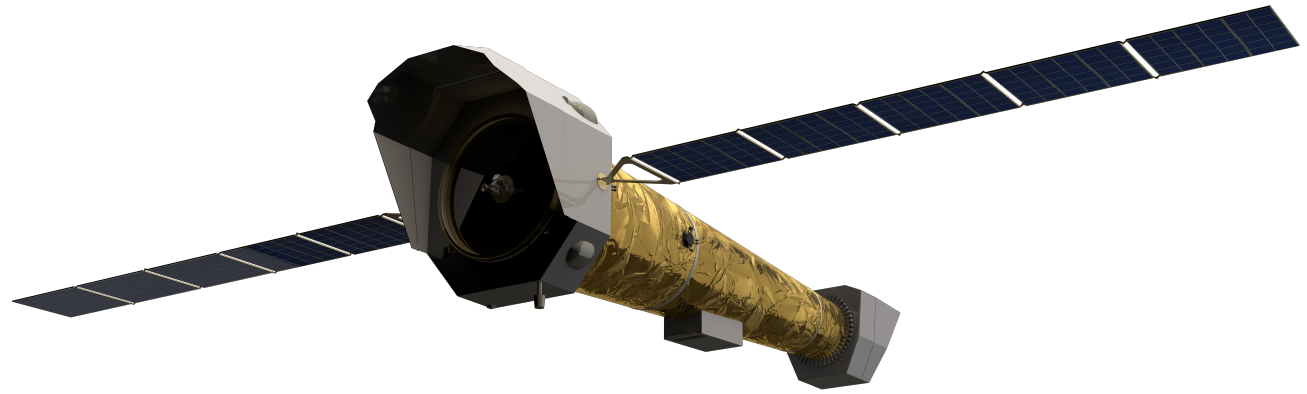
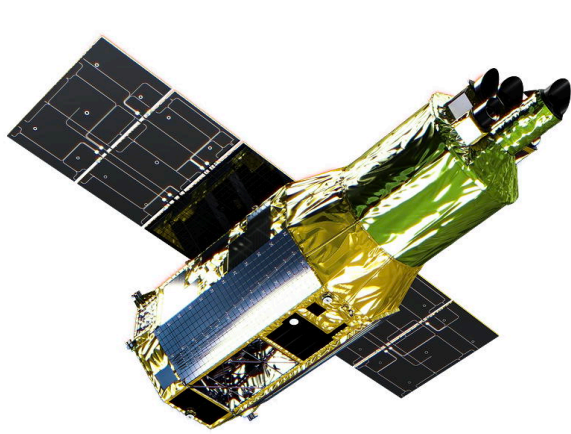




From XRISM to NewAthena

Aurora Simionescu



Netherlands Institute for Space Research

**XRISM proposal preparation workshop
SRON, 13.02.2024**

NewAthena is an ESA L-class mission that will serve as *the* major X-Ray observatory, world-wide, in the late 2030's and beyond.

Like XRISM, *NewAthena* carries an X-ray micro-calorimeter (the **XIFU**), and a wide field CCD imager (the **WFI**), but with **significantly enhanced sensitivity and spatial resolution** compared to Resolve and Xtend.

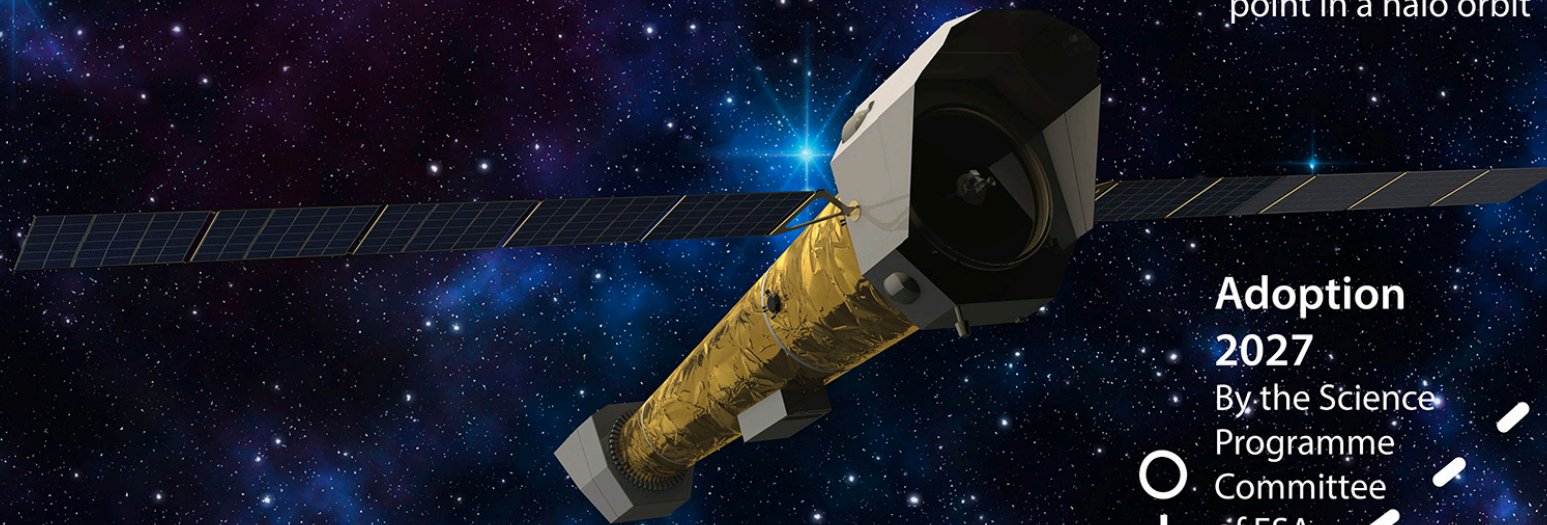
Athena, originally selected in 2014, underwent a successful re-design in 2022/2023, aiming to achieve compliance with the ESA long-term budget with minimal change on the science case.

***NewAthena* retains nearly *all* of the *Athena* science, and can also answer new questions that have emerged over the last decade. The new systems design was deemed realistic, technically and financially, and was unanimously endorsed by the SPC in November 2023.**

(New)Athena



Charting a course forward



Selection

2014

Hot and Energetic
Universe proposal

Phase A

2024

Restarting
industrial activities

Planned Launch

2037

By an Ariane 6.4 vehicle to the
first Sun-Earth Lagrangian
point in a halo orbit

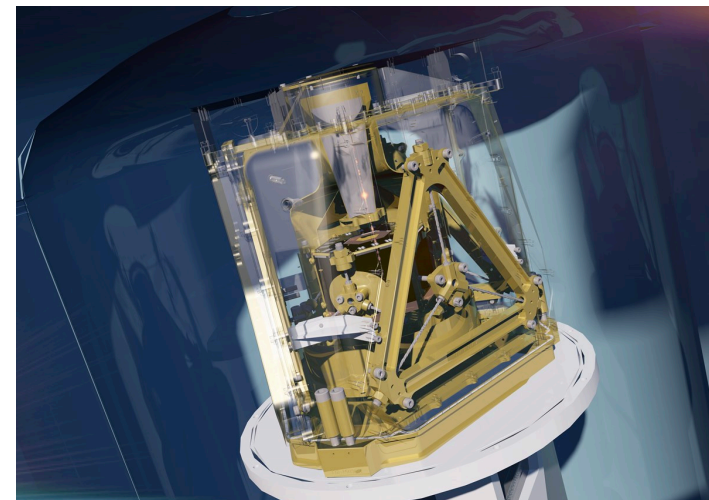
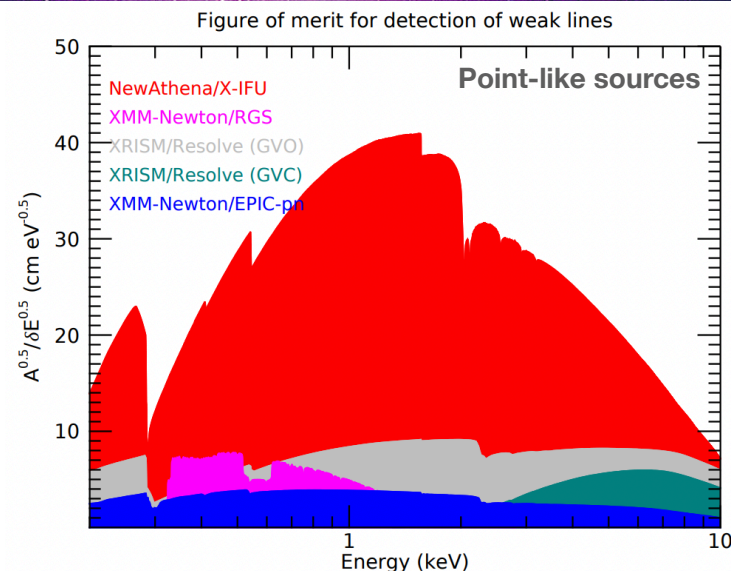
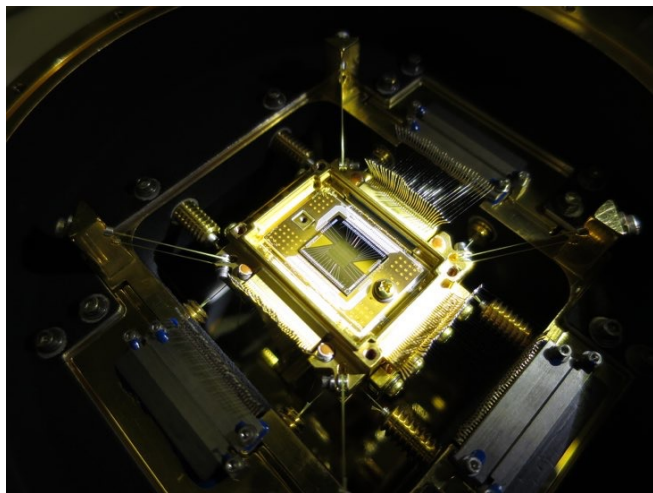
Adoption

2027

By the Science
Programme
Committee
of ESA

Happy New Year 2024!

