EHIME UNIVERSITY

領域研究会
2024 Nov. 18

and outflows

Probing hot Comptonizing plasma in the vicinity of black holes through observations of X-ray binaries

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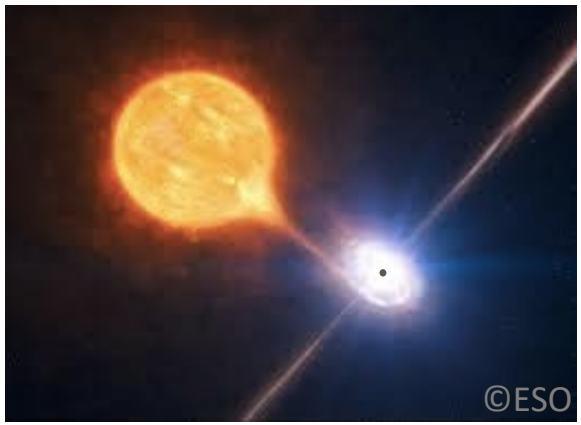
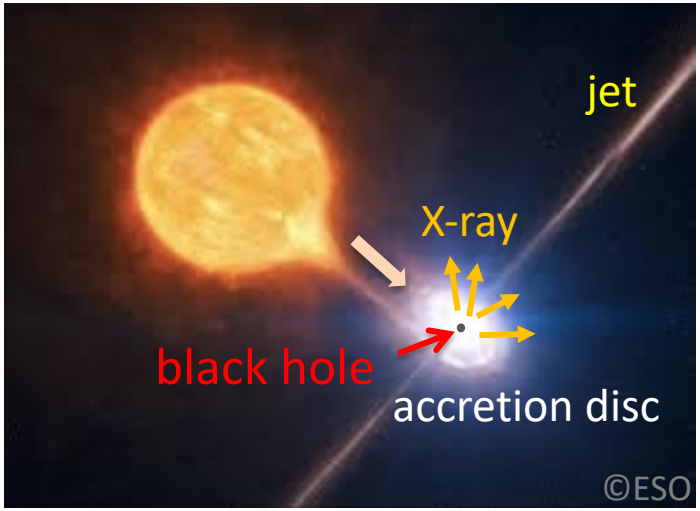
（Ehime Univ.）

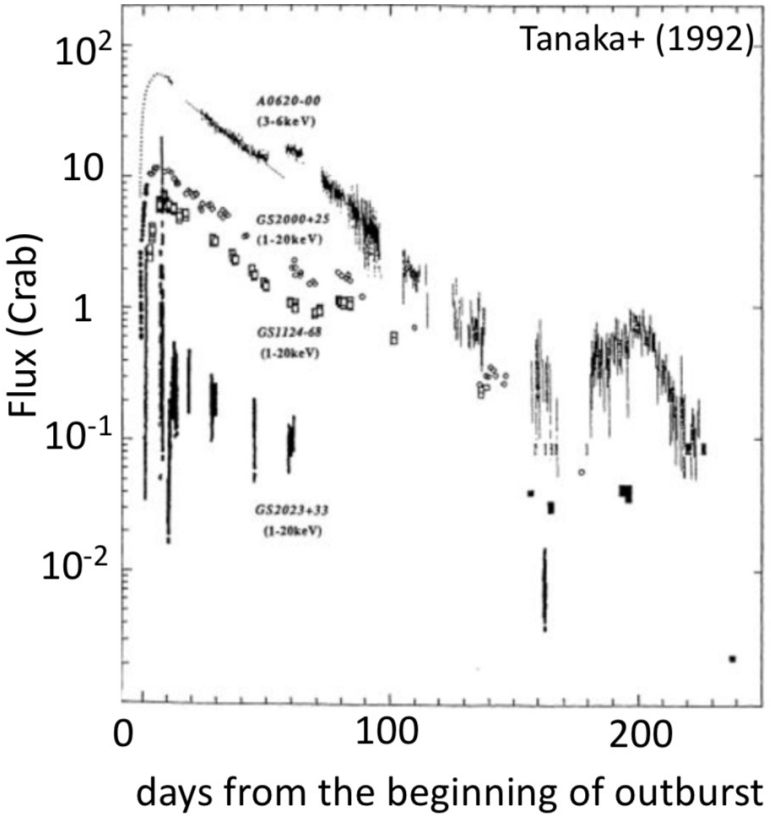
Special thanks to:
Wataru Iwakiri, Hitoshi Negoro, Taiki Kawamuro, Chris Done, Maria Diaz Trigo, Maxime Parra, Teo Munoz Darias, Yoshihiro Ueda



Black hole (BH) X-ray binaries



light curves of BH X-ray binaries



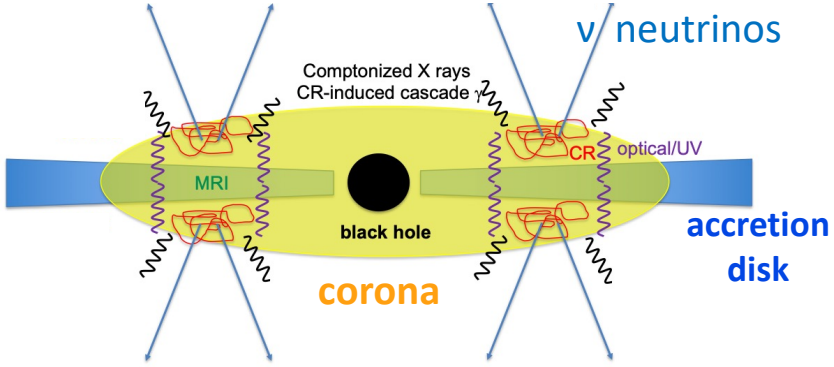
Most sources found so far are transients,
increasing the X-ray flux
by ~several orders of magnitude
in their outbursts

