Hot Universe Baryon Surveyor (HUBS)

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On behalf of the HUBS team

Background image credit: ILLUSTRIS

Hot baryons in the Universe

Image credit: Cerini et al. 2023

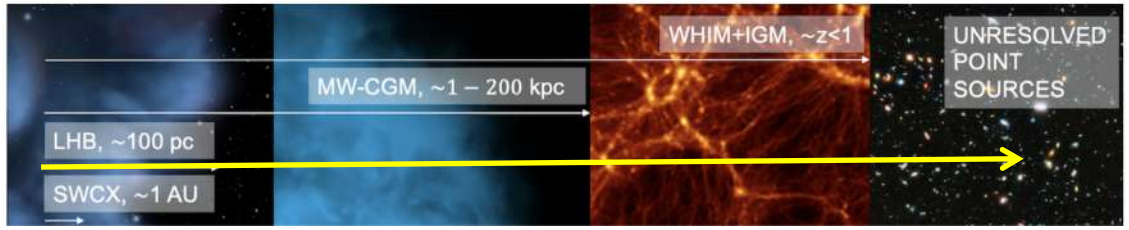
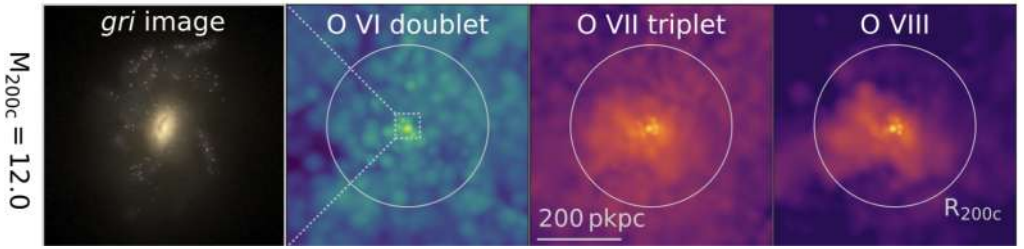