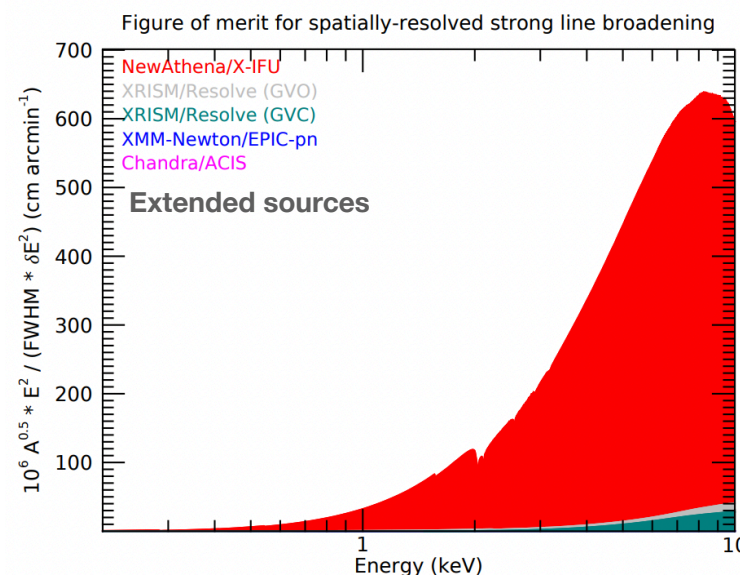
Spectroscopy: from *Resolve* to XIFU



XRISM/Resolve (GVC):

- 170 cm² effective area at 7 keV
- 1.3' PSF
- 35 pixels
- 3x3' FOV
- ~5 eV spectral resolution
- 2 - 12 keV bandpass

4 spatial resolution
elements per FOV



NewAthena/XIFU:

- **870 cm²** effective area at 7 keV
- **9" PSF**
- **over 1500 calorimeter pixels**
- 4' diameter FOV
- <4 eV spectral resolution
- **0.3 - 12 keV** bandpass

>2200 spatial resolution
elements per FOV

Imaging: from *Xtend* to WFI

XRISM/Xtend

~440 cm² effective area @1.5 keV

1.3' PSF

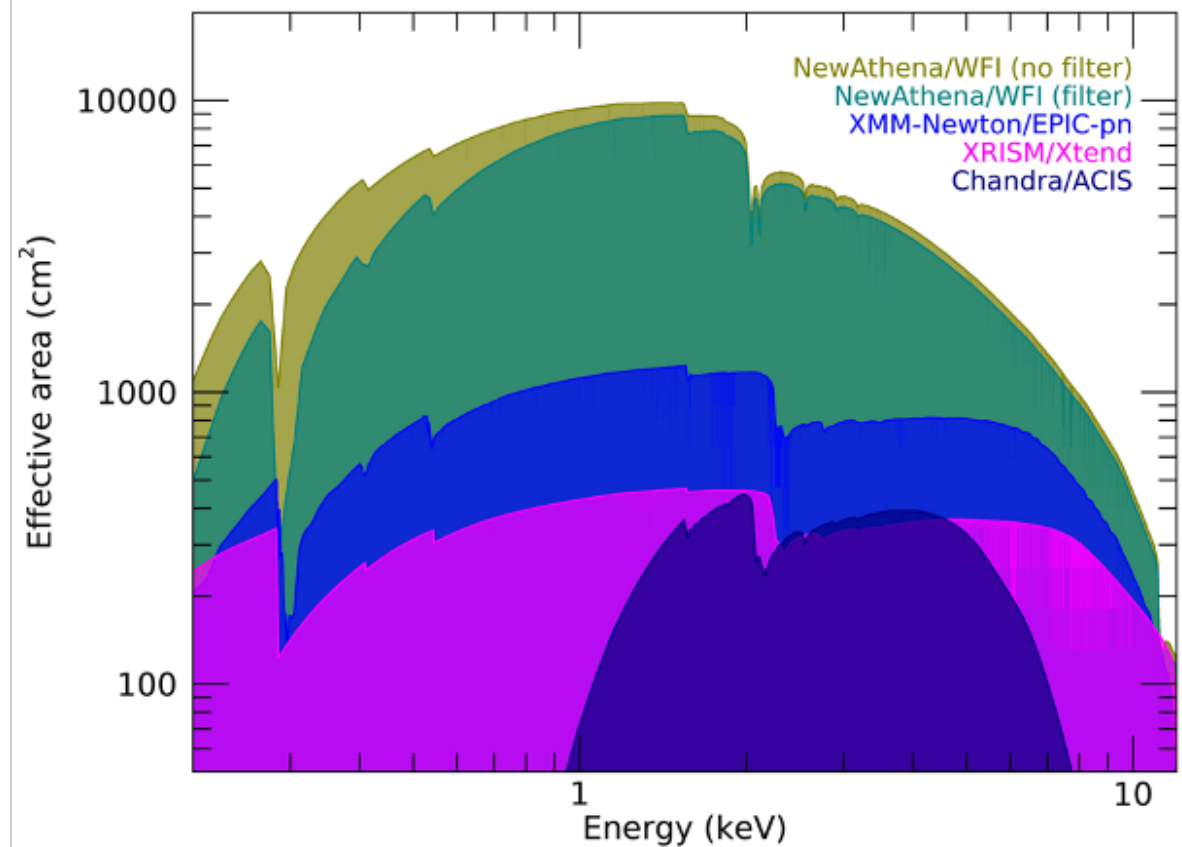
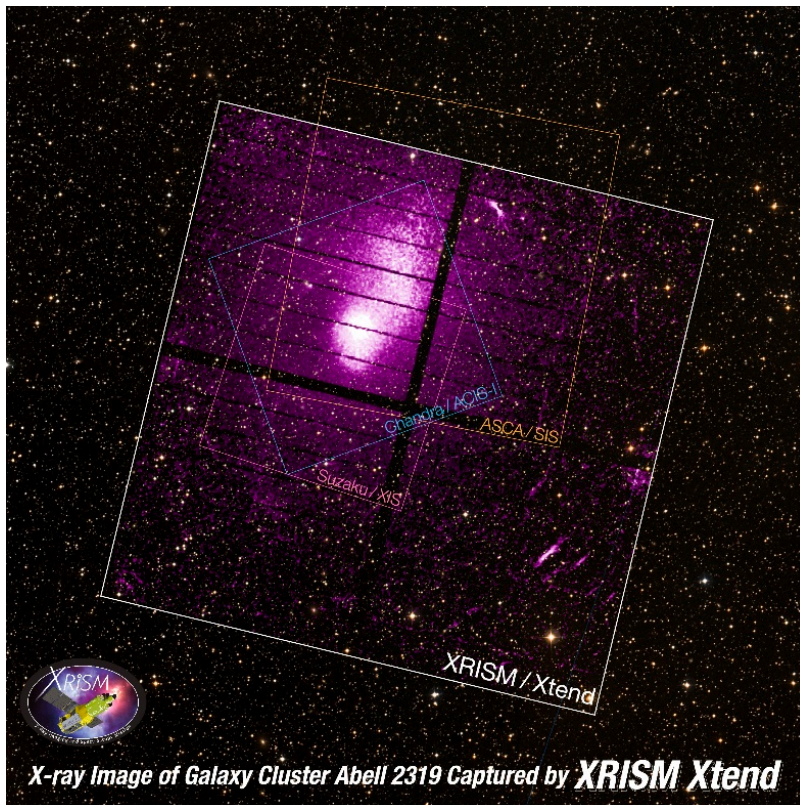
38x38' FOV

NewAthena/WFI

- **10000 cm² effective area @ 1 keV**

- **9" PSF, stable across FOV**

- 40x40' FOV



From XRISM to NewAthena: the science



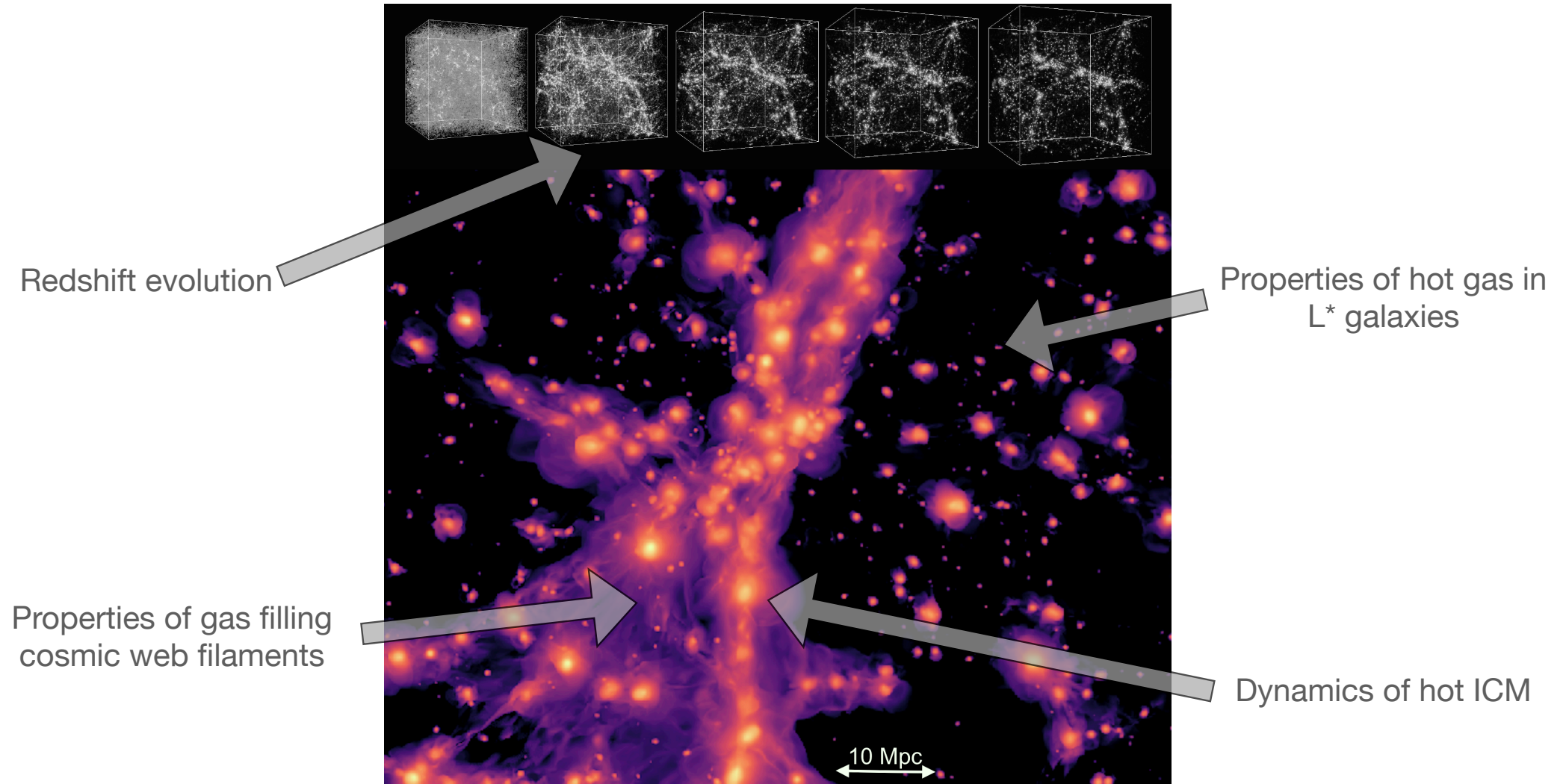
Galaxy and cluster evolution

Diffuse gas in local environments,
Physics and dynamics of cosmic plasmas

Formation and evolution of compact objects

The lives and deaths of stars

Galaxy and cluster evolution



Galaxy and cluster evolution

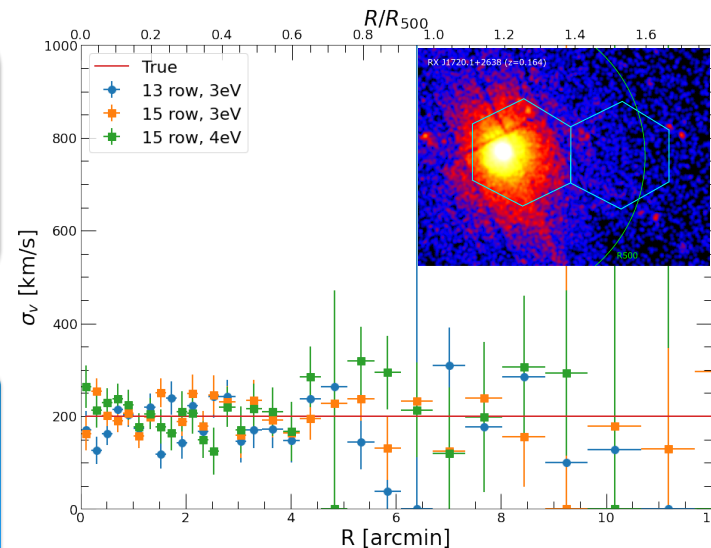
Fundamental science question

Quantify the dissipation of gravitational energy into bulk motions and turbulence of the intracluster medium

