- Thanks to Qing-Cui Bu for sharing the eXTP slides

eXTP and 3D Monte-Carlo simulation of radiative transfer

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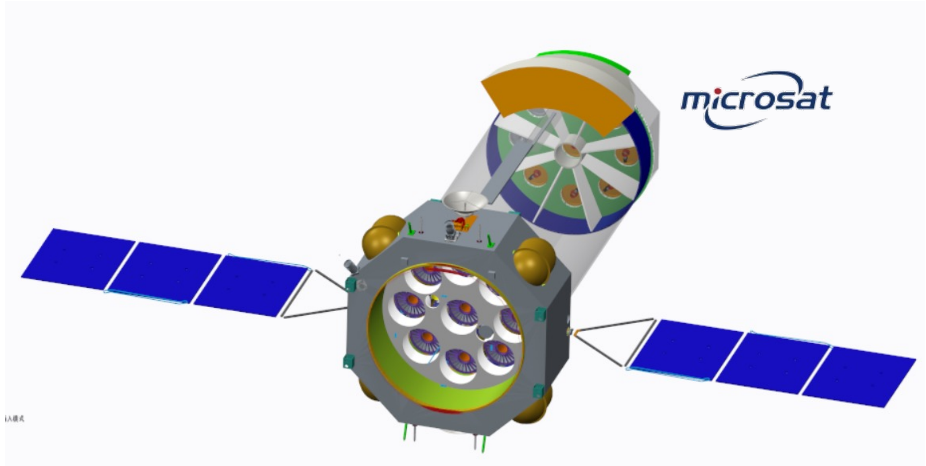
- Led by IHEP (CAS)
- Study fundamental physics under extreme conditions (matter density, gravity and magnetism)
- Fully approved for launch in early 2030
- More than 200 scientists from over 80 institutions in 17 countries participating in the consortium
- Zhang Shuang-Nan et al., 2026, “The enhanced X-ray Timing and Polarimetry mission - eXTP for launch in 2030”

20 Feb 2026

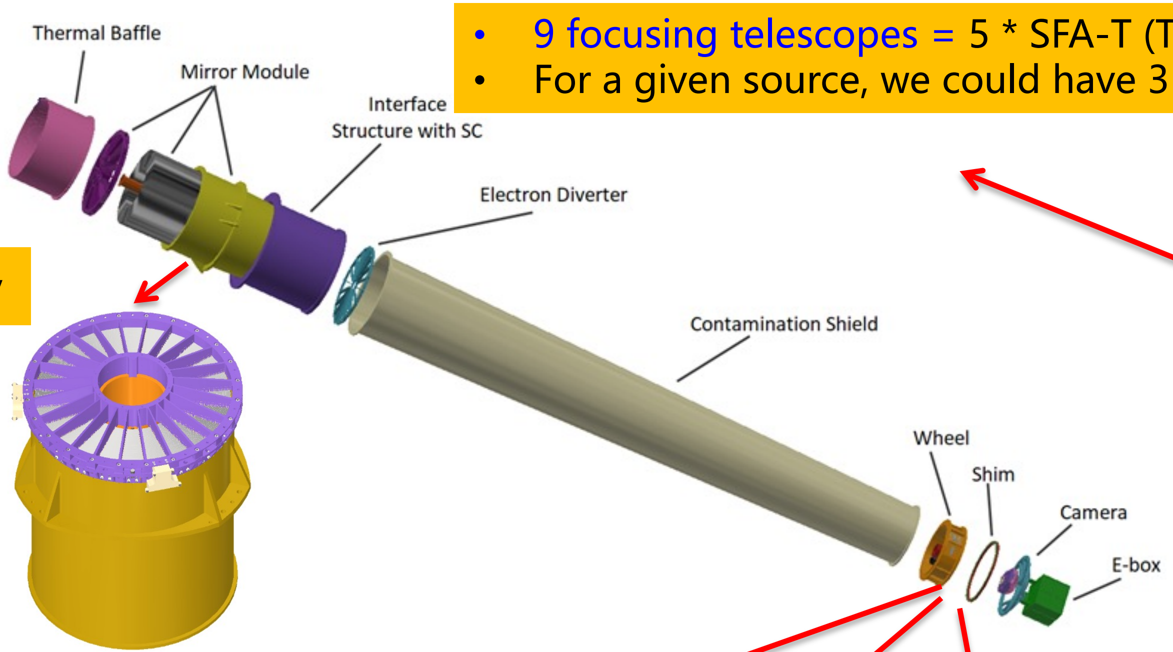
eXTP Mission Overview

Parameter	Value
Orbit	Not finally determined
Pointing	3-axis stabilized, < 0.01° (3σ)
Launcher	CZ-3B, from Xichang (28.5° N)
Launch mass	~4000 kg
Telemetry	Max 1.7 Tb/orbit (Ku-band)
ToO response	≤ 13 h
Mission duration	5 years
Launch date	2030



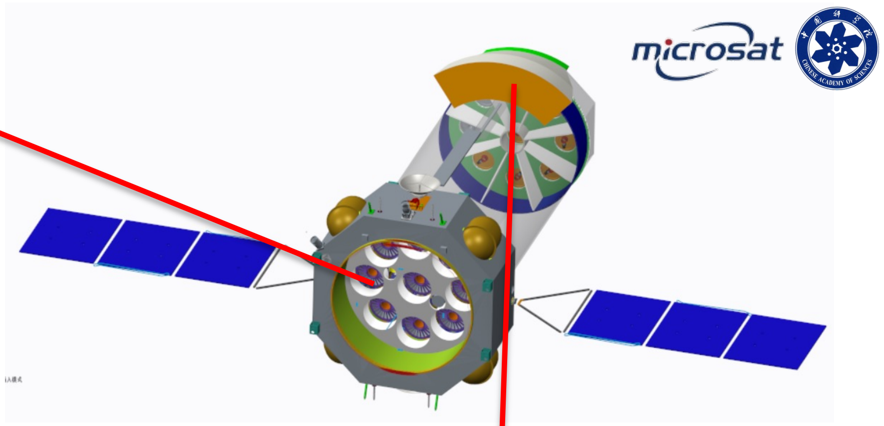
eXTP payload (= 2 * NICER + 5 * IXPE)

- 9 focusing telescopes = 5 * SFA-T (Timing/Spectrum) + 3 * PFA (Polarimetry) + SFA-I (Image)
- For a given source, we could have 3D (spectrum + timing + polarimetry)

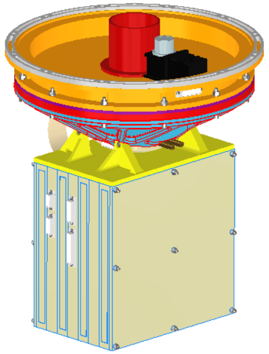


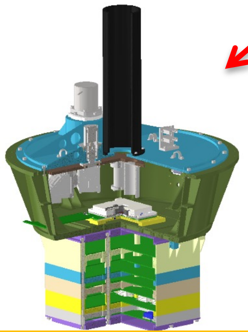
better stability

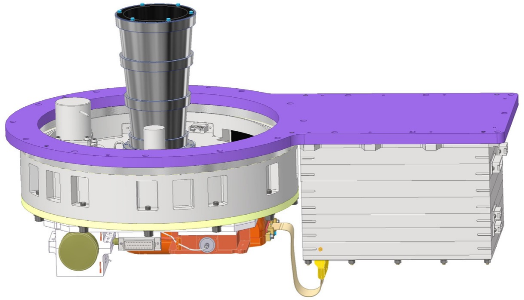
Mirror module (9)

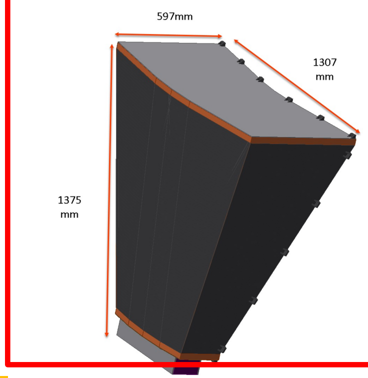


Silicon Drift Detector (SDD)









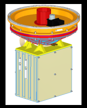
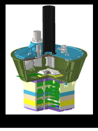
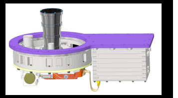
SFA-T Camera * 5
Spectroscopy focusing array

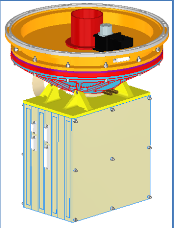
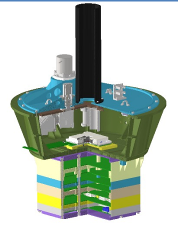
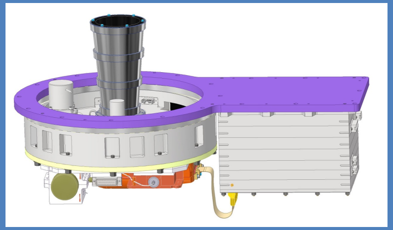
PFA camera * 3
Polarimetry focusing array

SFA-I
pnCCD imaging Focusing Telescope

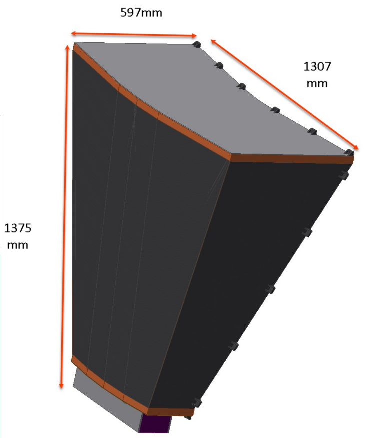
W2C (newly approved)
Wide-band and Wide-field Camera

general performance

	SFA-T 	PFA 	SFA-I 
Total unit number	5	3	1
Focal length	5.25±0.01m	5.25±0.01m	5.25±0.01m
Effective area	2750 cm²@1.5keV 1670cm²@6 keV	250 cm² @ 3 keV	550 cm²@1.5keV 330 cm²@6 keV
Energy range	0.5-10keV	2-8keV	0.5-10keV
Energy resolution (FWHM)	180eV@1.5keV	1.2keV@6keV	180eV@1.5keV
FoV	18′×18′	9.8′×9.8′	18′×18′
Angular resolution	≤1′(HPD)@1.5 keV	30″(HPD) @ 3keV	≤1′(HPD)@1.5 keV