Image credit: Simionescu et al. 2018



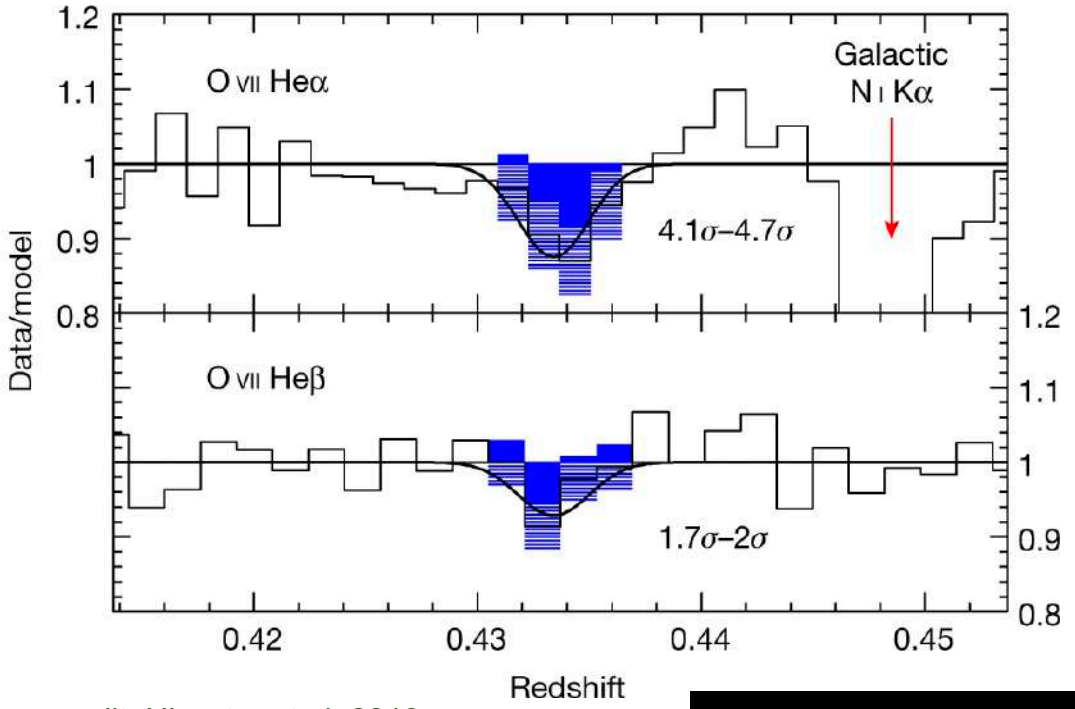


Image credit: