Bright Black Hole X-ray Binaries recently discovered by MAXI

— MAXI J1535–571 and MAXI J1820+070 —

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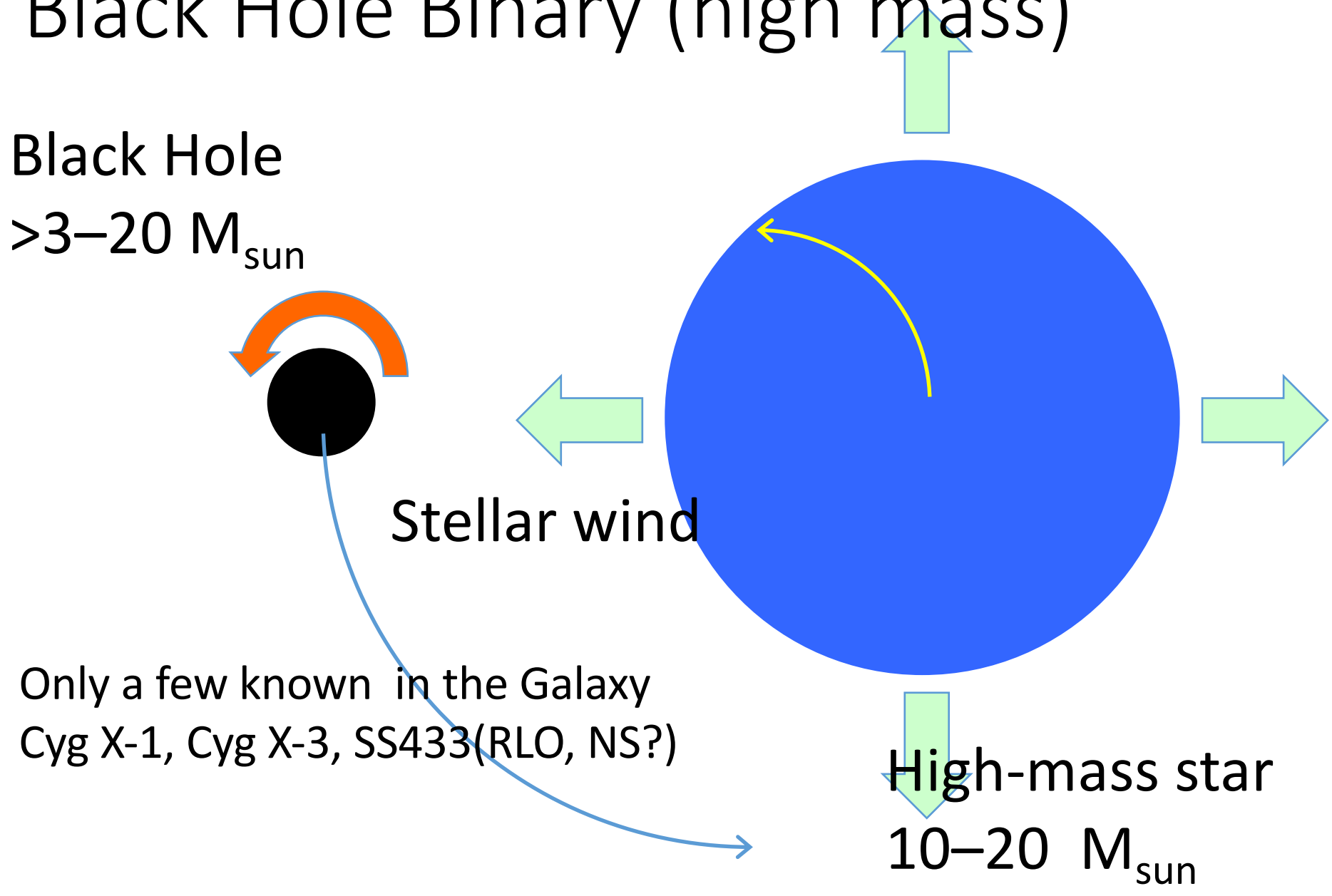
High-energy gamma-rays from NS/BH binaries

- NS (pulsar) + OB star
  - PSR B1259+63: pulsar wind + stellar wind ➔ shock
- NS (ms pulsar) + low-mass star
  - “Black widow”
- BH + OB/WR star
  - Cyg X-1, Cyg X-3
  - Gamma-ray emission related with “**X-ray states**”

Observational study of black holes is even more interesting now

- GW observation of ≈30 $M_\odot$ black holes
  - Mass range and population? Origin?
- Better sky/time domain coverage for transients
  - (near) all-sky X-ray monitoring by MAXI, Swift, …
  - All-sky optical monitoring
    - e.g. All-Sky Automated Survey for Supernovae (ASAS-SN)
- Timely multiwavelength follow-up observations
  - More radio-IR-optical facilities available for monitoring or follow-up
  - All-sky gamma-ray monitoring – Swift, HAWC, etc.
  - CTA coming online for sensitive follow-up

Black Hole Binary (high mass)

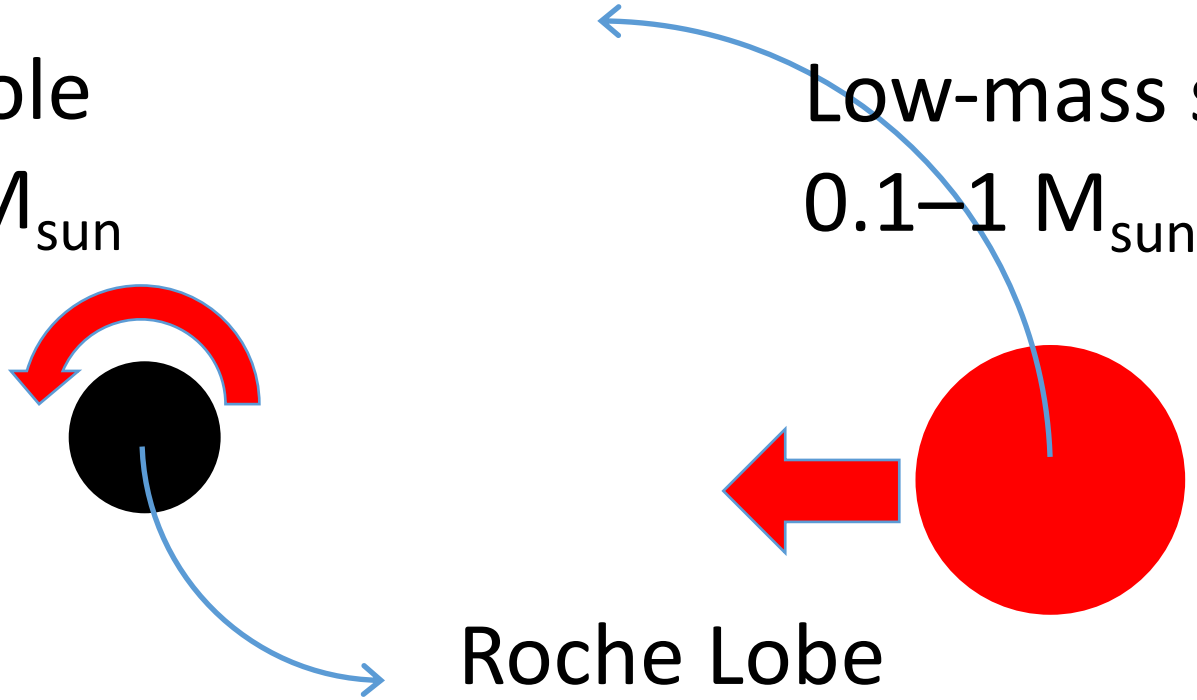


- Only a few known in the Galaxy
- Cyg X-1, Cyg X-3, SS433(RLO, NS?)

Black Hole Binary (low mass)

Black Hole
>3–20 M_{sun}

Low-mass star
0.1–1 M_{sun}



Roche Lobe
overflow

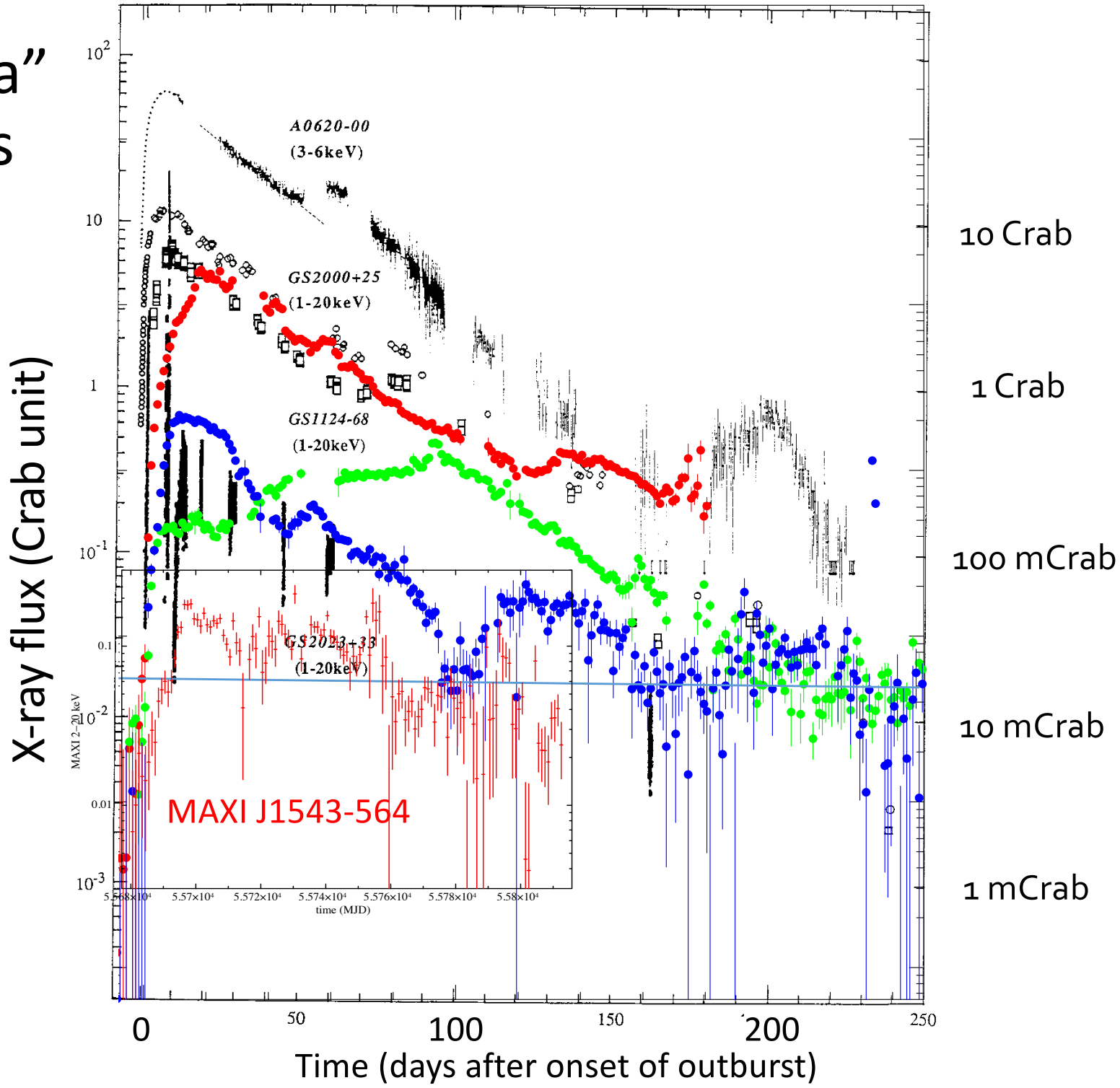
- mostly transient (“X-ray nova”)
- ~1/year new BHB discovered