Best laboratories to study the evolution of black hole accretion flows and outflows over a wide range of mass accretion rates

Also important in terms of particle acceleration

Hot plasma around BH as a source of high energy neutrino

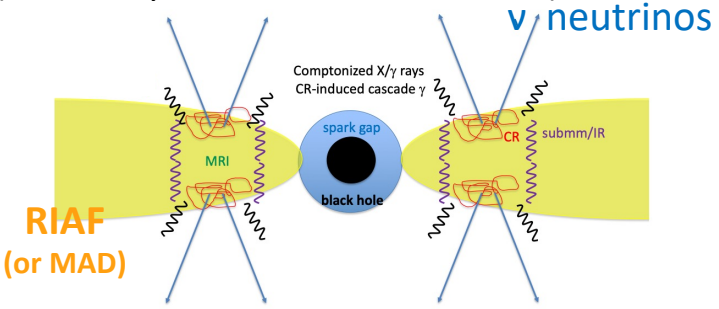
accretion disk corona



CR: Cosmic ray
MRI: magneto rotational instability

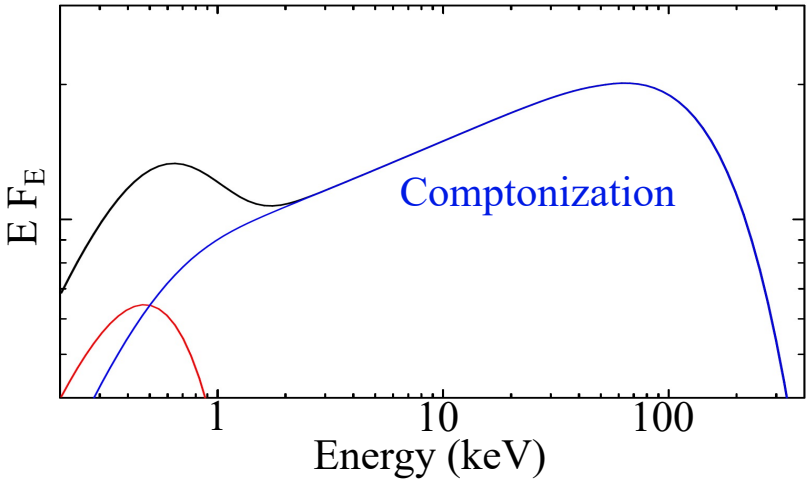
RIAF

(radiatively inefficient accretion flow)



Murase & Stecker 2022

Essential parameters of hot plasma (such as the T, τ, size) can be determined from broad-band X-ray spectra



Compared with AGN, BH X-ray binaries:

- are located much closer to us and become very bright in X-rays

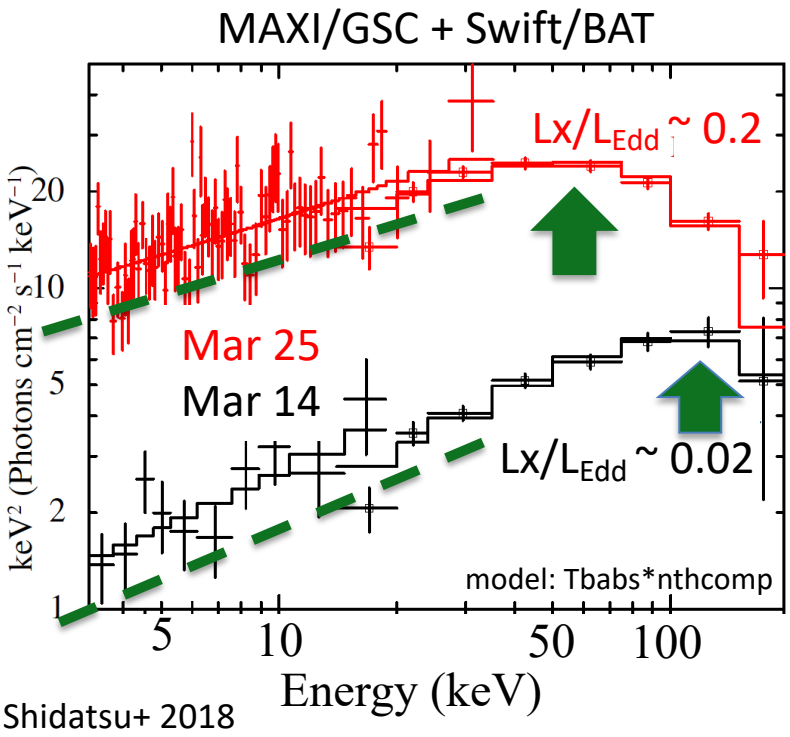
→ **We can get data with very good statistics!**