Nicastro et al. 2018

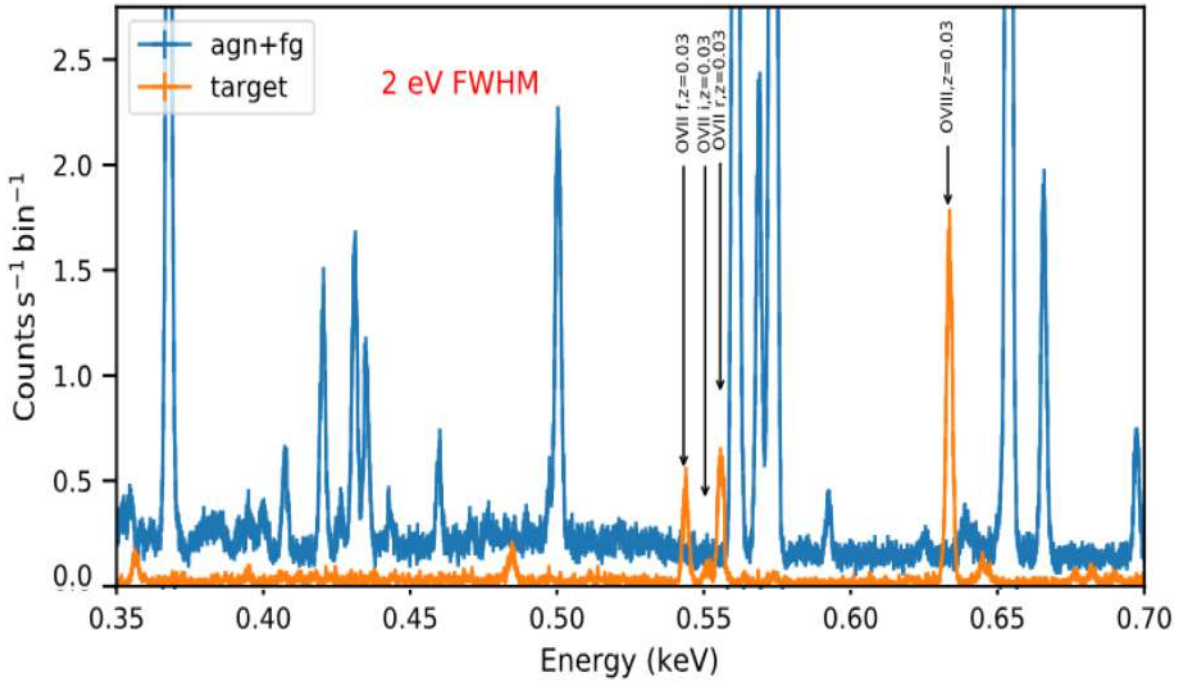
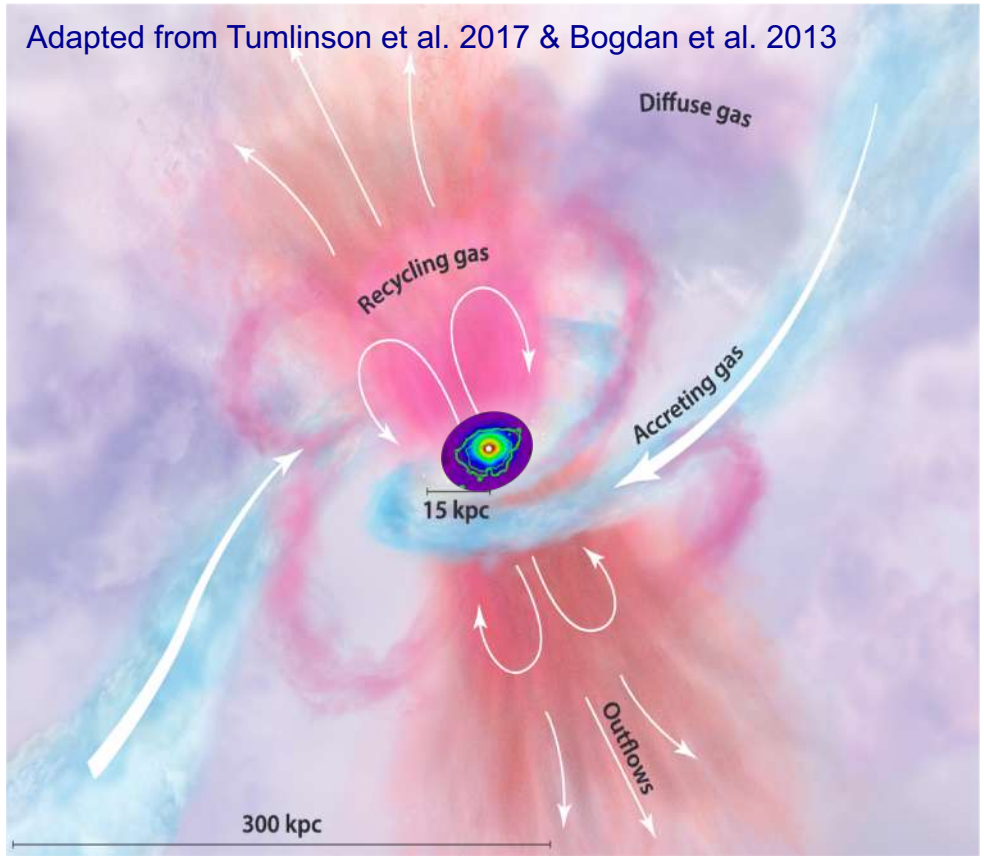