“X-ray Nova” light curves

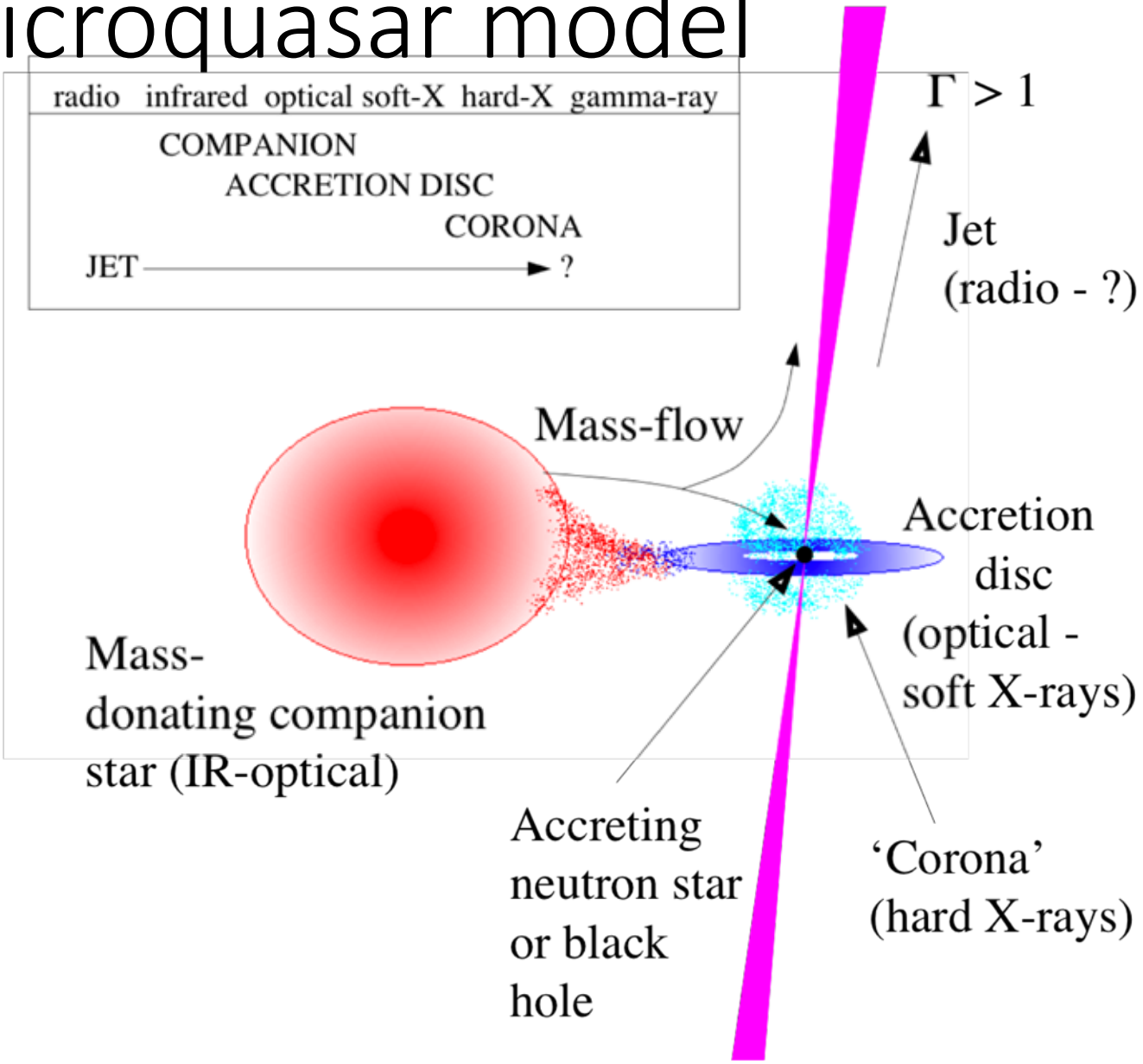
MAXI J1535-571

MAXI J1910-057

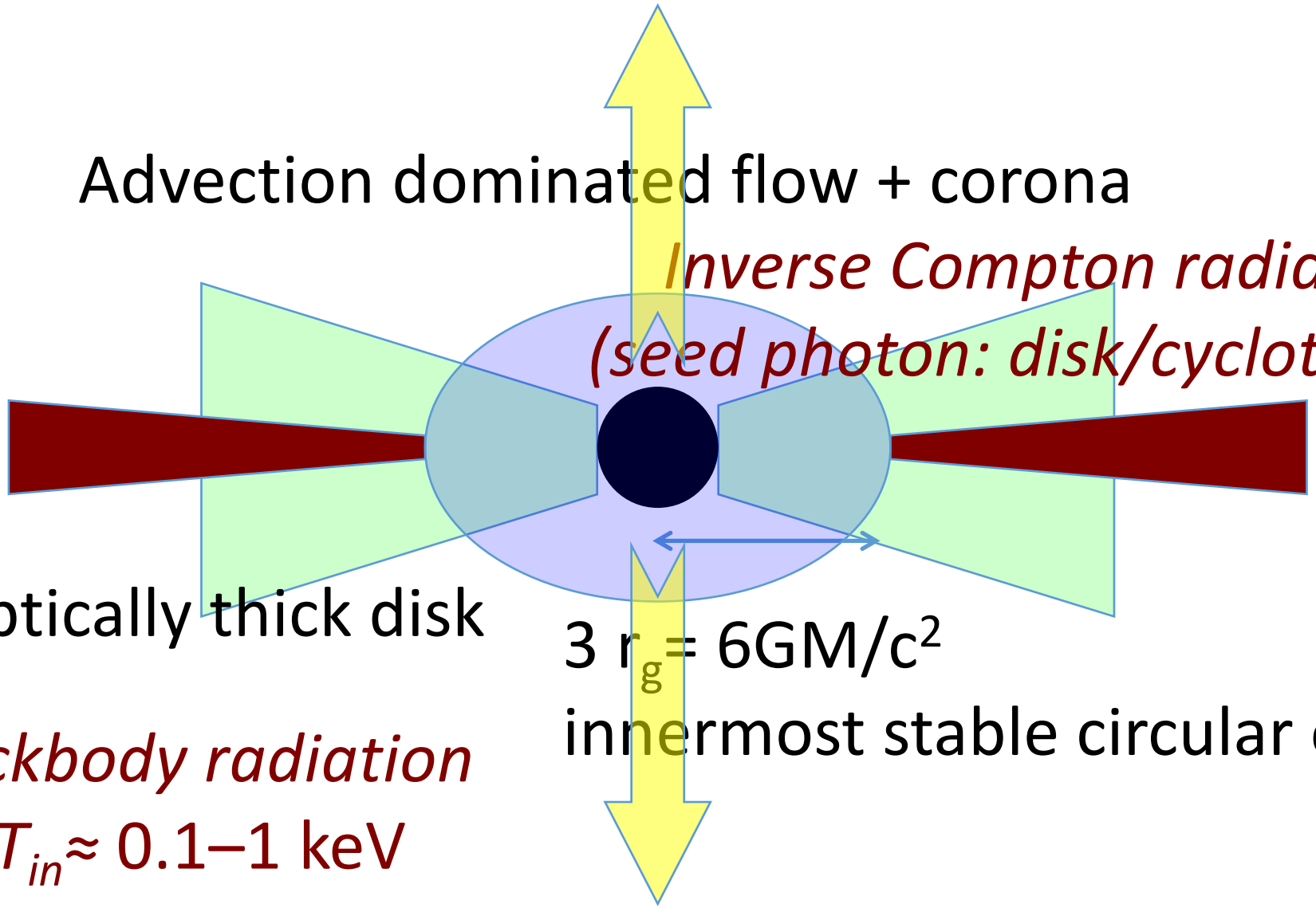
XTE J1752-223



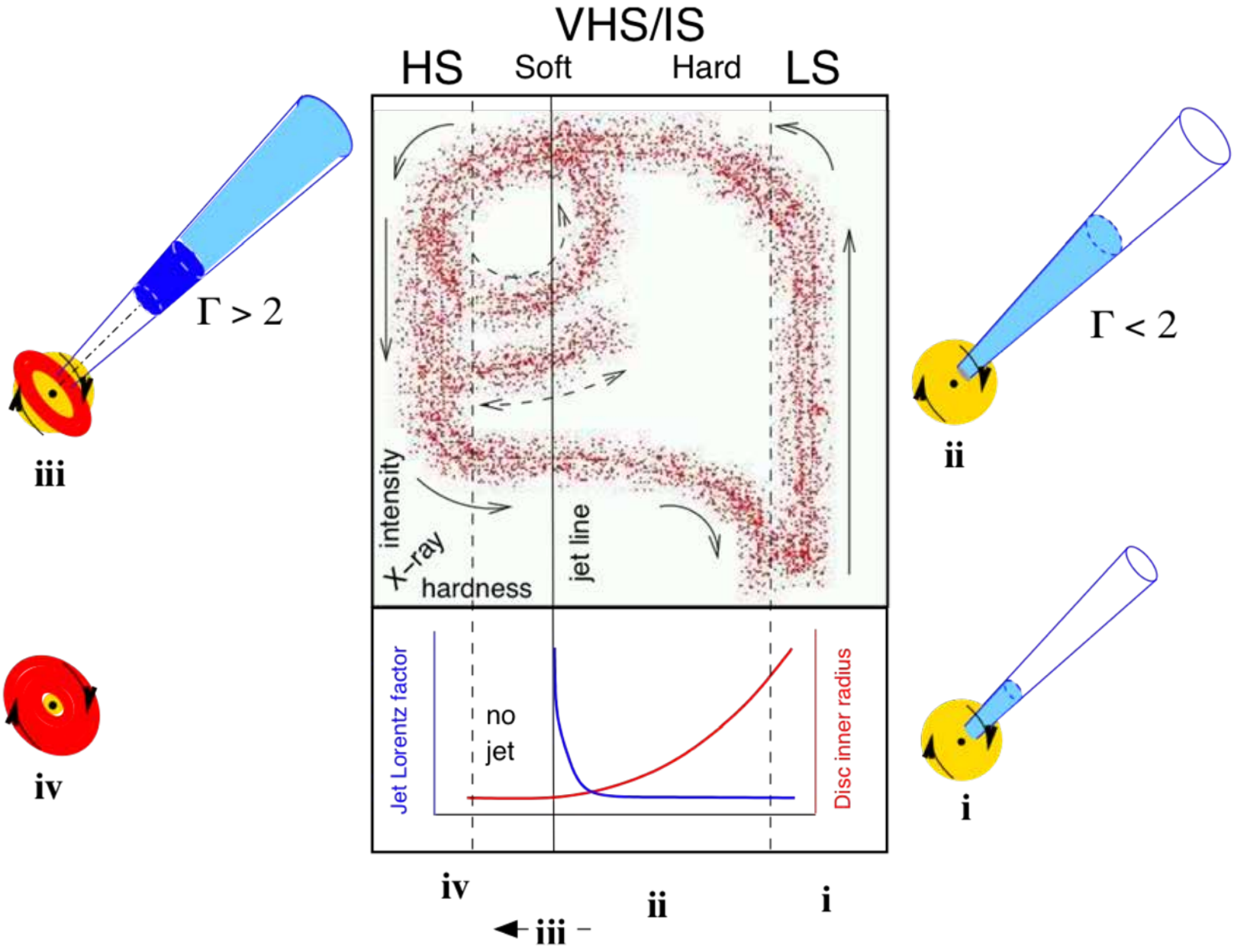
Microquasar model



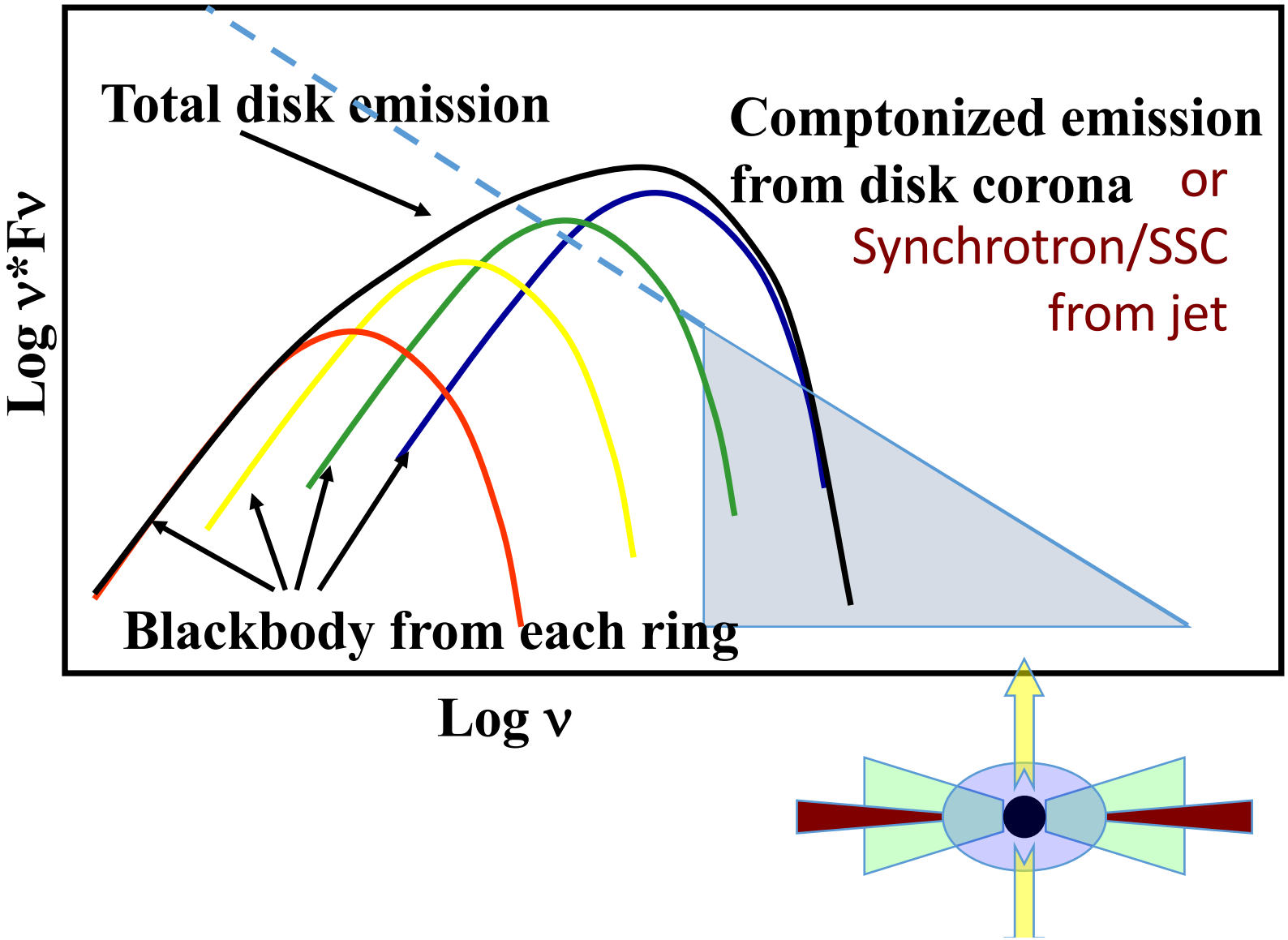
Anatomy of an accreting black hole



Spectral States and Disk-Jet Coupling in Black Hole Binaries (Fender 2004,…)

