

The NICER Mission & Prospects for Black Hole Binaries

Ron Remillard (MIT) &
NICER Observatory Science Working Group



NICER Instrument Summary

- X-ray Cameras and Capabilities
- Mission Timeline (and your invitation to join)
- Observatory Science Working Group (beyond NS)

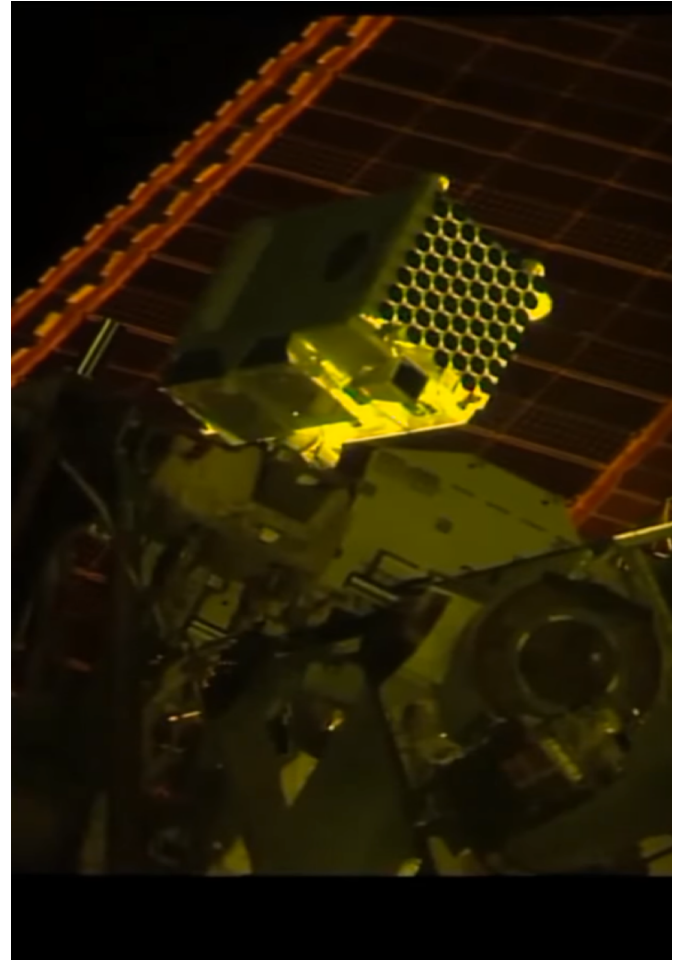
Observations of Black Hole Binaries

- Targets and Goals
- Early Results (RR, continuing on to Jack Steiner):
Cyg X-1 ; MAXI J1535 ; GRS1915

X-ray Timing Instrument (XTI)

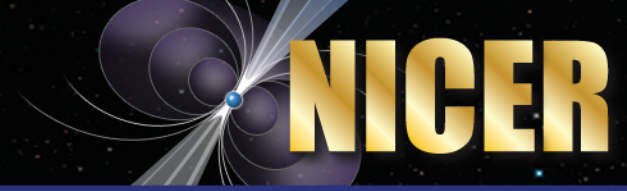
- **56 identical cameras**
(concentrators + Si drift detectors)
- **0.2-12 keV bandwidth**
- **140 eV FWHM at 6 keV**
- **Absolute Timing to 100 ns**
- **Source count rates $>\sim$ RXTE**
- **Background rate $< 10^{-2}$ RXTE**
- **Unique combination:**
 - Soft X-ray coverage
 - Great Spectral & Timing Resolution
 - Event Mode : 100% info
 - Sensitivity to sub-mCrab sources
 - 1% deadtime @ 3 Crab intensity