Image credit: Cui et al. 2020

- A critical element in the cosmic ecosystem
- Challenging to detect with current instruments
  - ✓ High-resolution X-ray spectroscopy

HUBS science goals

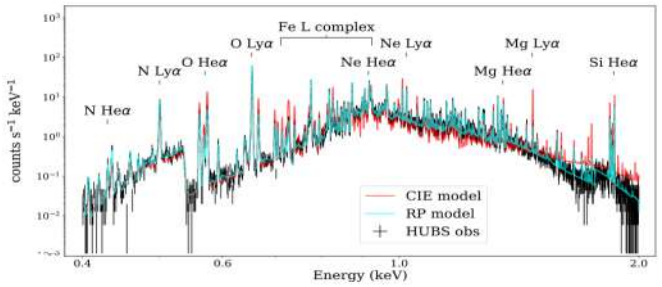
Not just to detect, but also to perform plasma diagnostics via high-resolution X-ray spectroscopy to measure temperature, density, abundance, kinematics, etc.



Scientific driver:

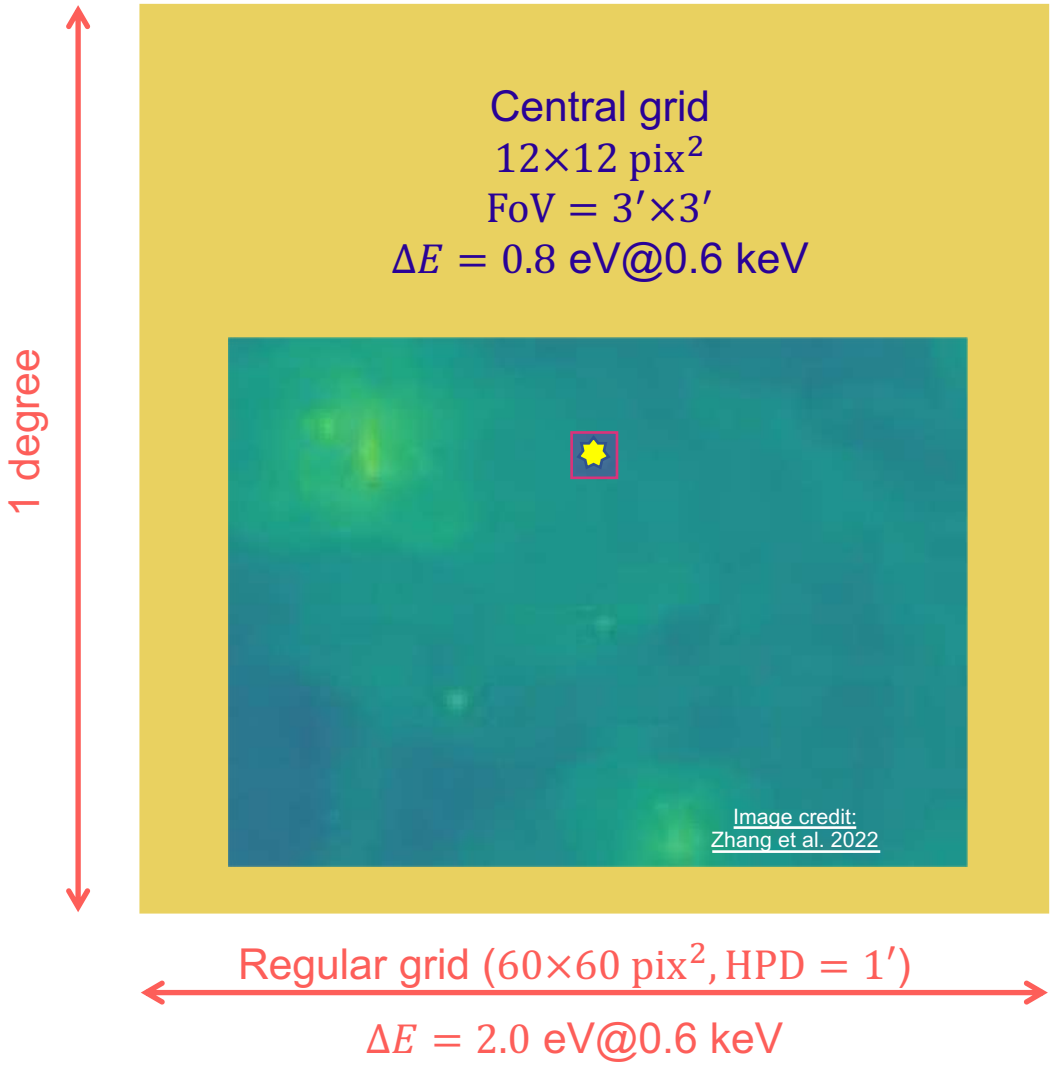
- ✓ Unravel the AGN and stellar feedback physics
- ✓ Probe the (multi-phase) baryon budget

HUBS will also study: galaxy clusters, AGNs, SNRs, compact objects, diffuse X-ray backgrounds, etc.



HUBS white paper (Science China: Mechanics, Physics & Astronomy in press, arXiv:2307.05672)