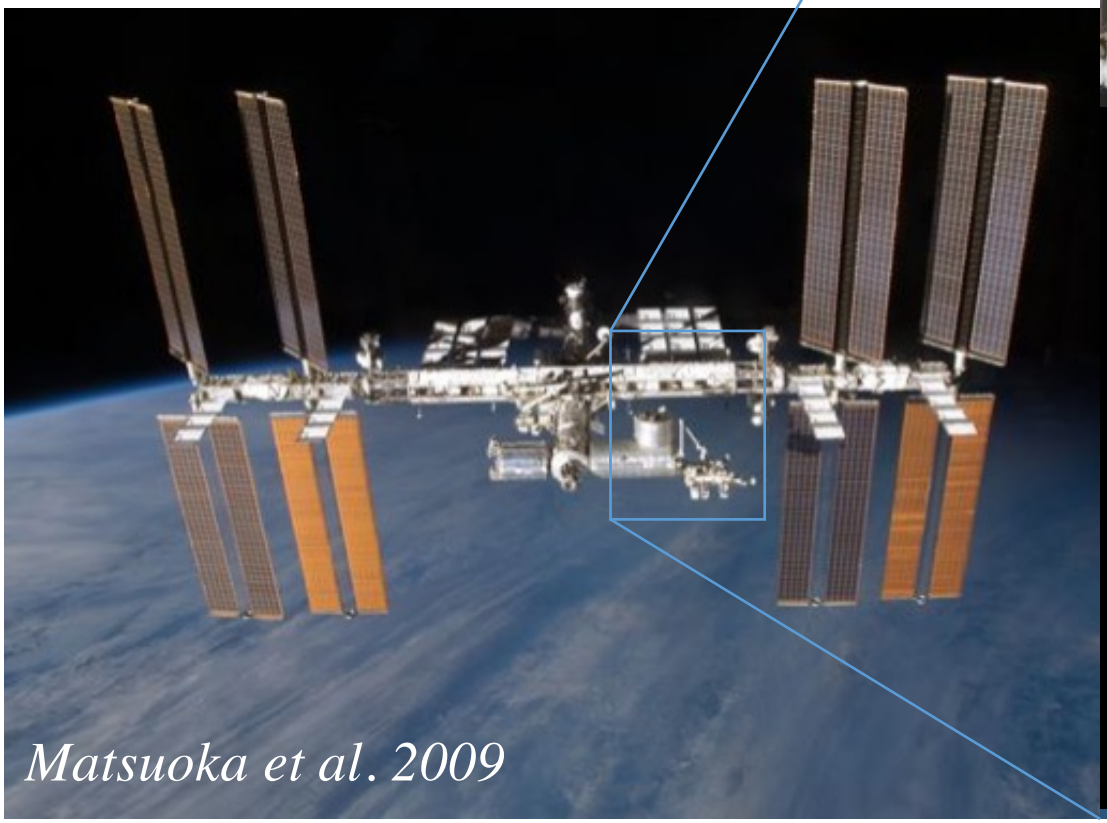


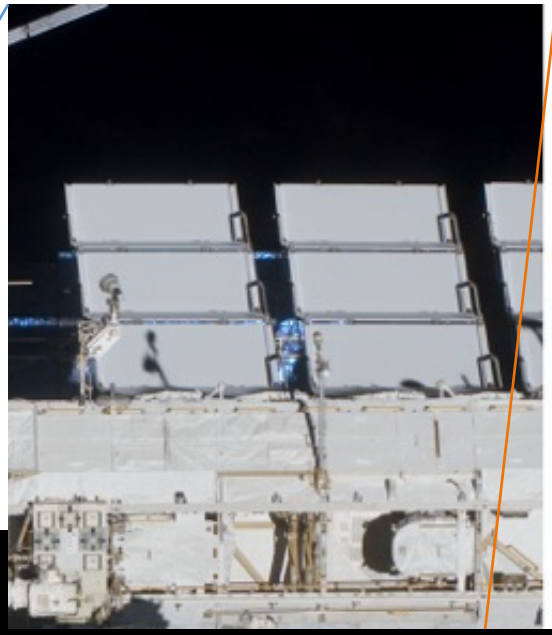
X-ray spectrum of a black hole binary

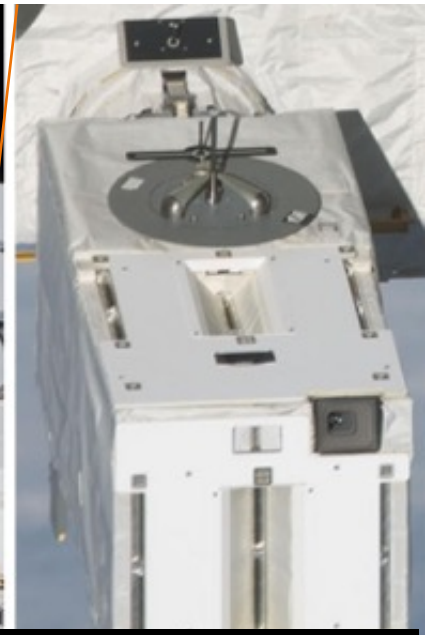


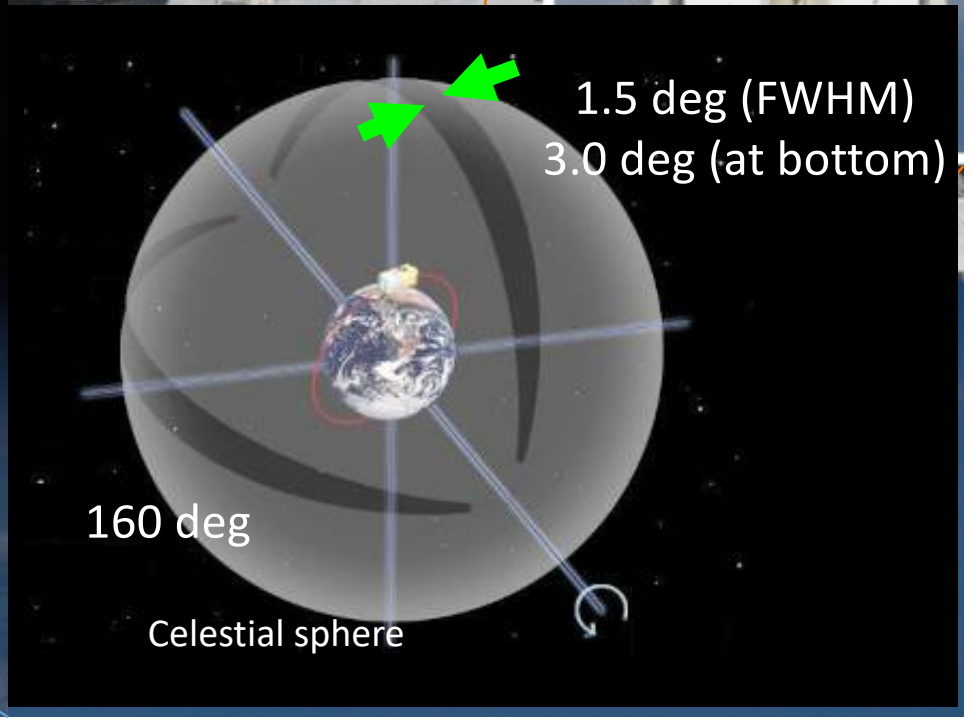
Monitor of All-Sky X-ray Image

- Mission started August 2009
- Ops approved until Mar 2021
- Real-time link ~70%
- "MAXI 10-Year" Symposium planned in Fall 2019