ISS photo: 2017 June

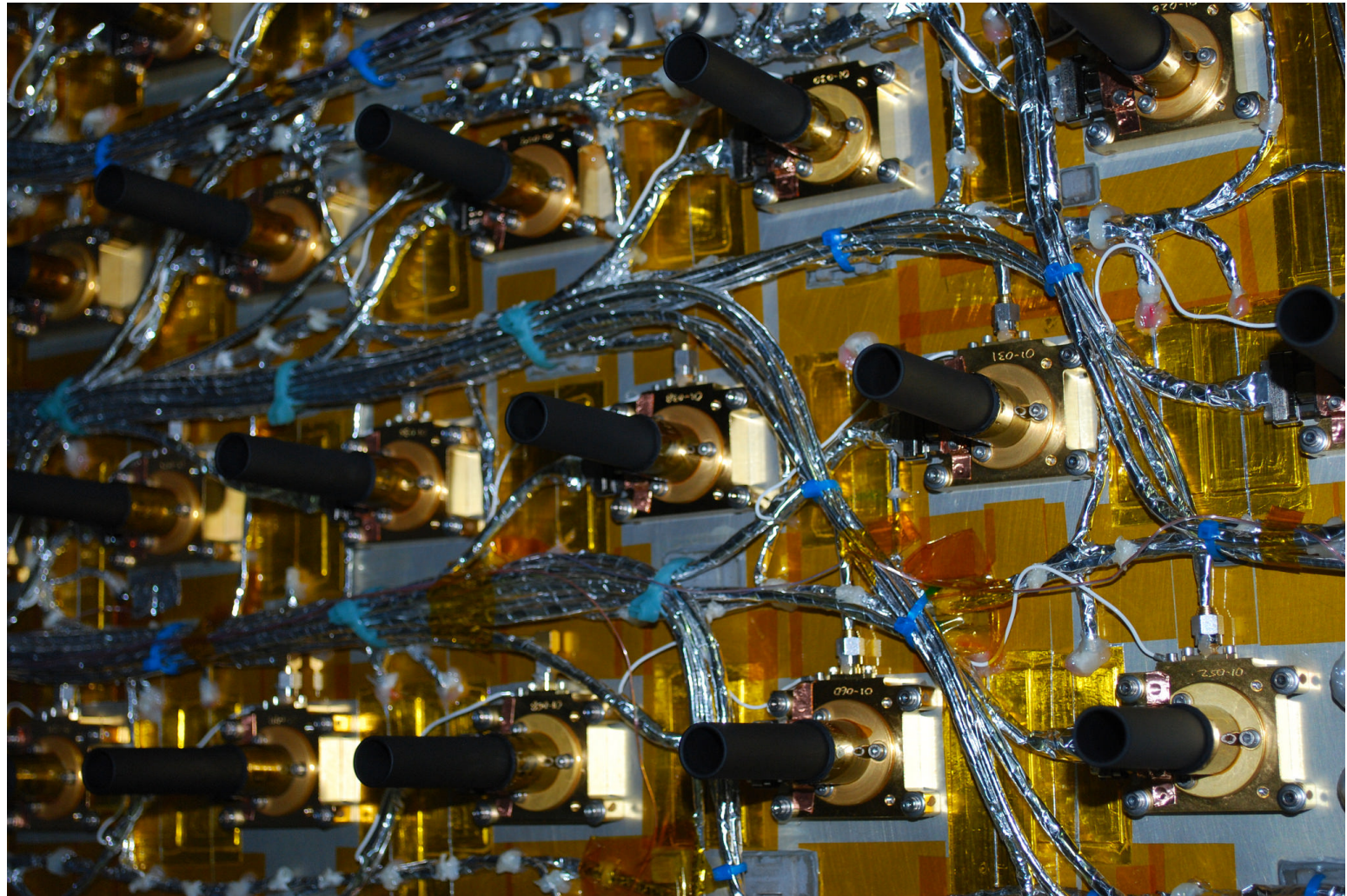


Youtube keywords: **NICER deployment ISS**

Si Drift Detectors in Focal Plane



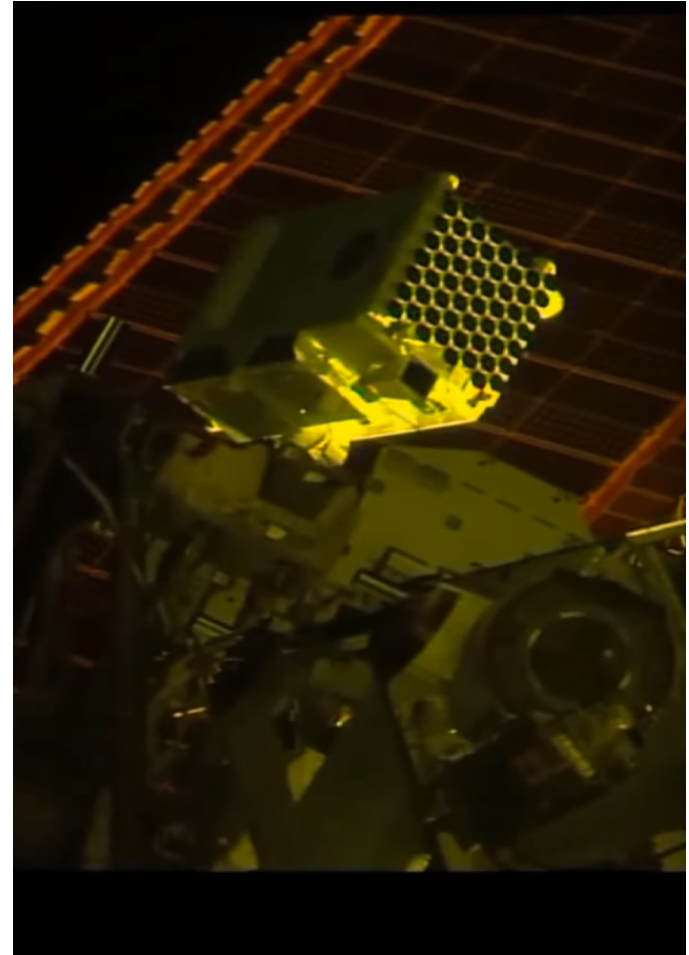
EMI Test Room, January 2016



In-Flight Performance

- **52 of 56 detectors are 100%**
(problems: harness[2], window, noise;
known since I&T)
- **Response curve slightly better than calculations**
- **Background model working down to ~ 0.25 keV**
- **One issue: Solar light leak**
(manageable; increases deadtime due to increased detector resets)

ISS camera: 2017 June





- *Delivery to Kennedy Space Center* 2016 June 10
- *Launch on Falcon 9 from KSC* 2017 June 3
- *Begin Checkout & Commissioning* 2017 June 14
- *Begin Science Mission (pass NASA Review)* 2017 July 14

- ***Public Data Release (~ launch + 6 mo)*** **2018 January ?**
- ***Proposals due for GO Program (contingent)*** **2018 March ?**

- *Propose Extension to NASA Senior Review* 2018 December
- *Begin 100% Guest Observer Program* 2019 January
- *Recommendation from Senior Review* 2019 April

