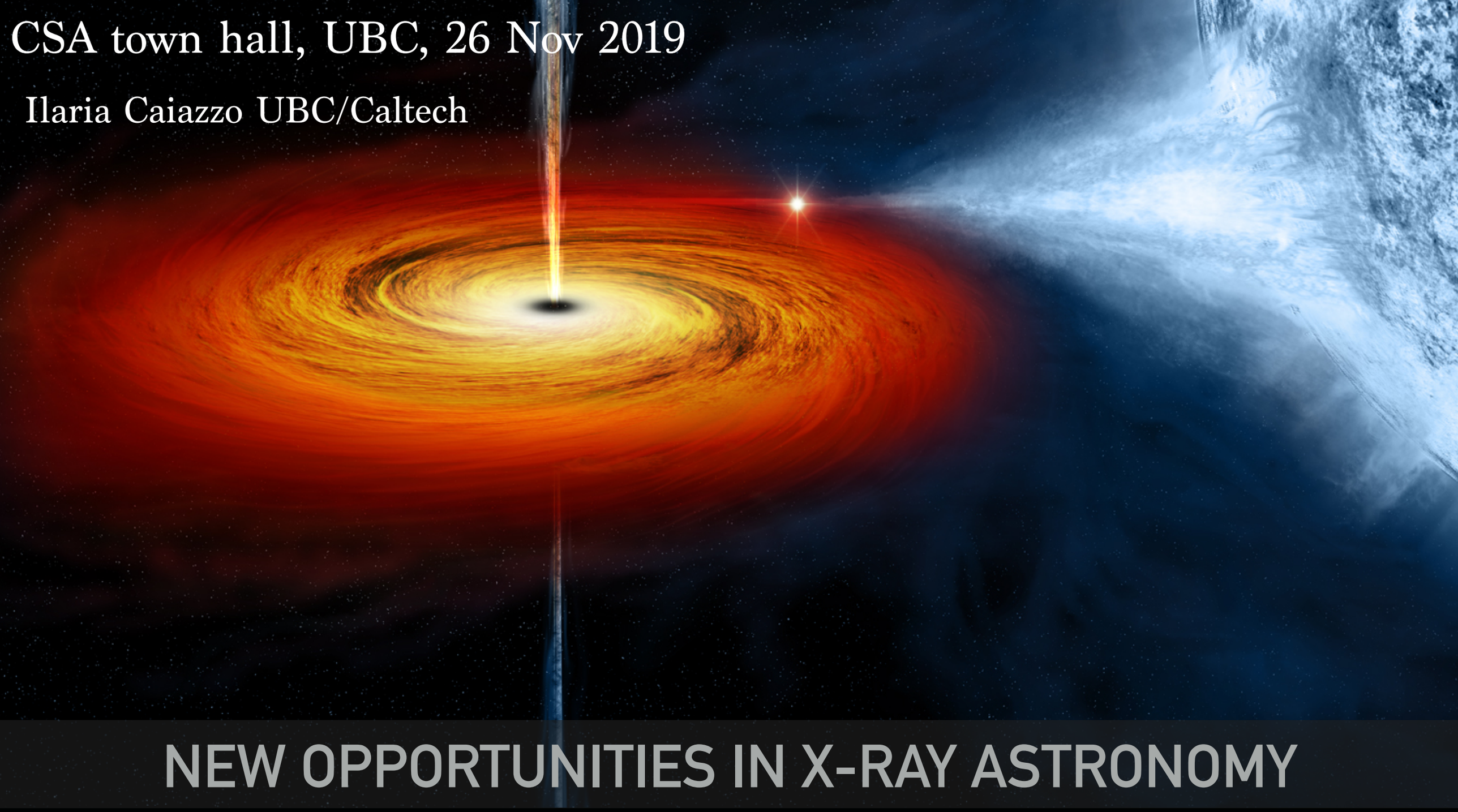
CSA town hall, UBC, 26 Nov 2019

Ilaria Caiazzo UBC/Caltech



NEW OPPORTUNITIES IN X-RAY ASTRONOMY

HIGH-RESOLUTION & HIGH-THROUGHPUT X-RAY SPECTROSCOPY & TIMING

LRP 2020 WHITE PAPERS

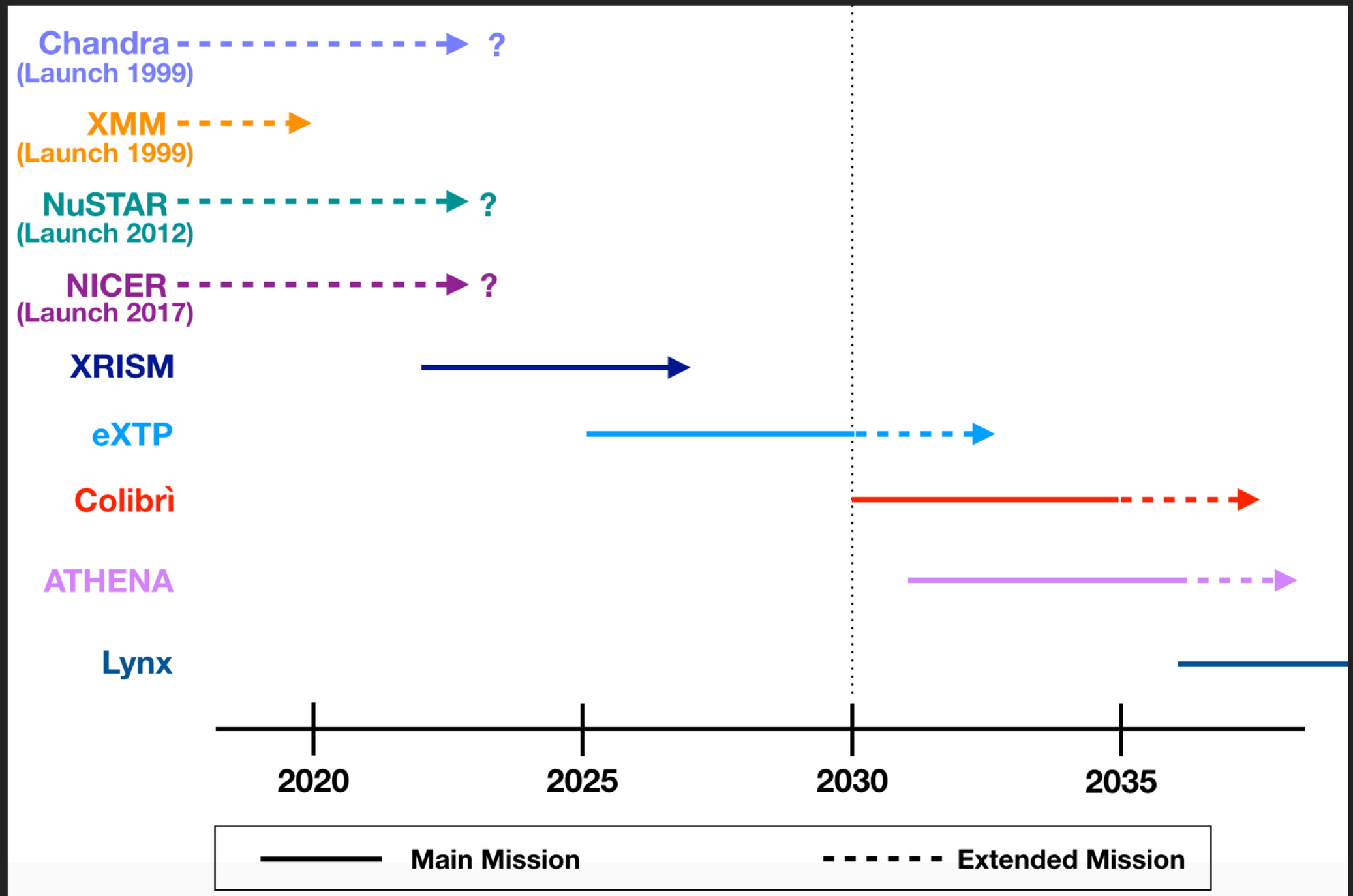
Main WP

- **E053 - W036**: Unveiling the secrets of black holes and neutron stars with high throughput, high energy resolution X-ray spectroscopy