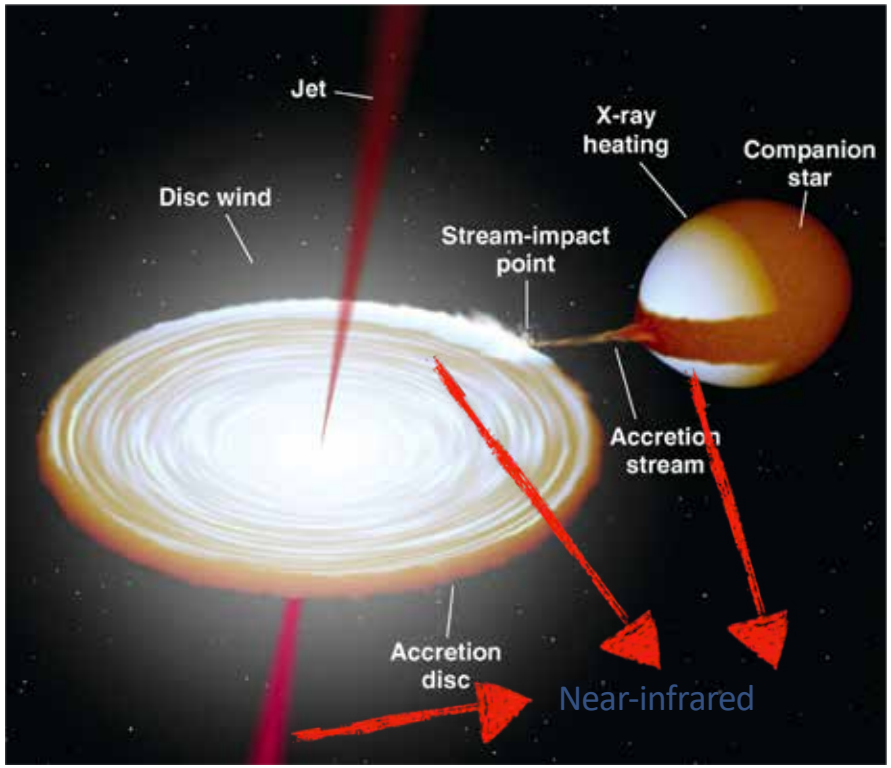






Optical/NIR emission from Low-mass X-ray binaries

- Thermal emission from the X-ray irradiated disk and/or the companion
- Synchrotron emission from the jet
- Cyclotron emission (or Comptonized —) from ADAF

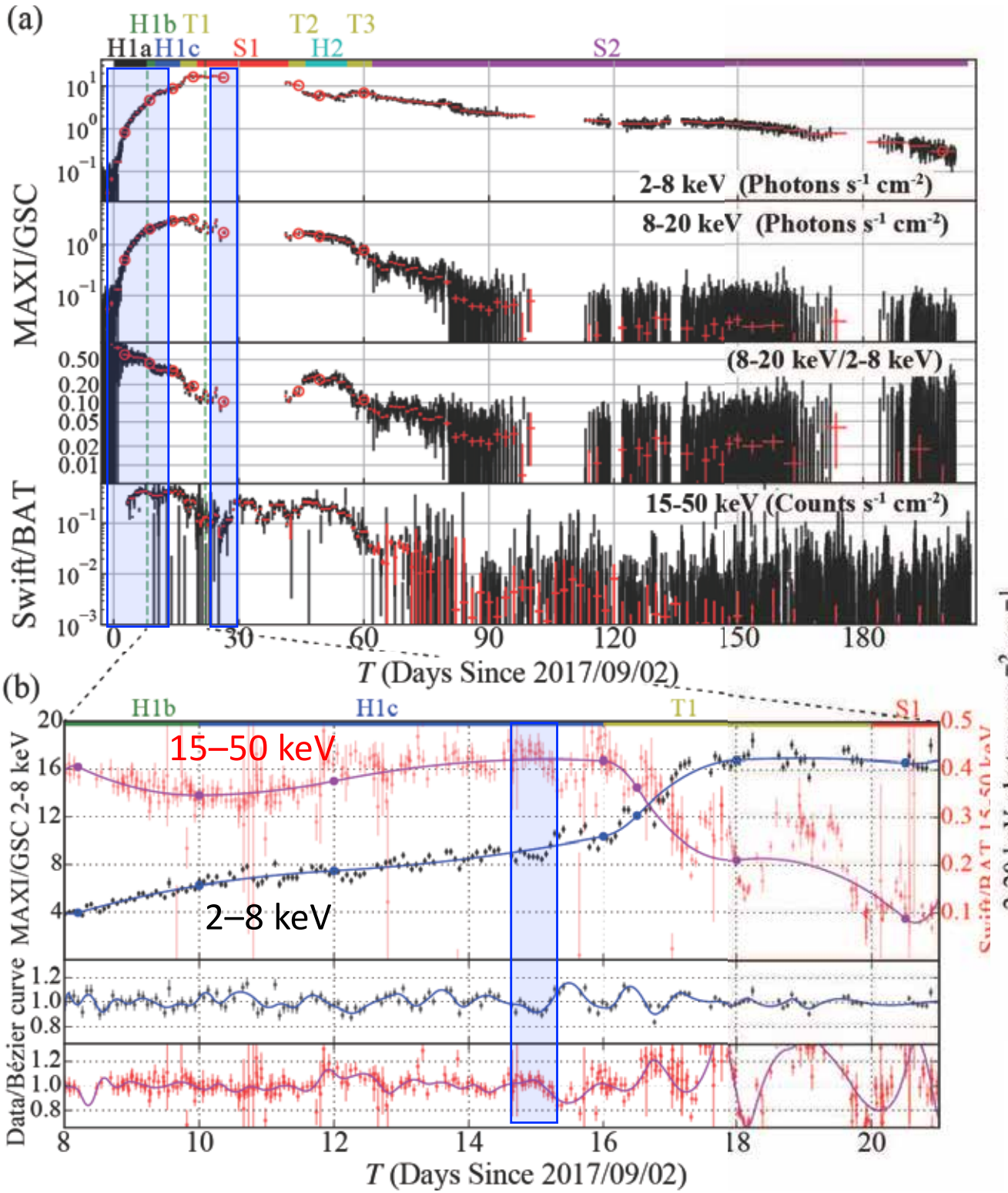


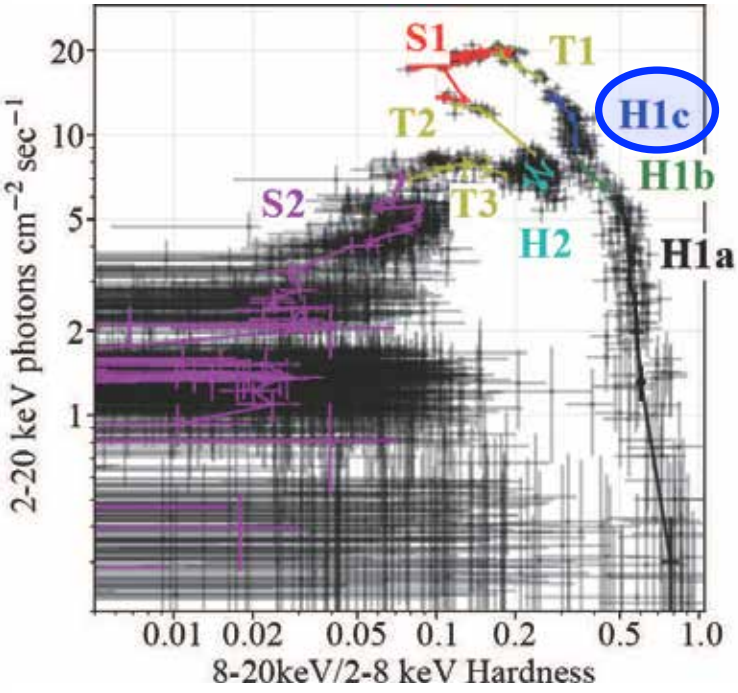
may constrain the system geometry and dynamics, and provide information on accretion and radiation processes

MAXI J1535–571

⇦ X-ray light curves

Hardness-Intensity Diagram (HID) ⇩





Nakahira et al. 2018

Follow-up observation with IRSF 1.4 m telescope

Near-infrared

- J (1.2μm), H (1.6μm), Ks (2.3μm)
- less dust extinction than optical and UV
- galactic plane source such as MAXI J1535-571

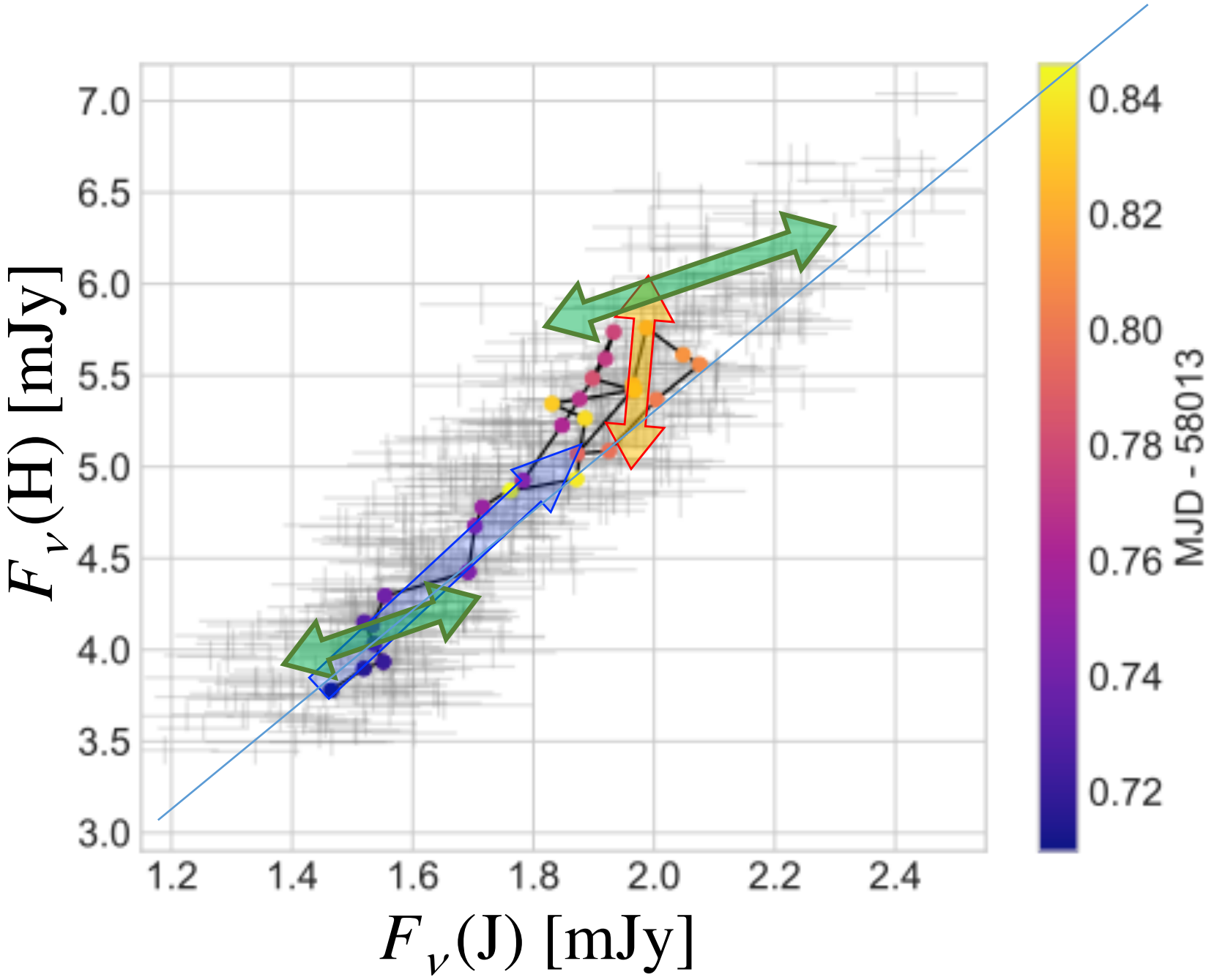
Sutherland observatory in South Africa

- Southern Hemisphere
- MAXI J1535-571

Observations

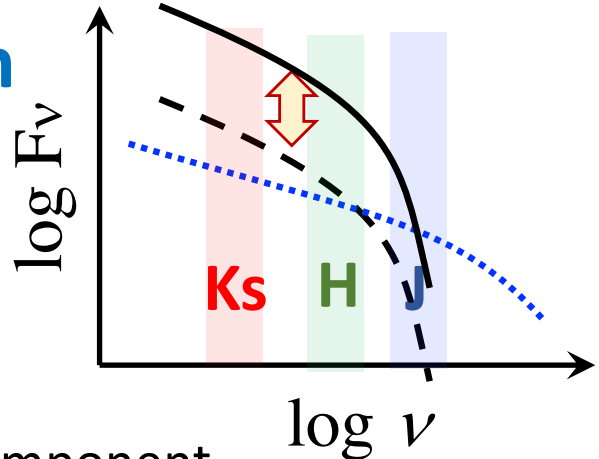
- Sep 6—17: Kumiko Morihana, Takahiro Nagayama
- Sep 28 — Oct 2: Katsuhiro Murata, Ryosuke Itoh