Experiment

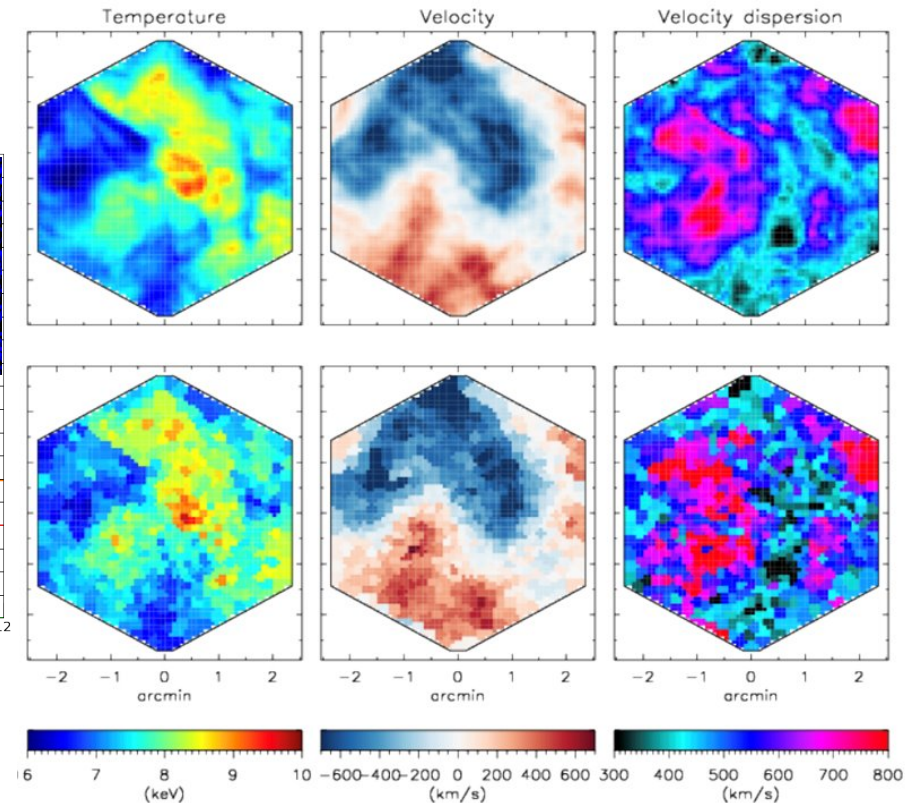
Spatially-resolved measurement of turbulent line broadening and shifts *out to R500*

XRISM will start addressing this (e.g. Coma Center 200ks, A2029: 250ks at R2500!) but NewAthena will move us towards representative samples and detailed mapping.



Credit: D. Eckert (UniGe)

100ks pointing centred around R500 of a fiducial $z=0.15$ cluster similar to RX J1720.1+2638.



True (top) and reconstructed (bottom) maps for a fiducial Coma-like simulated cluster observed with the X-IFU (Roncarelli et al. 2018).

Galaxy and cluster evolution

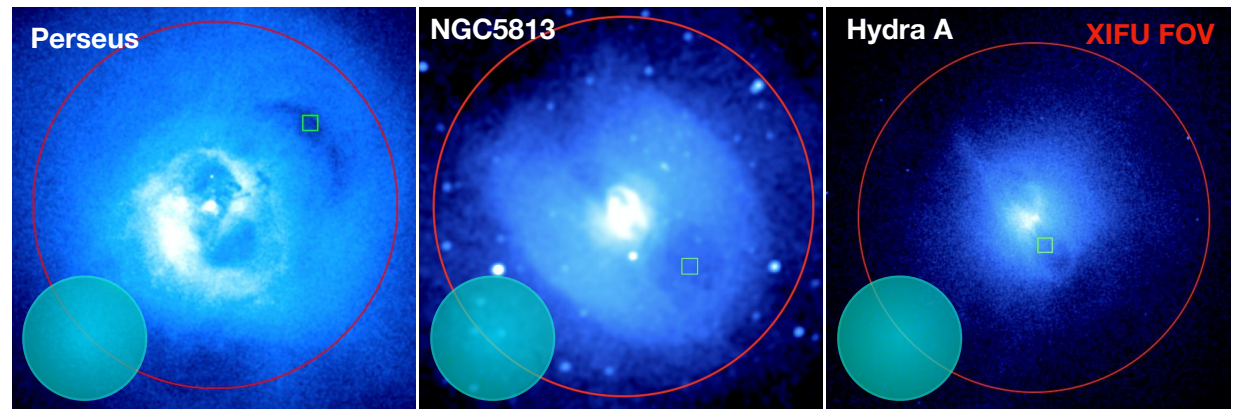
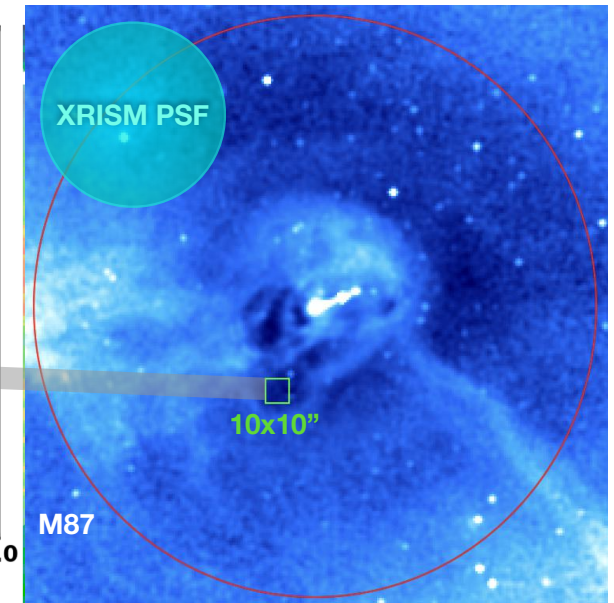
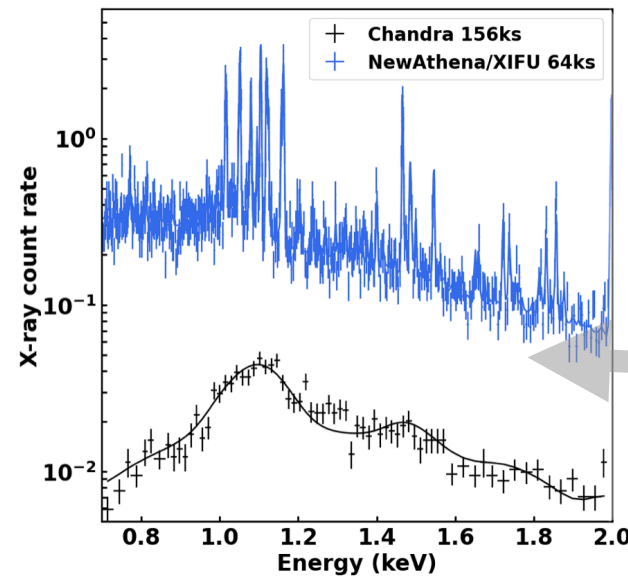
Fundamental science question

Quantify how AGN feedback
is dissipated into bulk
motions and turbulence

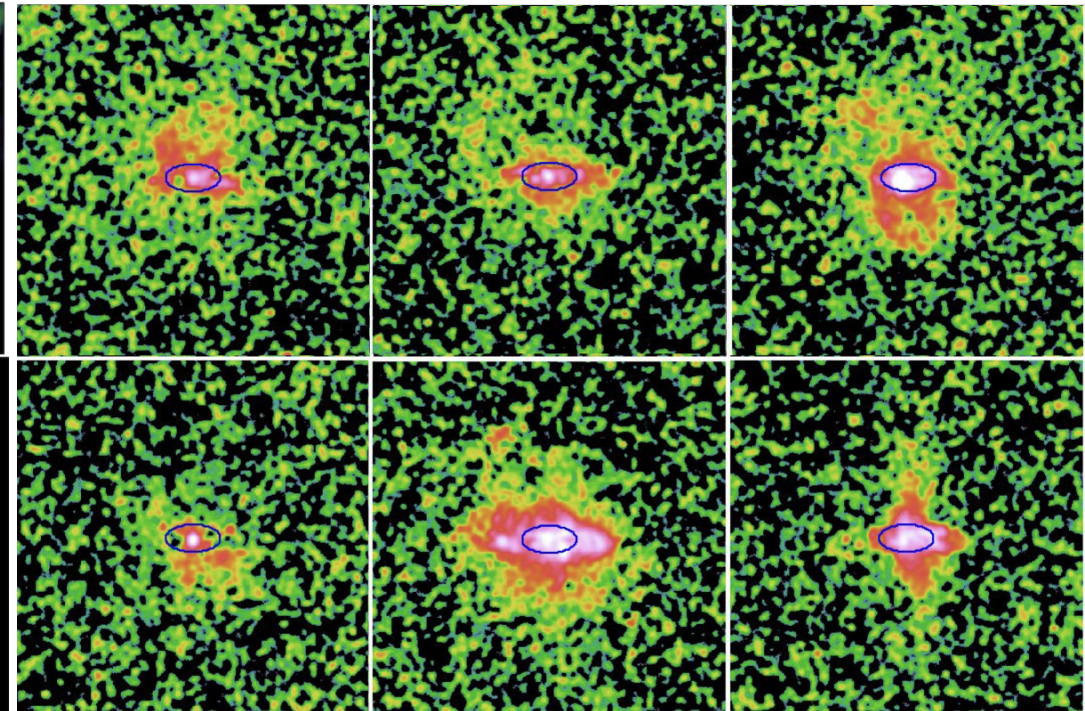
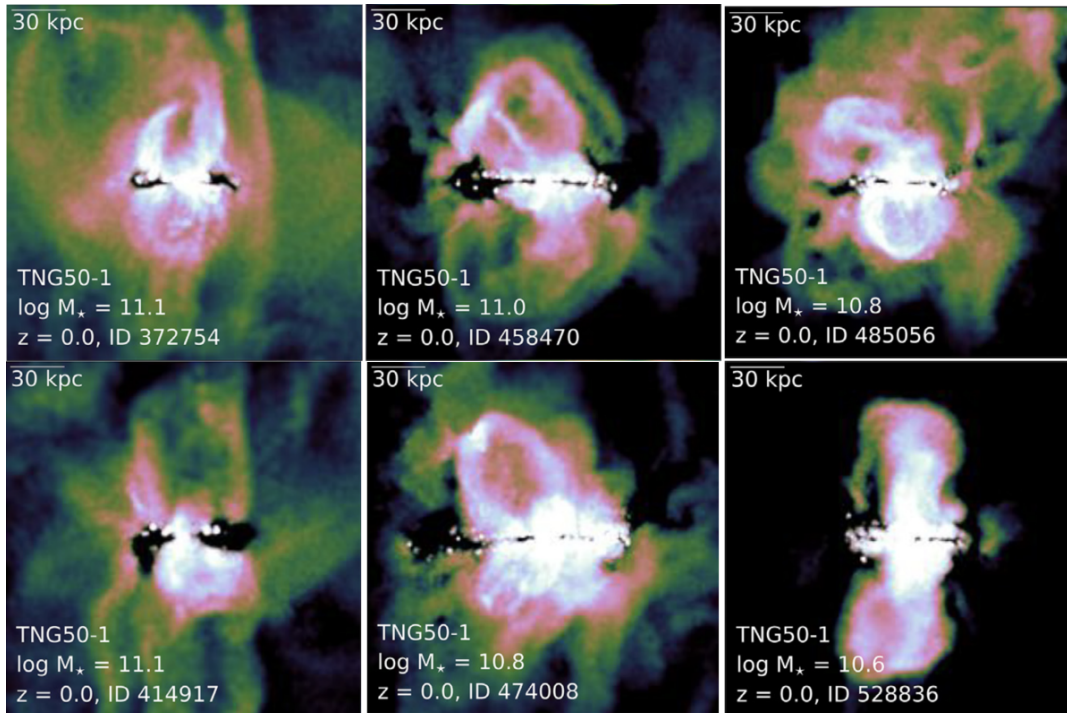
Experiment