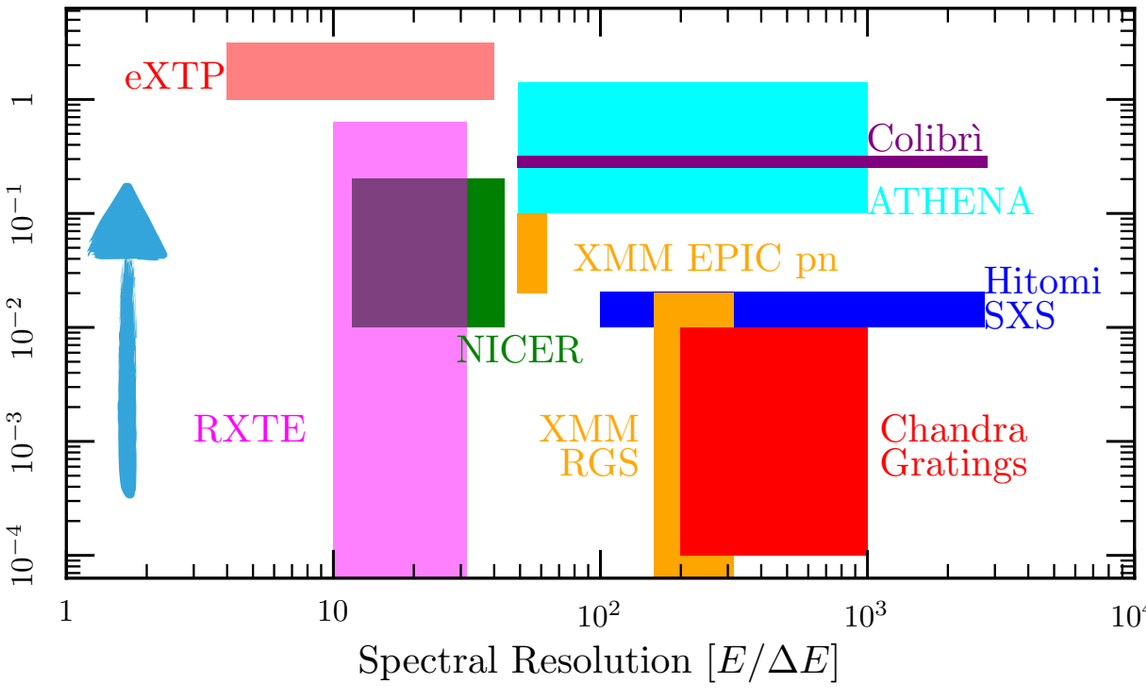
Also relevant:

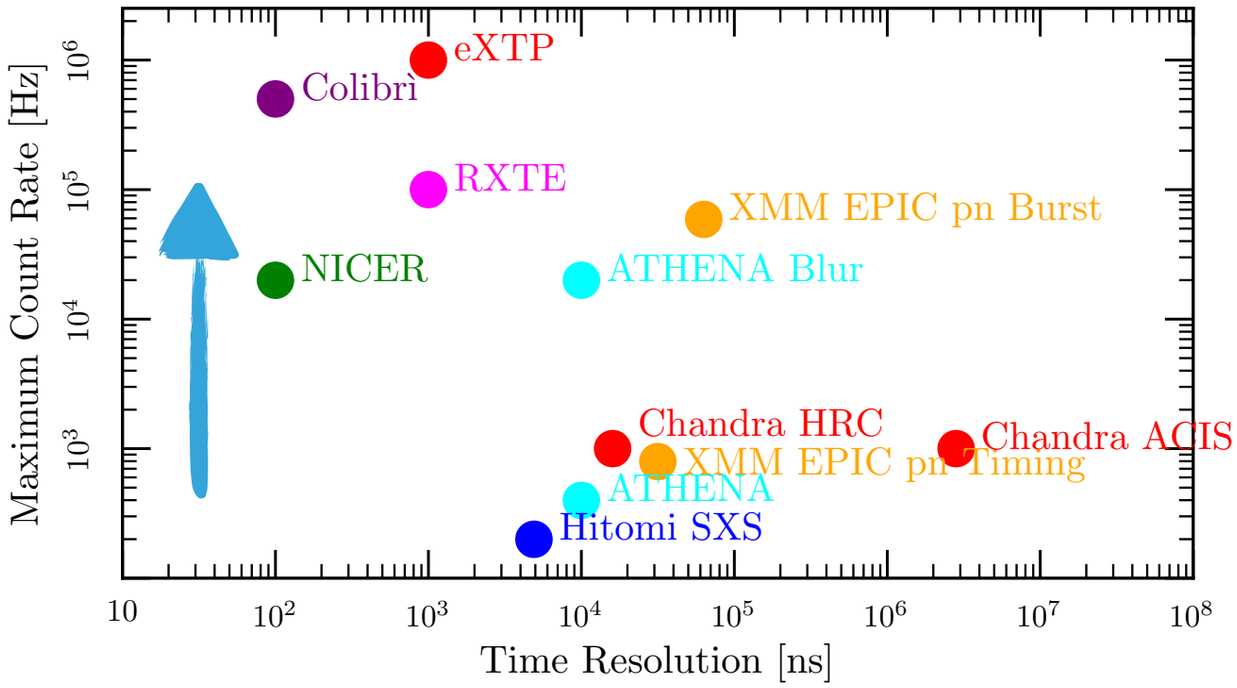
- **E037 - W024**: Star Clusters Near and Far
- **E043 - W034**: Revealing the Origin and Cosmic Evolution of Supermassive Black Holes
- **E057 - W041**: The cosmic origin and evolution of the elements
- **E064 - W055**: Cosmic Magnetism

THE HIGH-RESOLUTION X-RAY MISSIONS LANDSCAPE



HIGH-THROUGHPUT, HIGH-RESOLUTION





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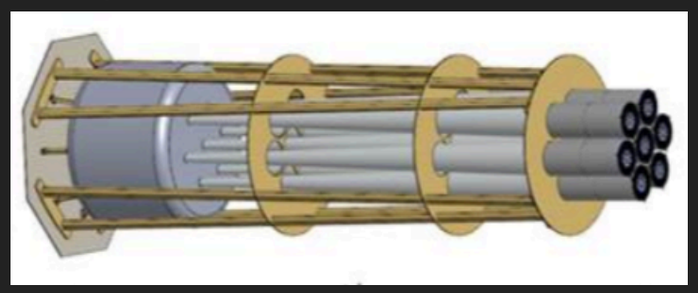
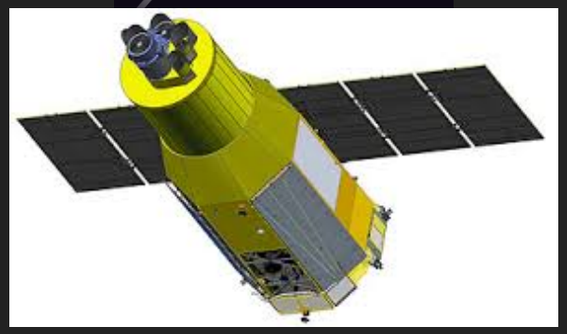
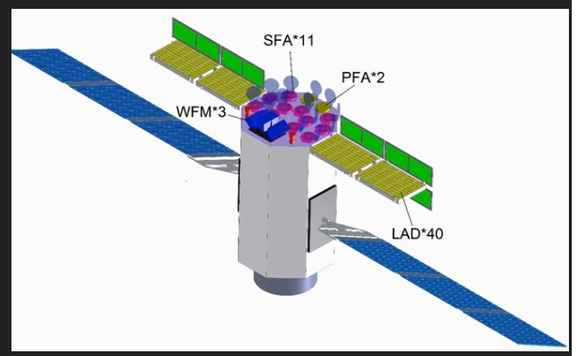