- vary Lx on much shorter time scales

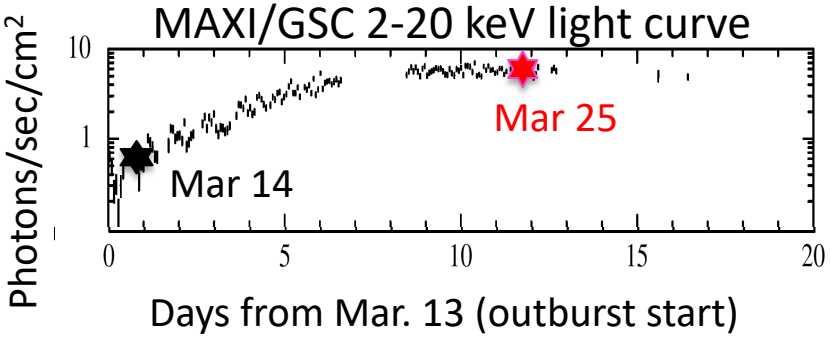
→ **We can probe the evolution of hot plasma over a wide range of mass accretion rate**

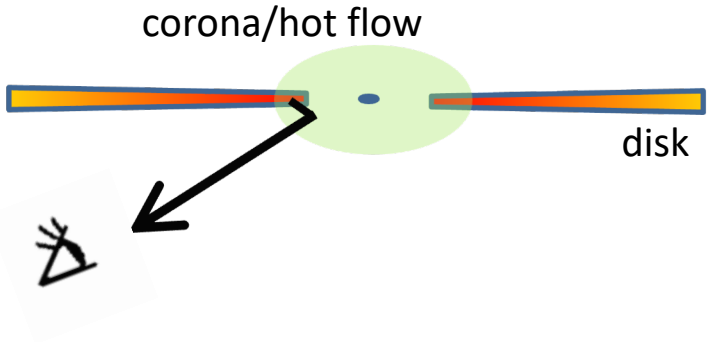
Evolution of hot plasma with the X-ray luminosity

MAXI J1820+070 (BH X-ray binary)



Shidatsu+ 2018





- cutoff energy (-> kTe)
- photon index
  (-> Compton y parameter)

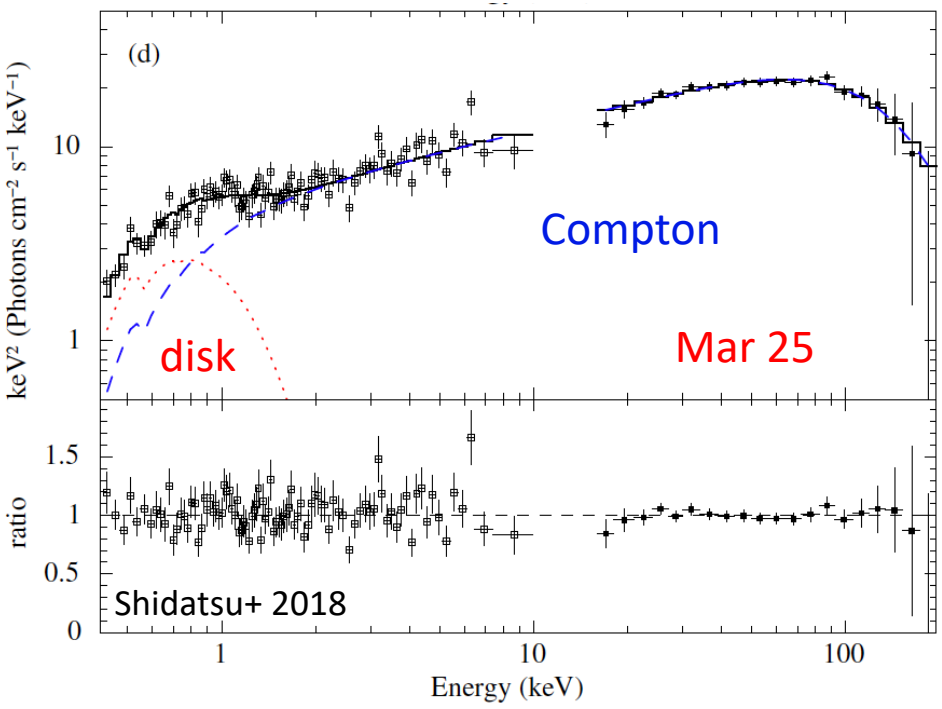
significantly change with Lx!

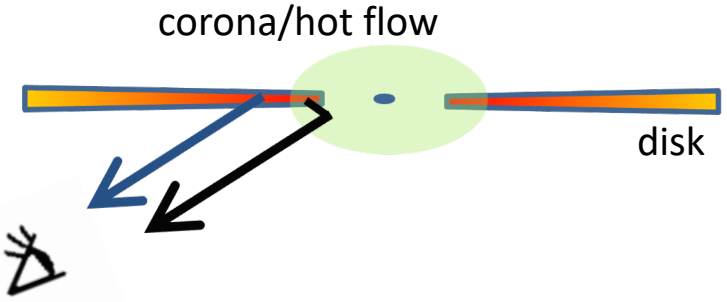
Compton $y = 4 \tau kT_e/m_e c^2$

Evolution of hot plasma with the X-ray luminosity

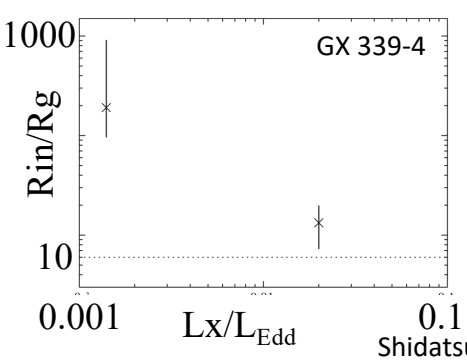
MAXI J1820+070 (BH X-ray binary)