MAXI J1535–571: 2-color fux (H vs. J)



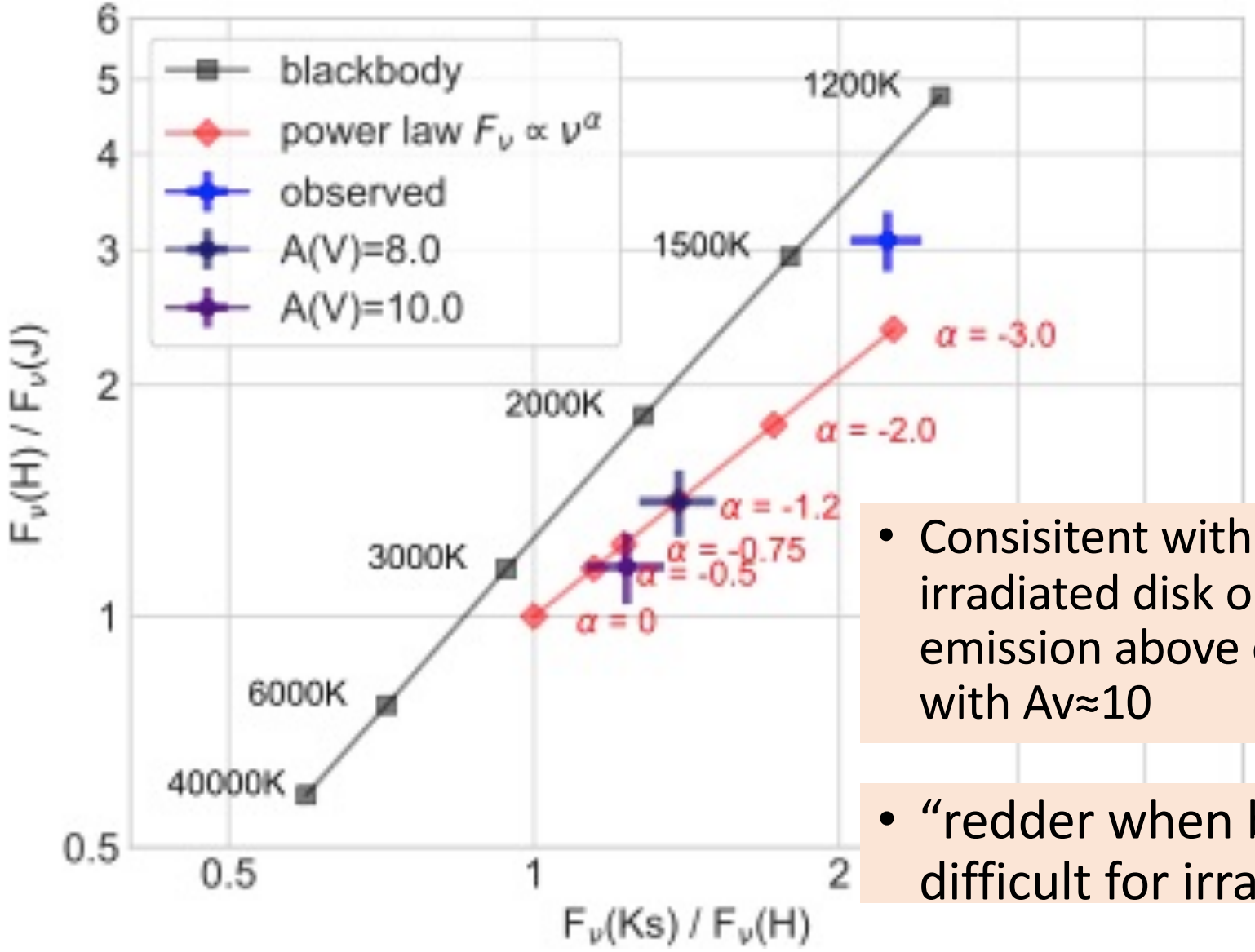
MAXI J1535–571: NIR flux properties

- **Variable on three time scales**
  - Slow gradual rise (τ ≥ 10 ks)
  - Intermediate variation (τ ~3 ks) at plateau
  - Rapid variation (τ<20s)
- **Slow and rapid variations share common properties**
  - Rapid var. amplitudes scales with total flux
  - Similar colors
  - Redder when brighter
    - → suggest existence of underlying stable blue component



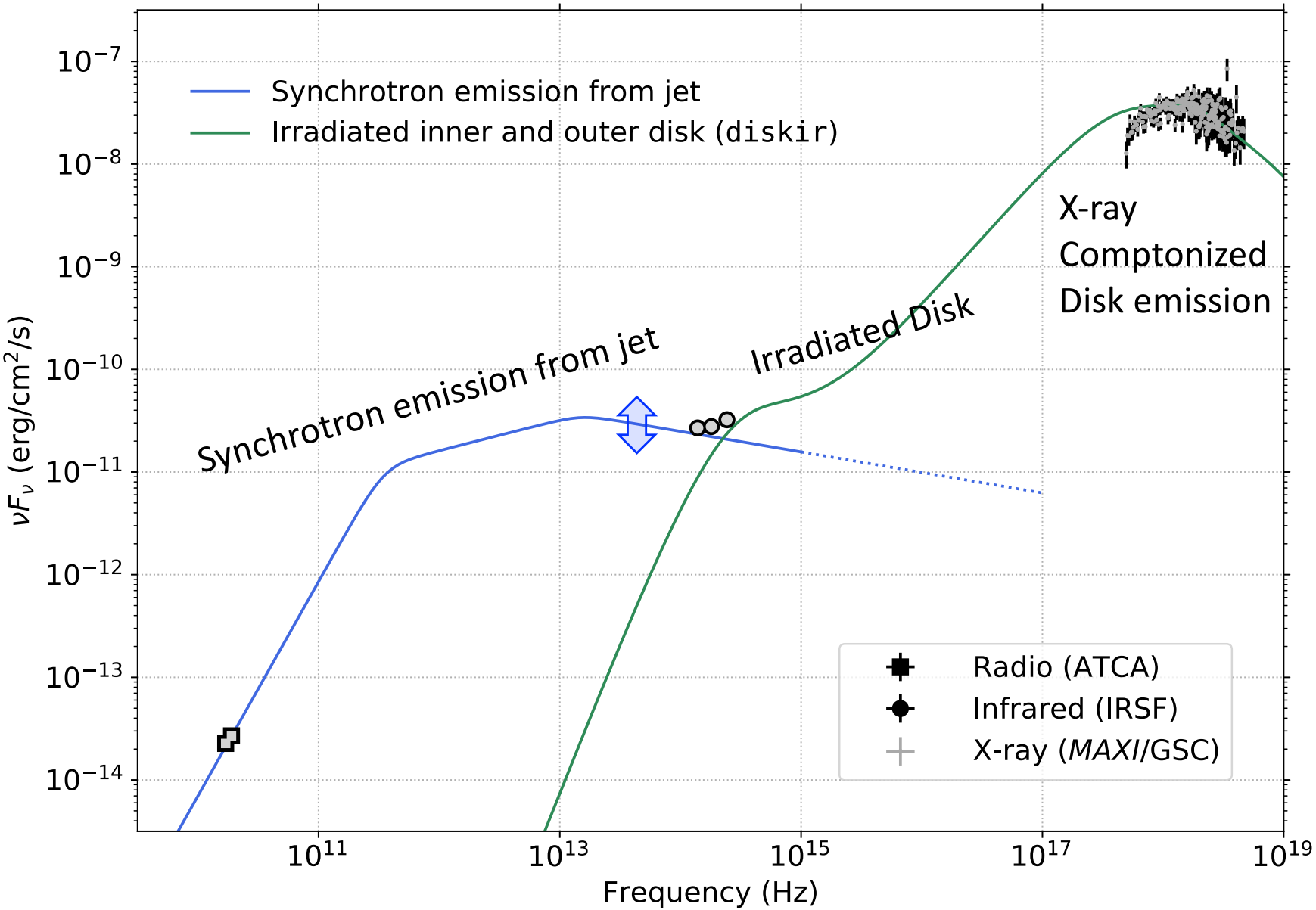
- **Intermediate variation is different**
  - Redder when brighter in J-H, small amplitude in J band
  - Little change in H-Ks color

Rapidly variable component on **color-color diagram**



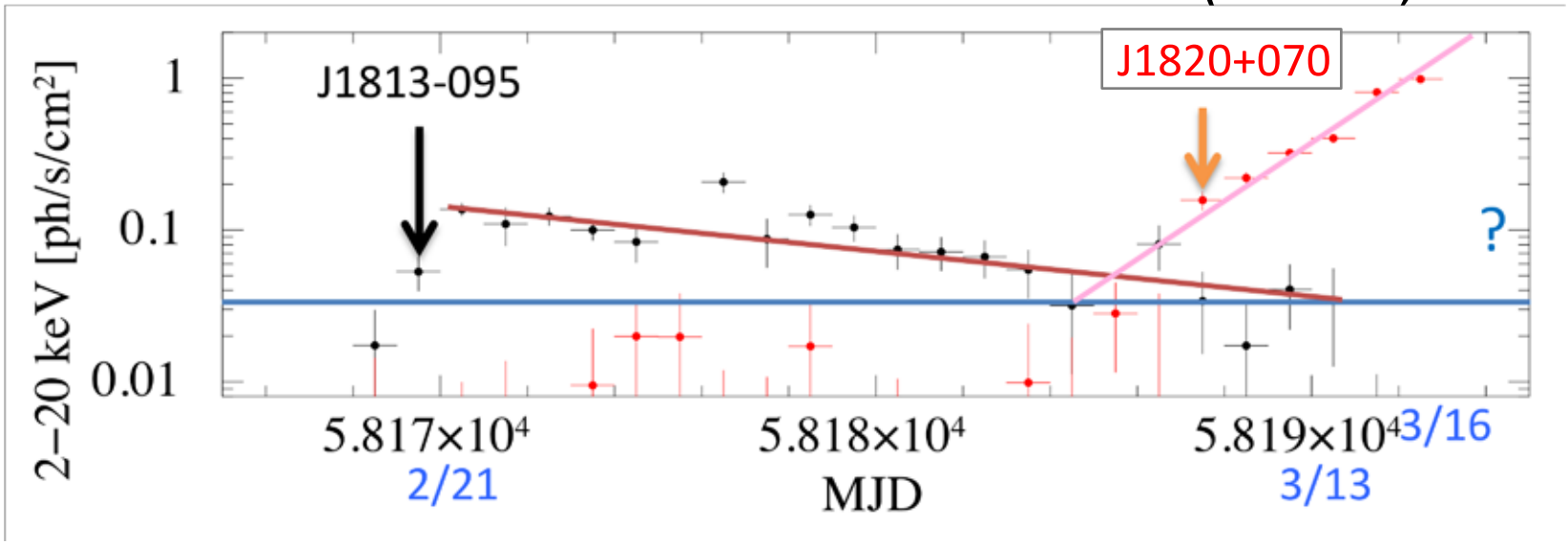
- Consisitent with either irradiated disk or synchrotron emission above cooling break with Av≈10
- “redder when brighter” difficult for irradiated disk

