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The 2nd XRISM Community Workshop

# Geometric constraints for AGN and ULX with XRISM and MONACO

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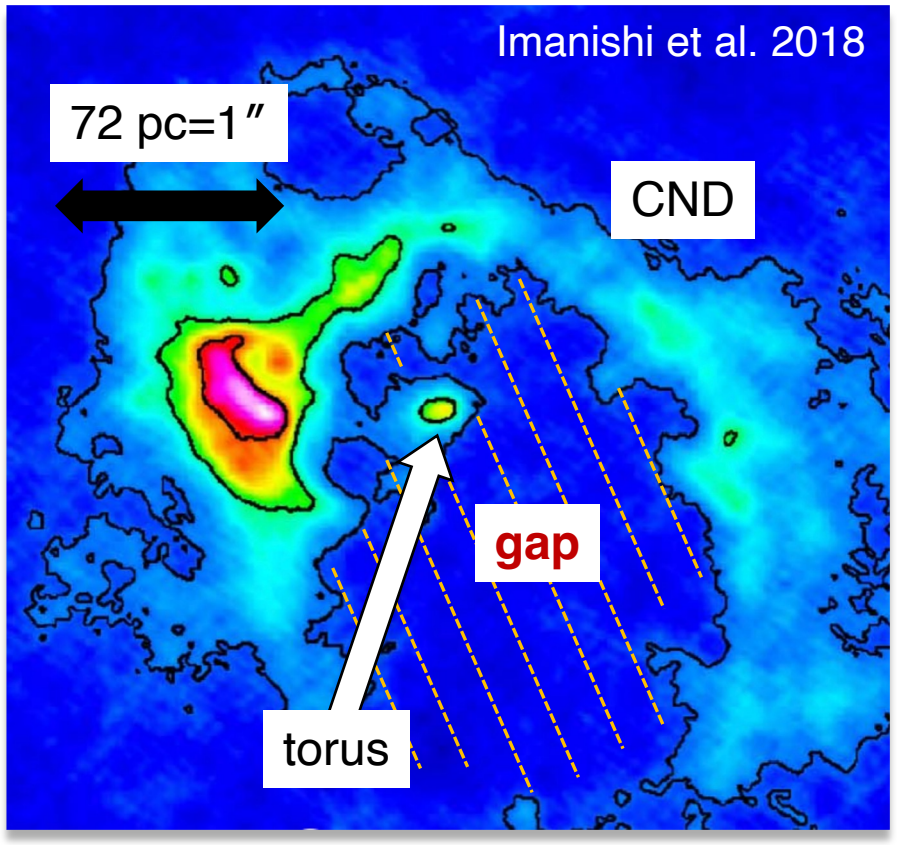
# Molecular Gas Gap around AGN

e.g., NGC1068 AGN region

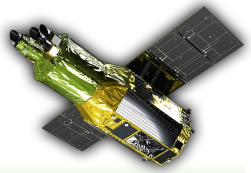



HCN (J=3-2) moment 0 map

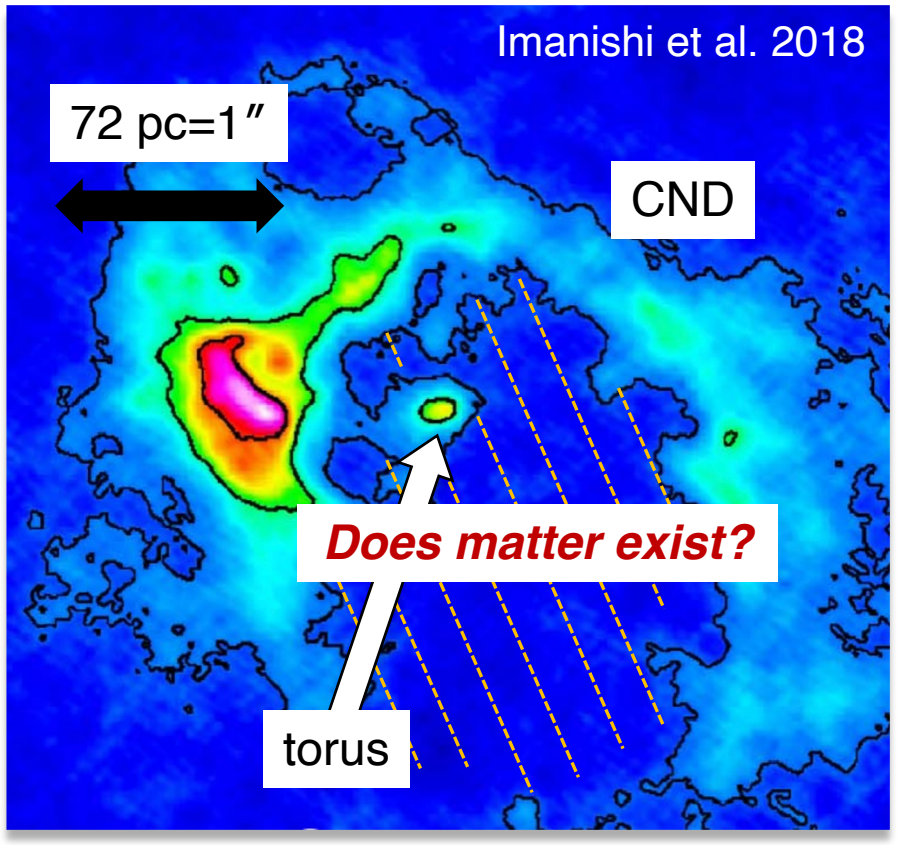
- The **mechanism of mass transport from host galaxies to SMBHs** ( = how they lose angular momentum) is still unclear