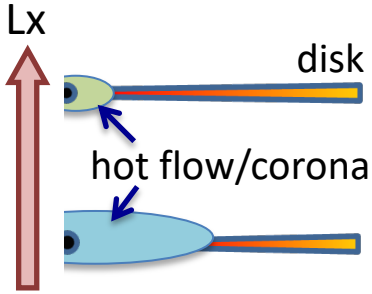
Swift/XRT + Swift/BAT





- The inner radius of the disk can be determined from soft X-ray spectrum
  → information of the size of the hot plasma





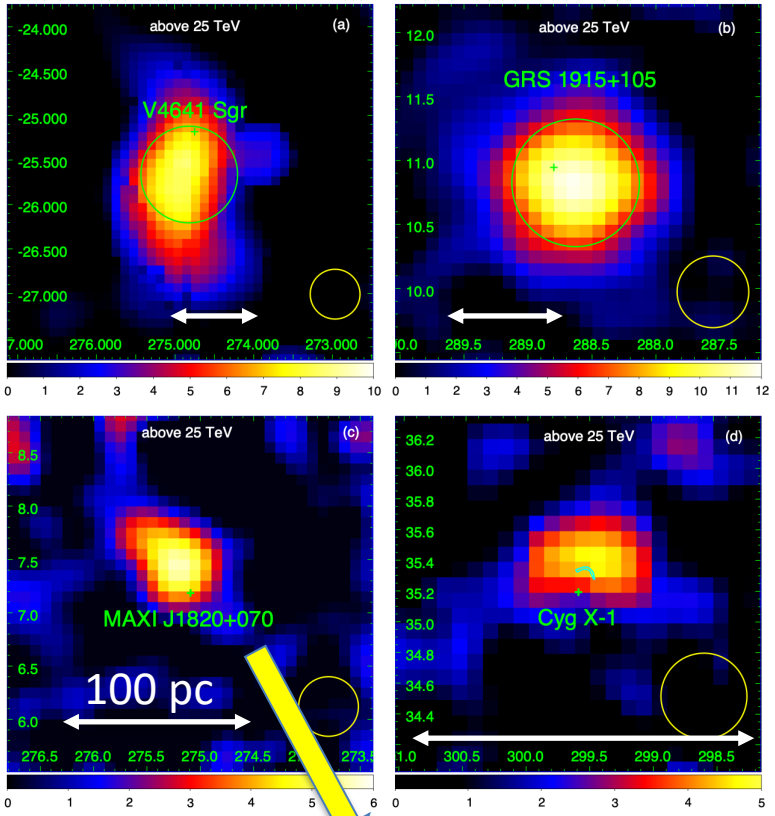
Monitoring broad-band X-ray spectrum enables to understand how the properties of the hot plasma evolves with Lx

BH X-ray binaries with jets (microquasars) are ultra-high-energy gamma-ray emitter?

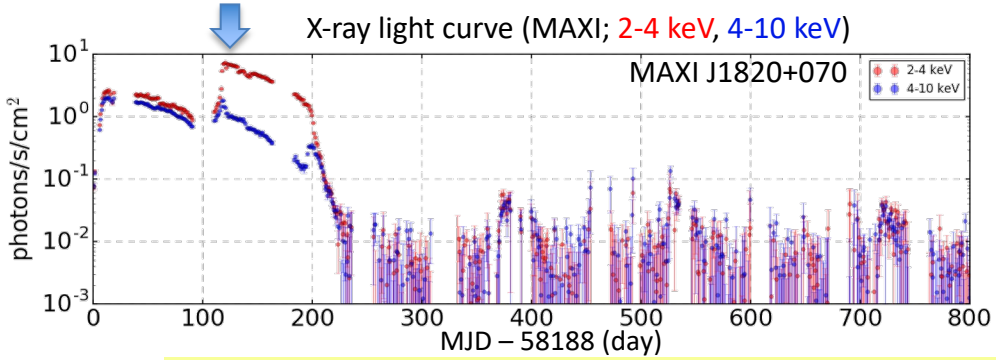
LHASSO and HAWC detected extended (~10-100 pc) ultra-high-energy (1-100 TeV) diffuse emission around several microquasars.
→ Efficient producers of PeV cosmic rays via jets - ambient matter interaction?

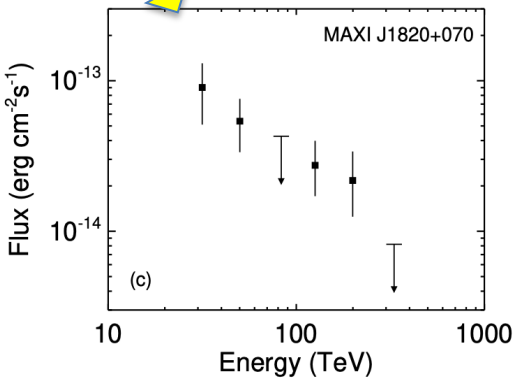
But…

Relativistic large-scale jets are only seen in a very limited period.
Can they provide the large-scale high energy gamma-ray structure??