Spatially-resolved
measurement of turbulent line
broadening and shifts on
scales $<$ AGN cavities

XRISM will map dynamics around
larger (older) AGN lobes in a few
nearby systems.



Galaxy and cluster evolution



100 ks NewAthena/WFI images of 6 simulated L^* galaxies showing bubble feedback in TNG50

Fundamental science question

Determine how (AGN) feedback impacts typical L^* galaxies

Experiment

Image substructures in the circumgalactic medium of $z \sim 0.01$ L^* galaxies

Galaxy and cluster evolution

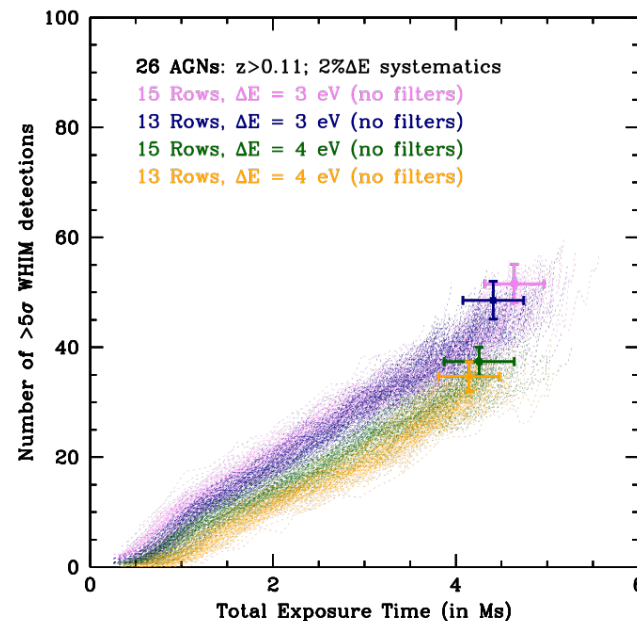
Fundamental science question

Detect the extremely tenuous gas *typical* of cosmic web filaments

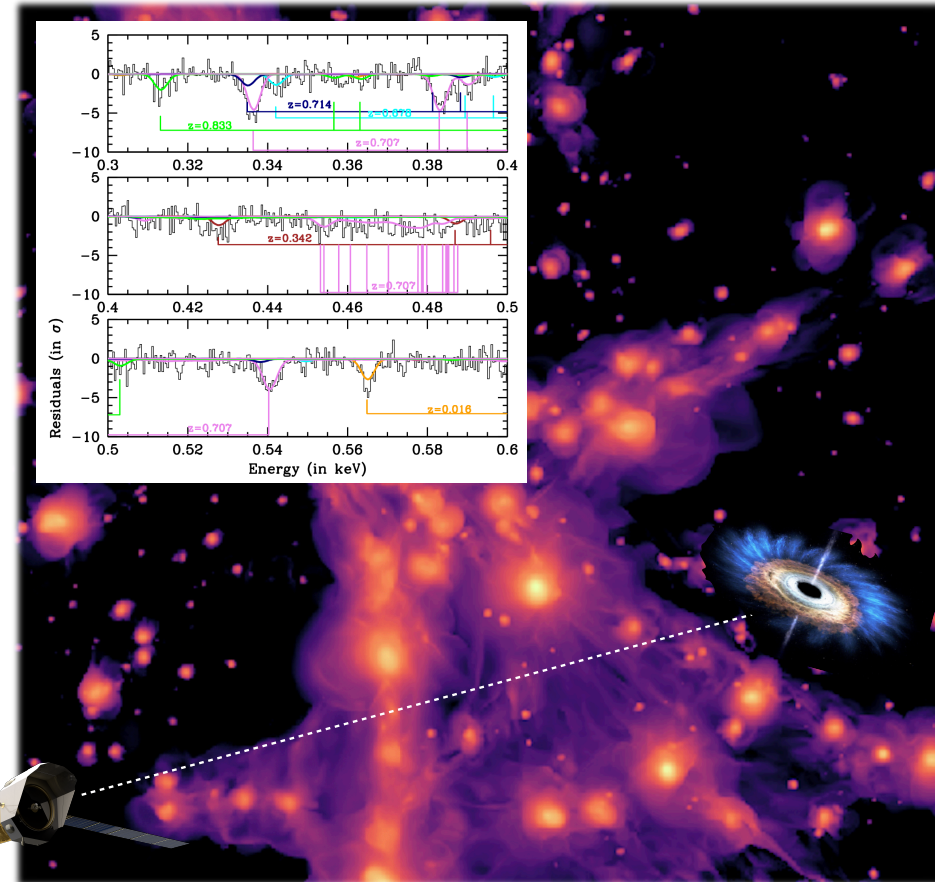
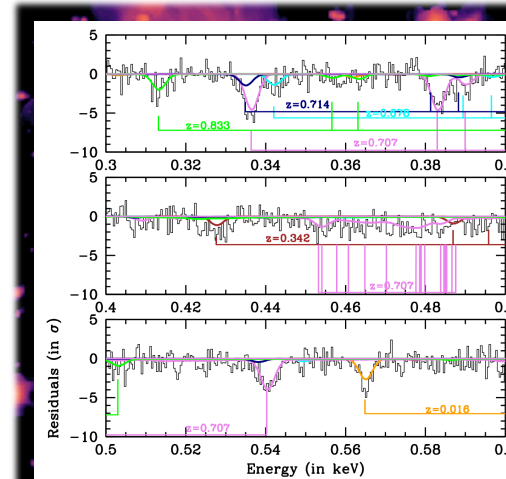
Experiment

Absorption spectroscopy of the Warm-Hot Intergalactic Medium using quasars as backlight

+Mapping filaments connecting to nearby clusters with WFI!



25 WHIM detections with 4 Ms
[assumes 2% uncertainty on relative effective area calibration]
Credit: F. Nicastro (OAR)



Galaxy and cluster evolution

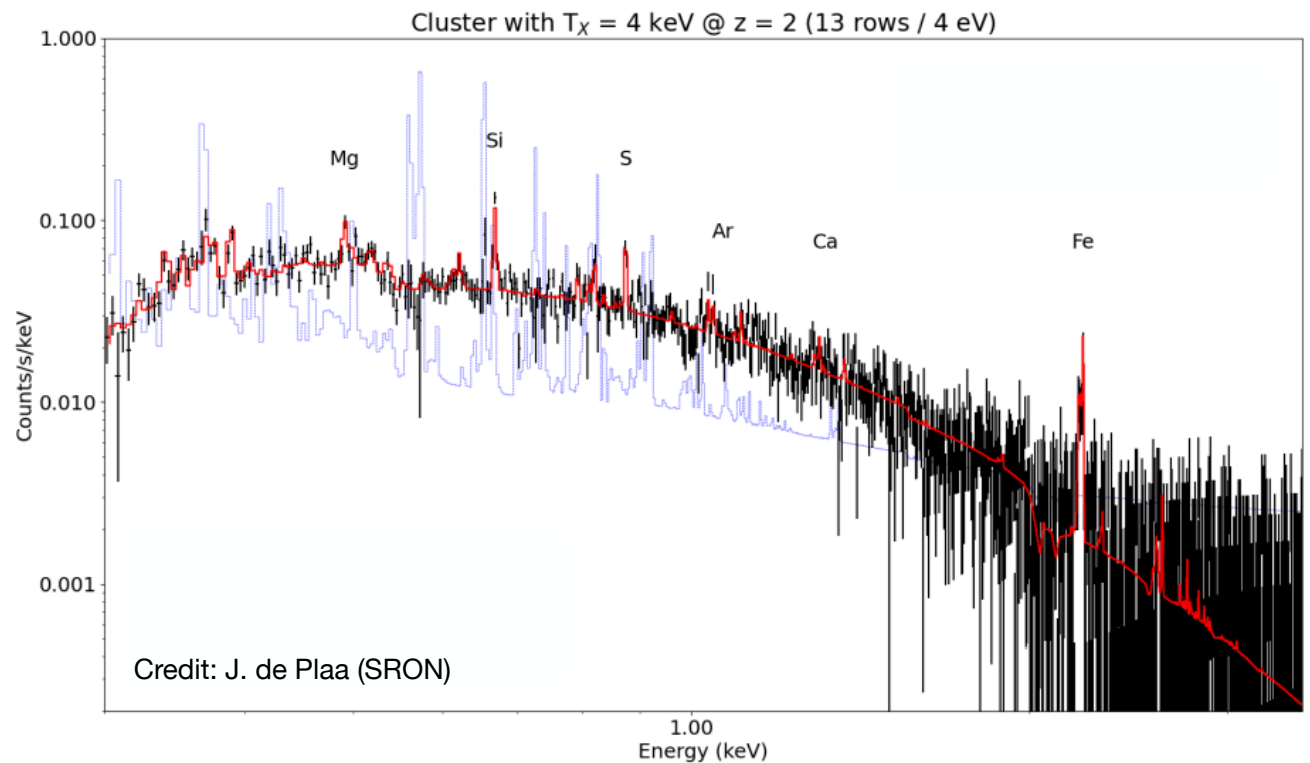
Fundamental science question

Quantify chemical enrichment in the ICM since the early epochs of structure formation