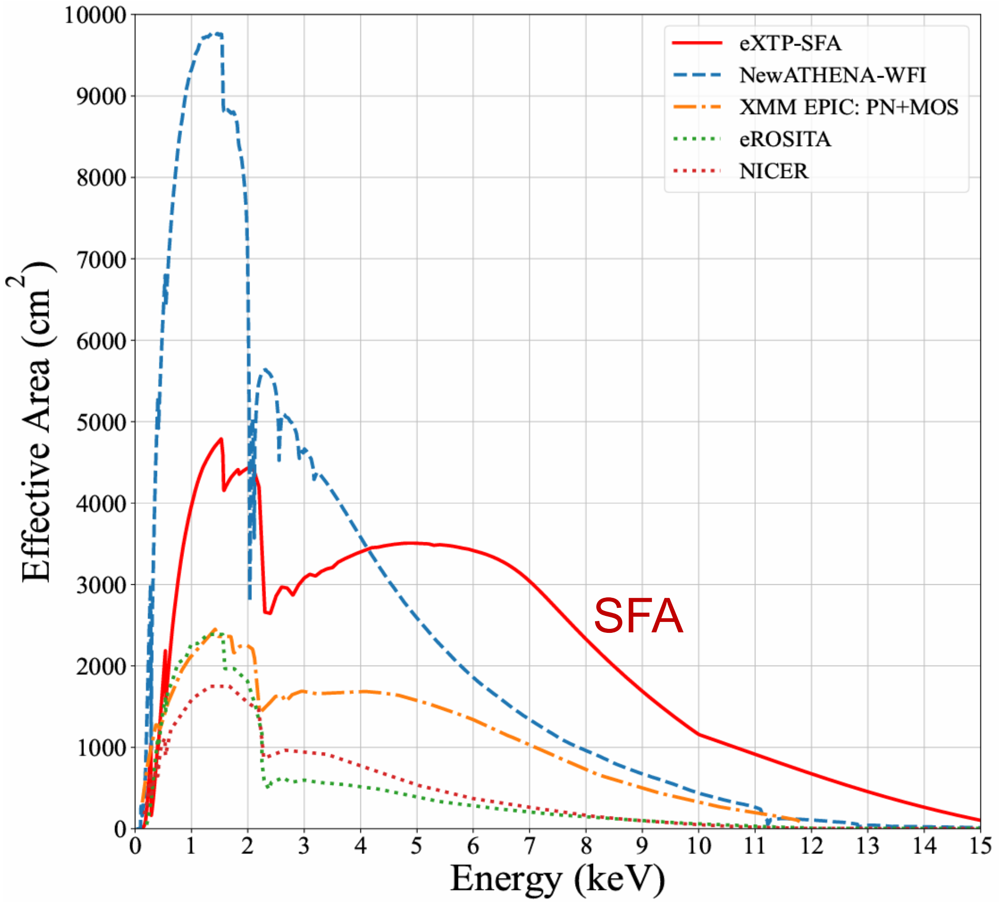
Payload	Special performance
Spectroscopy Focusing Array（SFA-T） 	Time resolution: < 10 μs Time accuracy: 2 μs Dead time fraction: 5% @ 1Crab Sensitivity: 4×10^{-15} erg cm^{-2} s^{-1} (0.5-10 keV，5σ，10^6 s; 4 units) Telemetry limit: 15Crab source up to 300 min; no limit for a 1Crab source Power: 70 W; Mass: 36 kg (1 unit)
Polarimetry Focusing Array (PFA) 	Time resolution: 10 μs Time accuracy: 4 μs Dead time fraction: 15% @ 1Crab Stability : ΔP/P = 5% MDP: 1.8% (1mCrab, 10^6s) Telemetry limit: no limit for 1 Crab source Power: 30 W; Mass: 28 kg (1 unit)
CCD imaging Focusing telescope (SFA-I) 	Time resolution: 50 ms (full) and 240 μs (timing) Pile up fraction: < 6% @ 1Crab Sensitivity: 8×10^{-15} erg cm^{-2} s^{-1} (0.5-10 keV，5σ，10^5 s; 2 units) Telemetry limit: no limit for a 1Crab source Power: 80 W; Mass: 50 kg (1 unit)

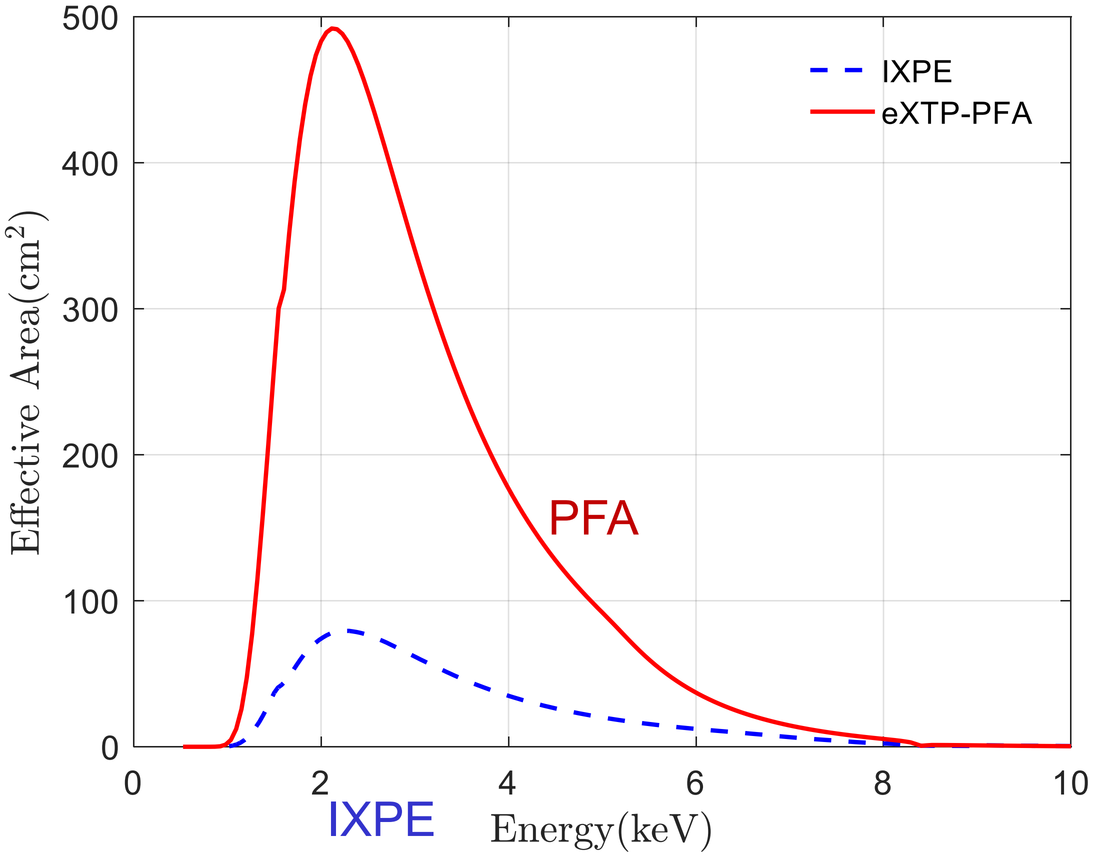
W2C performance



	requirements
FoV	Full coding:49° x 9.6° Half coding:60° x 16° FWZR:68° x 22°
Effective area	160cm²@60keV
Angular Resolution	20′@30-100 keV
Position accuracy	5′@30-100 keV
Energy range	30 - 600 keV
Energy resolution (FWHM)	30% @ 60 keV
Time resolution	< 25 μs
Sensitivity	4 $\times 10^{-7}$ erg cm^{-2} s^{-1}

Effective area

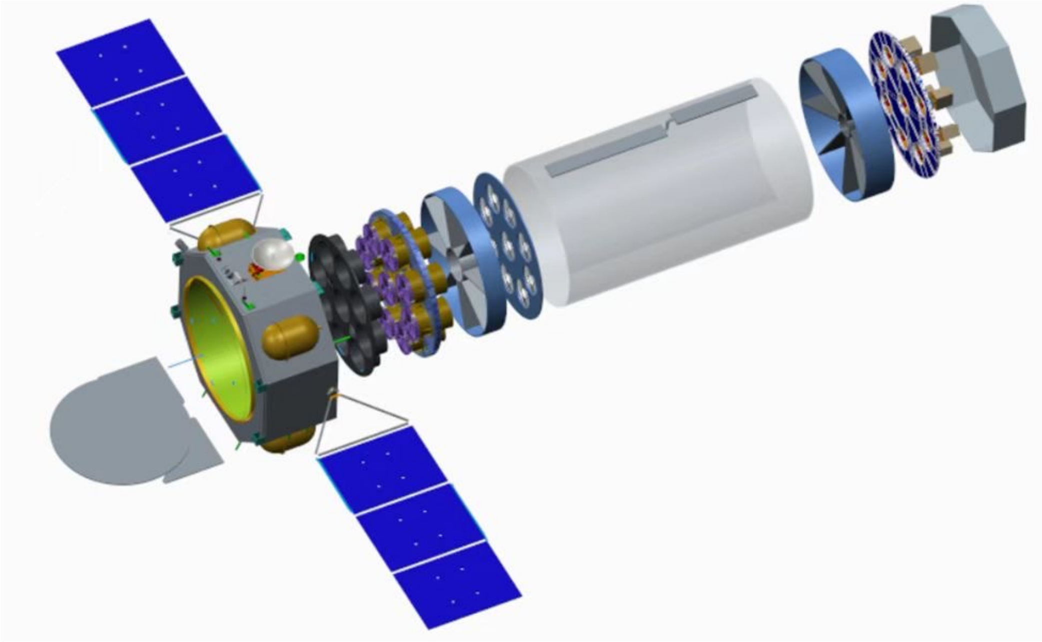




- The large effective area of SFA, combined with its excellent timing resolution (10 μs), makes eXTP a premier facility for X-ray timing studies
- comparable to having 2 NICER instruments plus 5 IXPE instruments in terms of combined capabilities.

