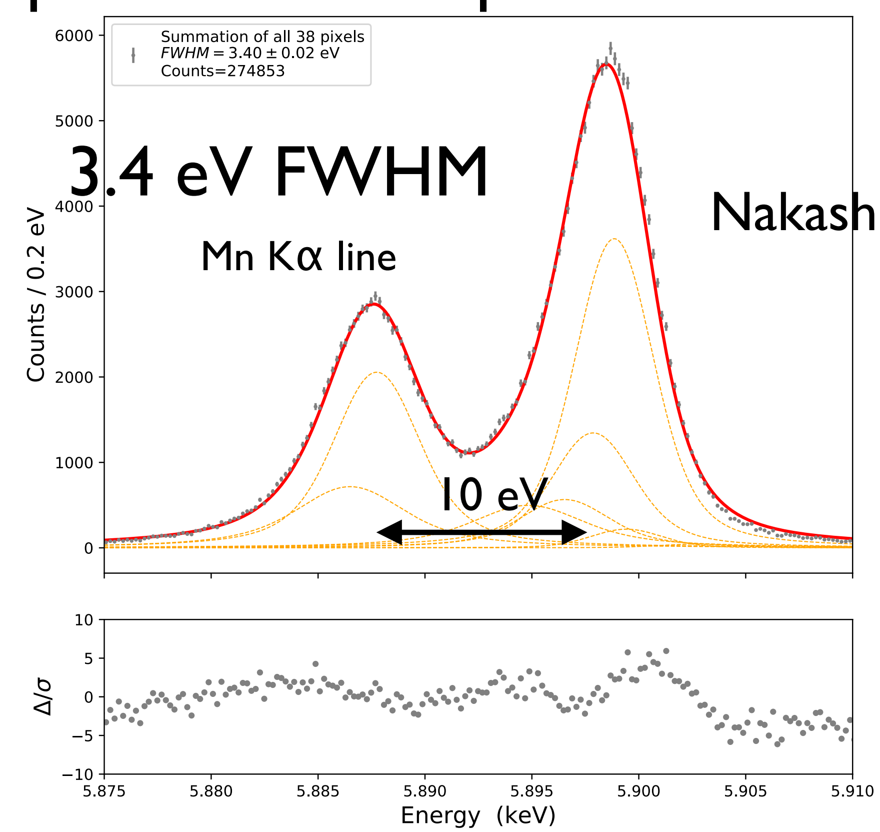
40ch microwave resonators
100mK stage

80 frequency combs



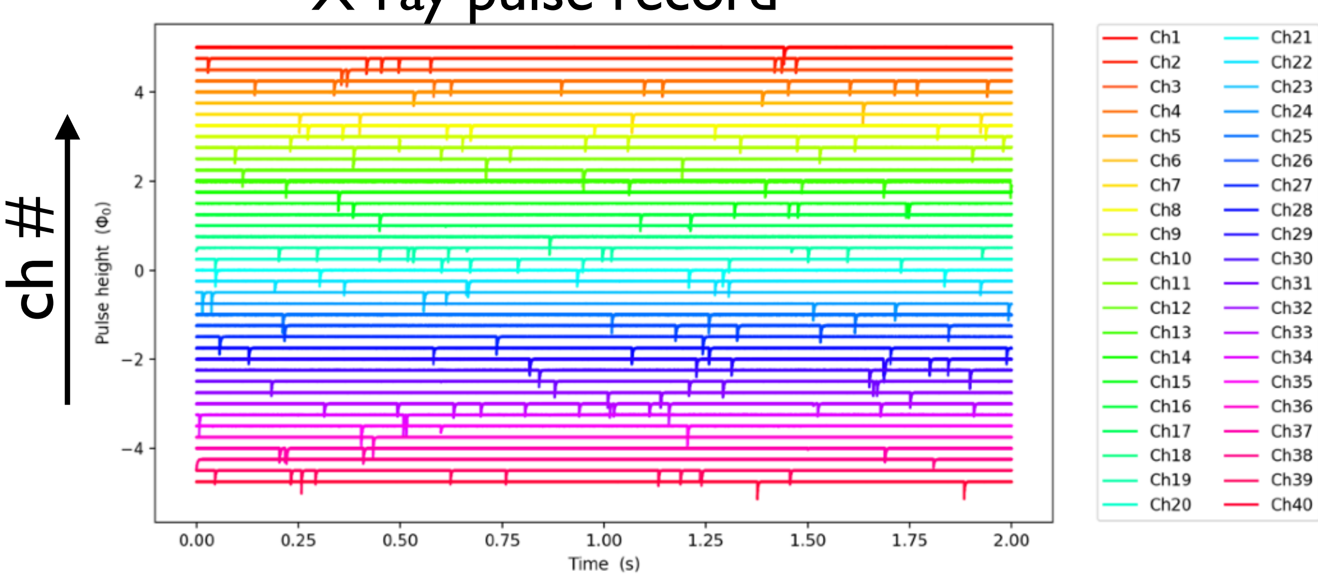
close to the Athena X-IFU requirements
(40 pix MUX, 2.5 eV FWHM)