Experiment

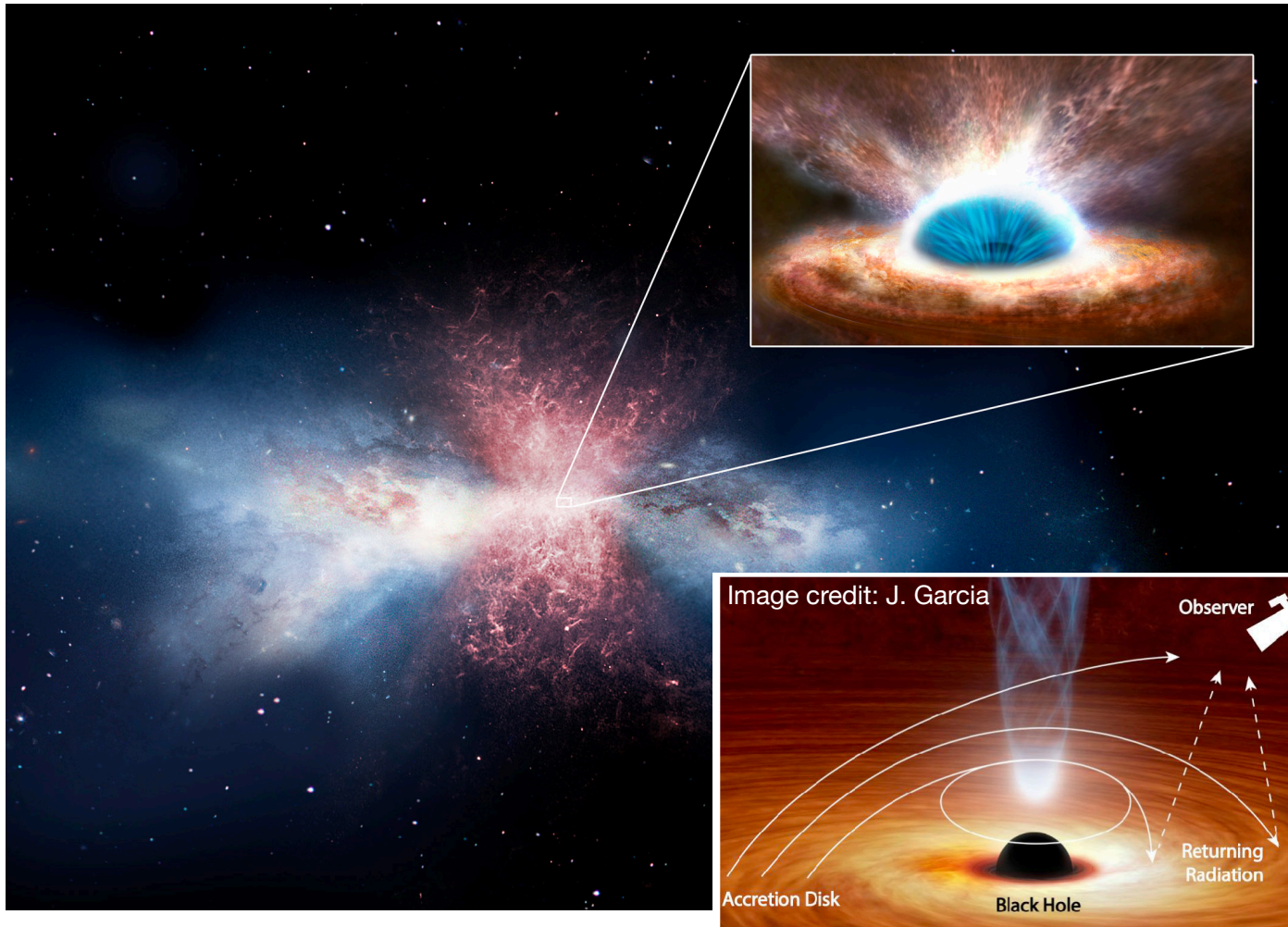
Measure abundances of both alpha- and Fe-group elements up to $z=2$

XRISM: excellent measurements of Si, S, Ar, Ca, Fe, Ni in local clusters; O, Ne, Mg inaccessible if GVC; high- z targets too faint even for GVO



3-sigma detection of Mg in $z=2$ galaxy cluster in 140 ks of NewAthena XIFU.

Formation and evolution of compact objects



Black hole spin distribution

Geometry of X-ray emitting corona

Wind launching mechanisms and energetics

Growth of early SMBH at high- z

Multimessenger science and GW

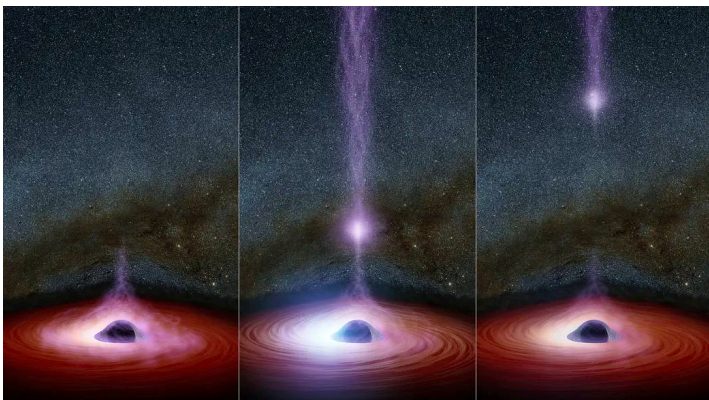
Formation and evolution of compact objects

Fundamental science question

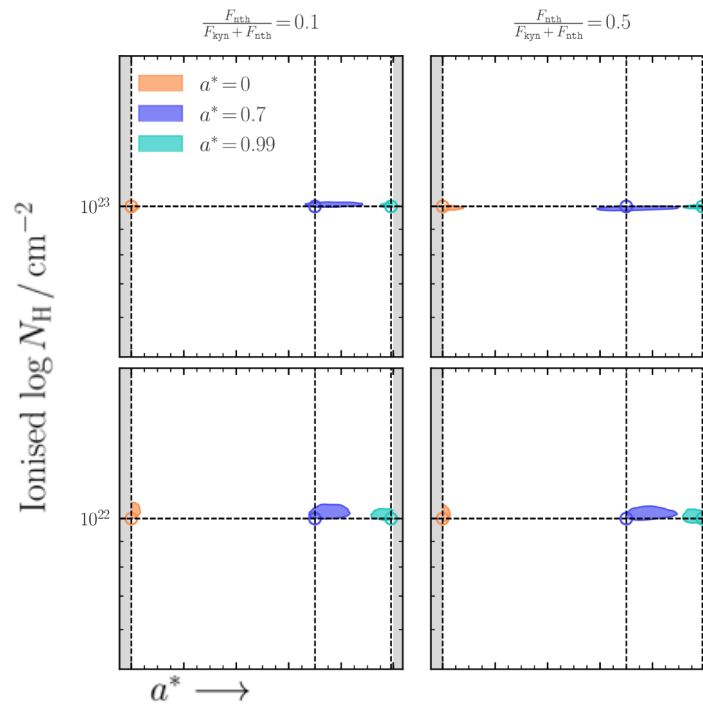
Determine the nature of the primary X-ray source in Active Galactic Nuclei (AGN) and stellar compact objects

Experiment

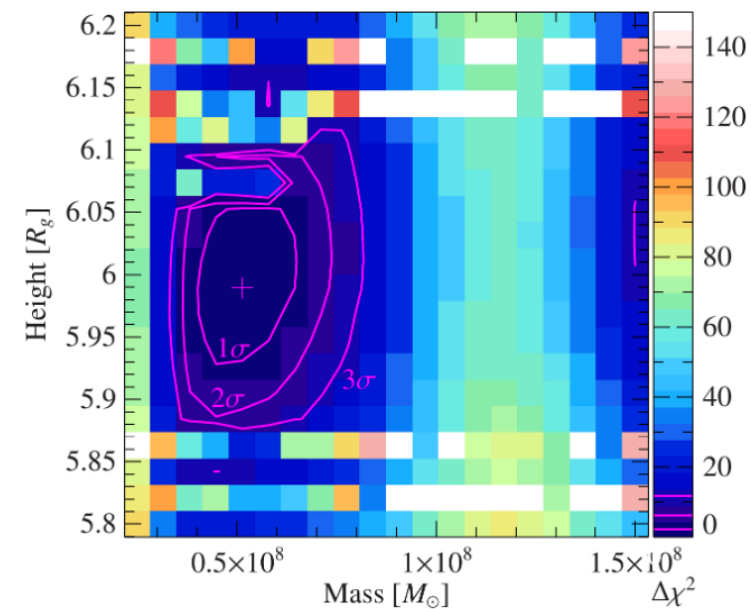
High-resolution spectral-timing, accretion disk reverberation mapping (time lags)



Statistical constraints with 100 ks (4x25) NewAthena/X-IFU



Black hole spin vs. ionised outflow density



Black hole mass vs. corona height

Credit: P. Boorman, G. Mastroserio (CalTech), O. König (FAU)