TES array & FoM



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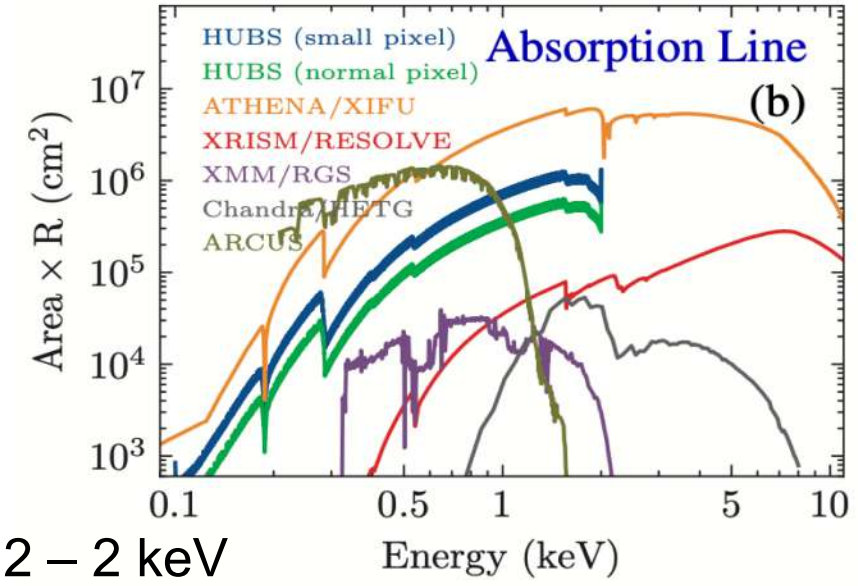
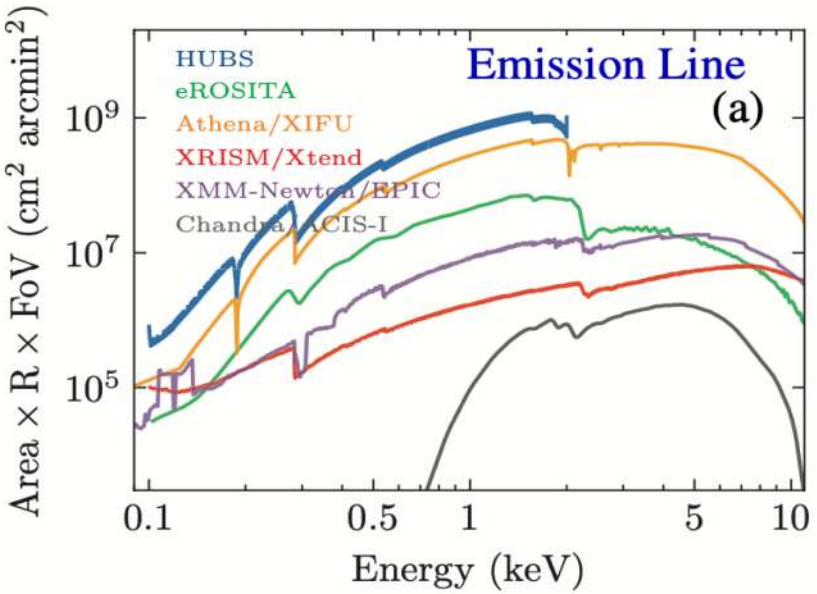
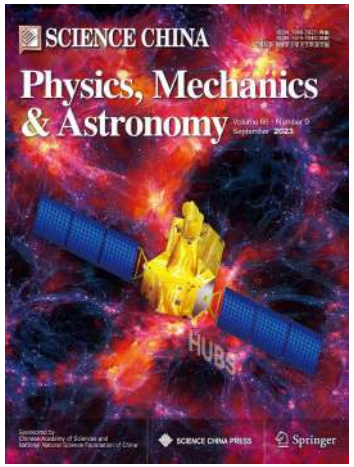
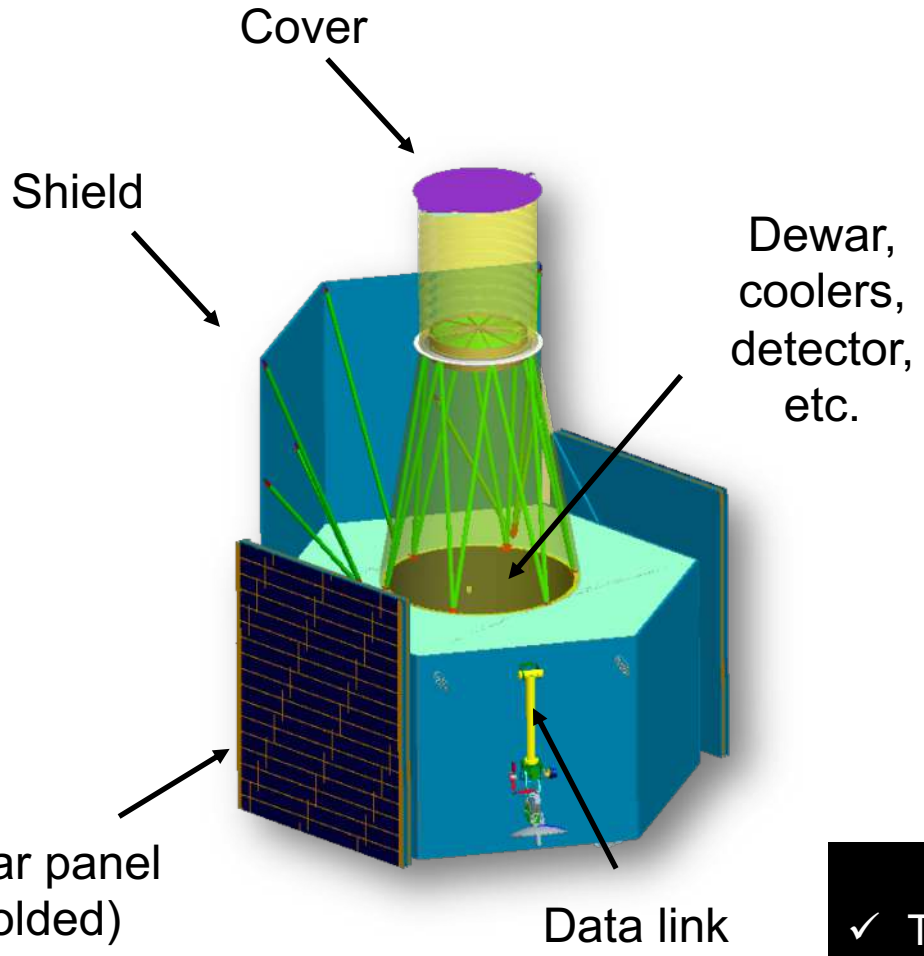