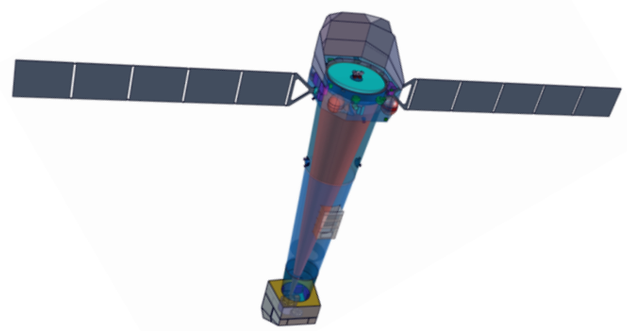
XRISM



eXTP



ATHENA



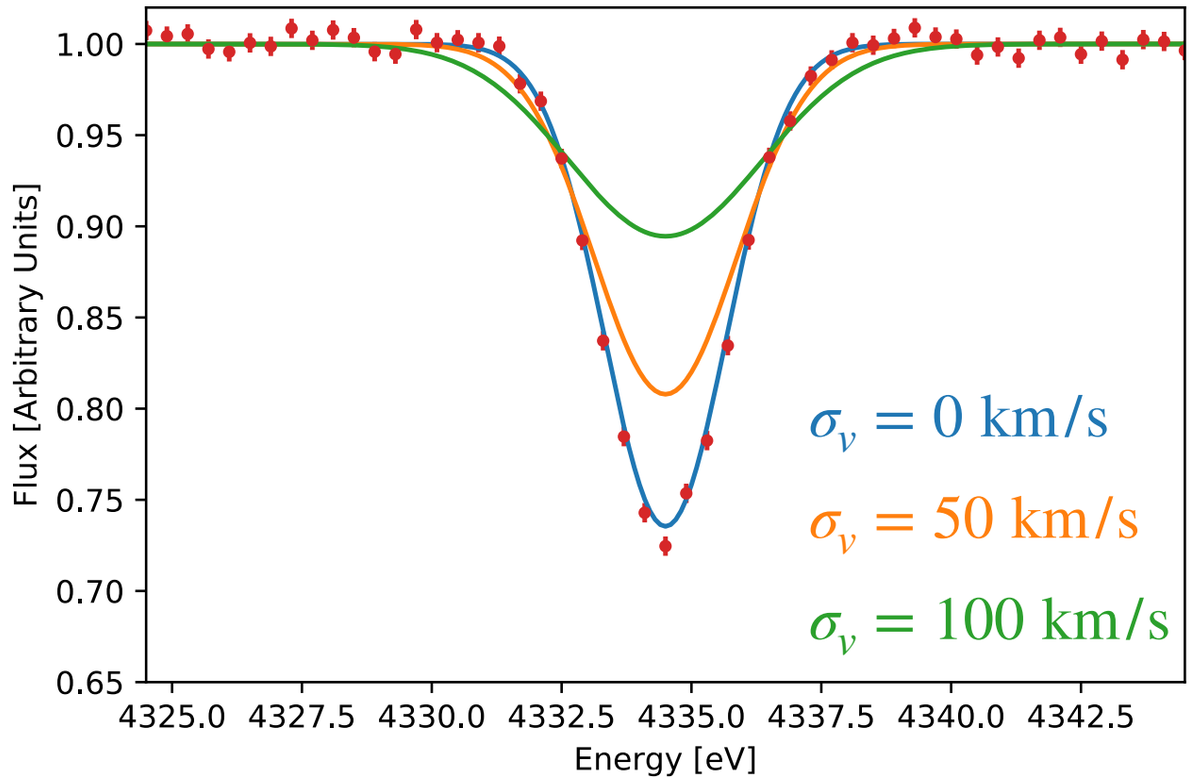
HIGH RESOLUTION SPECTROSCOPY

Detection of absorption and emission lines gives information about the source's:

- Composition - line identification
- Ejecta speed - red/blue shift
- Rotation - width and depth
- Gravity - red shift
- Magnetic field - cyclotron line
- …

Main targets:

- Neutron stars
- Black Holes (stellar mass and AGNs)
- SNR
- Galaxy clusters
- …

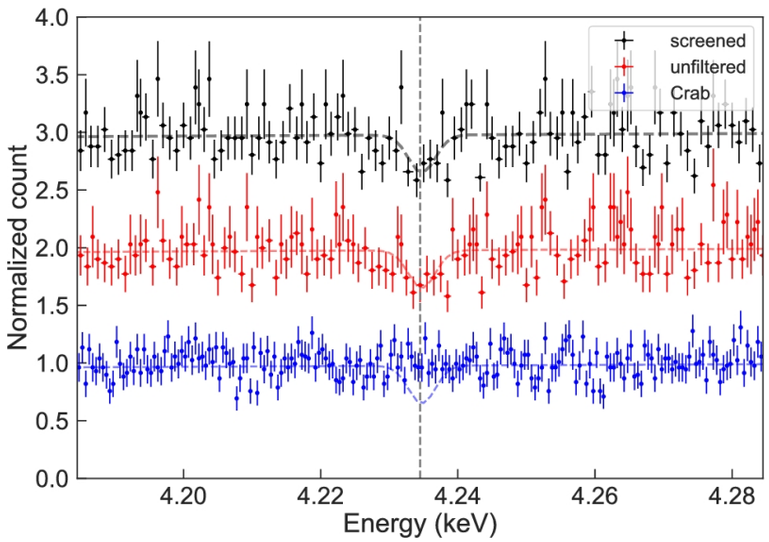


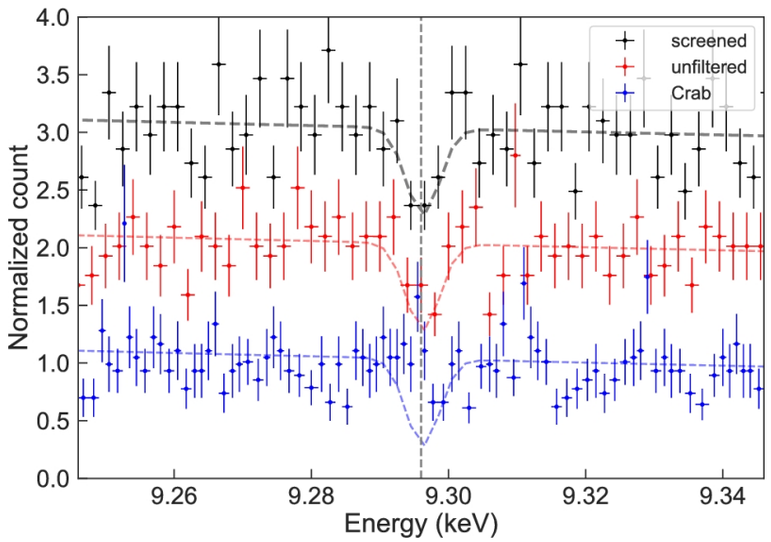
Example: absorption line from a neutron star surface

- From width and spin -> Radius
- From redshift -> surface gravity (M/R)

mass-radius relation

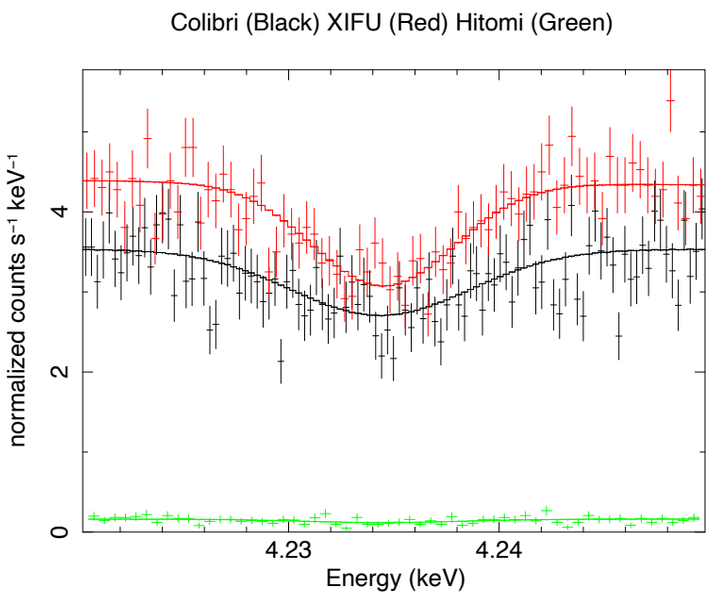
PSR 1833–1034 – THE NEUTRON STAR IN SNR G21.5–09