Formation and evolution of compact objects

Fundamental science question

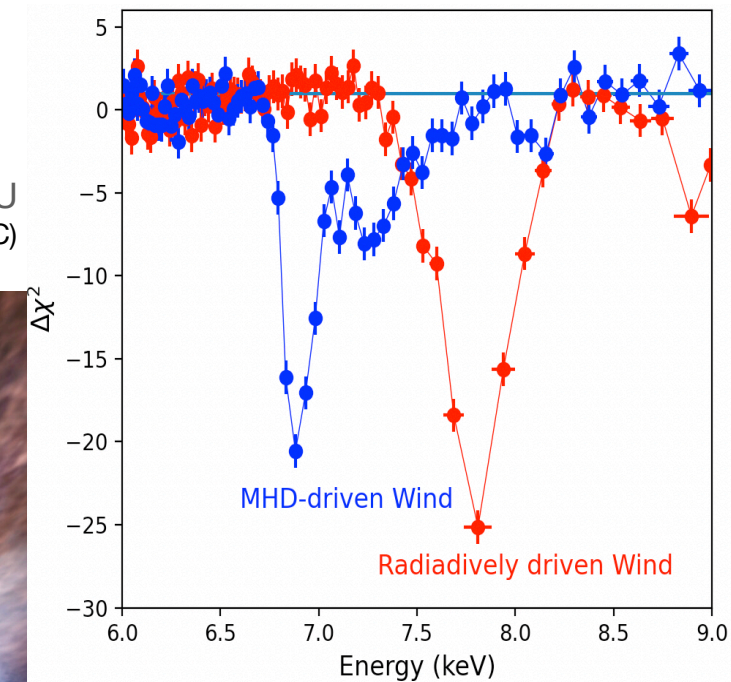
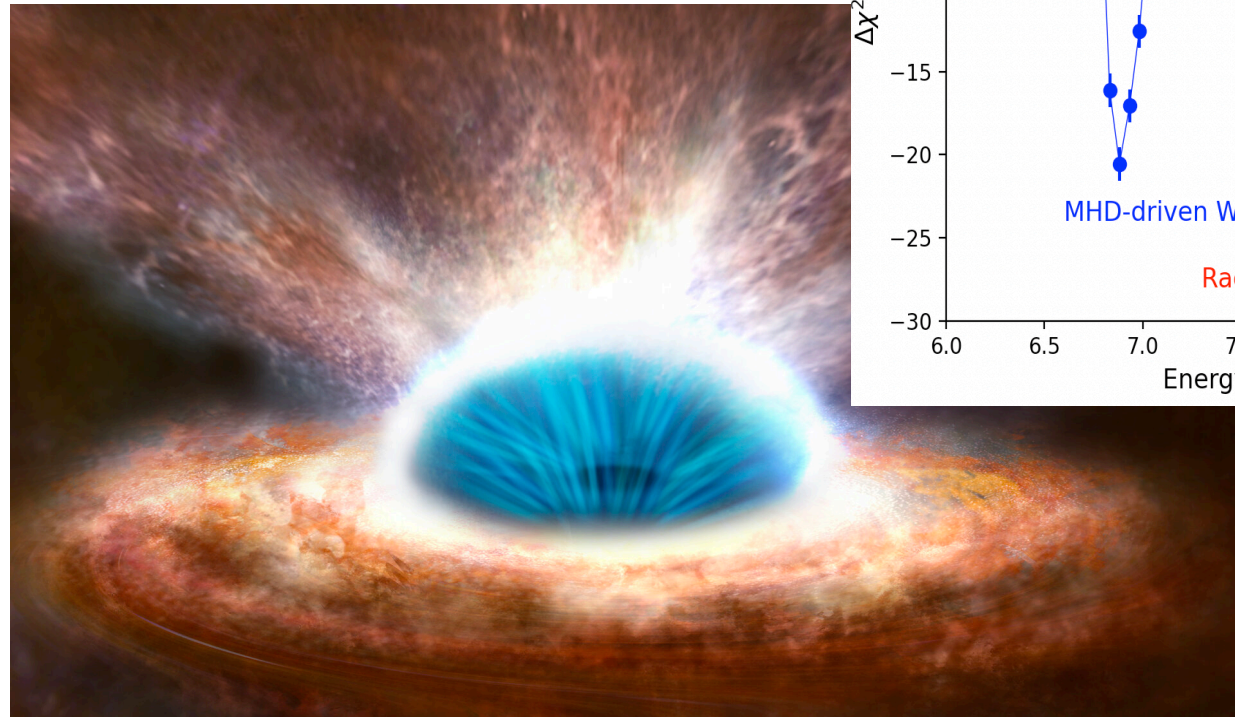
Determine how powerful AGN outflows are launched and how they impact the evolution of galaxies

Experiment

Track evolution of disk outflows on their dynamical time-scale; probe launch mechanism via line shapes

XRISM requires integrating signal over longer exposure times.

25 ks NewAthena/XIFU
simulation credit: M. Dadina (OAS), G. Matzeu (ESAC)



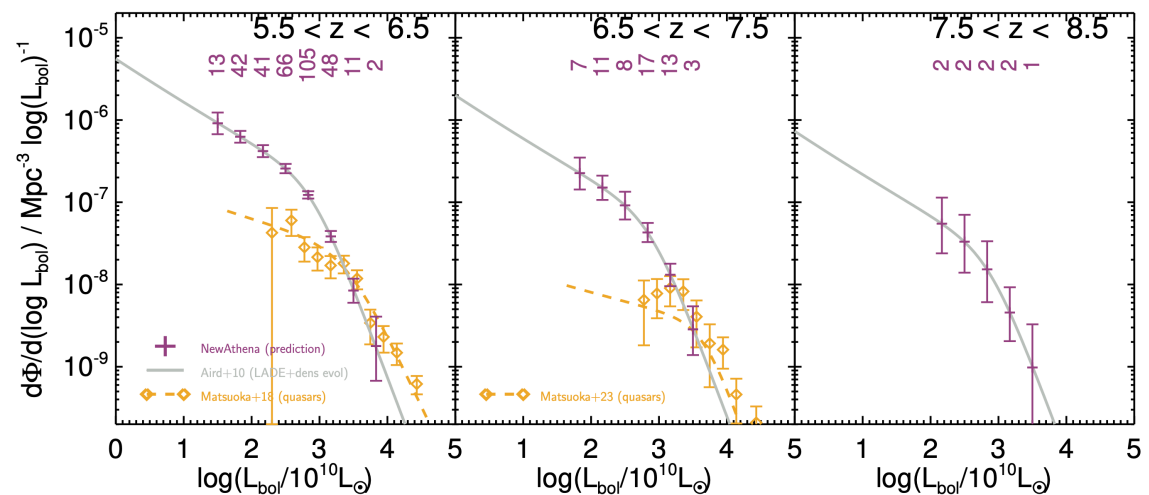
Formation and evolution of compact objects

Fundamental science question

Determine the space density of AGN that dominate black hole growth up to the EoR

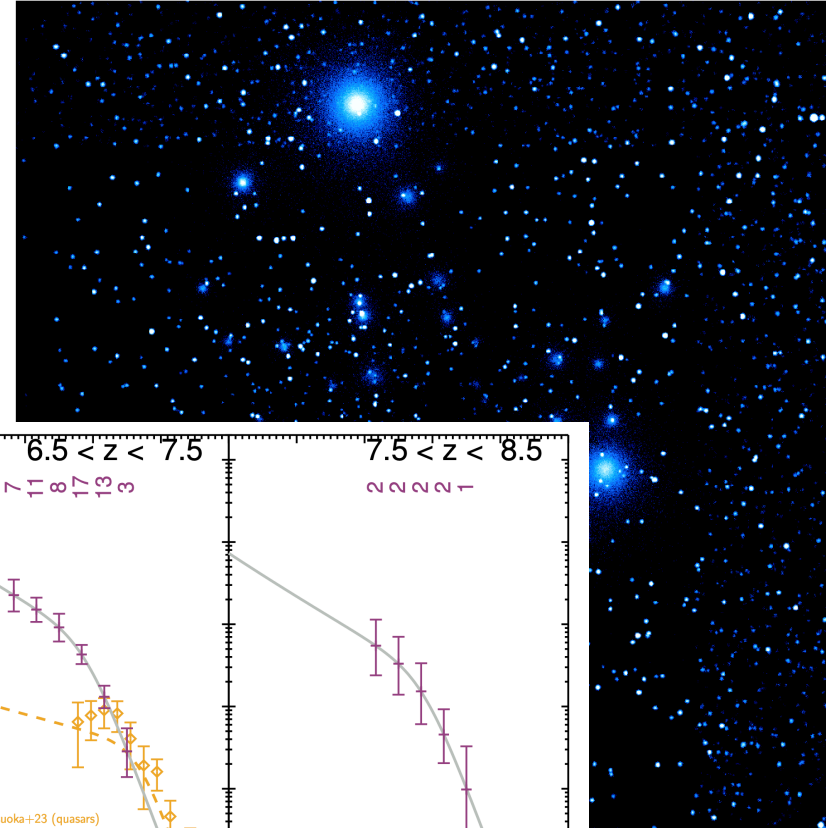
Experiment

Measure the population of moderately obscured ($N_H=10^{22}$ cm $^{-2}$) AGN up to $z\sim 8$



Conservative predictions for 31.6 Ms survey covering 40 deg 2 . Recent JWST results show space density may be much higher than assumed.

Credit: J. Aird (UoE), F. Carrera (IFCA)



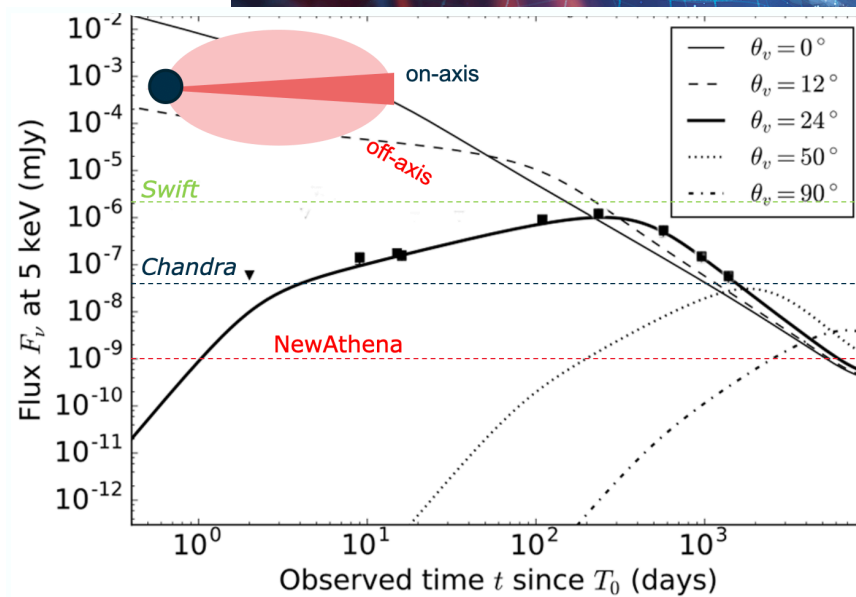
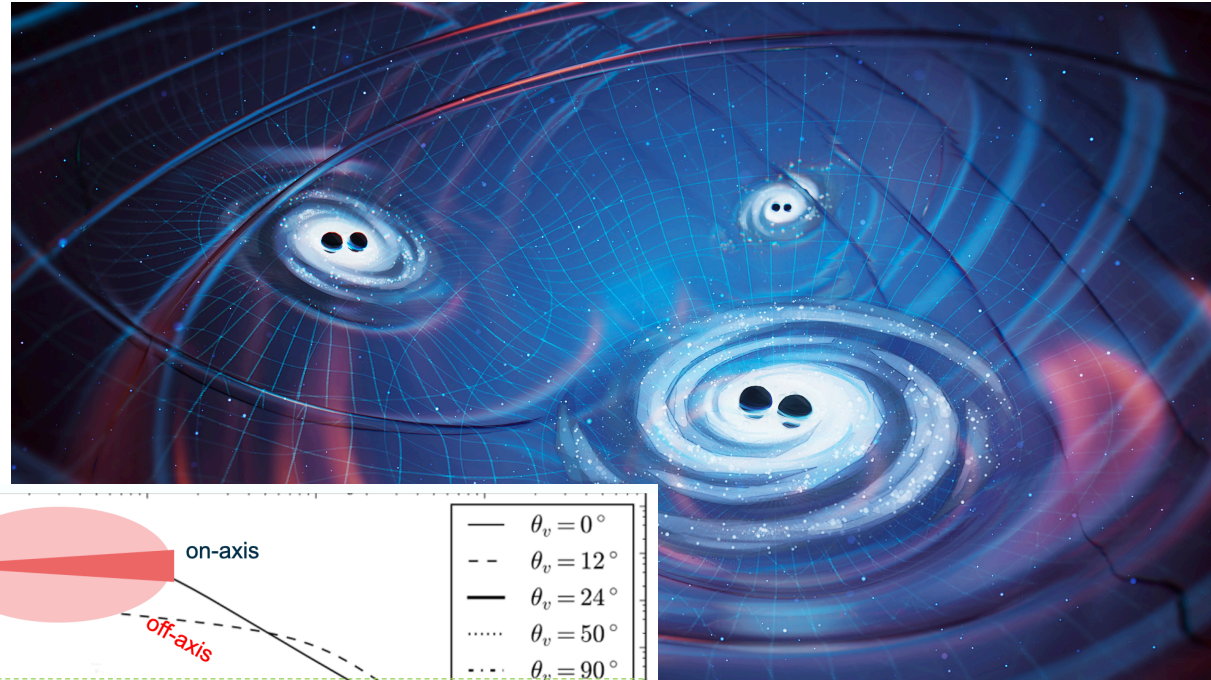
Formation and evolution of compact objects