Energy range: 0.2 – 2 keV

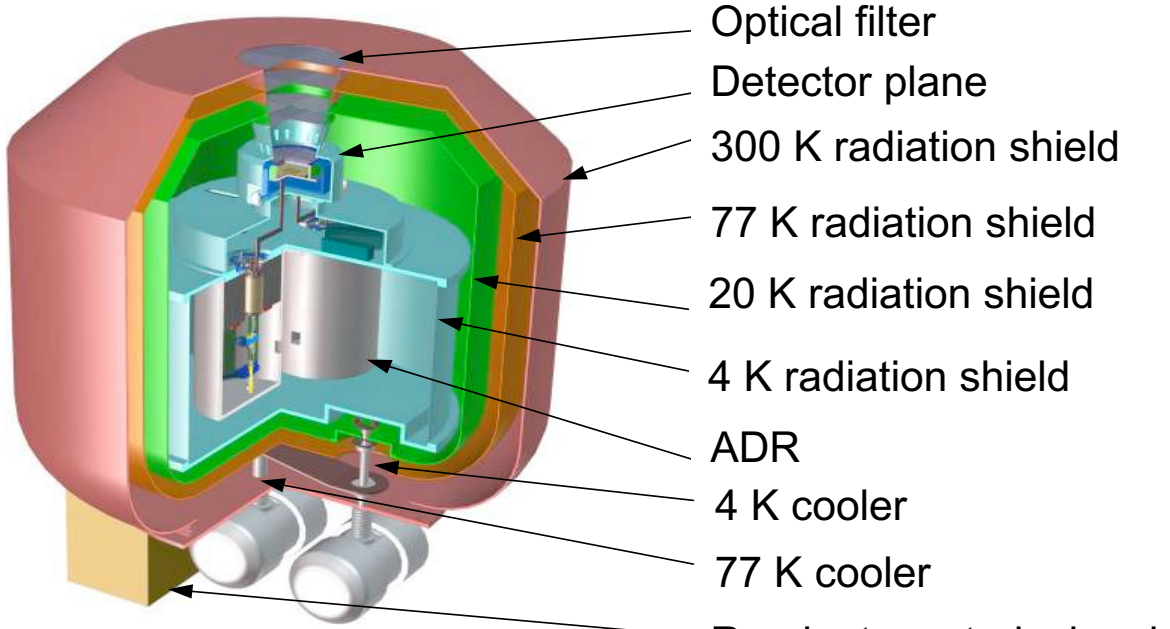




Preliminary design of HUBS



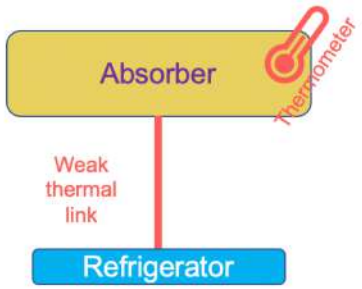
Low-earth orbit: ~550km, <30° incl.



Playload & Cryogenic system

Key technologies

- ✓ TES microcalorimeter
- ✓ Mechanical cooling + ADR
- ✓ FDM readout
- ✓ Slumped glass



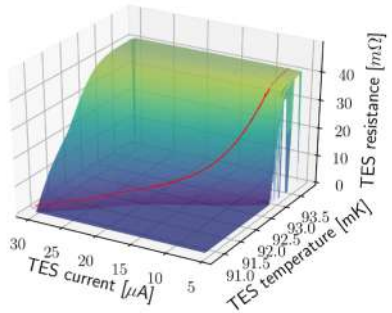


Image credit: Gottardi & Nagayashi (2021)

Timeline

Concept studies

- ✓ 1st collaboration meeting 2017@Beijing
- ✓ Focus meeting at the IAU General Assembly meeting 2018@Vienna
- ✓ 1st HUBS Workshop 2018@Shanghai + 2nd HUBS workshop 2022 (online)