- **“molecular gas gaps”**
  - < 10 −100 pc
  - between a circum-nuclear disk (CND) and a torus
  - in radio band

# Beyond Radio Observation



e.g., NGC1068 AGN region




**HCN (J=3-2) moment 0 map**

− Radio Observation

・high angular resolution (< 0.1 arcsec)

・high statistics

⇨ Suitable for measuring matter distribution

but … depends on

**specific molecule** and **rotational transition level**

− For the **molecular gas gaps**, we cannot distinguish…

・**matter exists but is unobservable in the radio band ( “connected model” )**

⇨ radio observations are not enough to trace mass transport…

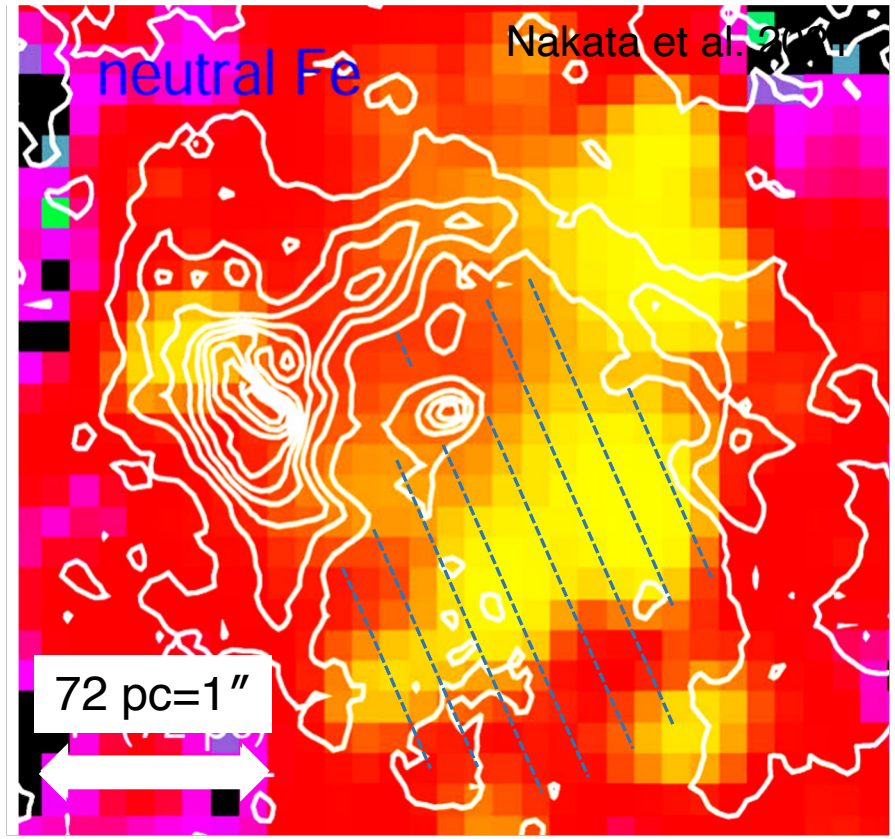
and

・**matter does not exist ( “gap model” )**

⇨ new mechanisms to decrease angular momentum are needed!

# X-ray Observation

e.g., NGC1068 AGN region




**Fe 6.4 keV Equivalent width map from a Chandra observation**

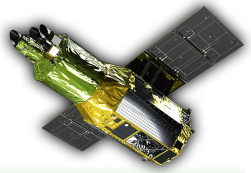
- X-ray observation
  - Atomic emission lines (e.g., Fe 6.4 keV) have **low temperature and density dependence**
  - The atomic distribution anti-correlated with molecular gas? (e.g., Nakata et al. 2021)

but …

- **Equivalent width maps are highly indefinite**
  - ⇨ affected by continuum components
  - ⇨ requires long observation time
- Highest angular resolution is ~ 0.5 arcsec

⇨ We try another way!