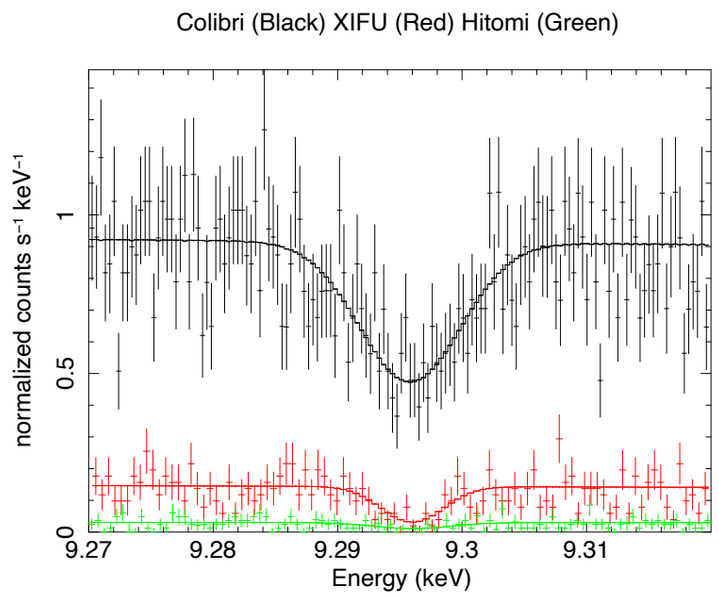




Hitomi Collaboration et al 2018
165 ks observations with SXS
on Hitomi

Period 61.8 ms





Simulations by Benson Guest,
PhD Student at U Manitoba

Colibrì

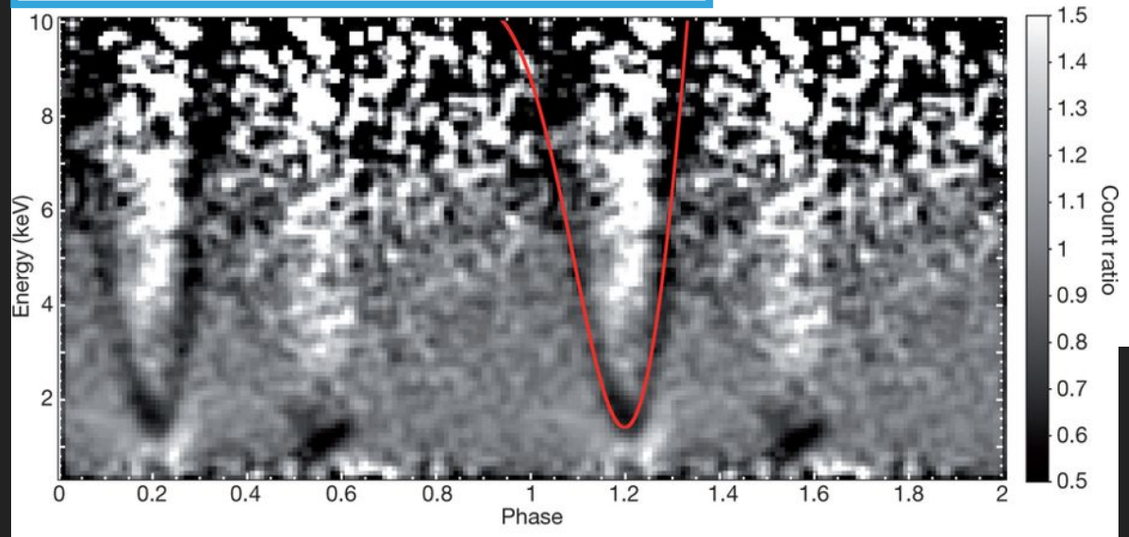
Athena

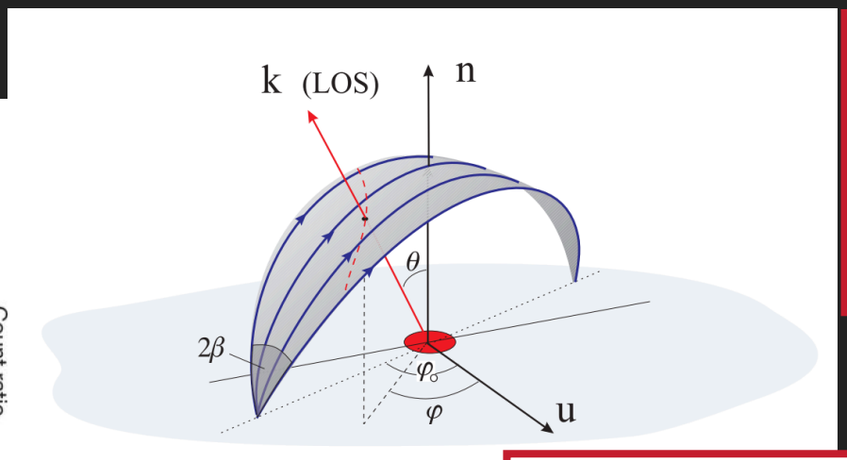
Hitomi/XRISM

Key mission specs:
High-Spectral Resolution
High Throughput
High Timing Resolution

SGR 0418+5729: MAGNETAR PHASE RESOLVED SPECTROSCOPY

Tiengo et al 2013, 30 ks observation with EPIC on XMM-Newton



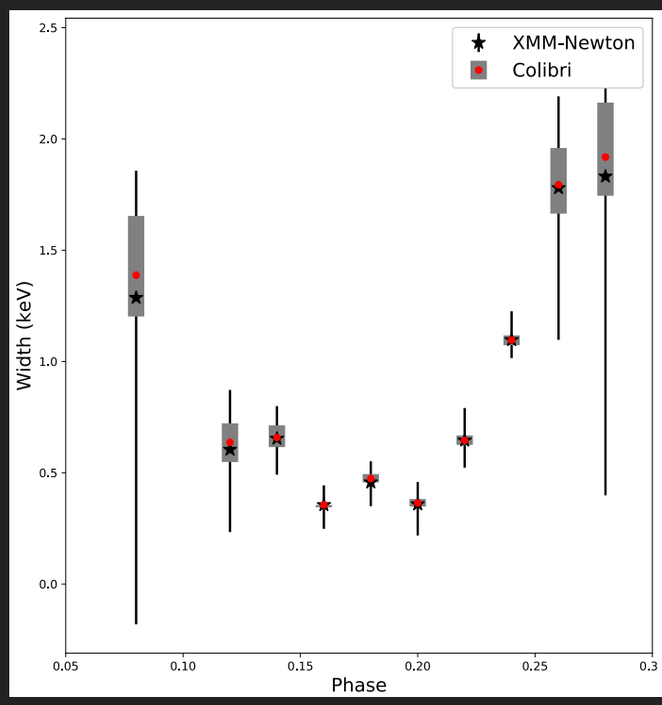


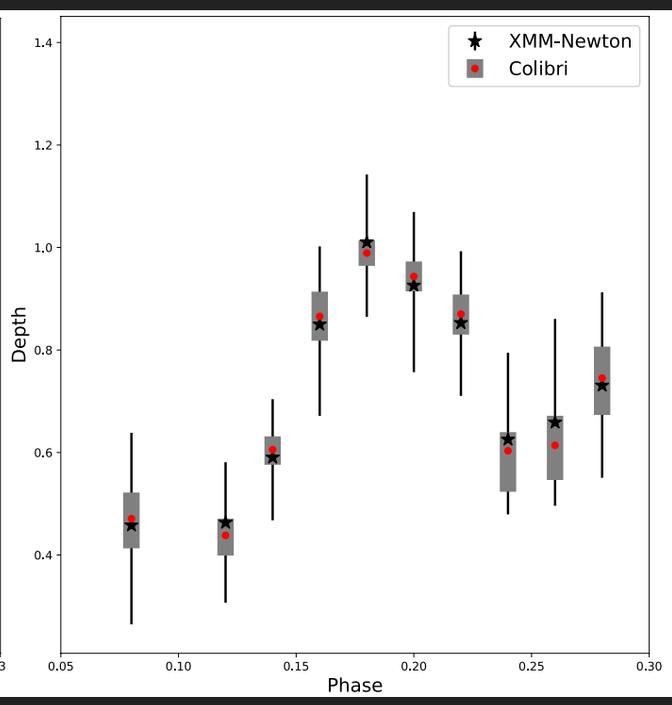
Key mission specs:

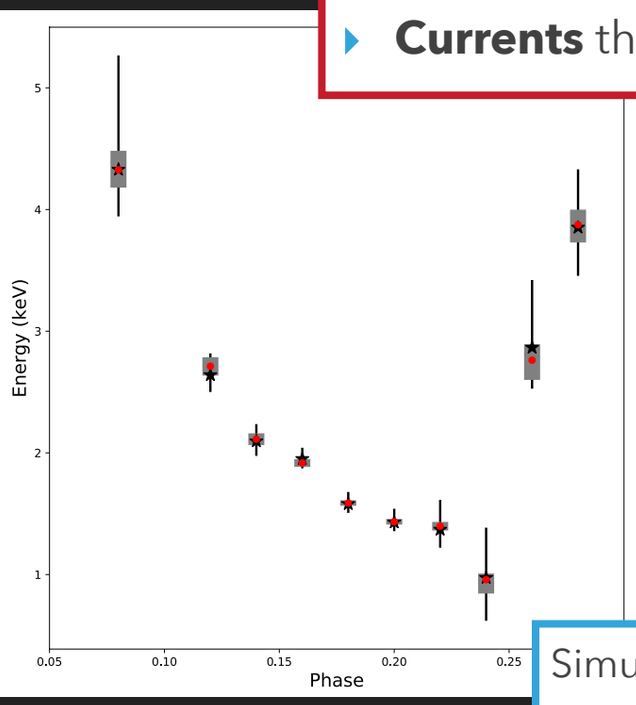
High-Spectral Resolution
High Throughput
Good timing

We can observe

- **Strength** of magnetic field
- Detailed **structure** of the magnetic field
- **Currents** threading the magnetosphere