Possible broad-band SED



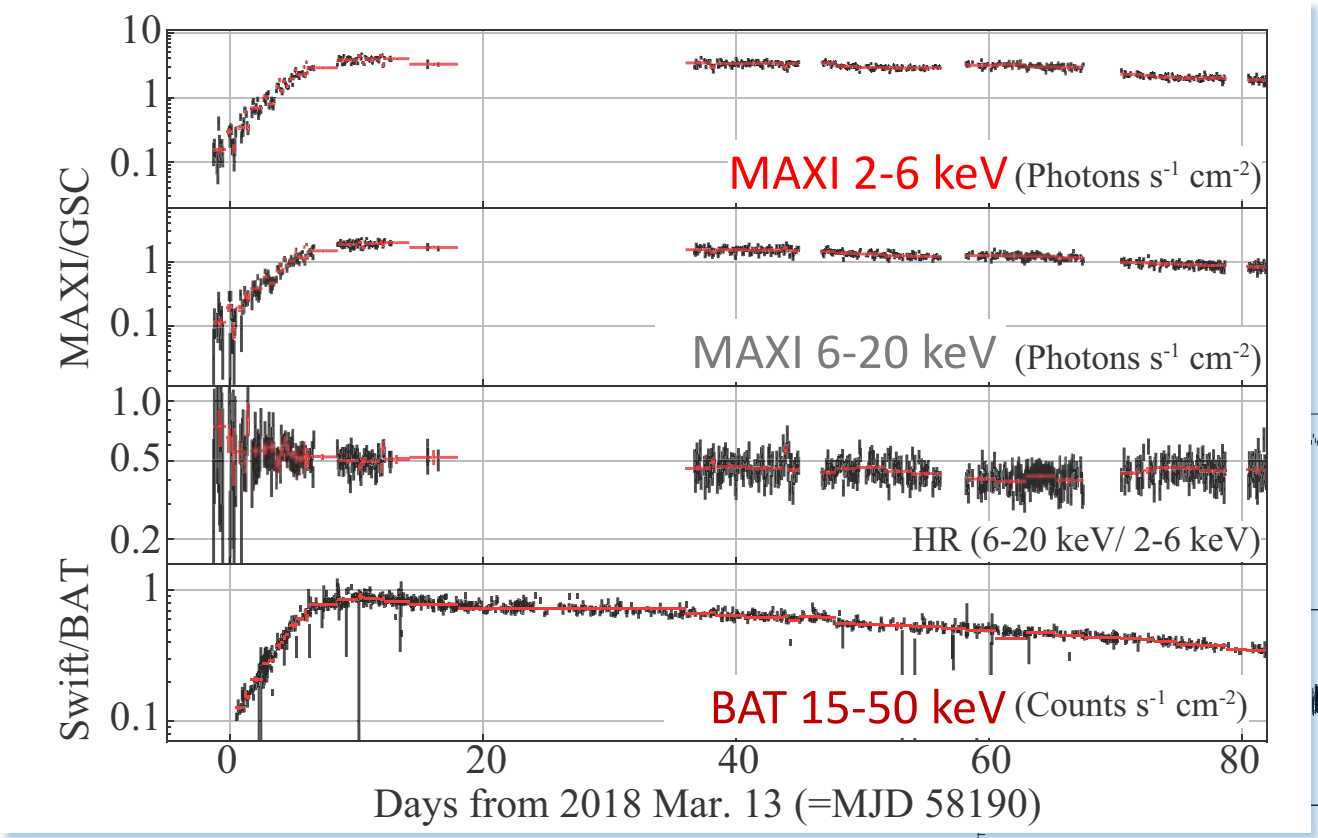
Two new BHCs discovered by MAXI in 2018
MAXI J1813-095, MAXI J1820+070

- MAXI J1813-095
  - 2/20 disocvery (Kawase+ ATel #11323)
  - Swift/XRT localization (Kennea+ #11326)
  - Radio-quiet BHXB (Russel+ #11356)
  - INTEGRAL: power-law w/cutoff at 140 keV → BHC hard state (Fuerst+ #11357)
- MAXI J1820+070
  - 3/11 discovery (Kawamuro+ ATel #11399)
  - 0+4h optical counterpart (Deniseko #11400)
  - Swift XRT localization (Kennea+ #11403)
  - Optical, Radio, X-ray observations suggests BHC hard state (#11418, 11420, 11423)