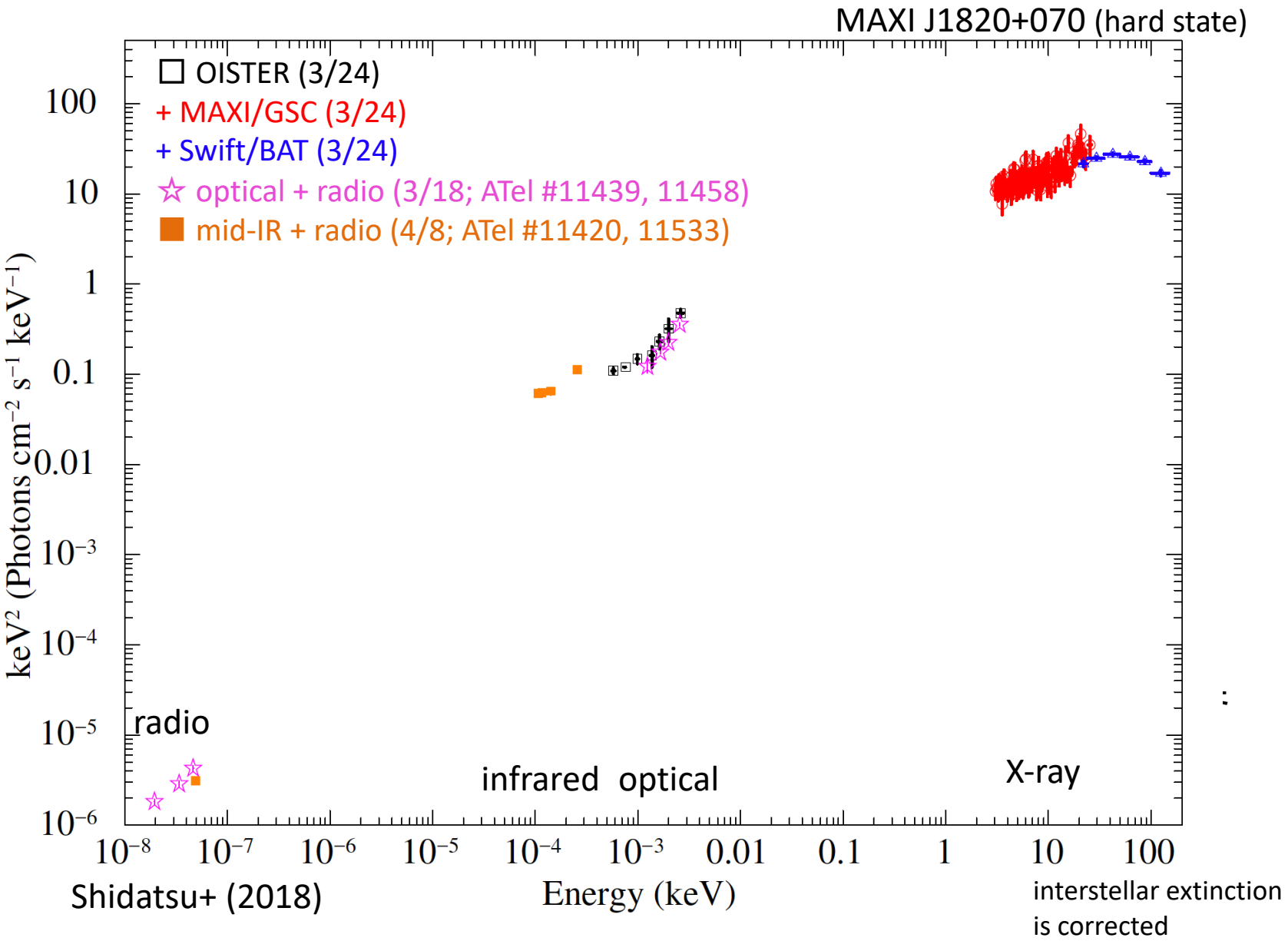
jet ejection



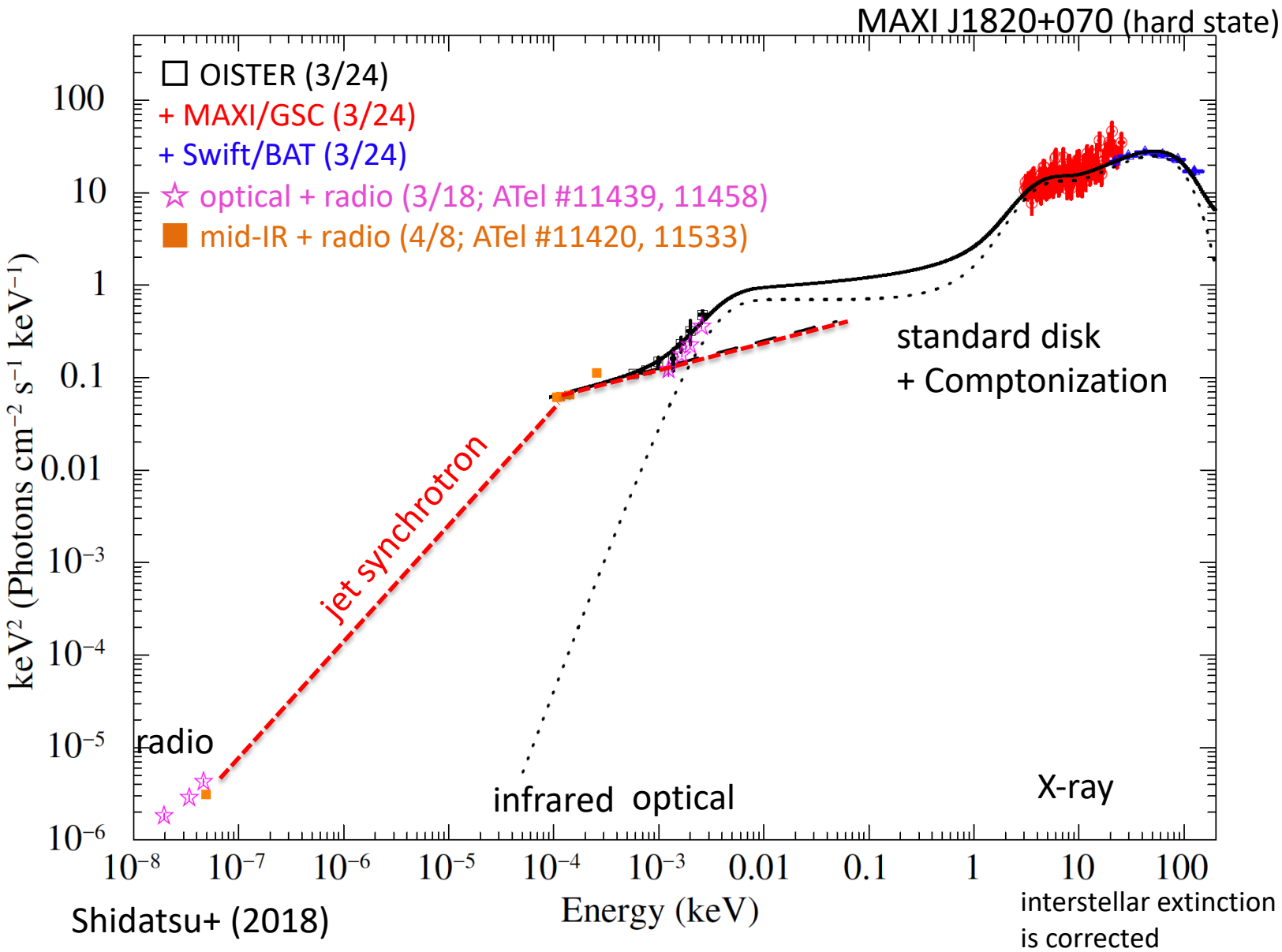


How much energy the large-scale jets carry?