Fundamental science question

Multi-messenger astrophysics
(e.g., counterparts of neutron star
merging gravitational wave
sources up to $z \sim 1$)

Experiment

Light curves can be followed for a
longer time and at greater angles
from the jet allowing more EM
counterpart detections



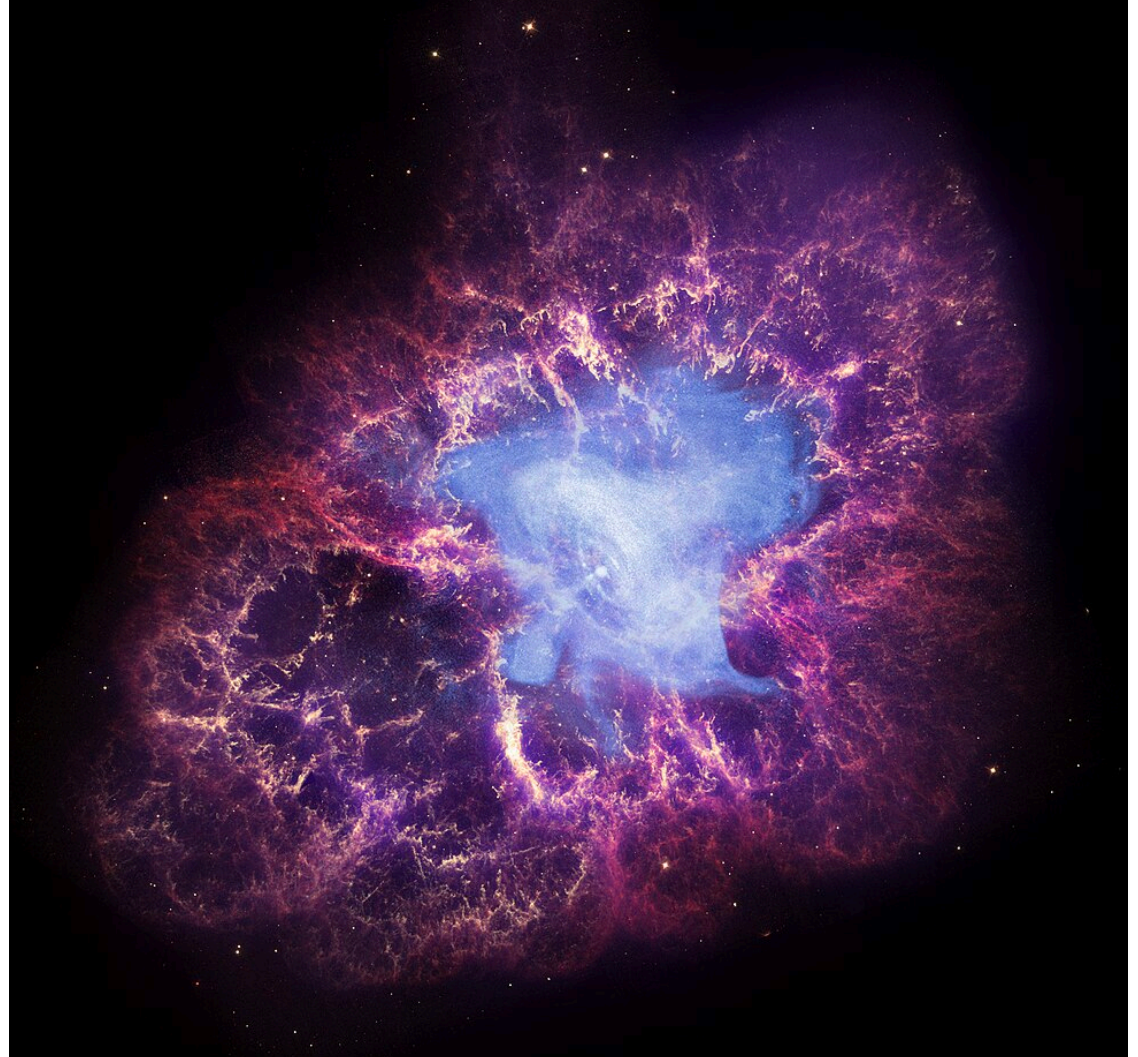
Credit: E. Troja (Uni. Rome)

The lives and deaths of stars

Stellar flare dynamics and (exo)planet habitability

Supernova progenitors, explosion mechanisms, and particle acceleration in SNR

Neutron star equation of state



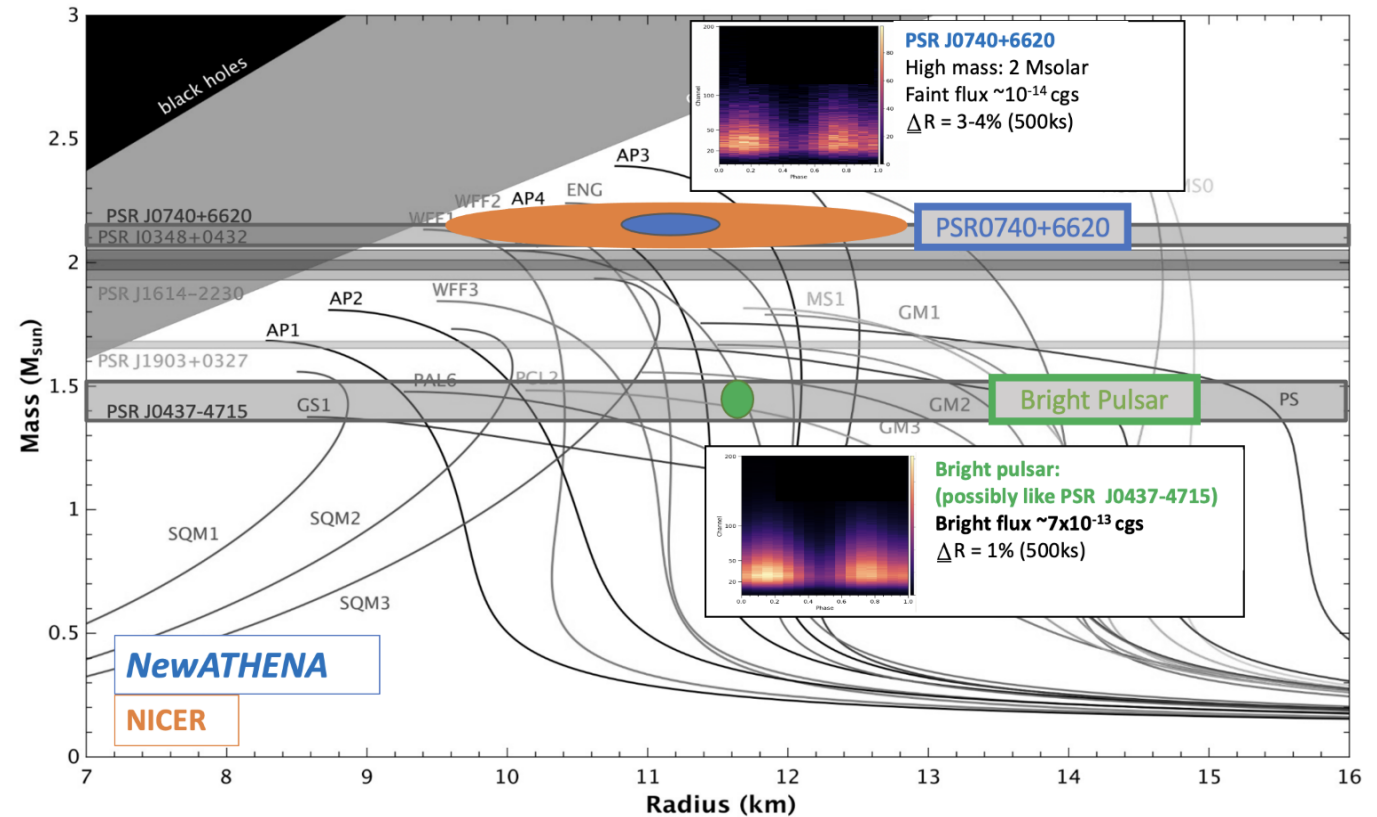
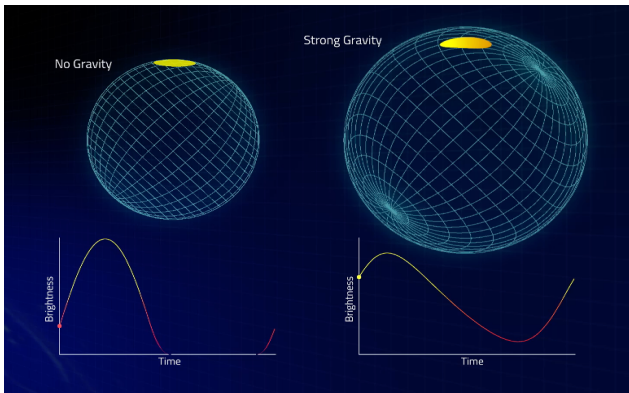
The lives and deaths of stars

Fundamental science question

Constrain the equation of state
of neutron stars

Experiment

Measure with %-level accuracy
the radius of rotationally-
powered pulsars through pulse
profile modelling



Credit: S. Guillot (IRAP), N. Rea (CSIC), T. Salmi, S. Vinciguerra, A. Watts (UvA)

The lives and deaths of stars (and planets!)