eXTP Mission Plan

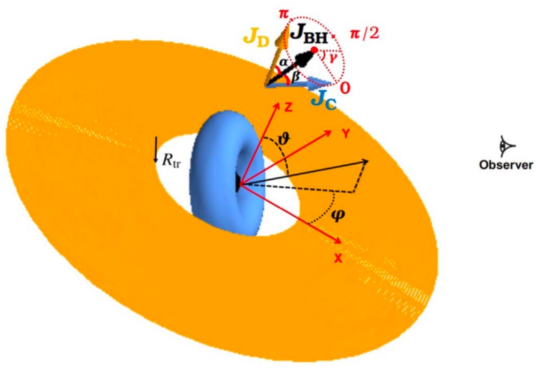
- Phase C: Detector/hardware development underway
- Lauch deadline: 2030



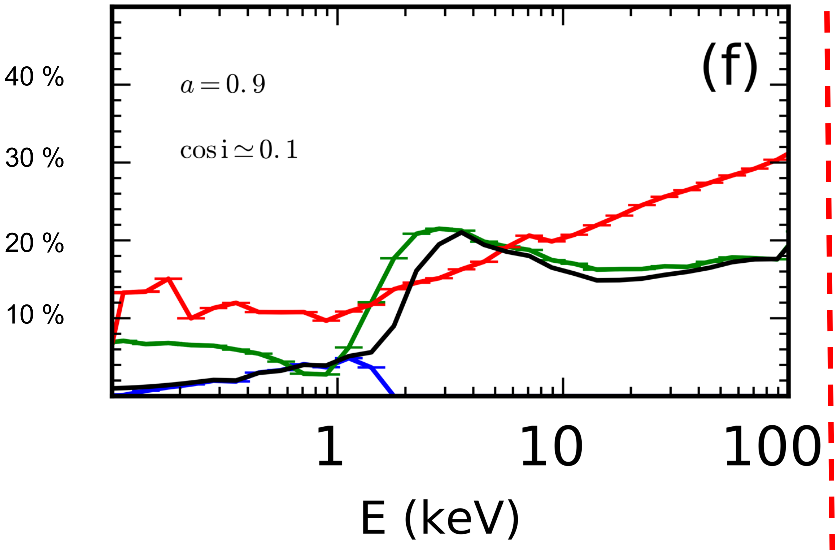
2D+1D Monte-Carlo simulation of radiative transfer

2018 2020 2025 2026

Simulation:

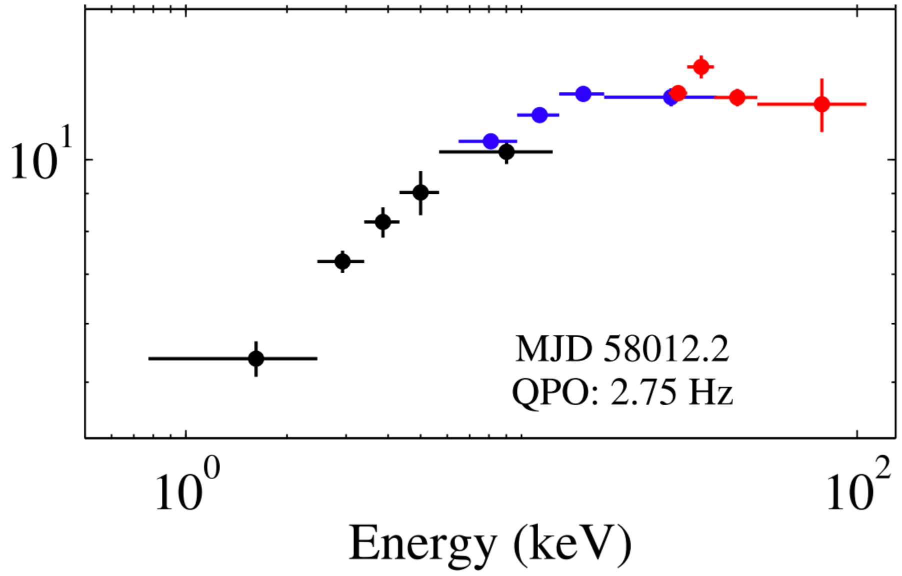


QPO-fractional RMS (YB+2018)



Observations:

Huang +2018

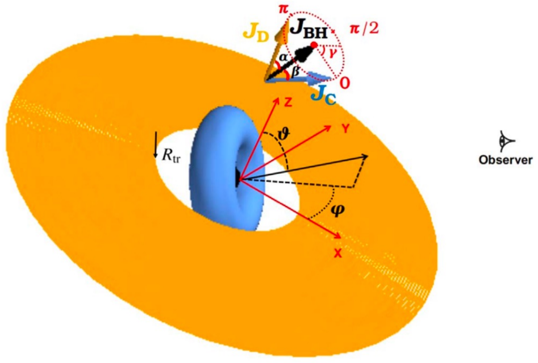


- Develop a Monte-Carlo code to compute the Compton-scattered X-ray flux arising from a hot inner flow that undergoes Lense–Thirring precession (Ingram + 2009)
- Predict a flat fractional RMS at high energy (> 10 keV)， proved by HXMT-obs up to 100 keV

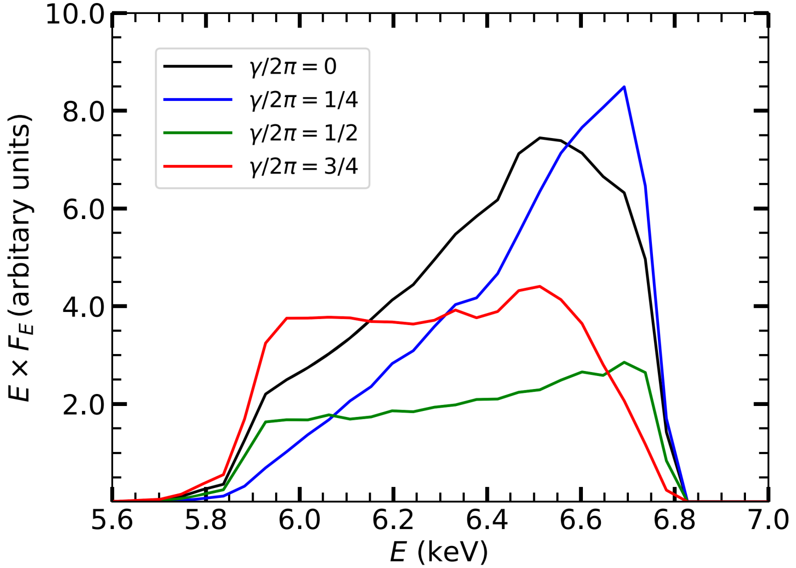
2D+1D Monte-Carlo simulation of radiative transfer

2018 2020 2025 2026

Simulation:



QPO-Fe Ka line (YB+2020)



Observations:

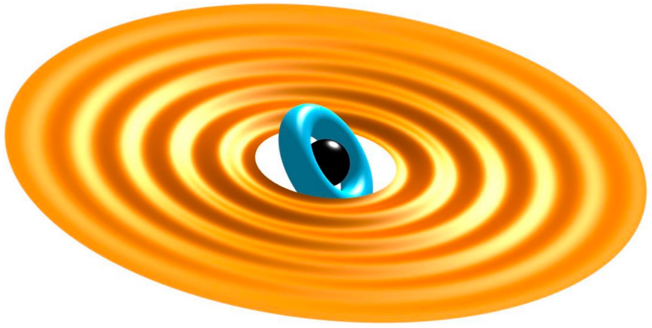
eXTP after 2030:
QPO phase-resolved Fe Ka line profile

- Ingram + 2012: study QPO phase-resolved Fe Ka line profile, by employing the spectral model
- YB + 2020: use the Monte-Carlo simulation (YB+2018) of radiative transfer to study the irradiation/ reflection and the resultant spectral properties, including the Fe Kα line as a function of precession phase.

2D+1D Monte-Carlo simulation of radiative transfer

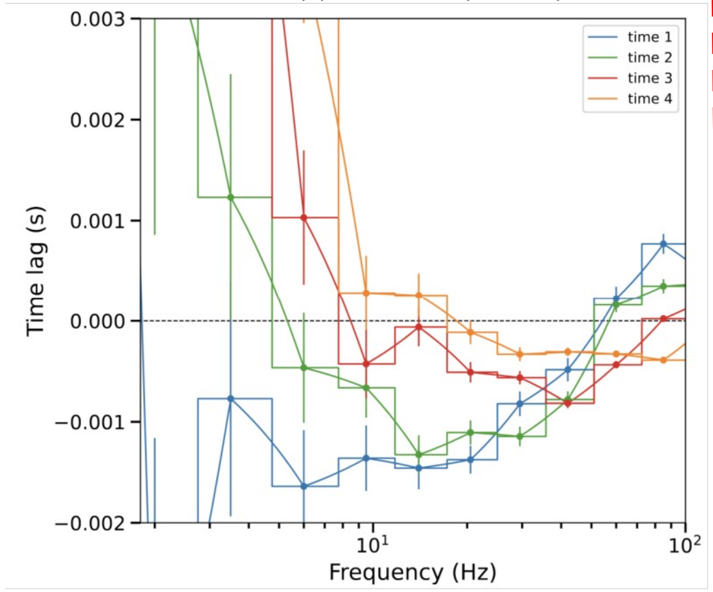
2018 2020 2025 2026

Simulation:

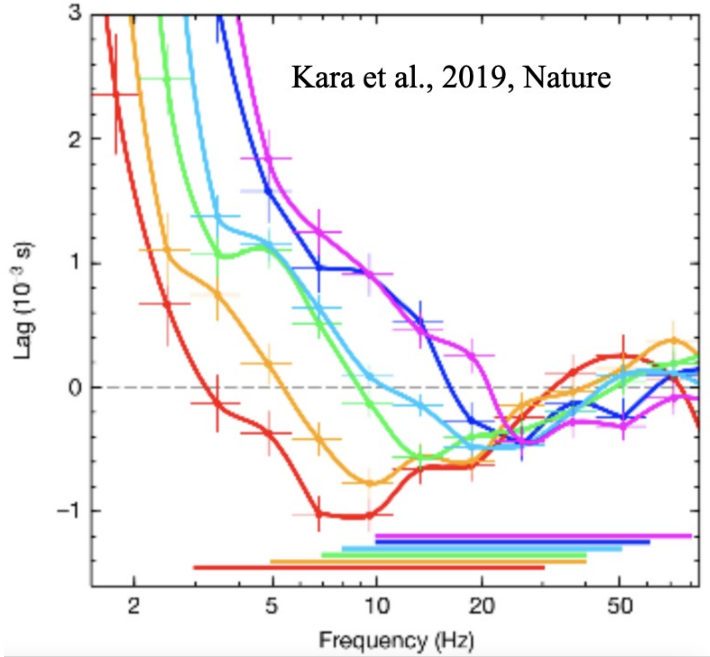


Frequency-dependent lag

Zhan Y.J., , **You B.***, et al., 2025



Observations:



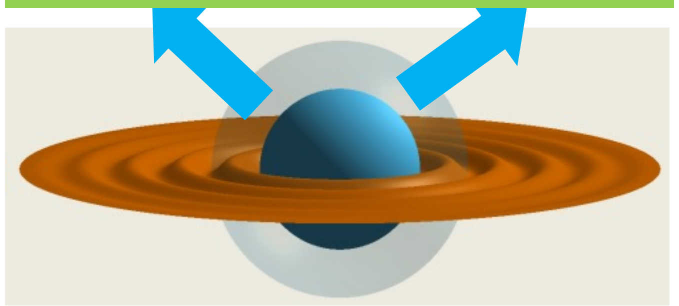
- We update the code to include both propagating fluctuations and X-ray reverberation
  - Implement of the reflection of the ionized disk, by interpolating relxill table model
- Simulate both low-frequency hard lags and high-frequency soft lags
- We successfully reproduce the obs of MAXI J1820 (Kara 2018)

2D+1D Monte-Carlo simulation of radiative transfer

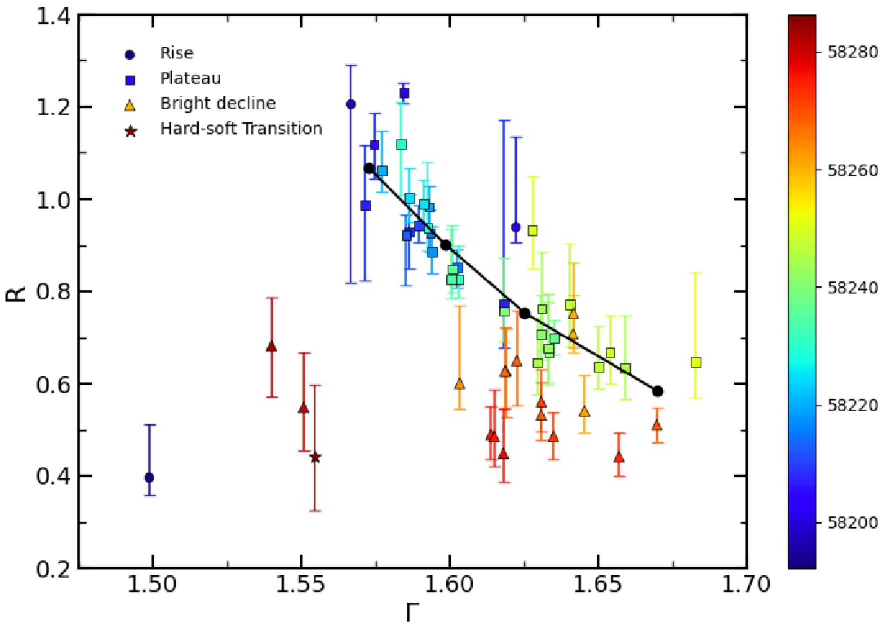
2018 2020 2025 2026

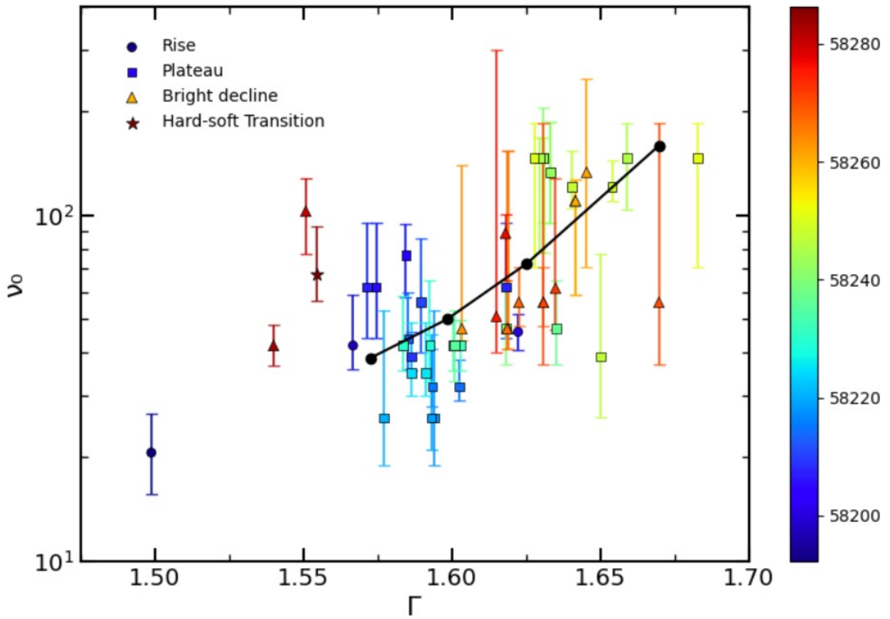
Simulation:

Role of the outflowing corona in Spectral + Timing + Polarimetry



Spectral-Timing of J1820 (Qin K., YB+2026, to be submitted)





- Correlation between the reflection fraction and photon index (YB+2021)
- Correlation between the zero-lag high frequency and photon index (De Marco+2021)
- The scenario of the outflowing corona could explain the spectral-timing of J1820 (YB+2021)
- Polarization will be included in our simulation in the next paper; eXTP obs will be highly expected (3D)

2D+1D Monte-Carlo simulation of radiative transfer

2018 2020 2025 2026

What we have: N(r, E, t)

- Geometry: flexible
- Radiative transfer (spectral):
  - Thermal disk
  - Inver Comptonization
  - Reflection (ionized disk)
- Physical process (timing):
  - L-T precession
  - Propagating fluctuation
  - Reverberation Mapping
  - Bulk motion of corona

What we will do: N(r, E, t, P)

- Polarization

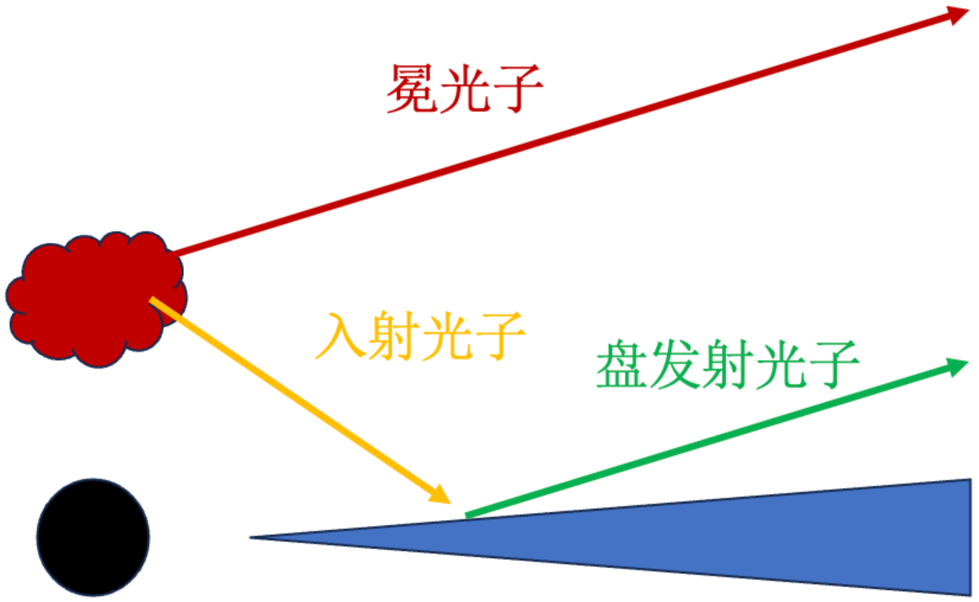
- Two more things should be discussed in this workshop

  – Spectral – Timing in high energy (> 50 keV)

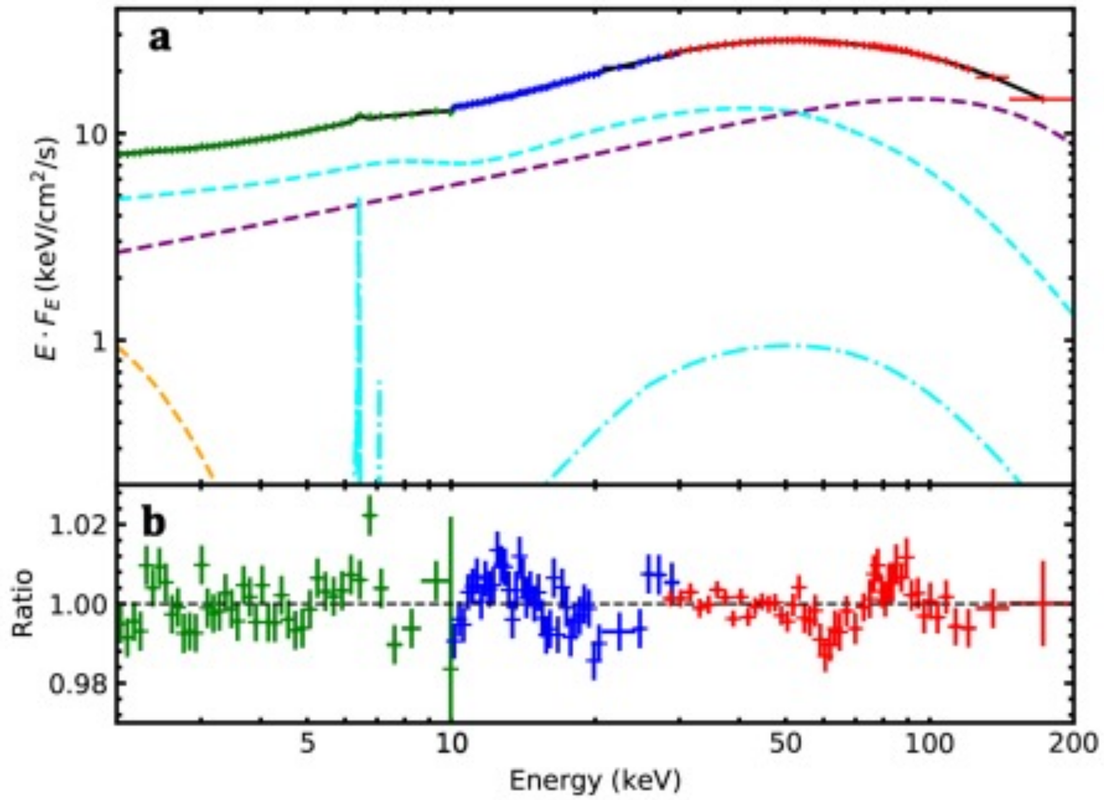
  – Geometry evolution in the soft-to-hard state

• Observation **Spectral- Timing in high energy**

X-ray reverberatiom mapping: reference band is very important



• MAXI J820+070: broad energy spectrum, up to 200 keV (You B., 2021, Nature Comm.)