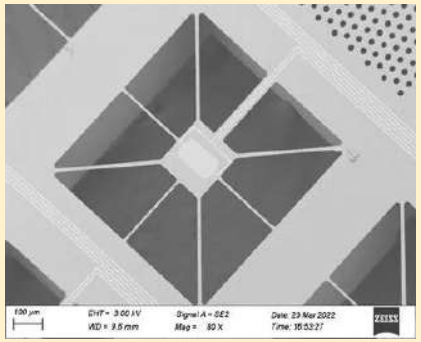
Concept development

- ✓ Preliminary development, CAS, 2018-2021
- ✓ Key technology development, CNSA, 2022-2023

Path forward

- ❑ Preliminary design and technology completion, ~2024 (3 yr)
- ❑ Construction ~2026 (5 yr)
- ❑ Expected science operation ~2031 (5+ yr)

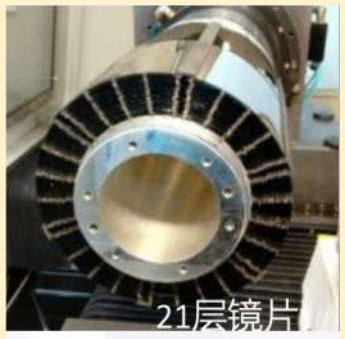
Current status



TES microcalorimeter
10×10 array, $\Delta E < 6$ eV

Mechanical cooler
53 mW@4 K

ADR
50 mK for ~3 hr

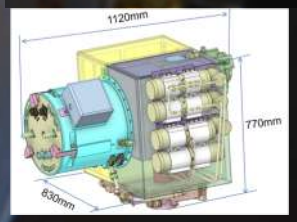


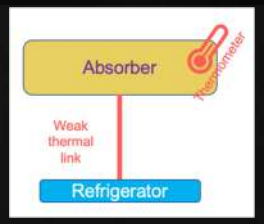
Slumped glass
21 shell

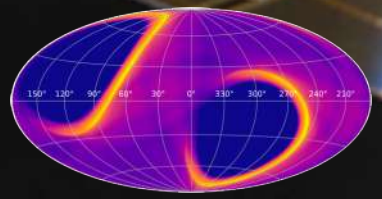
Background image credit: CMS

Pathfinder: DIffuse X-ray Explorer (DIXE)