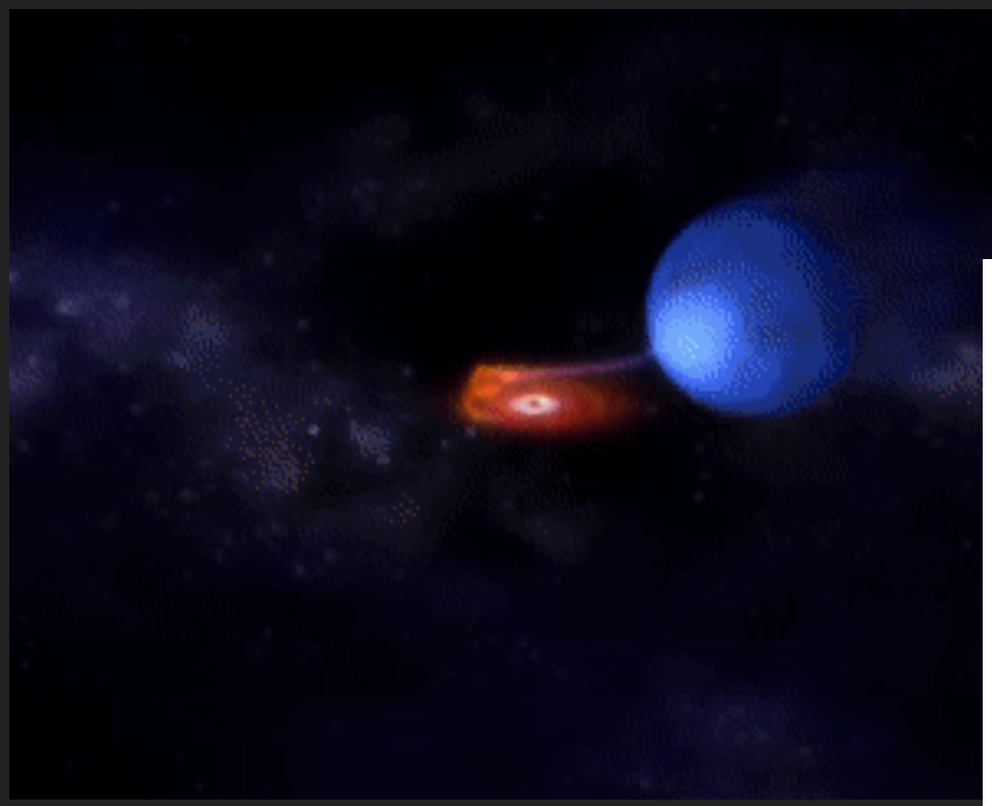




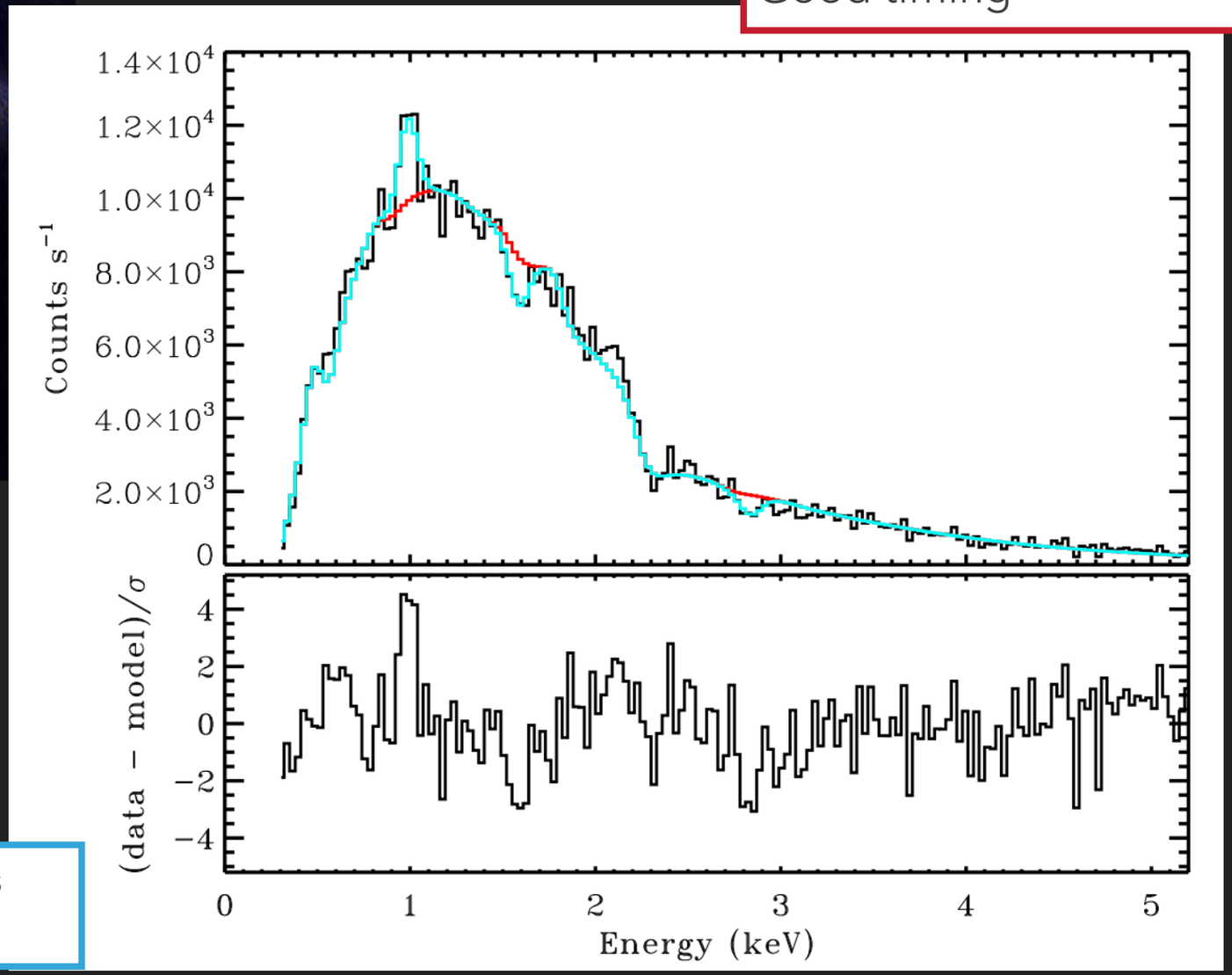


Simulations by Demet Kirmizibayrak, PhD Student at UBC

THE X-RAY BURST IN 4U 1820−30



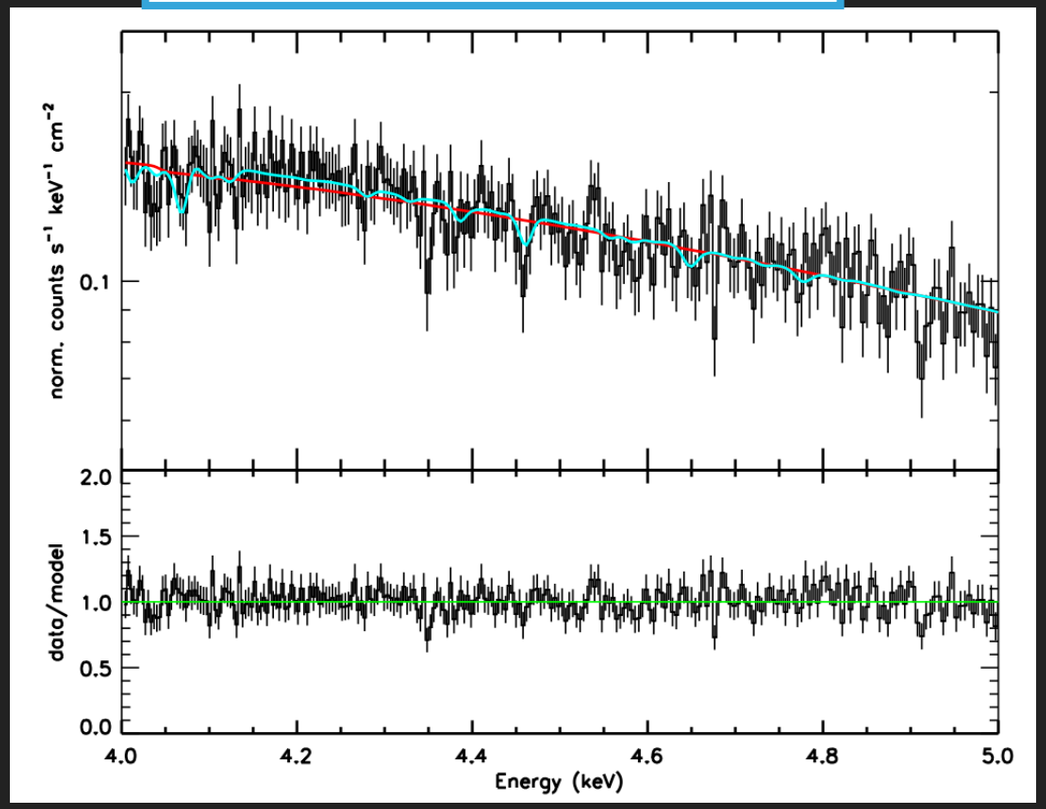
Key mission specs:
High-Spectral Resolution
High Throughput
Good timing