# Imaging to Spectroscopy



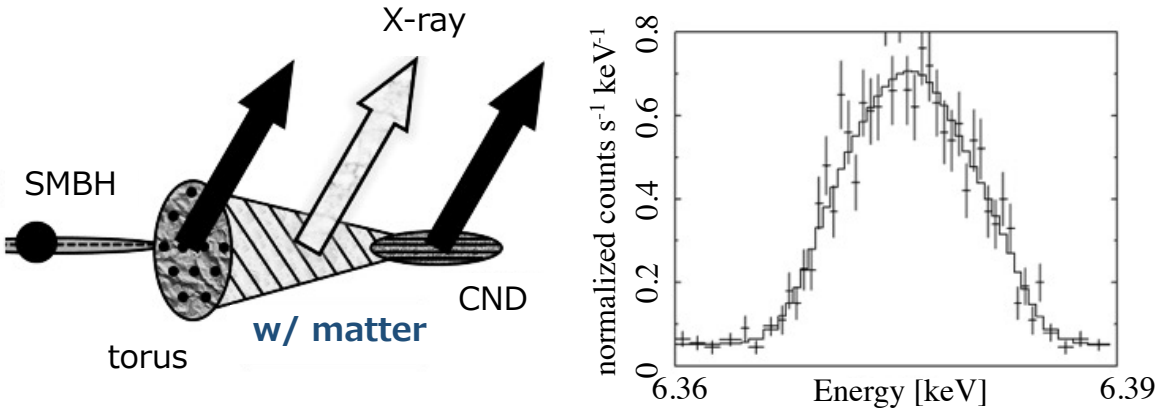
- We use the high energy resolution of XRISM/Resolve to reveal matter distribution!
  - Resolve achieves FWHM < 5 eV @ 6 keV

① Assume matter distribution (Fe 6.4 keV) with Keplerian for **molecular gas gaps**

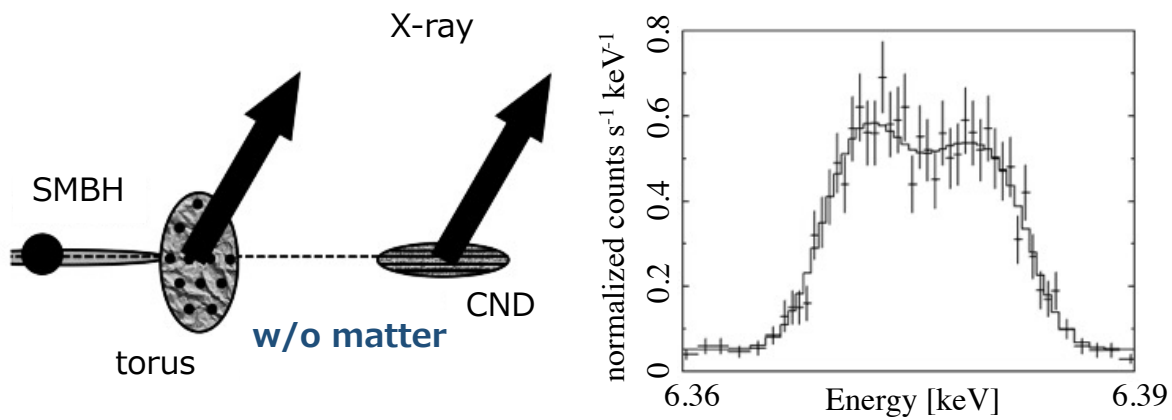
**a) matter exists continuously ( “connected model” )**

**b) matter does not exist ( “gap model” )**

② Compare the line models with the observations and determine the matter distribution from the highest likelihood



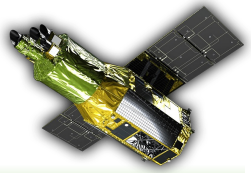

**a) connected model**




**b) gap model**

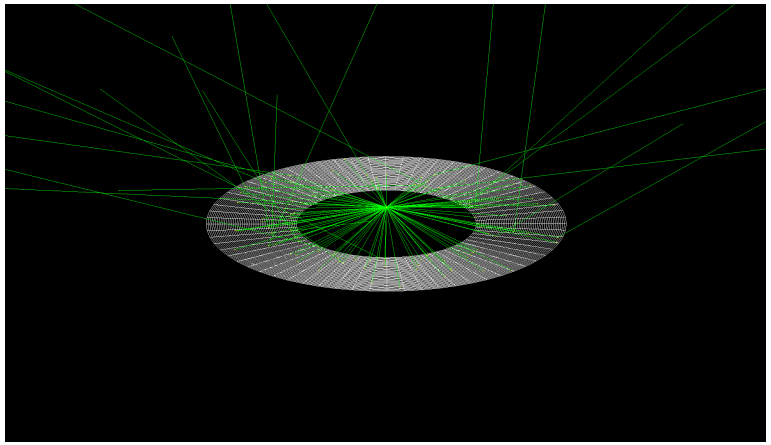
**simulation results of NGC1068 200 ks observation**