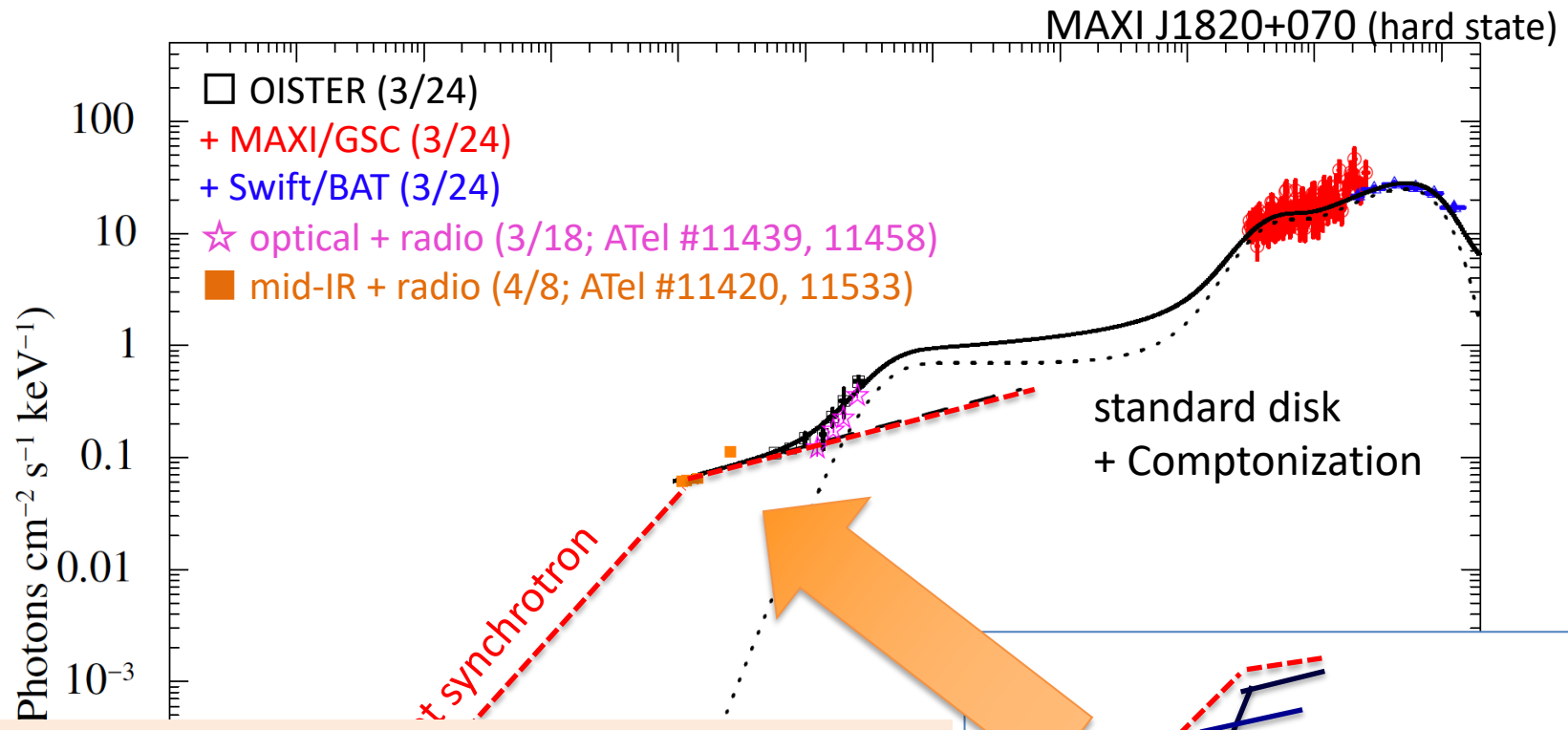
multi-wavelength SED

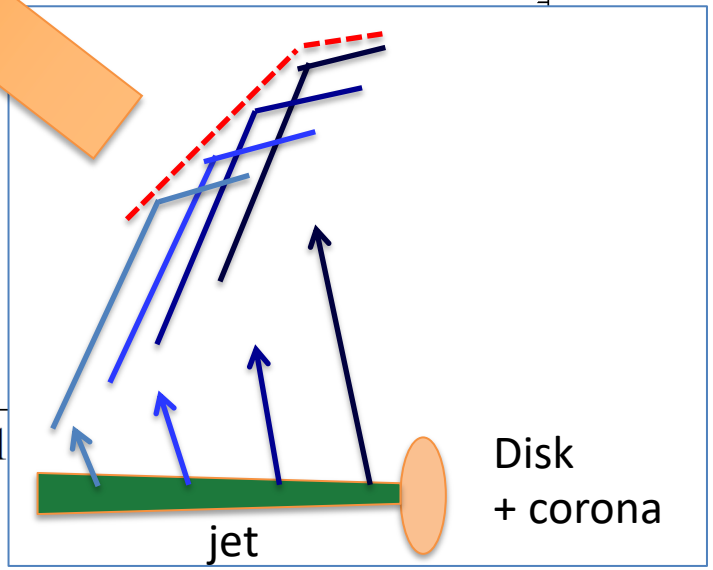


multi-wavelength SED



multi-wavelength SED





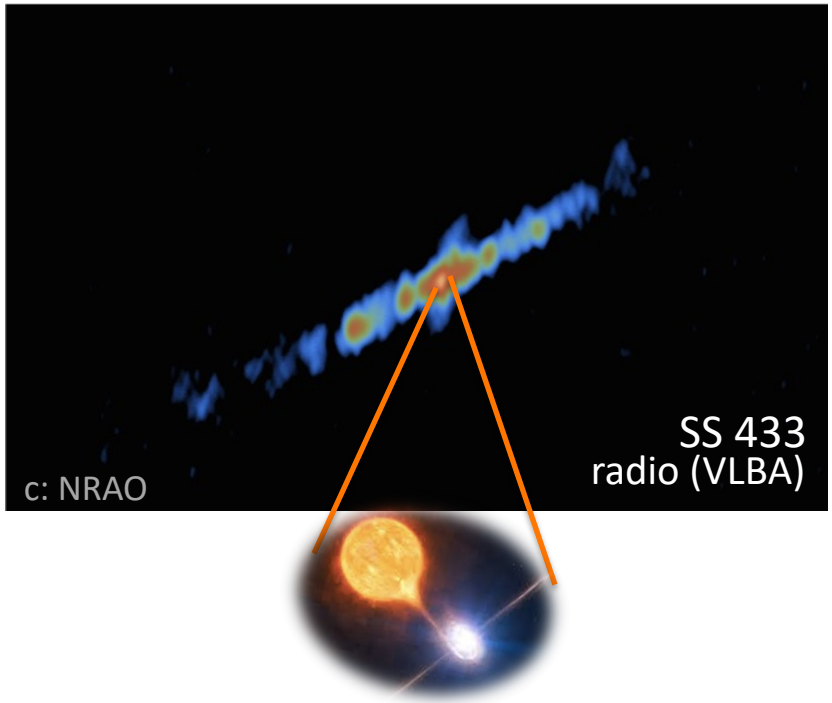
The spectral index above the break gives the energy distribution of electrons

Spectral break ($\tau \sim \alpha_{\nu_B} R \sim 1$) gives the size and magnetic field strength (B) in the **jet base**.

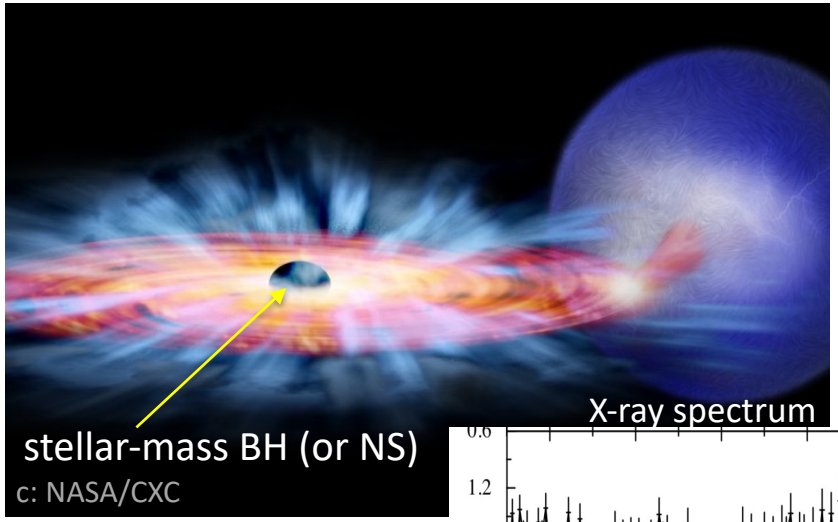
Multi-wavelength monitoring is essential to uncover the evolution of jet structure and energetics

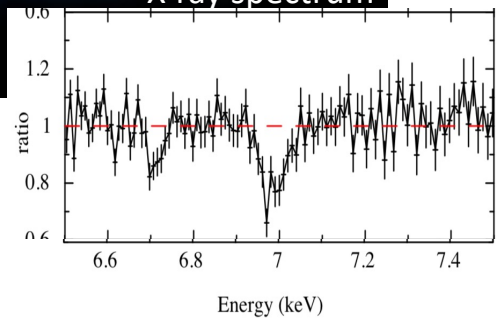
Powerful outflows from BHs

jet



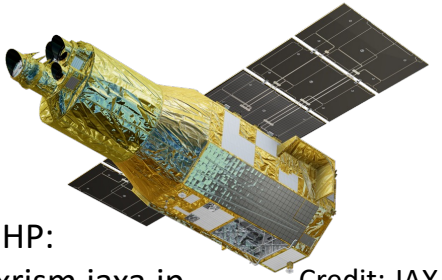
disk wind





- disk winds (observed as blueshifted lines) also carry a large amount of mass and energy
- how much the gravitational energy released by accretion is distributed into jets and winds?