Strohmayer et al 2019, 60 ks observation with NICER

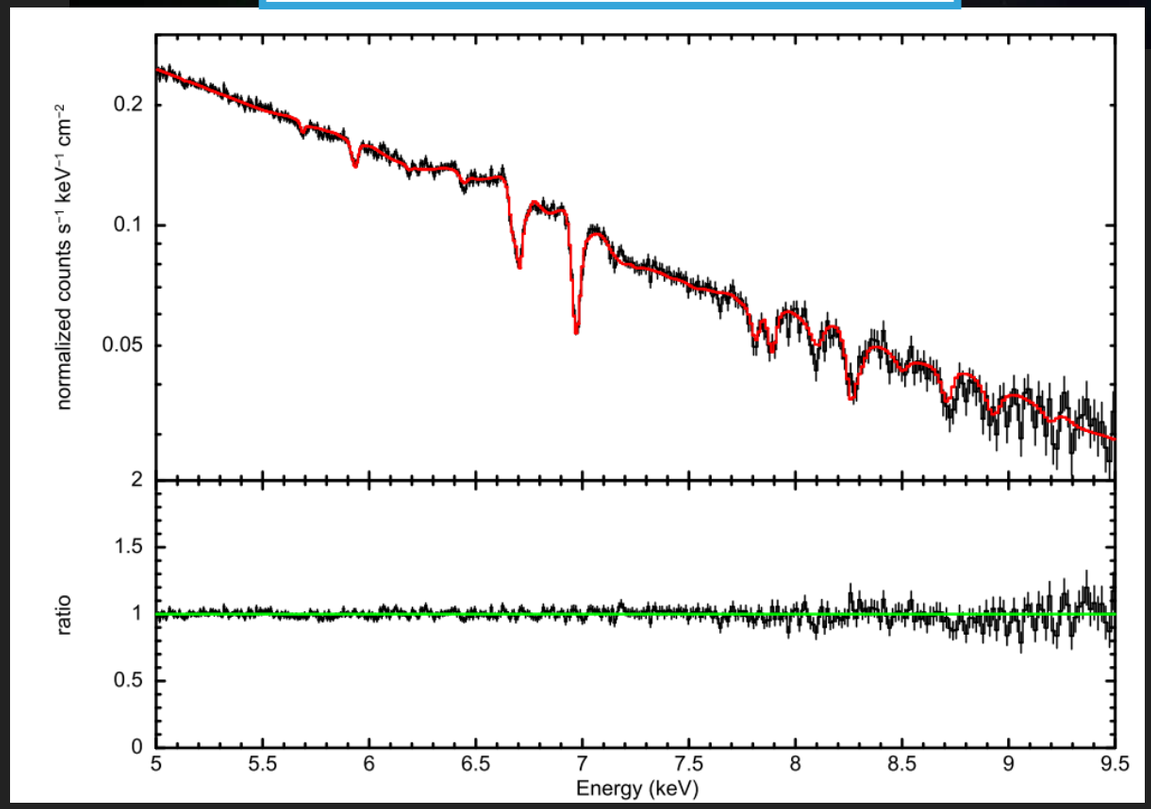
X-RAY BINARIES WINDS

Neutron Star Binary GX 340+0



Miller et al 2016, 6 ks observation with Chandra HEG

Black hole Binary GRS 1915+105



Miller et al 2016, 120 ks observation with Chandra HETGS

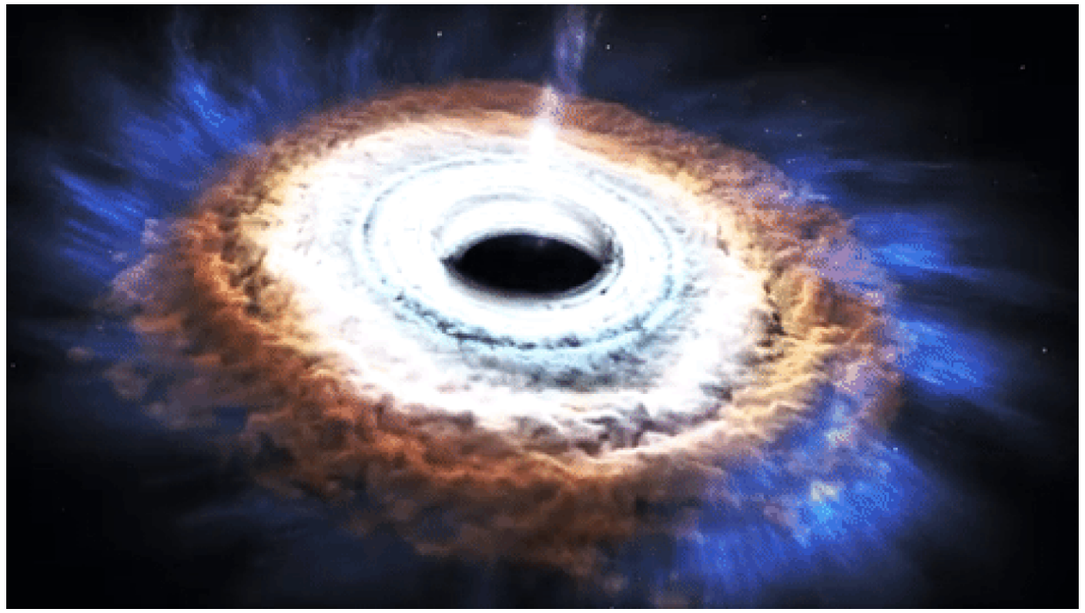
We can observe

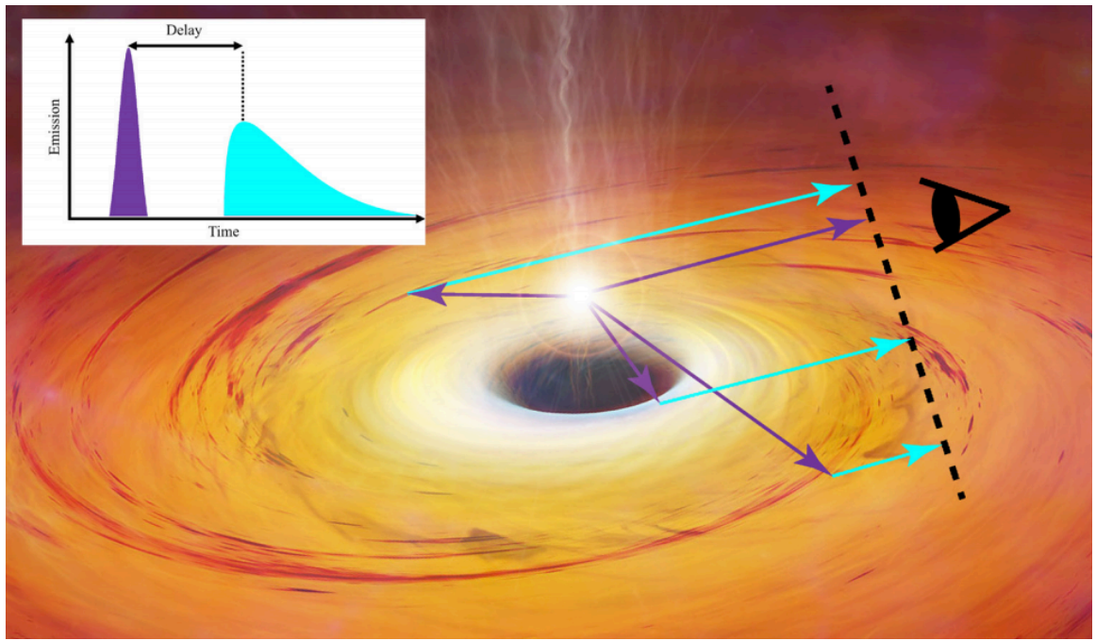
- **Speed** of the winds
- **Composition** and physical properties
- **Strength** of the magnetic field

Key mission specs:

High-Spectral Resolution
High Throughput
Good timing

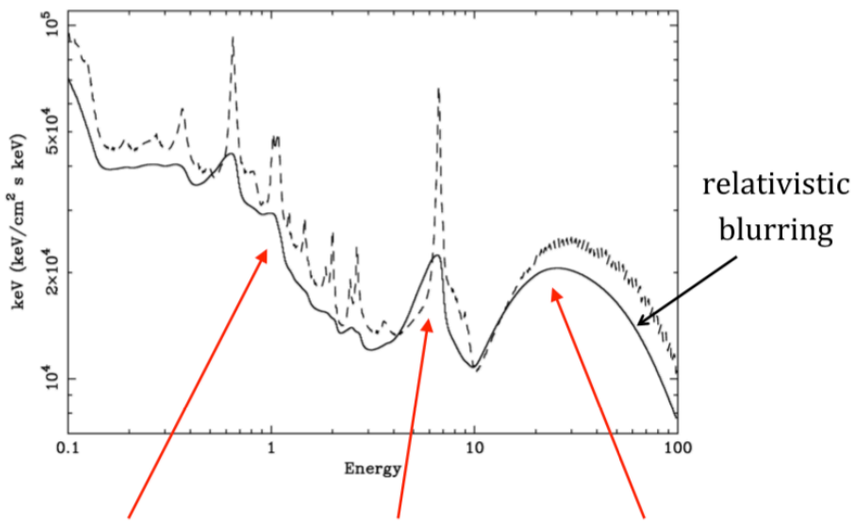
ECHOS FROM ACCRETING BLACK HOLES – REVERBERATION





In the X-ray emission from accreting black holes we can recognize different components:

- The accretion disk - multi-temperature BB
- A hot corona - hard power law
- The reflection of the coronal emission from the disk - observed with a time lag!