# Imaging to Spectroscopy

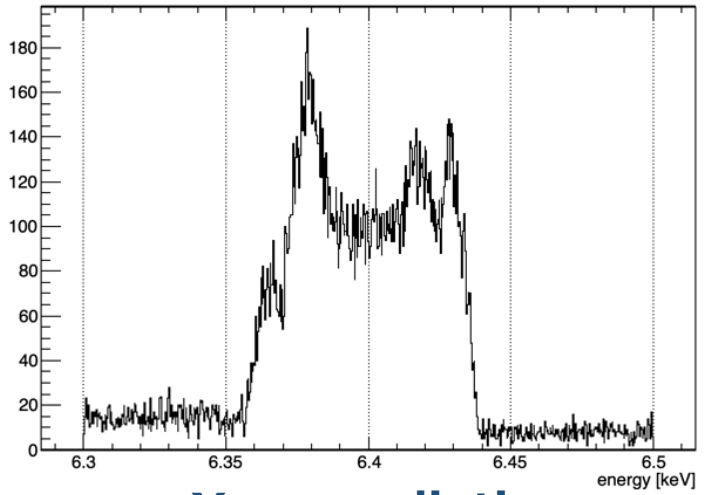


- **MONACO** (**Mon**te Carlo simulation for **A**strophysics and **Co**smology; Odaka et al. 2011) will be used to construct the emission line model from the Fe distribution
  - ・an X-ray radiation calculation code based on a Monte Carlo method
  - ・account for complex geometries, velocity distributions, and multiple interactions between photons and matter

⇨ Useful to constrain geometry of molecular gas gaps!

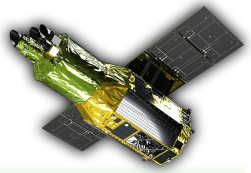


geometry




X-ray radiation

# Neutron Star ULX



- Ultraluminous X-ray Source (ULX)
  - $L_{\rm X} > 10^{39}\ {\rm erg\ s^{-1}}$
  - spectra resemble the Galactic binary
- Nature
  - IMBH in sub-Eddington accretion