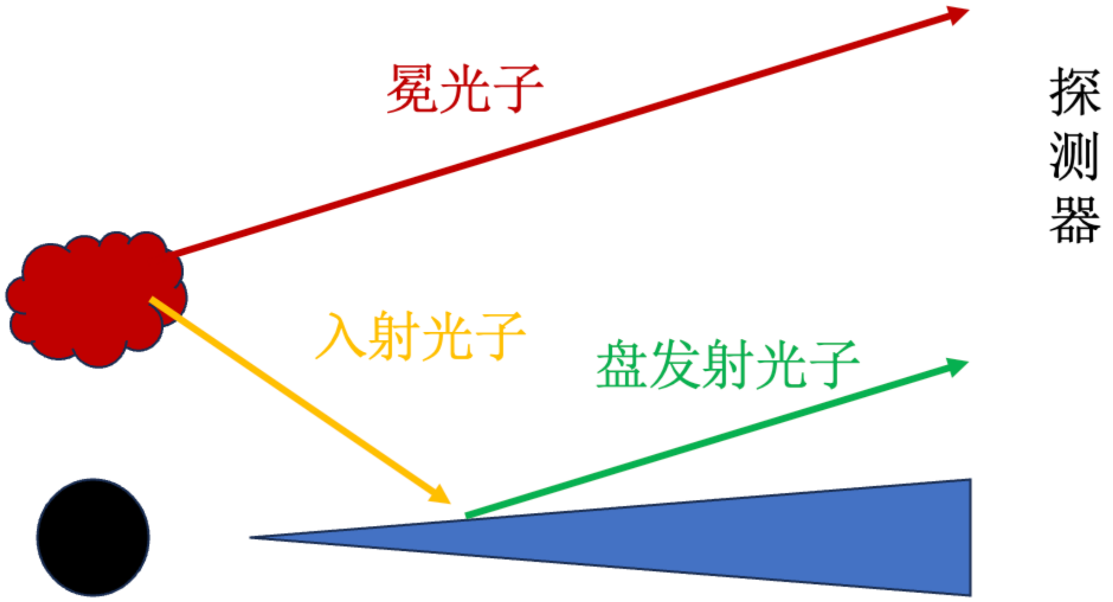
• Observation **Spectral- Timing in high energy**

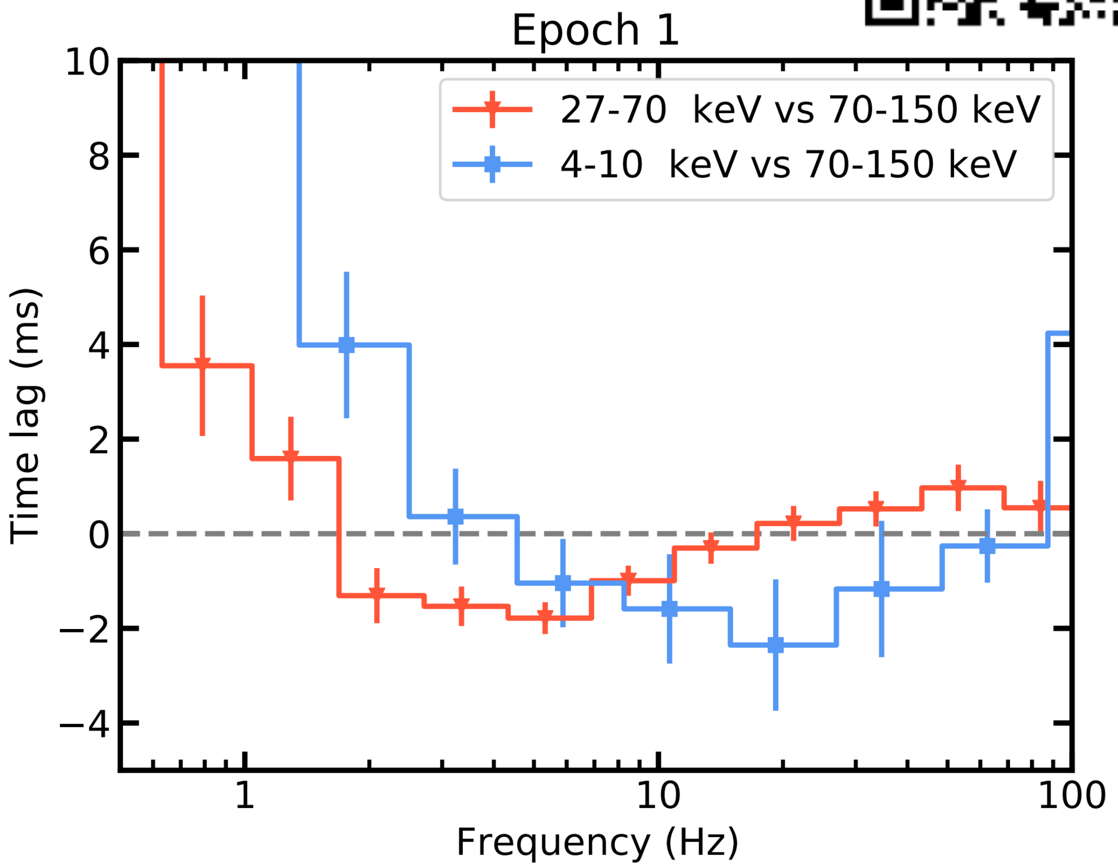
Reverberation lags viewed in hard X-rays from an accreting stellar-mass black hole

Show affiliations

You, Bei ; Yu, Wei ; Ingram, Adam ; De Marco, Barbara ; Qu, Jin-Lu ; Zhu, Zong-Hong ; Santangelo, Andrea ; Xu, Sai-En

- Accepted by Nature Communications (arxiv: 2509.16608)





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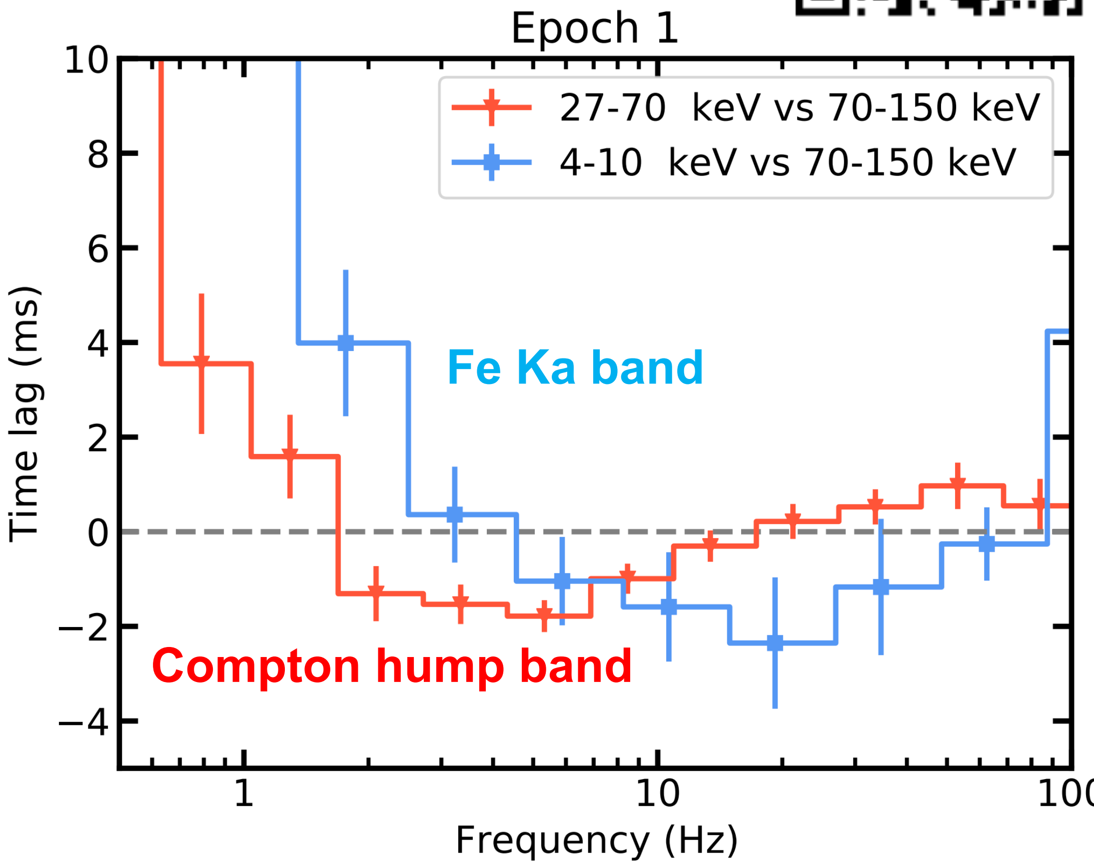
Results (1): Soft-lag frequency of Compton-hump < one of Fe Ka

- Reverberation of the Compton hump includes contributions from the entire disk. But, one of the Fe Ka line mainly comes from the inner flow
- Possible evidence of ionization gradient in the accretion disk ! ! !
- Looking forward to the reltran fits by Gullo and his student