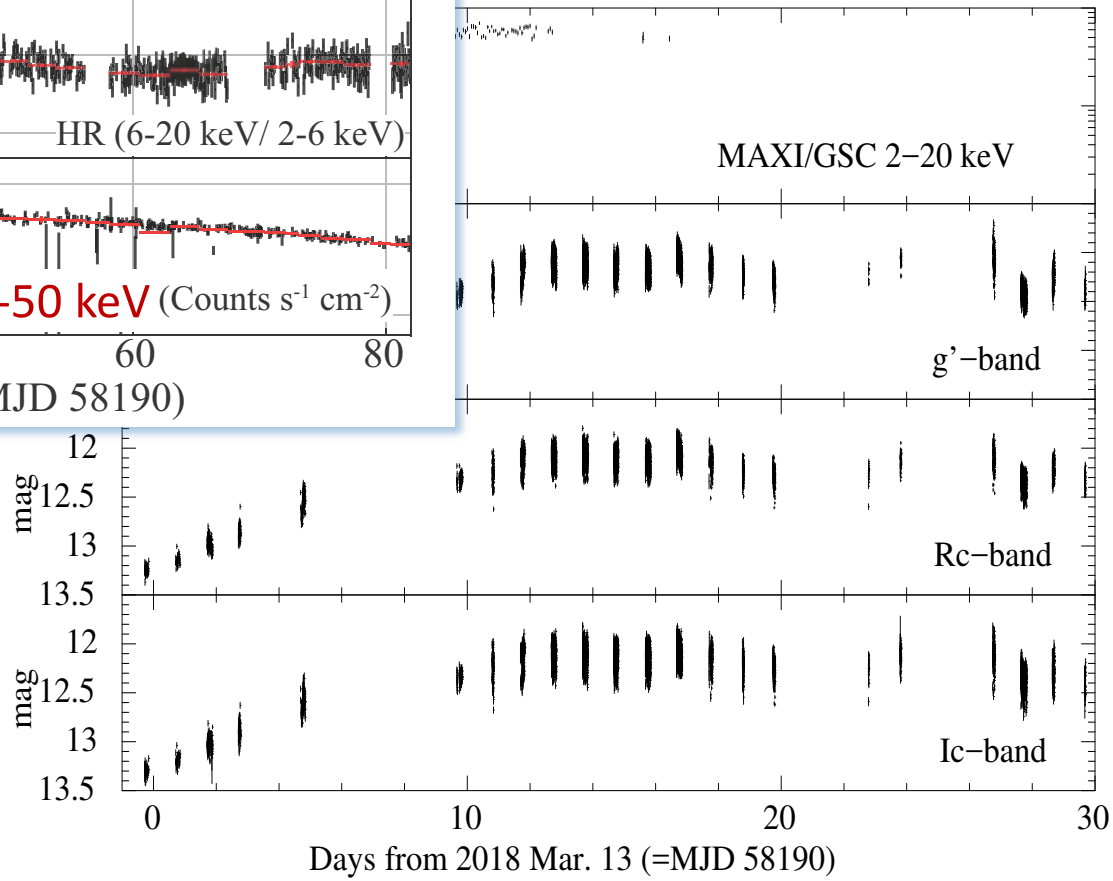
MAXI J1820+070

Shidatsu et al. 2018, ApJ



Hard state

No state transition for 80 days

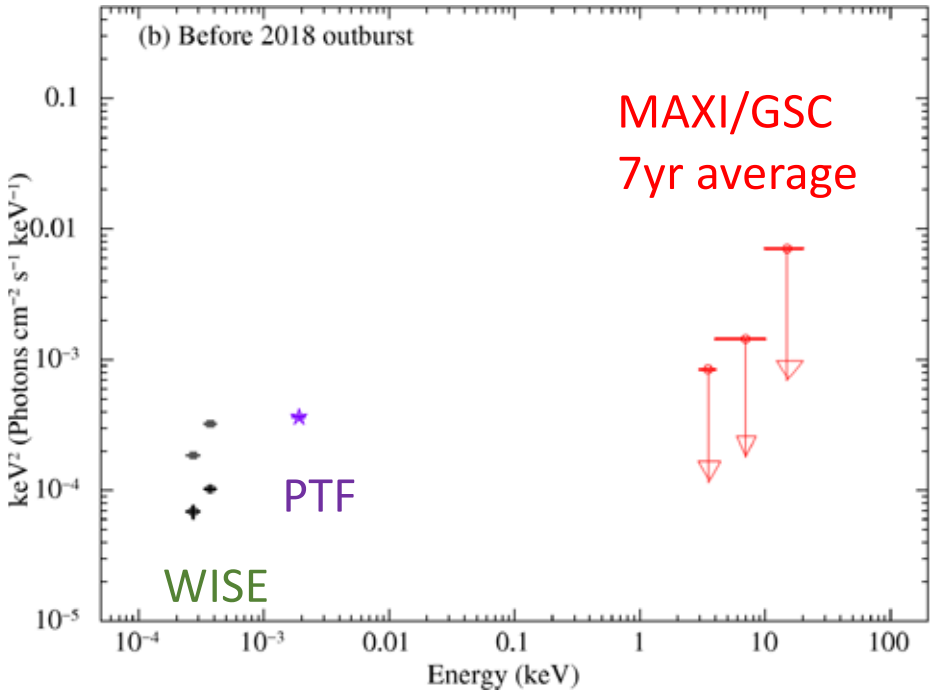


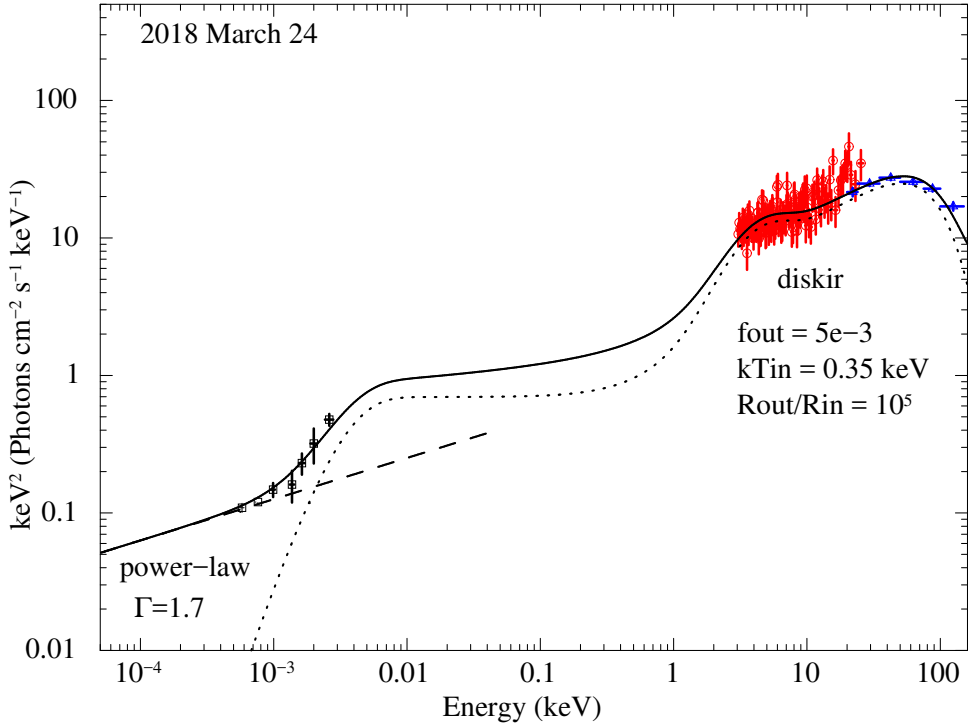
Optical/NIR

Bright and highly variable

MAXI J1820+070
NIR-optical-X-ray spectrum

Shidatsu et al. 2018
submitted to ApJ





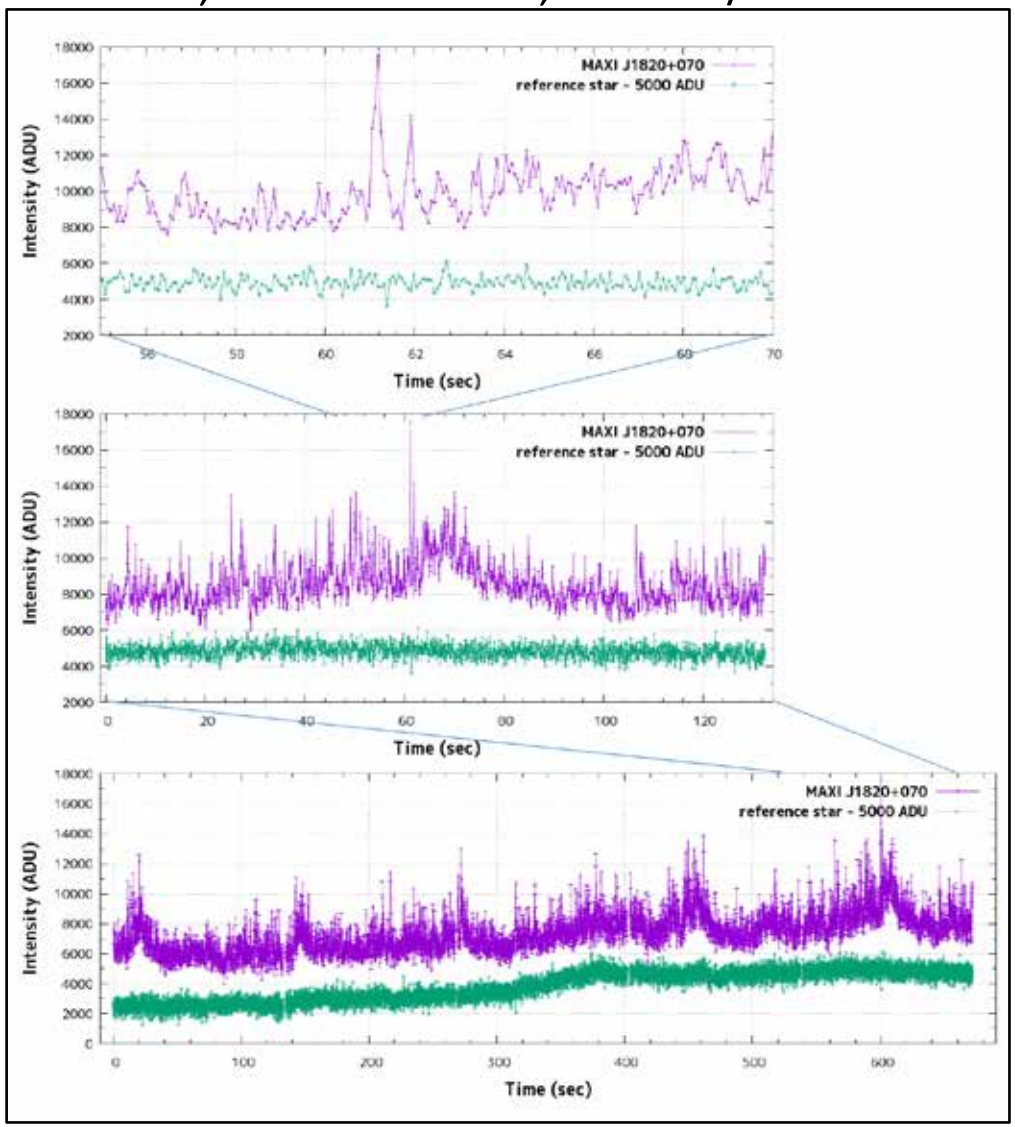
NIR variable in quiescent state

Optical/NIR
Irradiate disk + non-thermal

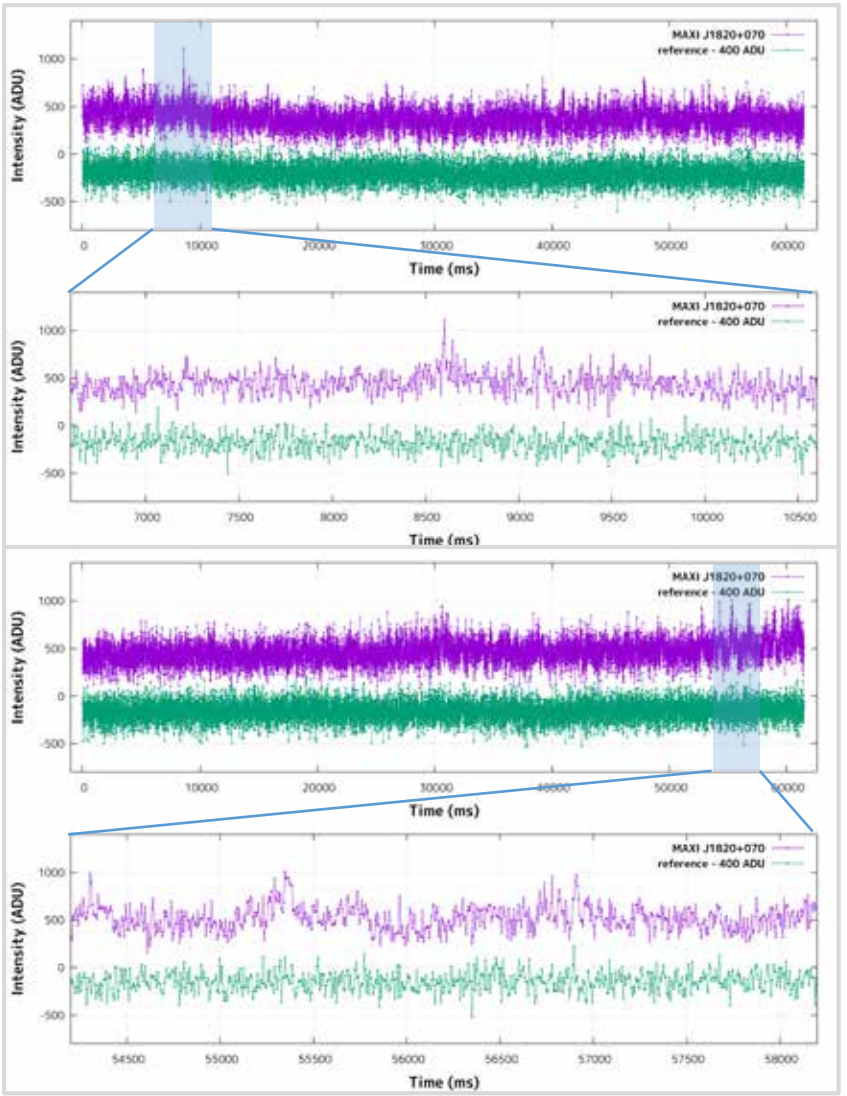
MAXI J1820+070
10-msec scale optical flares