    or
  - stellar mass BH or NS

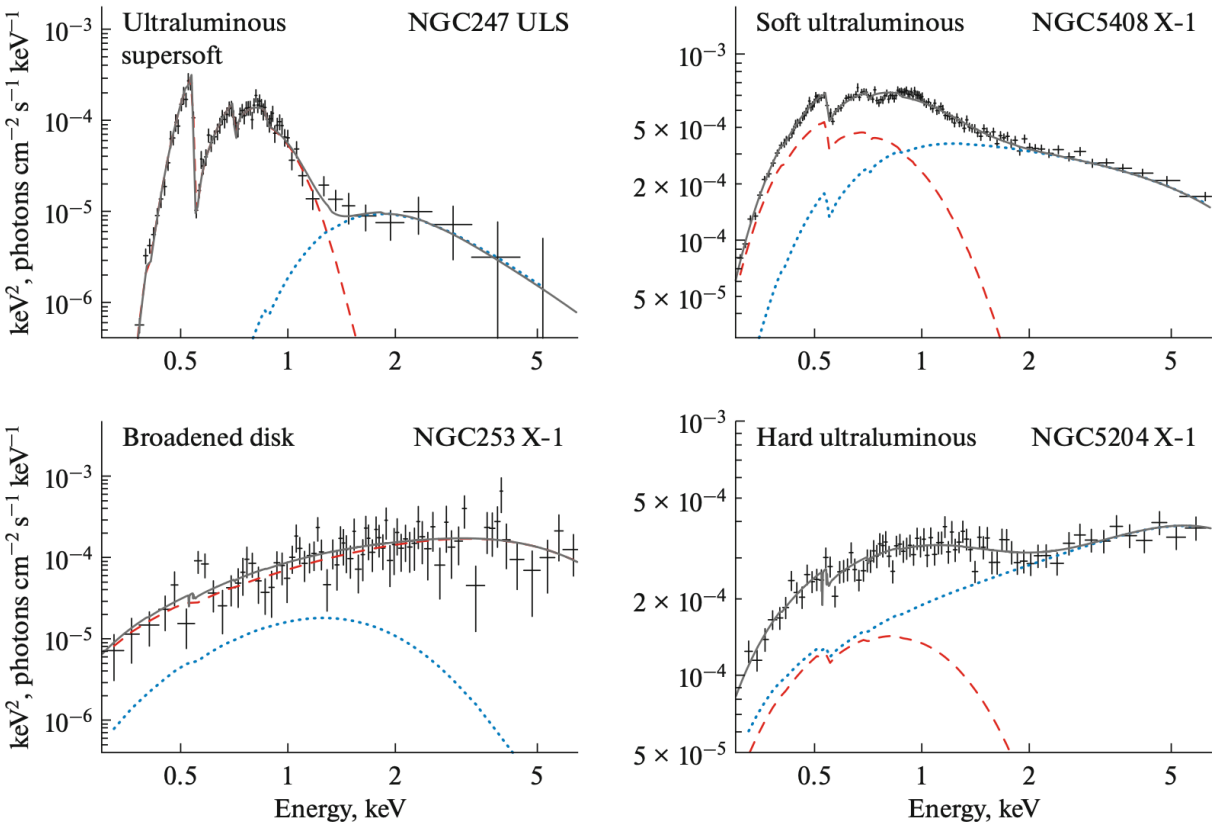
    in super-Eddington accretion

    ⇨ pulsation

    e.g., M82 X-2 (Bachetti et al. 2014)
    - 1.37 seconds
    - $L_{\rm X} = 1.8 \times 10^{40}\ {\rm erg\ s^{-1}}$