DIXE = TES microcalorimeter + sky survey + China Space Station

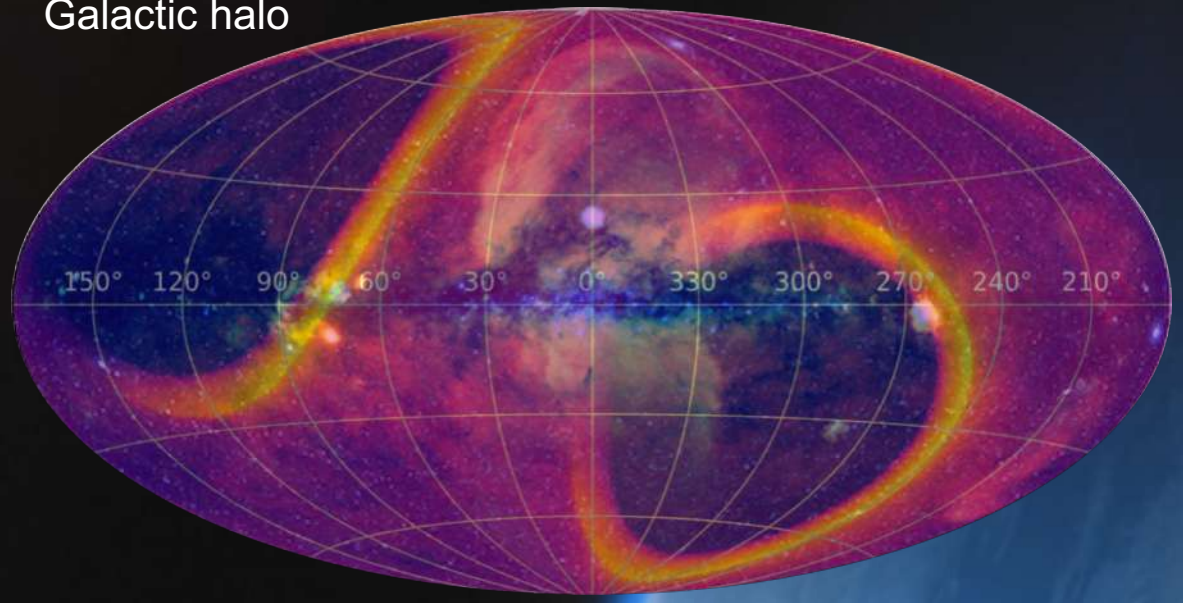




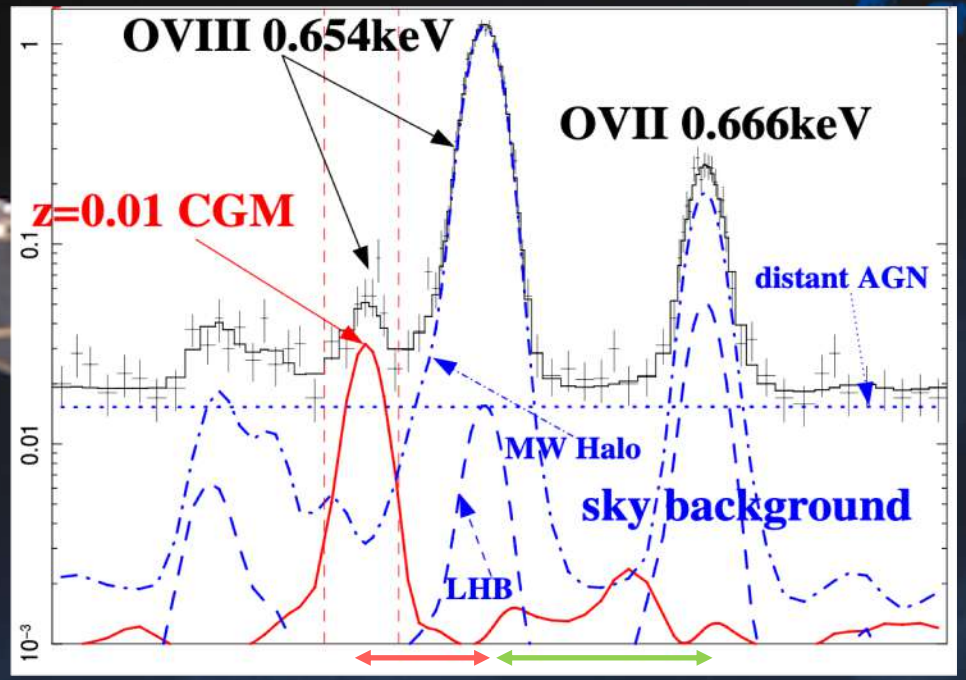


Milky Way hot baryons

- Diffuse soft X-ray background
- Galactic scale hot baryons (e.g., eROSITA bubble, SNRs)
- Galactic halo



0 ks — 1 yr exposure overlaid on the eROSITA map — 150 ks



6.5 eV to resolve by HUBS — 12 eV to resolve by DIXE

DIXE (CSS)
2027-2030
Sky survey
FoV (collimator): $10°\times10°$
TES array: 10×10
ΔE: 6 eV@0.6keV
0.1 – 10 keV
$A_{\rm eff}$: 0.5 $\rm cm^2$@0.6 keV
Milky Way hot baryons

HUBS white paper (SCMPA accepted)

HUBS (satellite)
2031-2036
Pointing
FoV (imaging): $1°\times1°$
TES array: 60×60
ΔE: 2 eV@0.6keV
0.1 – 2 keV
$A_{\rm eff}$: 500 $\rm cm^2$@0.6 keV
Cosmic hot baryons

Summary

- ❑ Hot baryons in the Universe
- ❑ HUBS (cosmic hot baryons, deep pointing)
  - ✓ Science
    - AGN + stellar feedback + baryon budget (driver)
    - CIGs, AGNs, SNRs, compact objects, diffuse soft X-ray background
  - ✓ Hardware
    - TES microcalorimeter
    - Mechanical cooling + ADR
    - FDM readout
    - Slumped glass
  - ✓ Software
    - Atomic data, plasma code, etc.
  - ✓ Expected science operation ~2031 (5+ yr)
- ❑ DIXE (Milky Way hot baryons, sky survey)
  - ✓ Expected science operation ~2027 (3+ yr)

Background image credit: ILLUSTRIS