Sako et al. 2018
ATel #11426
Tomo-e Gozen
CMOS camera/Kiso

March 14, 18:43-19:20 UT, 16.3 ms/frame

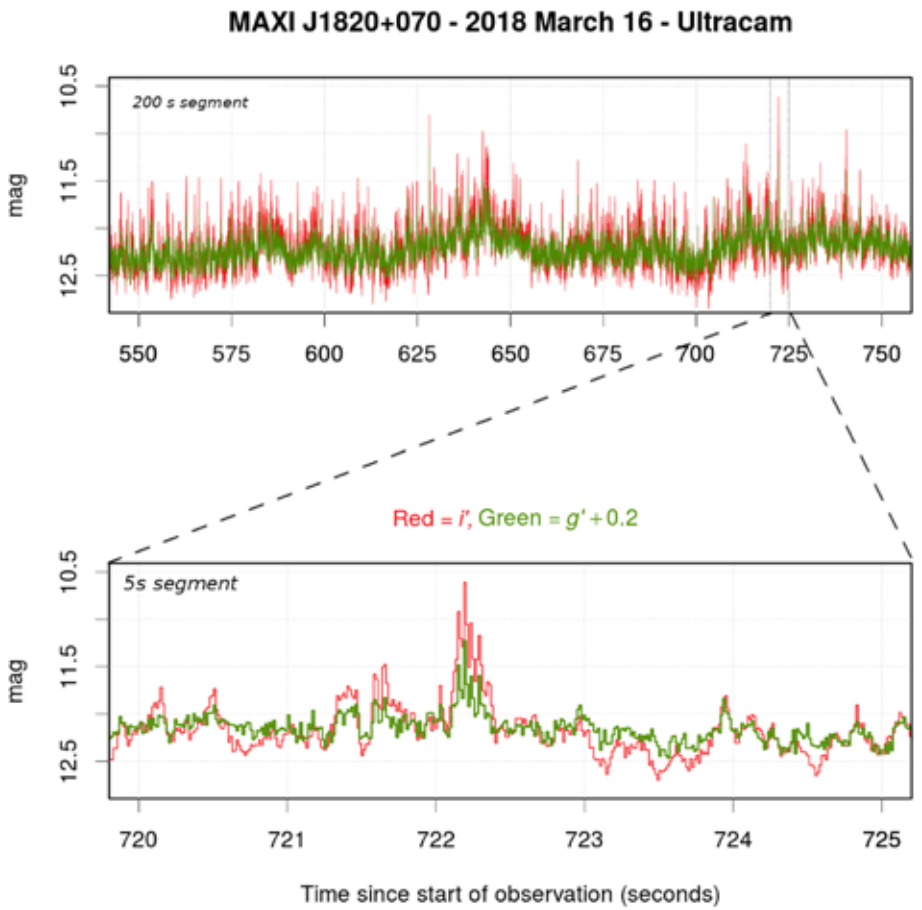


March 14, 19:30-19:45 UT, 6.15 ms/frame

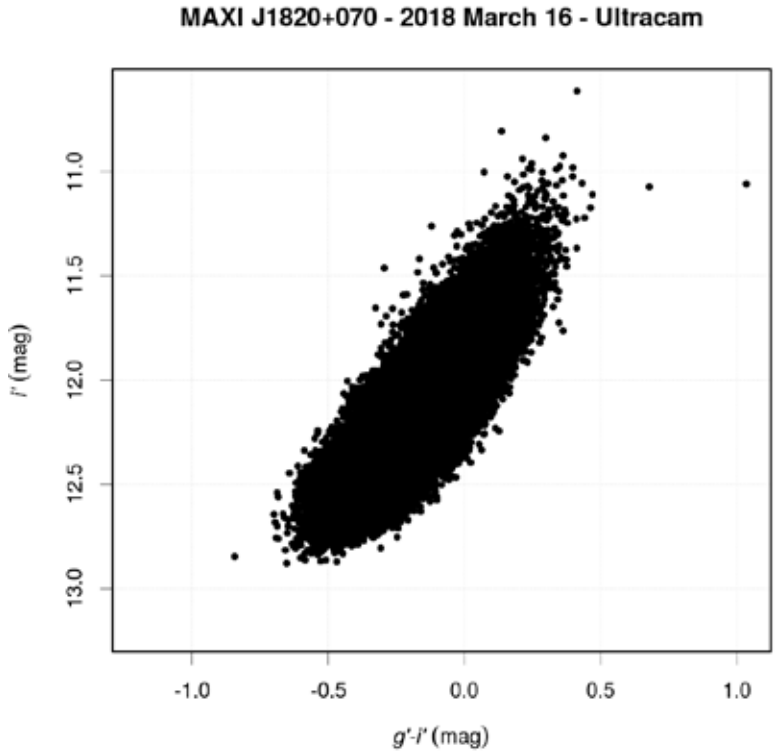


MAXI J1820+070
Red sub-second optical flaring

Gandhi et al. 2018
ATel #11437



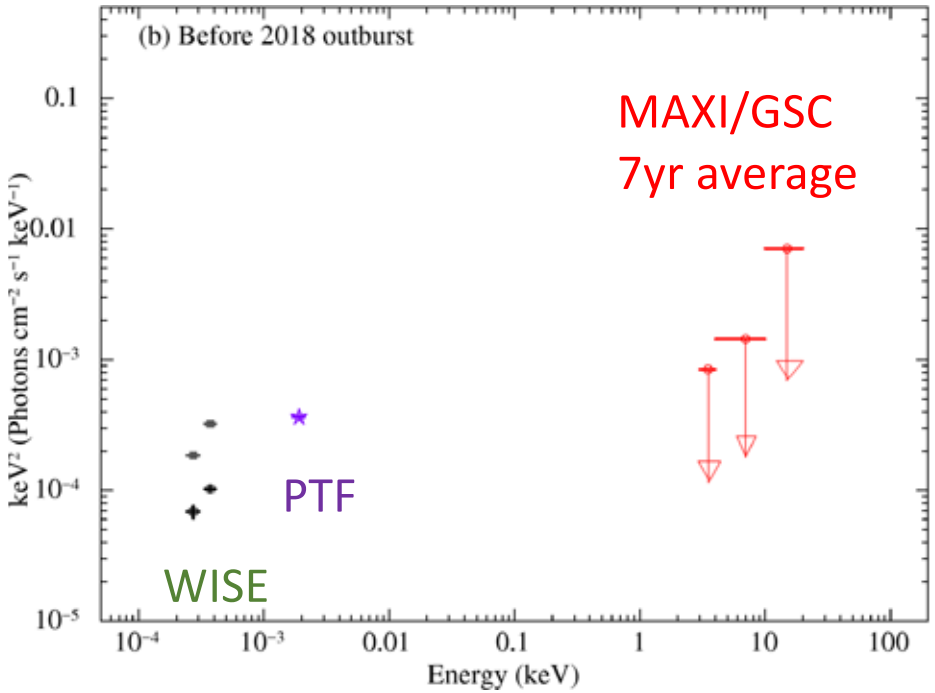
(Top) 200-second segment of simultaneous ULTRACAM lightcurves, sampled at a cycle time of 13.8 ms. The g' band lightcurve has been offset by 0.2 mag to match the r' median. (Bottom) Zoom-in around a rapid sub-second flare with a peak i' amplitude of 1.6 mag and substructure, all within 0.3 s. The stronger red sub-second flaring is apparent in both panels.

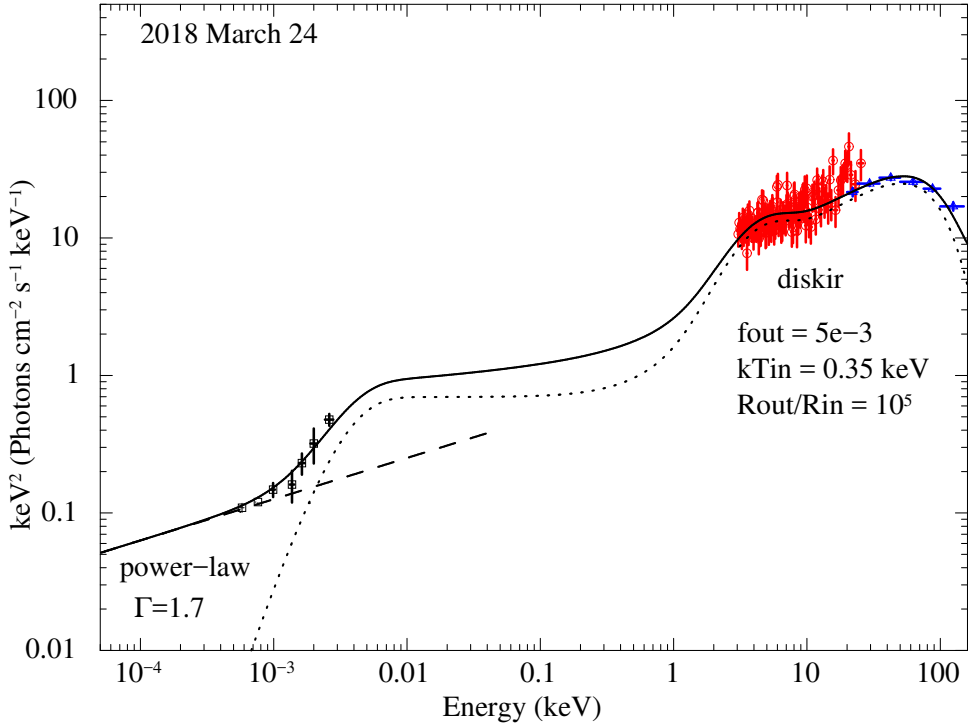


Colour-magnitude plot of the ULTRACAM lightcurves, showing the **redder-when-brighter** trend.

MAXI J1820+070
NIR-optical-X-ray spectrum

Shidatsu et al. 2018
submitted to ApJ

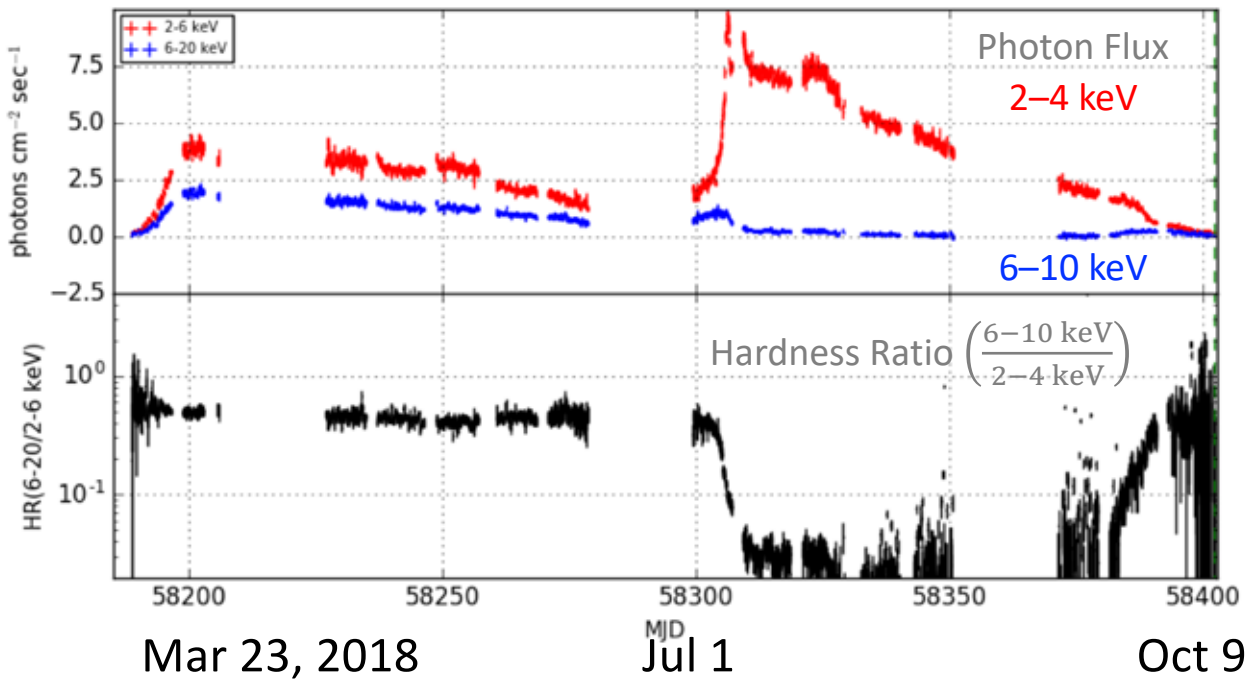




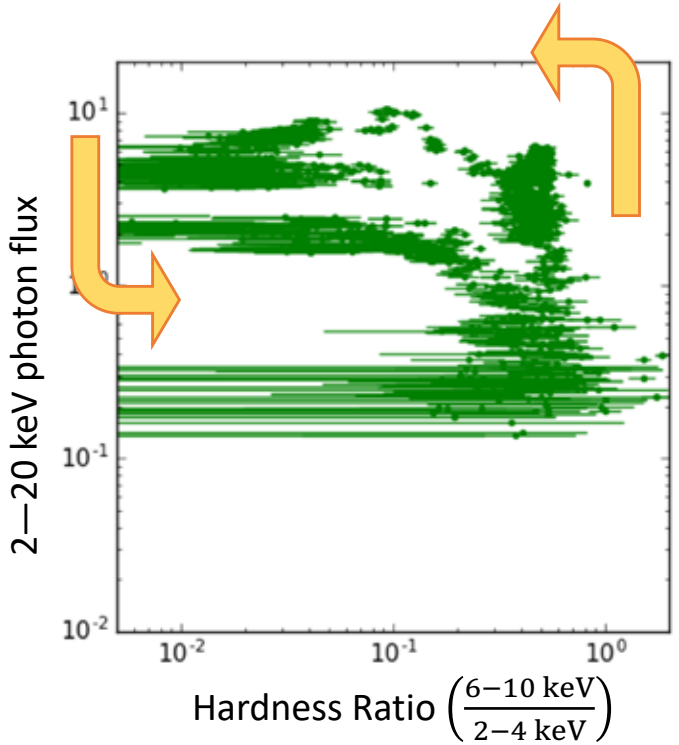
NIR variable in quiescent state

Optical/NIR
Irradiate disk + non-thermal

Latest news on MAXI J1820+070



Mar 23, 2018 Jul 1 Oct 9



Hard→Soft State transition at +120 days
Soft→Hard state transition at +190 days

Hardness-Intensity diagram

http://maxi.riken.jp/nakahira/1820monitor/

Summary

- Transient black hole binaries show non-thermal emission in radio-IR-optical bands.
  - Cf. non-thermal X-ray emission - Comptonized
- Probably synchrotron emission from the relativistic jet
- Jet activity in X-ray “low-hard” state
- Also in “very high” or “intermediate state” where the thermal disk emission is present
- Interesting to look for Inverse Compton gamma-ray emission