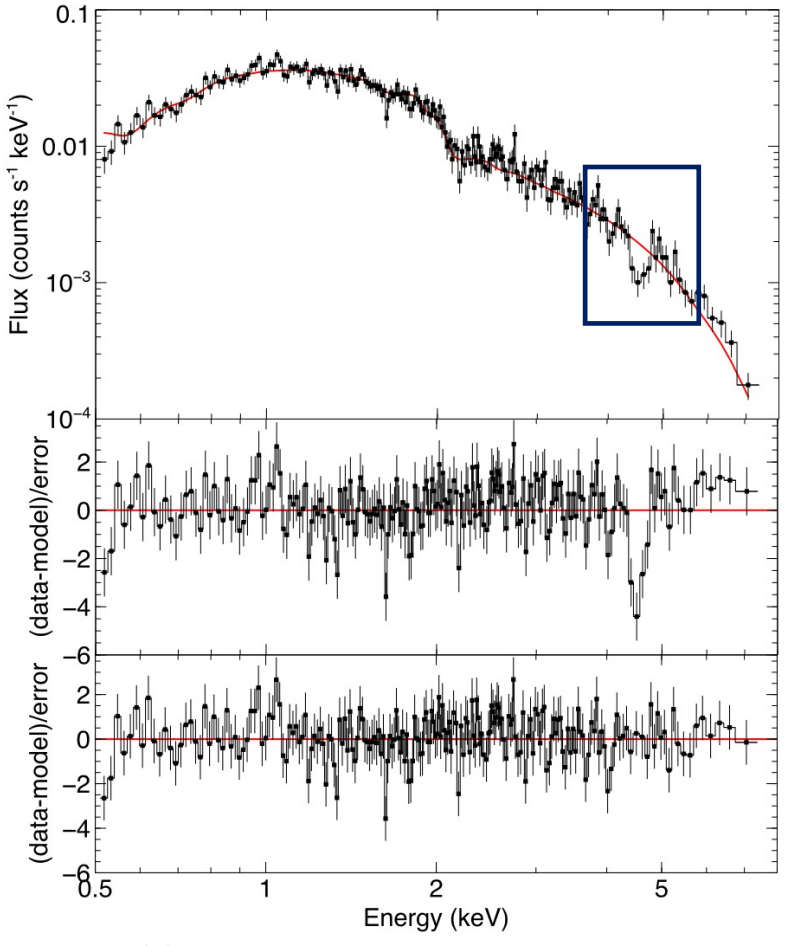
    ULX pulsar (ULXP) = NS

Fabrika et al. 2021



# Magnetic Field Geometry

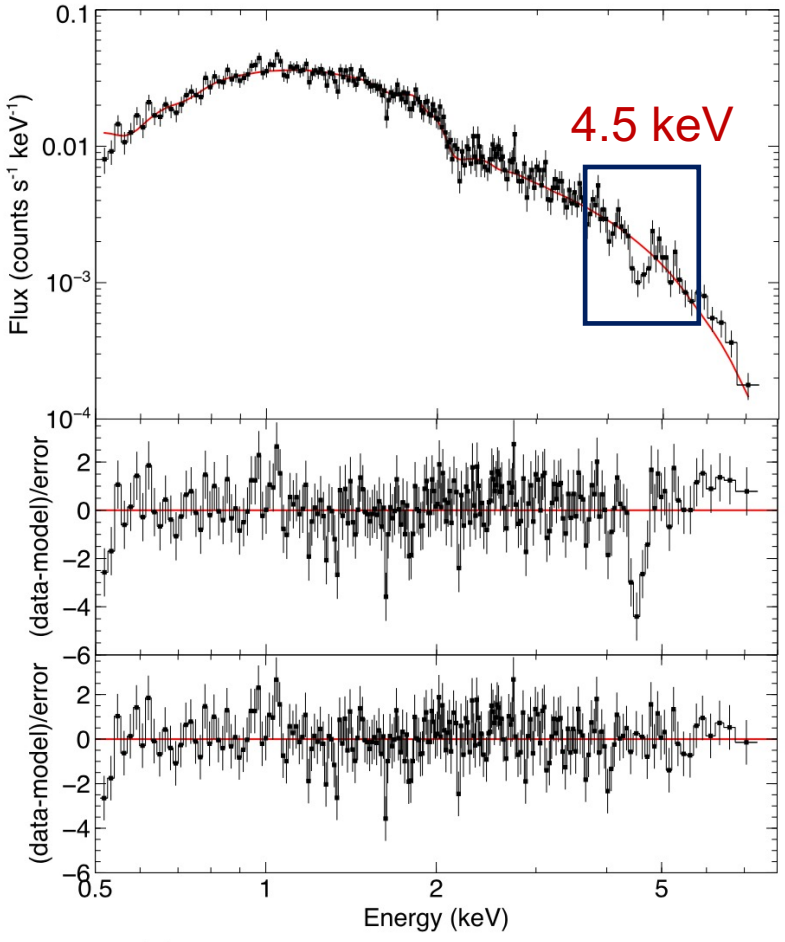
Brightman et al. 2018




- M51 ULX8
  - absorption line

# Magnetic Field Geometry

Brightman et al. 2018




- M51 ULX8

・absorption line at 4.5 keV (no major line)

⇨ Cyclotron Resonance Scattering Feature (CRSF)?

estimating the surface magnetic field:

・electron: $5\times10^{11}$ G

・proton: $9\times10^{14}$ G

(gravitational redshift: $z_g = 0.25$)

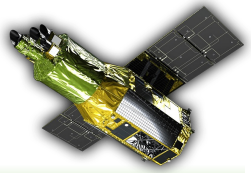
⇨ NS

but…

・**line is narrow ($\sigma\sim0.1$ keV)** compared with other CRSFs

・**pulsation is not detected** so far…

# Magnetic Field Geometry



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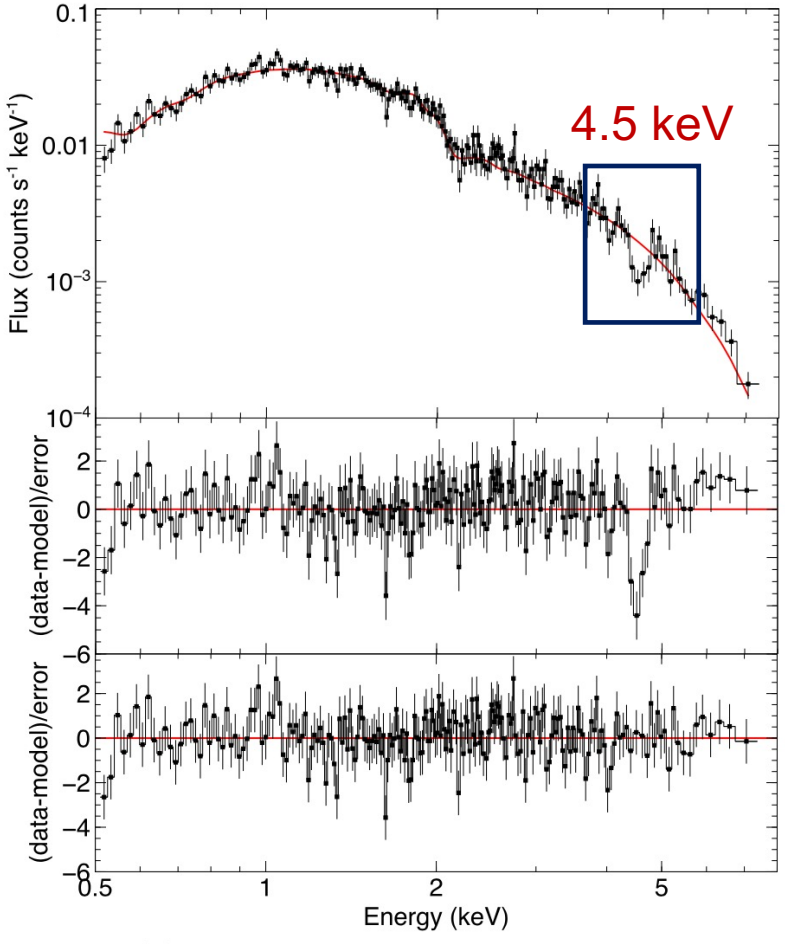