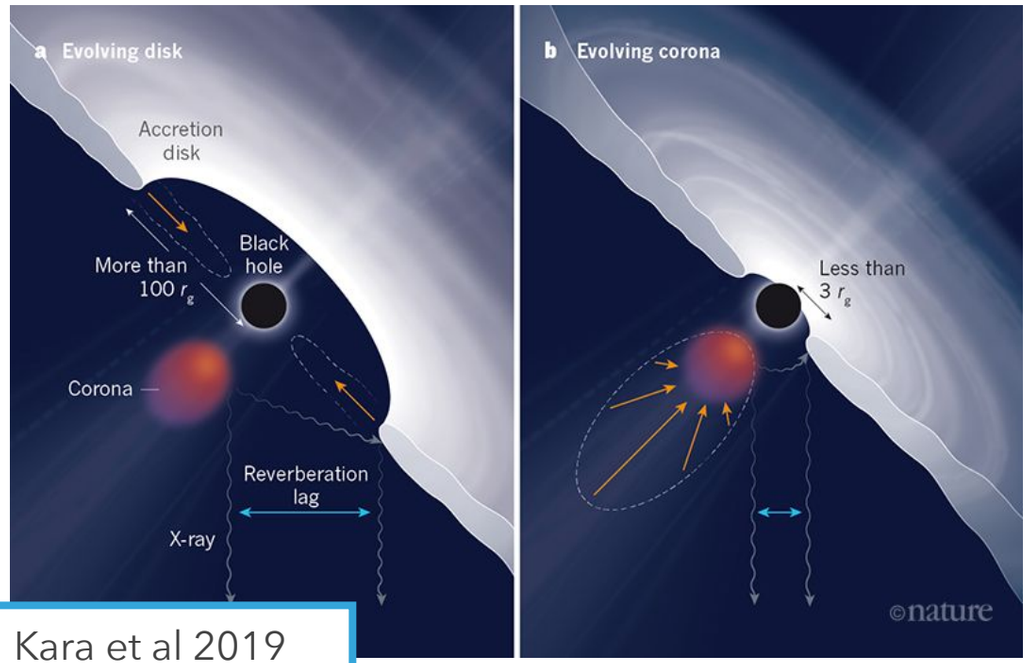


From reverberation is possible

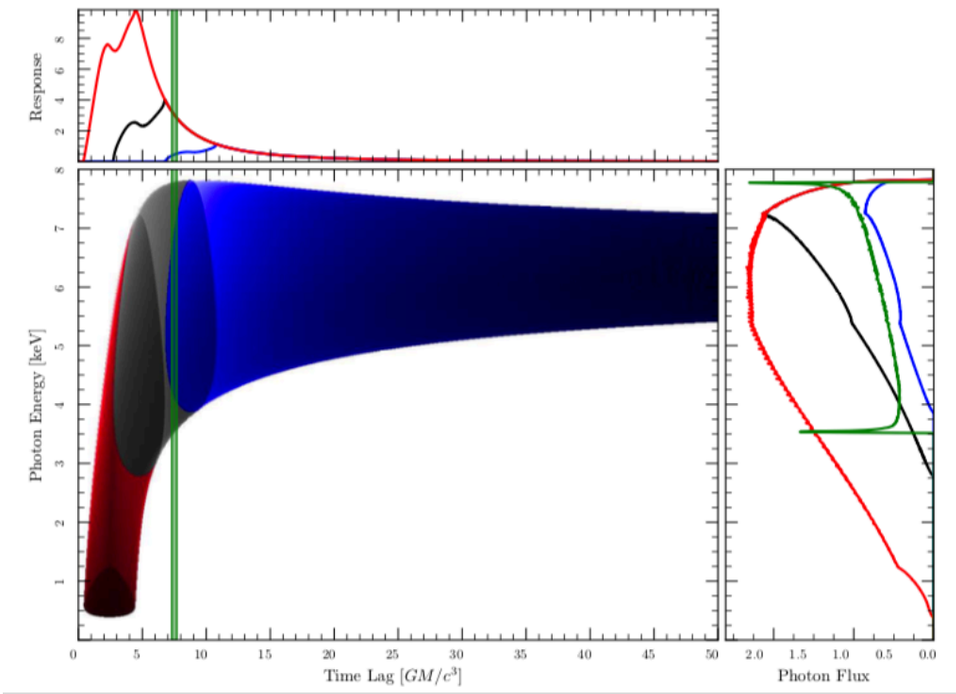
- Put constraints on the **mass** of the BH
- Investigate the **geometry** of the corona
- Study the physics of the **accretion flow**
- Probe the **strong gravity** regime close to the BH

ECHOS FROM ACCRETING BLACK HOLES – REVERBERATION

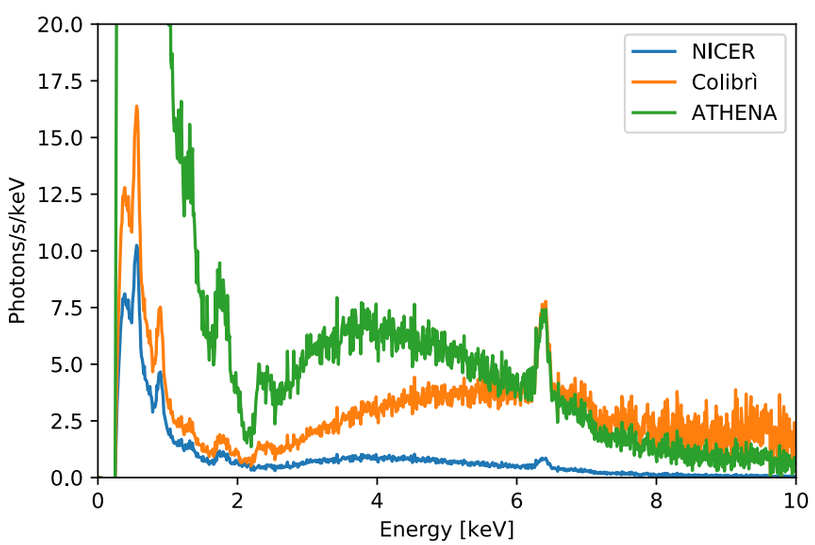
Current results are mainly for AGNs (longer timescales). NICER allowed using the technique for a stellar mass black hole.

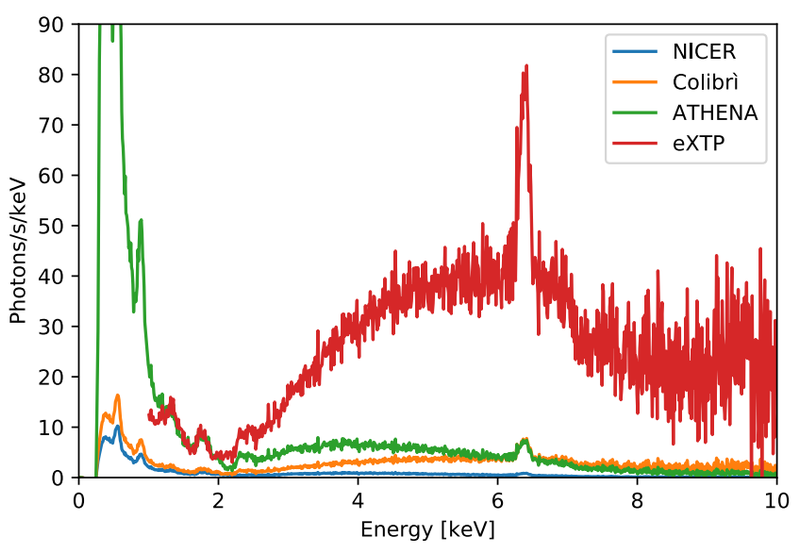


Kara et al 2019



However, in order to analyze the response function in time and energy we need better resolution and throughput