NASA approved NICER Science Enhancement Options

- Observe Sources other than Neutron Stars
- Showcase Instrument (bright sources; prompt publications)
- Achieve broad science to promote Extended Mission
- Confirm Intent to evolve NICER into a 100% Guest Obs. Facility

Observatory Sci. Working Group (28 affiliated scientists)

- Select non-NS targets with 2.5 Ms during Prime Mission (18 mo.)
- Target List covers 15 source classes



OSWG Members [28]

Zaven Arzoumanian (GSFC)

Esra Bulbul (CFA)

Peter Bult (GSFC)

Ed Cackett (Wayne State U)

Deepto Chakrabarty (MIT)

Mike Corcoran (GSFC)

Steve Drake (GSFC)

Steve Eikenberry (U Florida)

Teru Enoto (GSFC)

Andy Fabian (U Cambridge)

Keith Gendreau (GSFC)

Kenji Hamaguchi (GSFC)

Jeroen Homan (MIT)

Peter Jenke (MSFC)

Erin Kara (U Maryland)

Mike Loewenstein (GSFC)

Craig Markwardt (GSFC)

Jon Miller (U Michigan)

Joey Neilsen (Villanova)

DJ Pasham (MIT)

Paul Ray (NRL)

Ron Remillard (MIT)

Jack Steiner (MIT)

Tod Strohmayer (GSFC)

Francesco Tombesi (GSFC)