– XRISM/Resolve observation to investigate CRSF or NOT

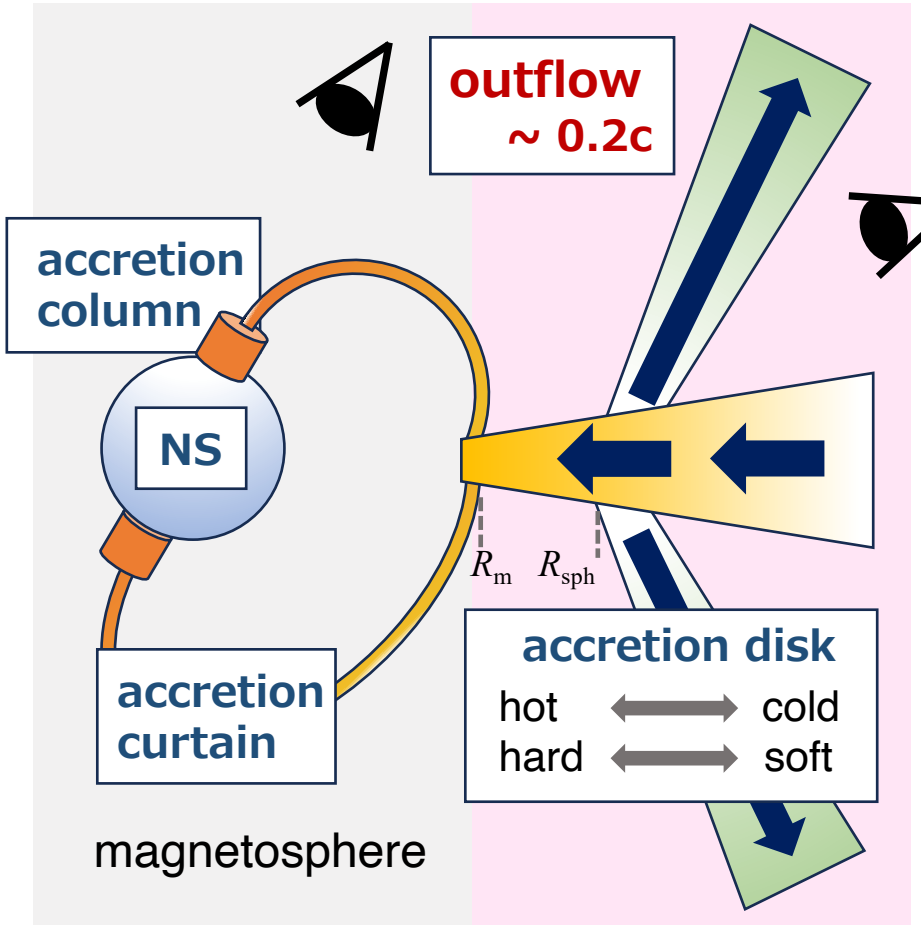
① resolve the absorption line
  a) assembly of atomic lines
  b) CRSF

② Using **MONACO to estimate the structure of the magnetic field**
  the narrow line can be explained by …
  a) multi-pole field
  b) dipole field

③ find second harmonics (expected at 9 keV)

**reveal the structure of surface magnetic field in NS ULX!**

# Outflow of ULX



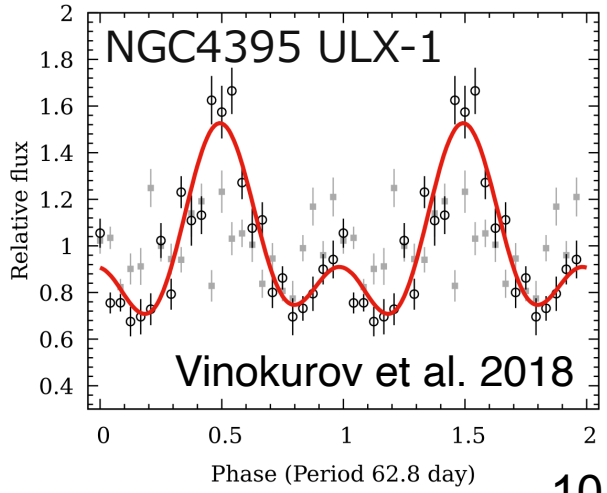

**Schematic picture of NS ULX**

(modified from Mushtukov et al. 2017, 2019)