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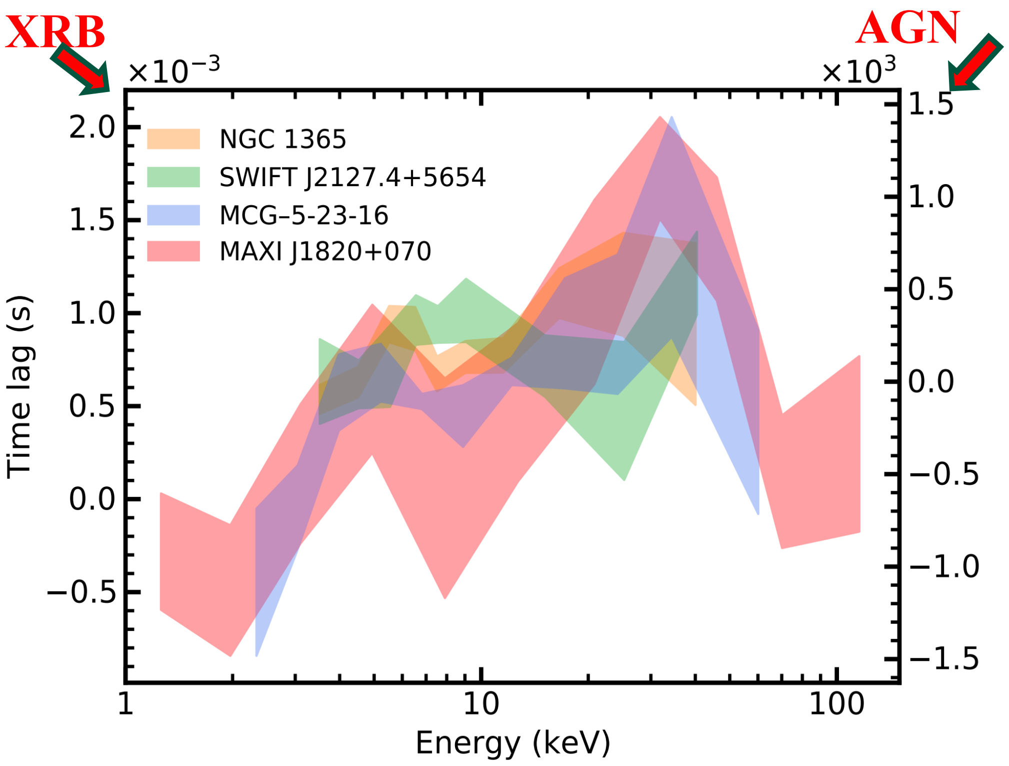
Results (2): First detection of Compton hump RM in XRB

■ AGN are mass-scaled of XRB

$$\tau \propto M_{\rm BH}$$



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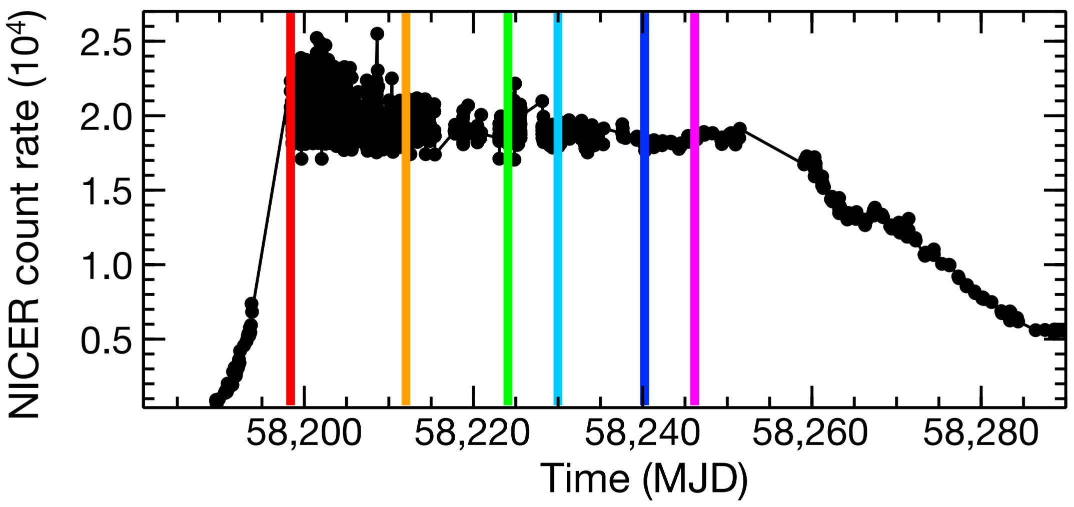

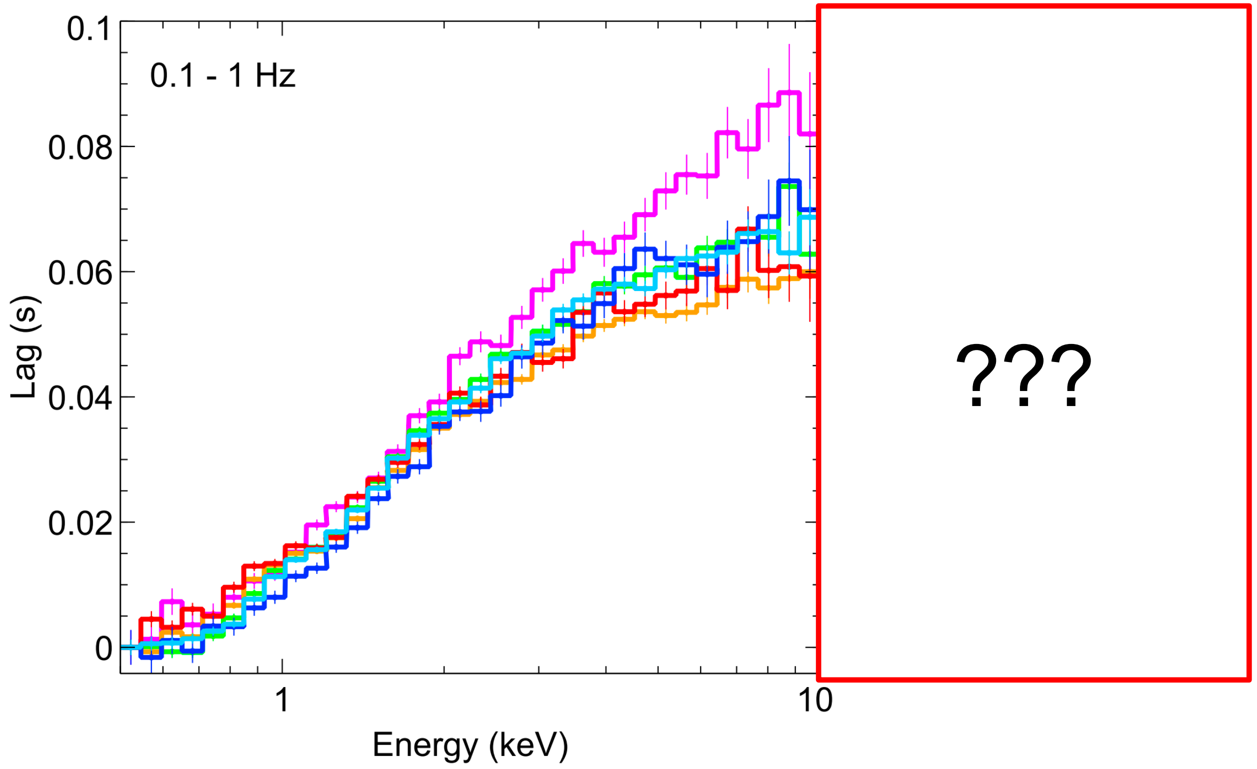

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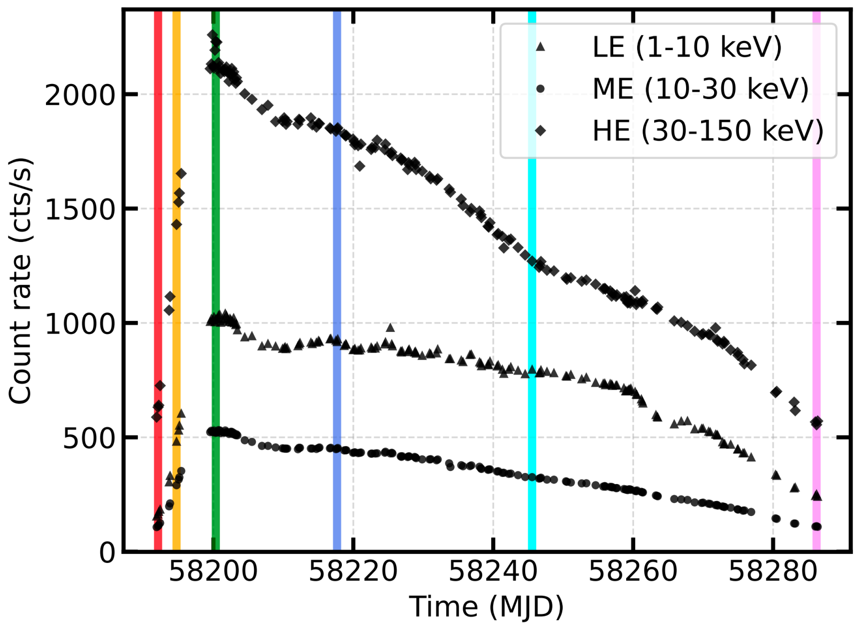