XRISM



official HP:
http://xrism.jaxa.jp

Credit: JAXA

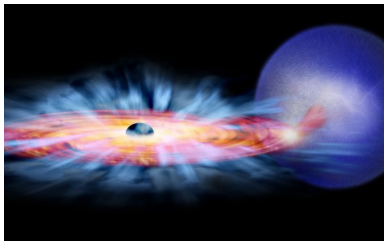
new X-ray satellite developed by JAXA
in collaboration with NASA & ESA

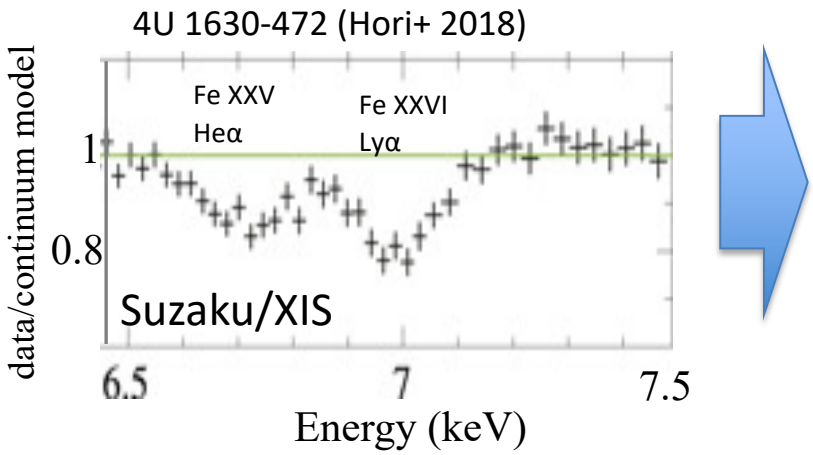
See Bamba-san's talk for more details

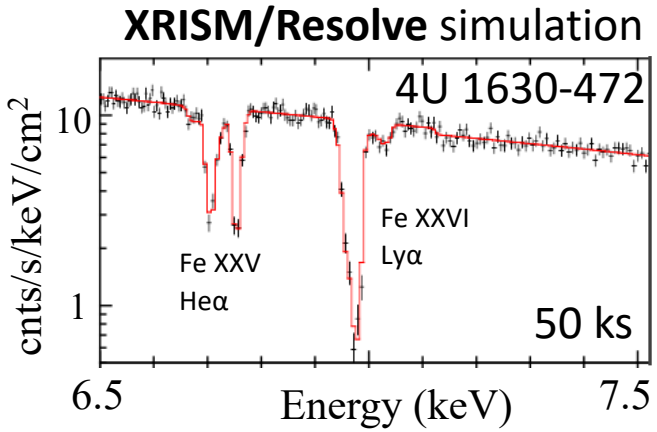
X-ray micro-calorimeter (Resolve)

unprecedented high energy resolution (~5 eV @ 6 keV)

→ **enables to uncover the launching mechanism and feedback effects of winds**





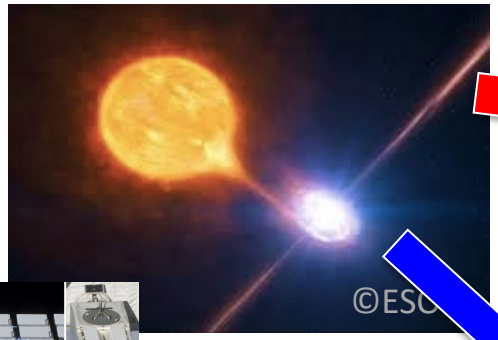


→ **Actually observed in 2024 Feb.**
(the first ToO observation;
XRISM collaboration, in prep)

XRISM + multi-wavelength monitoring program during the state transition has been approved!

Summary

- **broad-band X-ray spectroscopy** is important
  to get the essential information of hot accretion flow/corona
  (e.g., the electron temperature and the size)
- **multi-wavelength monitoring** is key to understand the
  energetics of accretion and outflow (jets and disk winds)
  and their interactions as a function of the mass accretion rate

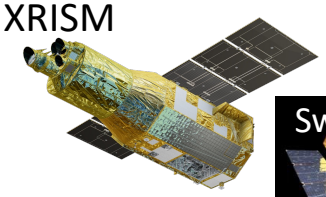


MAXI

jet (radio, IR, optical)

accretion disk/corona
& wind (X-ray)

XRISM



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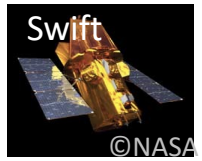
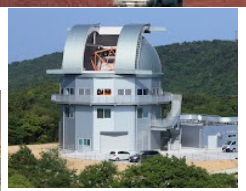


MiTSuME(Tokyo Tech.)



Seimei (Kyoto univ.)