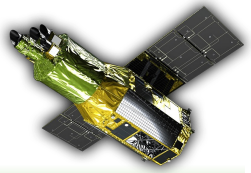
- ULX in supercritical accretion can be accompanied by **outflow**
  - **absorption (and emission) lines** (Pinto et al. 2016, 2017)
  - ultlafast (~ 0.2c)
- spectra components of NS ULX:
  accretion disk, outflow, accretion column, accretion curtain ?
- pulsation and CRSF cannot always be observable

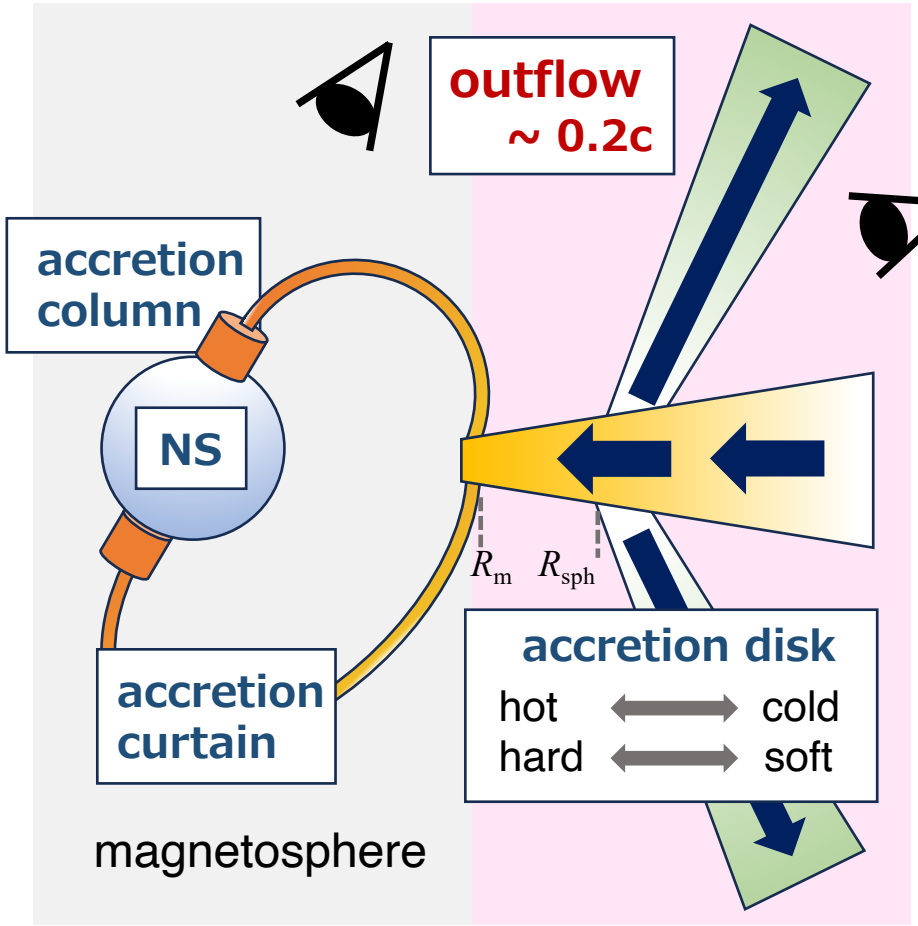
⇨ **The magnetosphere is hidden sometimes by the outflow due to precession of accretion disk** ?

e.g., NGC4395 ULX1: ~ 63 days
Holmberg XI X-1: ~ 266 days



# Outflow of ULX






**Schematic picture of NS ULX**

(modified from Mushtukov et al. 2017, 2019)

– We focus on **ULX Pulsar with known precession period** and **explore the outflow** with monitoring observation
e.g., NGC 5907 ULX-1

– If we detect Fe absorption lines (outflow) …

① constrain geometry in the line of sight with MONACO

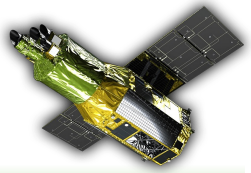
② investigate relations between…

- **outflow geometry in line of sight** and **phase of precession**
- **existence of pulsation** and **phase of precession**

⇨ **outflow and magnetic field are correlated?**

**reveal the geometry of ULX more clearly!**

# Summary



We use XRISM and MONACO to reveal…

- **mass transport mechanism in AGN (NGC1068)**
  by investigating matter distribution and motion in the **molecular gas gap** structure
- **surface magnetic field in NS ULX (M51 ULX8)**
  by investigating CRSF or NOT for **absorption line**
- **correlation between a magnetosphere and an outflow in Pulsar ULX (NGC 5907 ULX-1)**
  by investigating outflow structure for **absorption line**
  with **phase of precession and existence of pulsation**