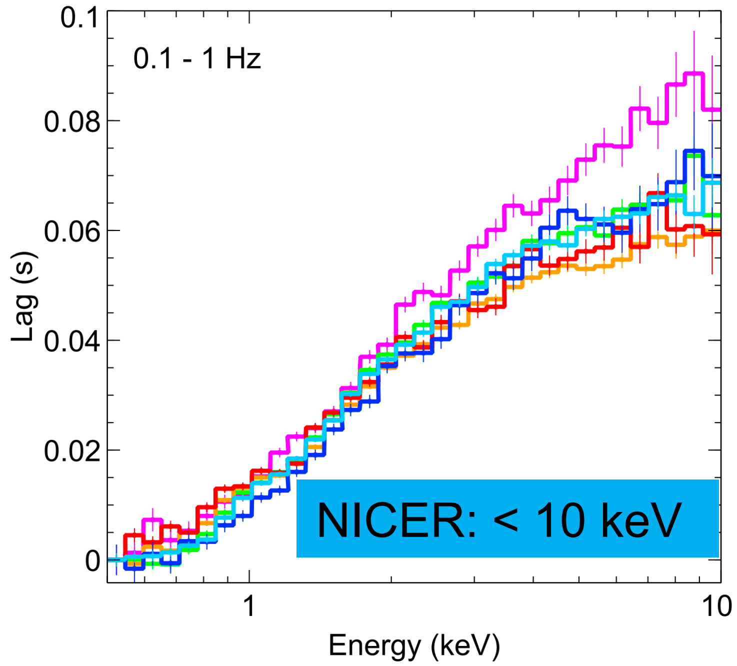

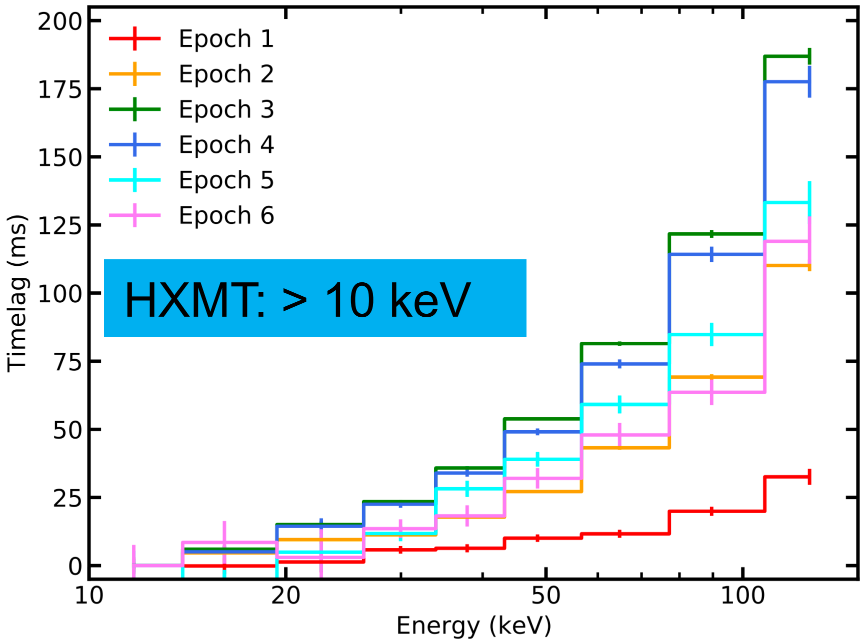

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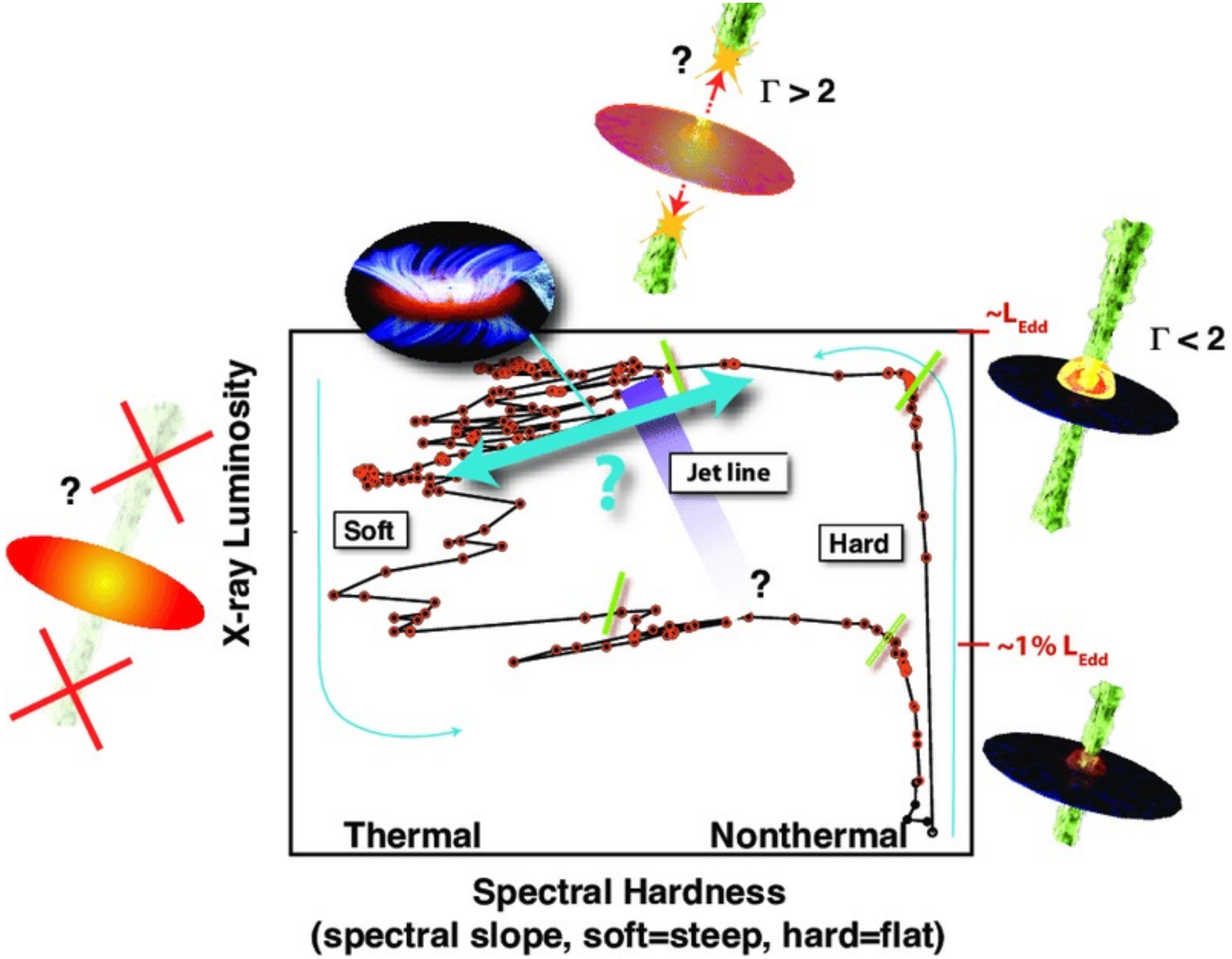
Results (3): Evolution of the hard lag spectrum up to 200 keV

- A stratified corona is required
- The corona size POSITIVELY coevolves with the luminosity, in J1820
- At the beginning of the J1820, the corona might be compact of ~ 20 Rg