Simulations for NGC 4151 by Demet Kirmizibayrak, PhD Student at UBC

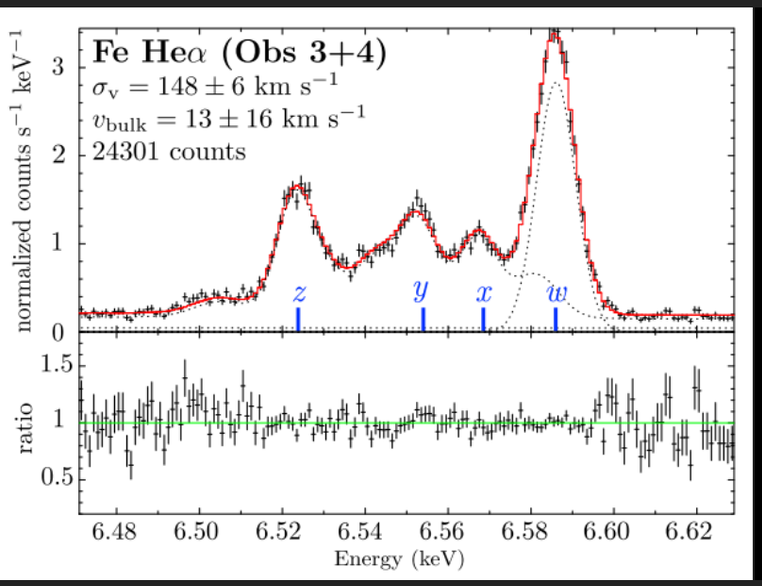
Key mission specs:

High-Spectral Resolution
High Throughput
High Timing Resolution

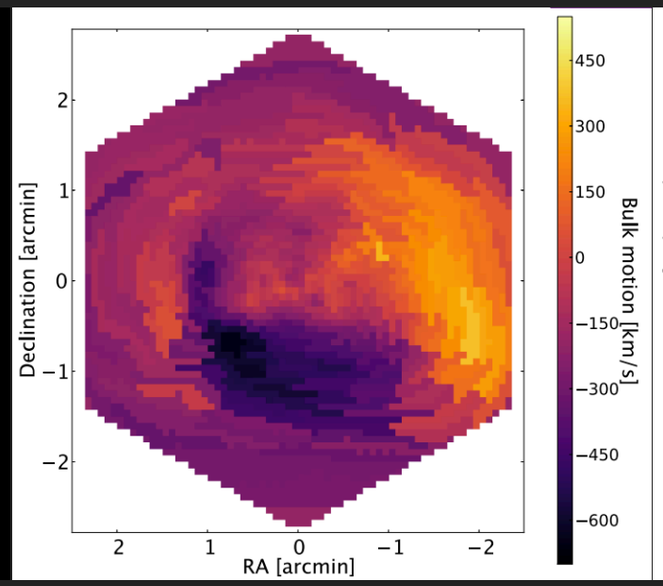
GALAXY CLUSTERS – BULK MOTIONS AND CHEMICAL EVOLUTION

The intracluster medium (ICM) is continuously enriched by supernovae and NS mergers in galaxies. The new telescopes will be able to measure

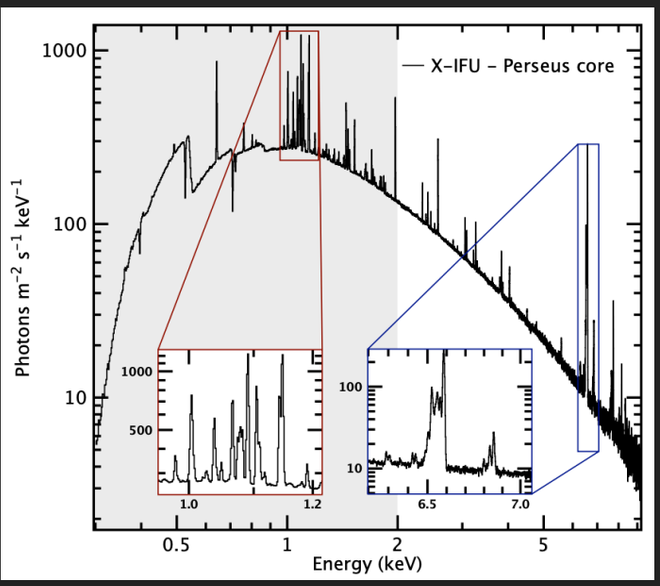
- Abundances of heavy elements
- Evolution of the abundance ratios
- Spatially resolved abundance profiles
- Bulk and turbulent motions through measurements of the shifting and broadening of the lines in the ICM



Hitomi Collaboration et al 2018
320 ks observations with SXS on Hitomi



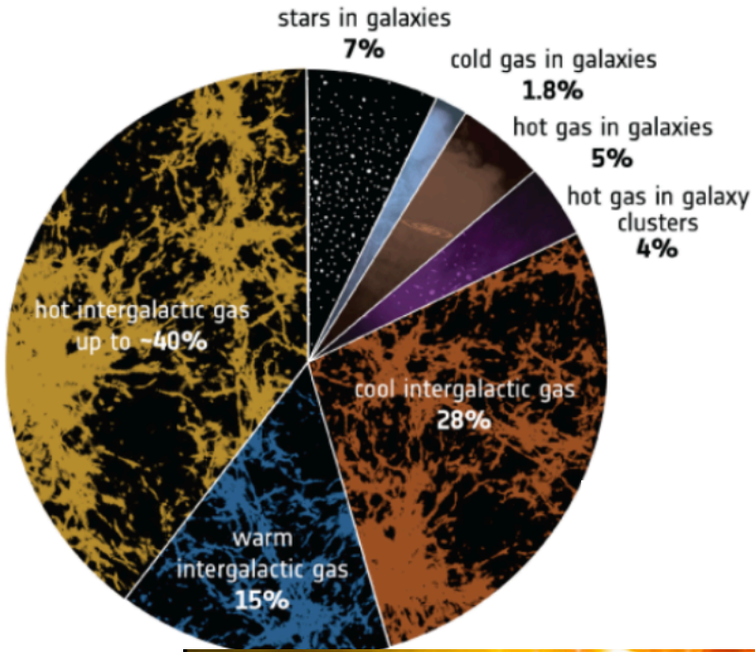
Rasia et al. 2015, Simulation for Athena X-IFU

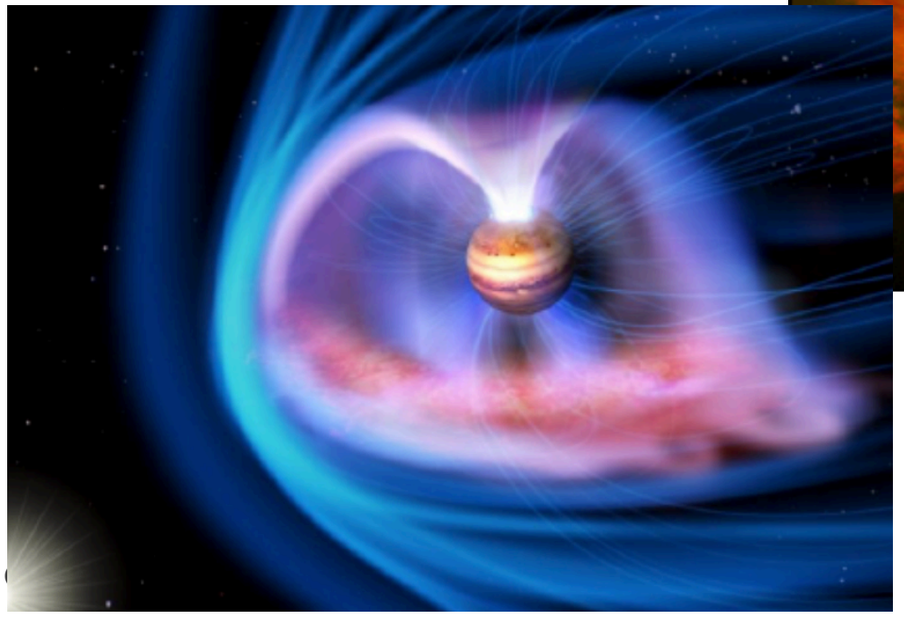


Barret et al 2016, 100 ks simulation for Athena X-IFU

AND SO MUCH MORE!

- Hunting for the missing baryons in the local Universe
- Study the composition of supernova remnants
- Understand the coronal mass ejection in stellar flares
- Investigate the mysterious ultra-luminous X-ray sources
- Studying the aurorae of Jupiter and Saturn
- Finding and mapping the earliest star formation sites with GRB afterglows
- Searching for the seeds of supermassive black holes
- …





RECOMMENDATIONS

- The Canadian high-energy astrophysics community is world-class level, and its members are playing leadership roles in HEA efforts across the globe; a focus and push on X-ray science will position them naturally as leaders in the new high-resolution spectroscopy era.
- “The Canadian space community is actively seeking to leverage their existing expertise to become a partner in the next-generation X-ray observatories”. At the same time, the Canadian Space Agency should seek participation in the facilities currently planned or under development. “Having access to next generation X-ray instruments will ensure that Canadian researchers can carry out the groundbreaking observations needed to lead in the field”.
- Many of the upcoming instruments are based on transition-edge sensor (TES) technology, and not only in the X-rays. The Canadian scientific community is already leading in this sector and shall keep pushing for the development of advanced TES arrays in Canada.