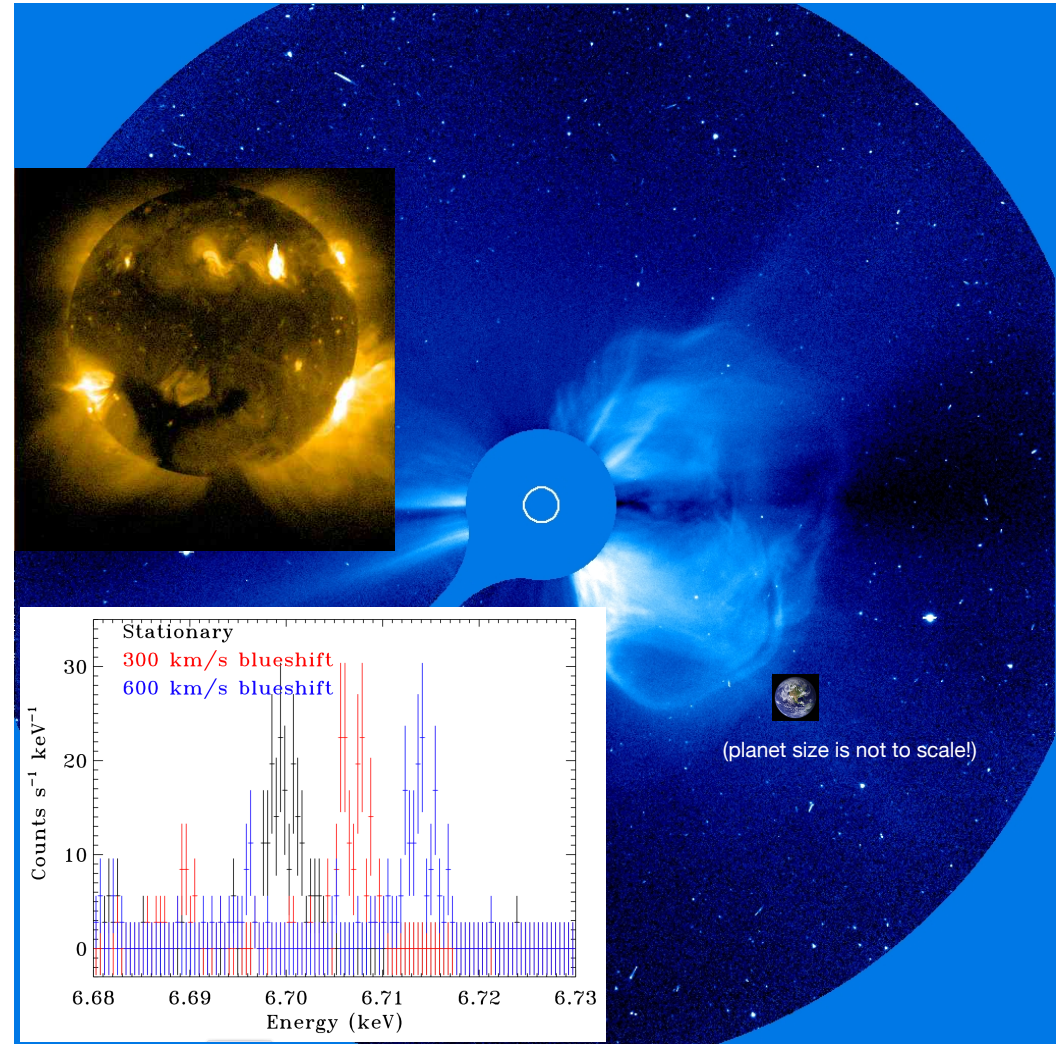
Fundamental science question

Determine if and how stellar coronal activity (may) impact planet atmospheres

Experiment

Dynamics of stellar coronae, estimate of coronal mass losses. Compare flares between planet hosting and non-planet hosting stars.

Spectral evolution of stellar flares in their own dynamical timescales (~ 500 s)
NewAthena/XIFU simulation of young (40 Myr) planet hosting star DS Tuc A
Credit: R. Osten (STScI)



The lives and deaths of stars

Fundamental science questions

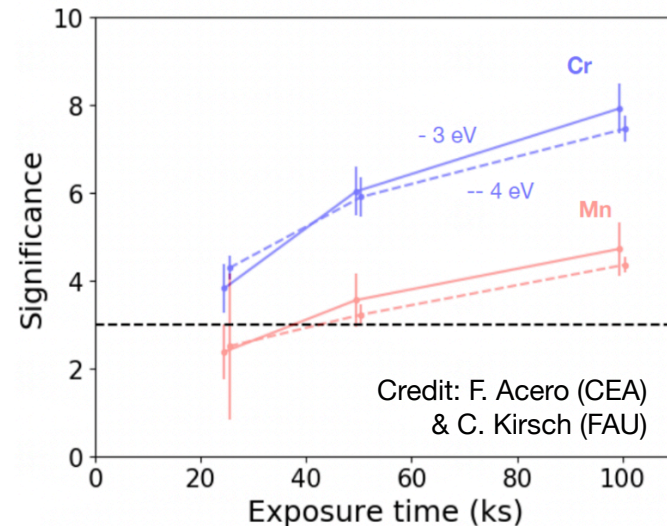
Constrain SN explosion mechanisms, progenitor and neutrino models, and particle acceleration mechanisms

Experiments

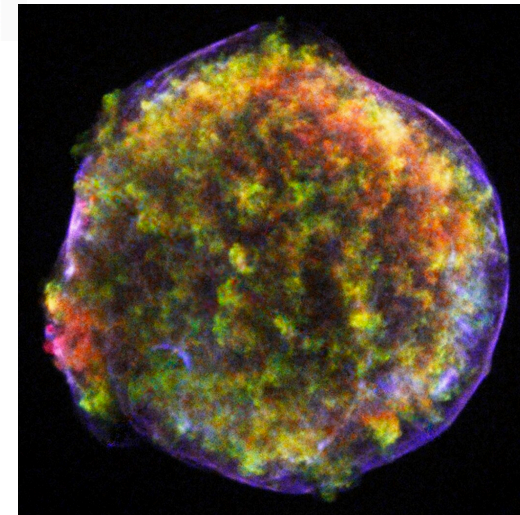
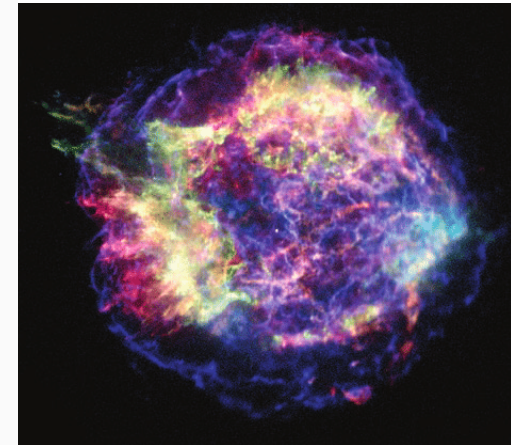
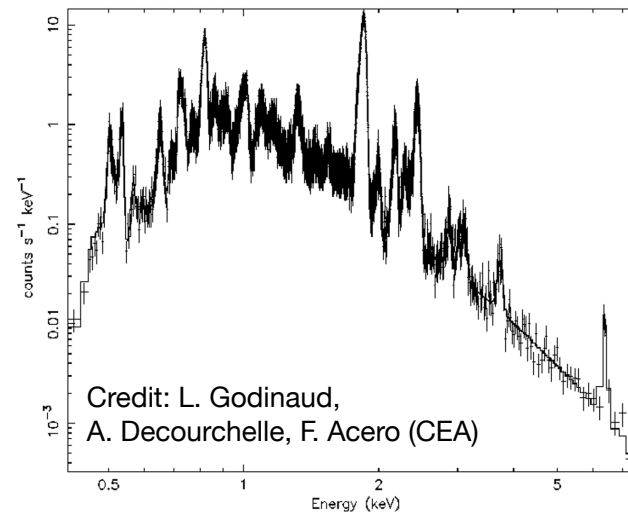
Rare metals metallicity determination, and disentangling thermal vs synchrotron emission on $\sim 10''$ scales

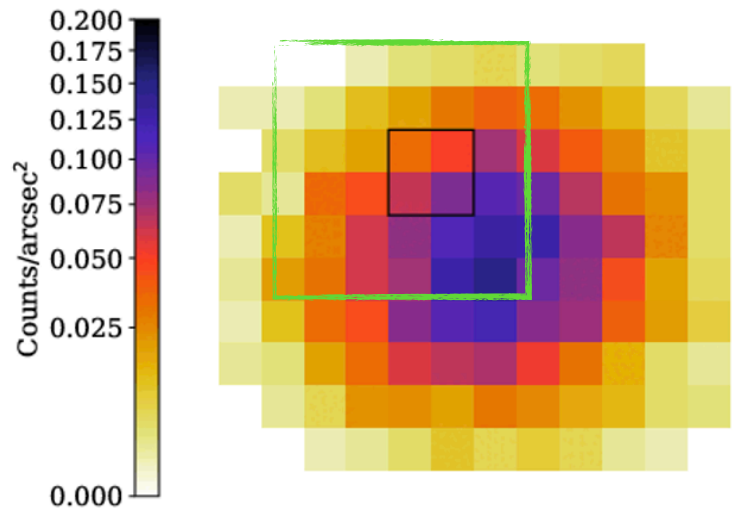
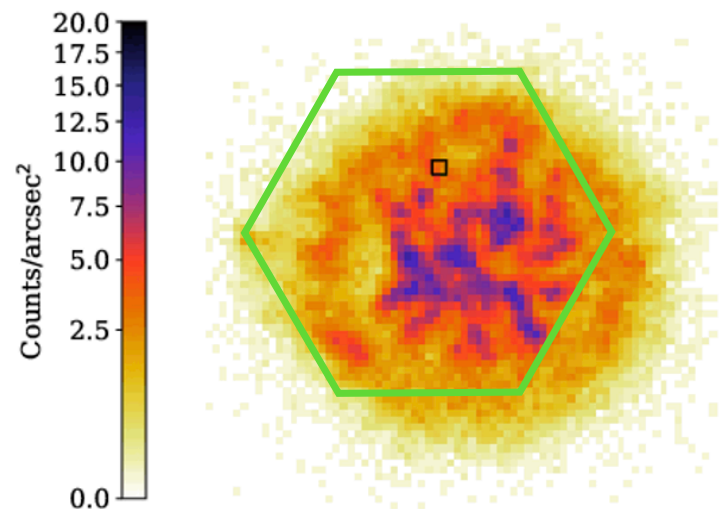
XRISM will start probing these questions but NewAthena will give us a much sharper view.

Cas A
Cr/Mn detected with $T_{\text{exp}} \geq 50$ ks
Ti detected with $T_{\text{exp}} \geq 100$ ks per $10''$ spatial bin



Tycho (50 ks
NewAthena/X-IFU)
3 non-equilibrium
thermal components
with velocity dispersion
2500 km/s +
Synchrotron power-law





FOV / PSF