• Observation **Geometry evolution in the soft-to-hard state**

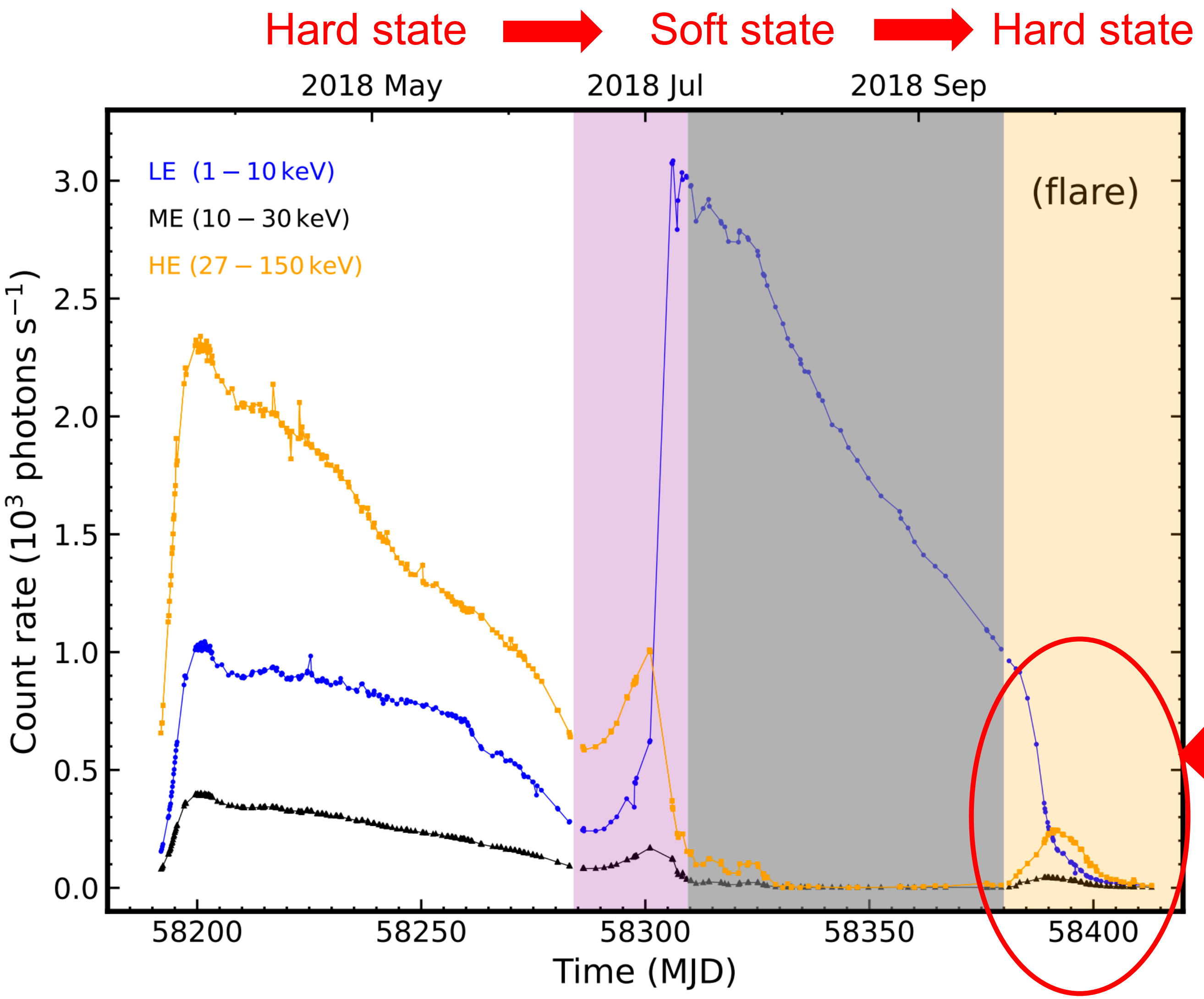
See Gullo's talk

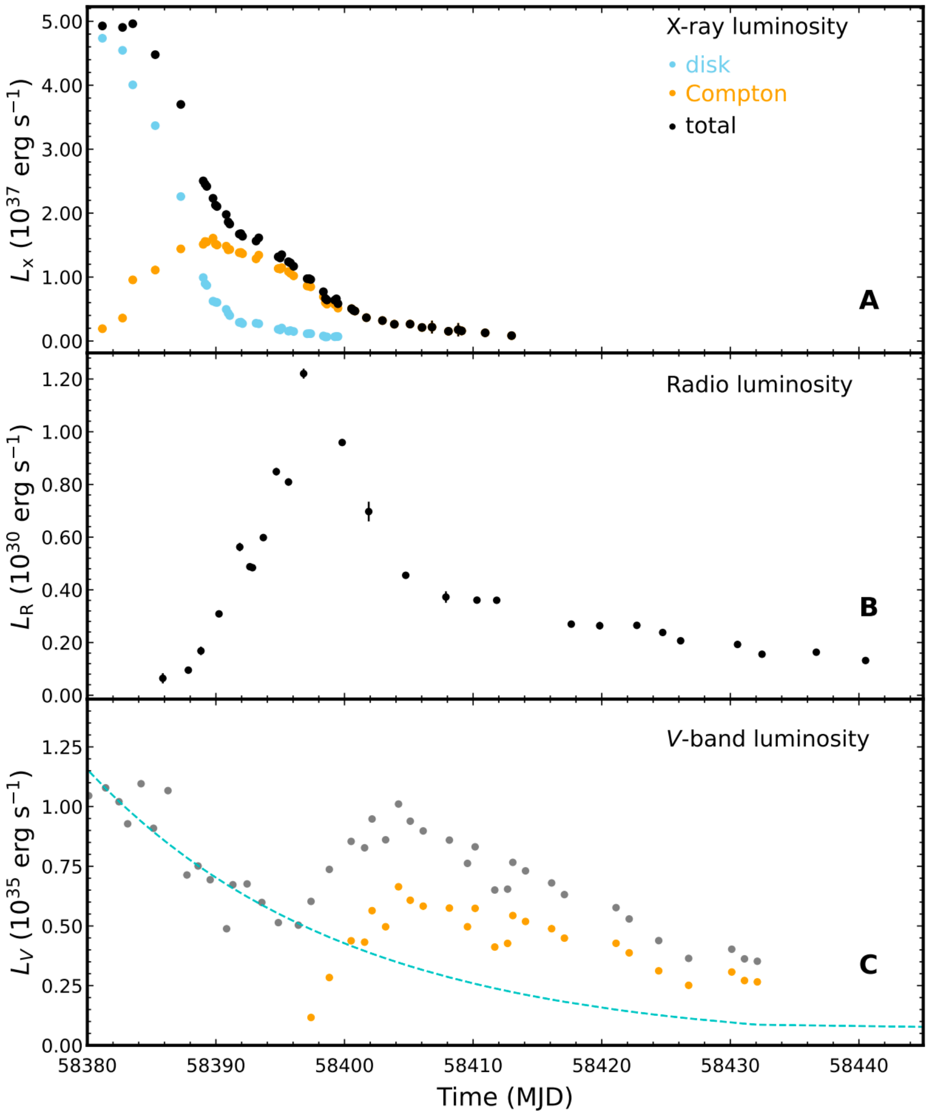


• Observation **Geometry evolution in the soft-to-hard state**

MAXI J1820 +070

You B.et al., 2023, Science





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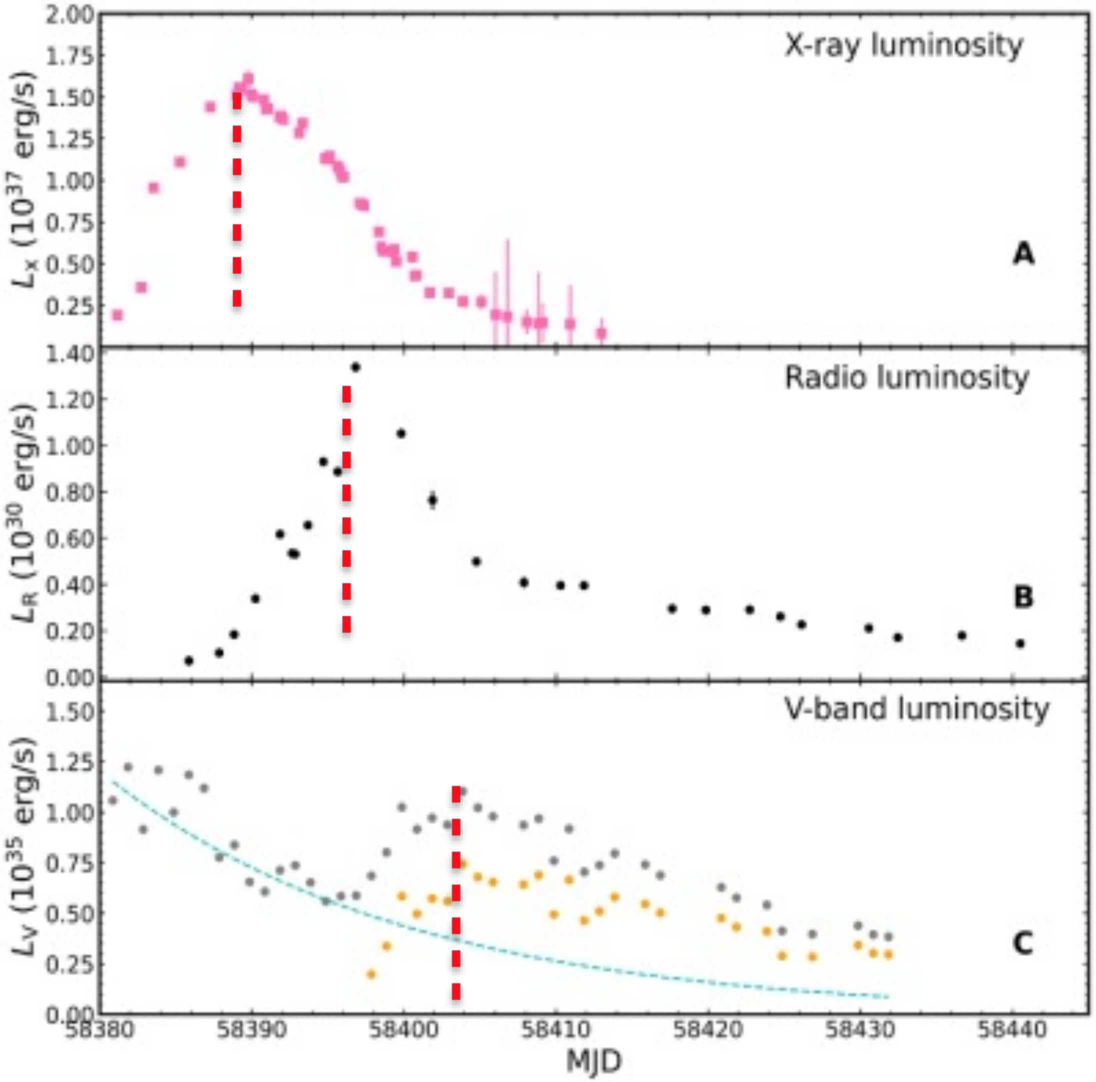
MAXI J1820 +070

You B.et al., 2023, Science

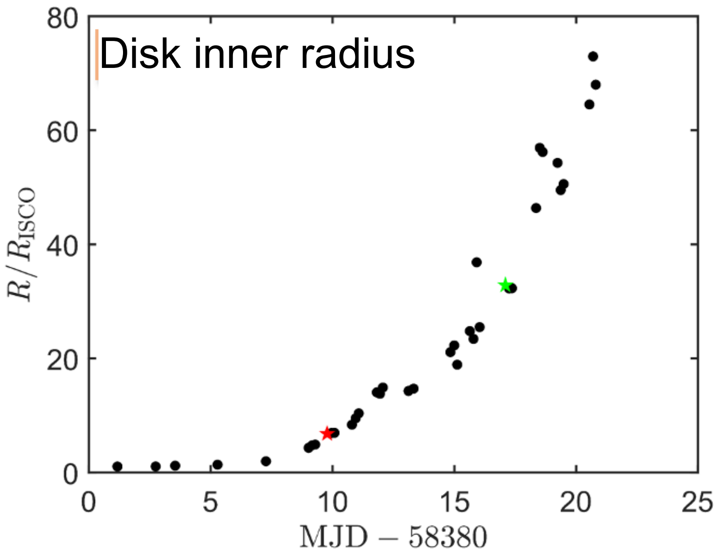


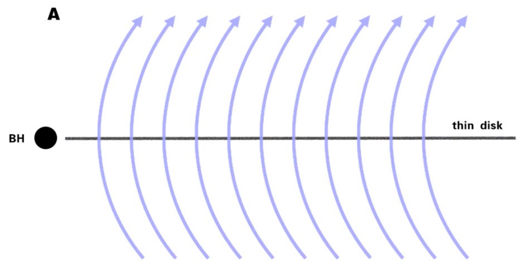
Observational highlights:

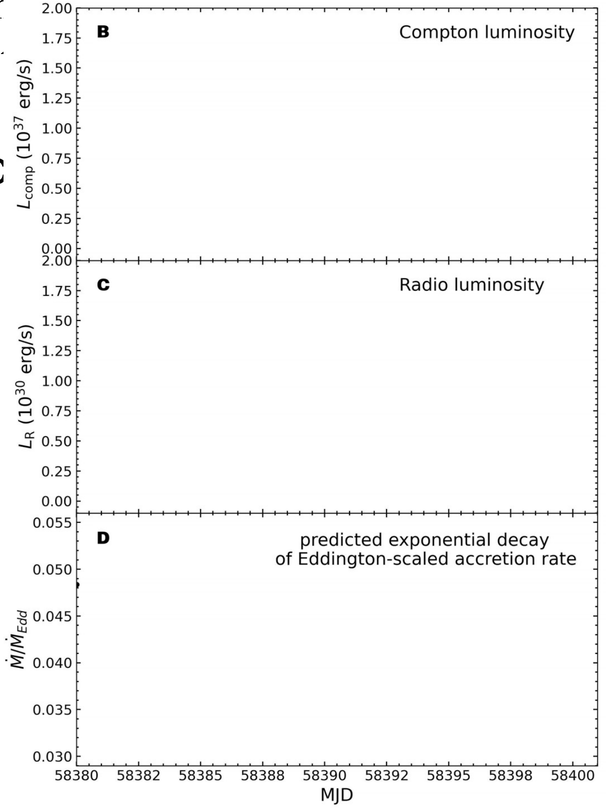
- Radio lags X-ray by ~ 8 days !
  - First detection in known B

Smoking-gun evidence: In th
J1820, X-ray from ADAF, rather

- The disk is receding, and the c
corona, as mdot decreases







Thank you for listening

谢 谢