38-pixel summed spectrum



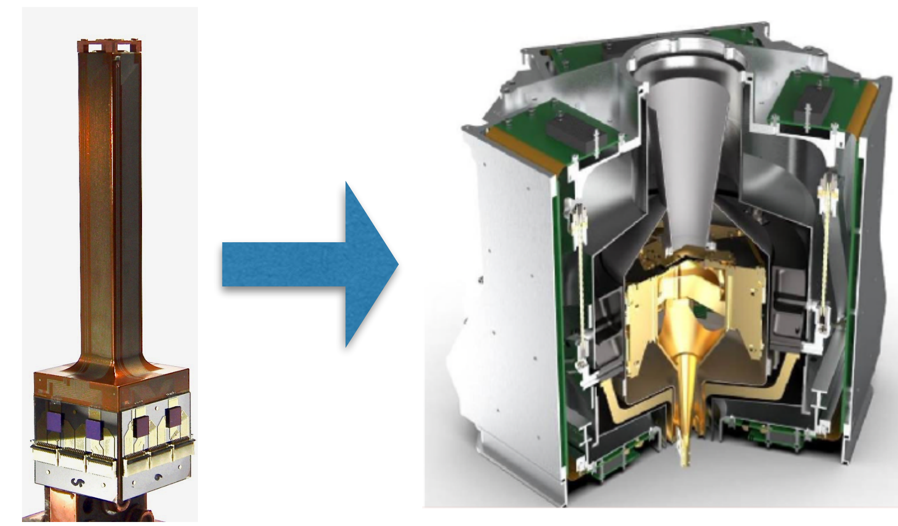
Evaluation using a 32x32 TES array from SRON

X-ray pulse record



Can Japan build a microcalorimeter space instrument alone?

- Engineering jump from laboratory technology proof-of-concept (TRL=3) to instrument working in the project environment, i.e. flight environment (TRL=5) is very large. A lot of high-quality engineering effort is required, which astronomers cannot provide.



Design of the X-IFU detector head by SRON

- JAXA does not have/provide engineer resources for cryogenic instruments. We thus need to collaborate with industry.
- However, as far as I know, no industry in Japan can provide better cryogenic engineering than ourselves, in particular for TES.
- Only solution is international collaboration for now. It is necessary to change this situation in order to make more essential contribution. One of my hope is ATC and engineers there.

TRL=Technology Readiness Level

Summary

- Japan's space astronomy missions adopted international collaboration from late 1980's, with Japan as a major partner.
- The situation is changing: it is likely that contribution to large space missions as a minor parter will become more common after 2020's.
- Participation as a minor parter is more difficult than as a major parter in some aspects.
- Athena X-IFU will provide a good lessons.
- Although at laboratory experiment level, the capabilities of instrument we developed in Japan are compatible with the requirements of the large mission, we can not construct a space instrument or its key component as a system by ourselves, because of lack of engineering power for space instrumentation. I hope to change such situation.