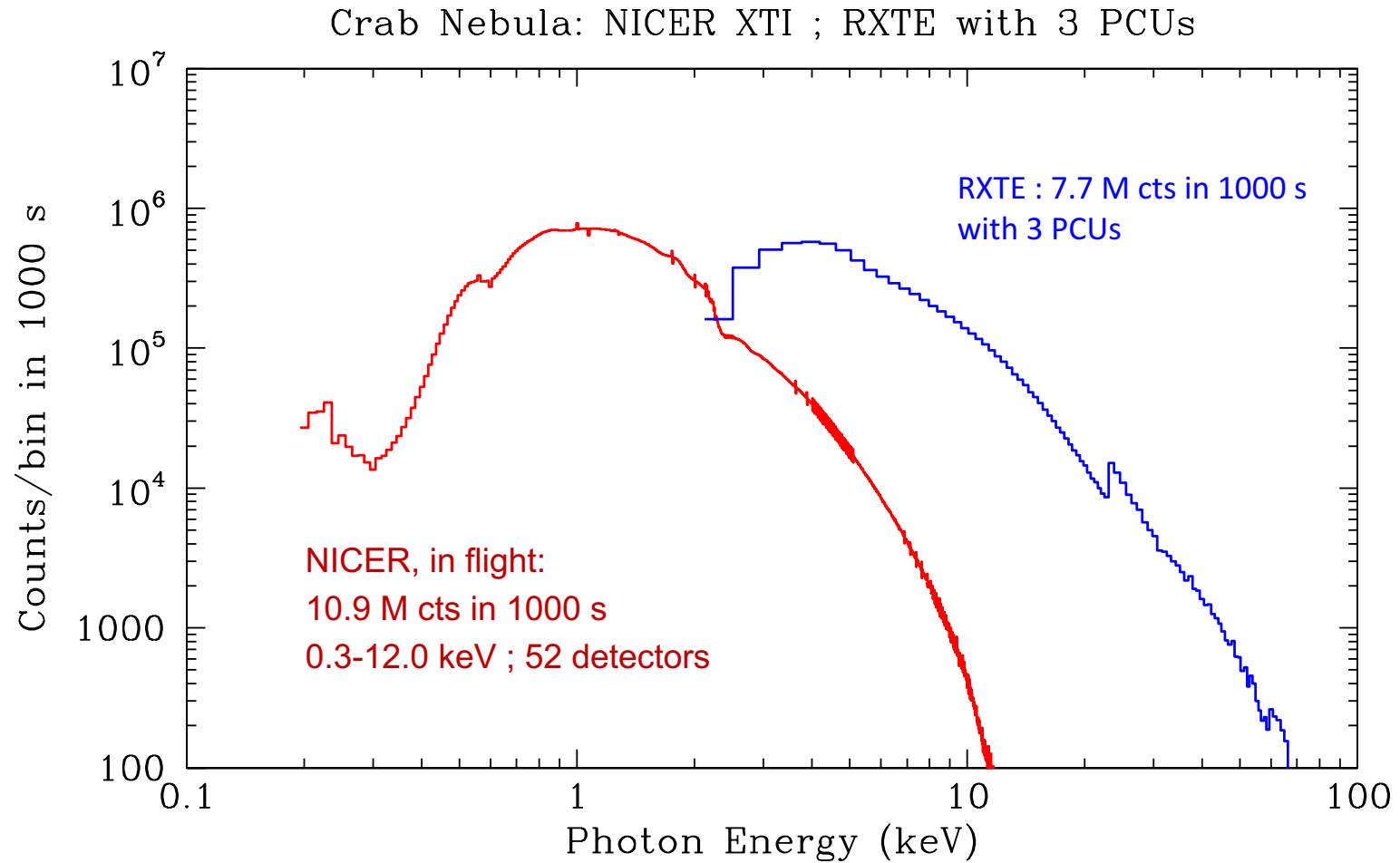
Phil Uttley (U Amsterdam)

Colleen Wilson-Hodge (MSFC)

Kent Wood (NRL)

OSWG Target Classes [15]

- Black Hole Binaries
- Accretion Disk Winds
- Gravitational Wave Sources – EM Counterparts
- Ultra-Luminous X-ray Sources in nearby galaxies
- Tidal Disruption Events in Supermassive Black Holes
- Active Galactic Nuclei
- Galaxy Clusters
- Neutron Stars – Accreting, Magnetized Pulsars
- Neutron Stars – Atoll Special Projects
- Neutron Stars – Z Sources
- White Dwarfs – Cataclysmic Variables
- White Dwarfs – Double-Degenerate Binaries
- White Dwarfs – Surface Nuclear Burning (supersoft sources)
- Stars – Active Coronae
- Colliding Stellar Wind Binaries



New Window on Visibility of the Accretion Disk

- Disk R_{in} , T , (*effective*) and disk *accretion rate* in all states & transitions
- Spin studies with both continuum and Fe line profile
- Campaign on disk:corona connection (key piece of disk;jet connection)
- New corona models constrained by visible seed photons
- Spectral-timing analyses for reflection and corona geometry
- High- & low-freq. QPOs in energy bands that deconvolve disk & corona
- Partnerships: NuSTAR, INTEGRAL, ASTROSAT for detailed studies of corona in hard state and steep power law states

Combined High Throughput & Spectral Resolution

- Disk Winds at different states & luminosity (absorption in highly ionized Fe (6.7 keV), plus Mg, Si, S, & Ar (1-4 keV))
- Spectral-Timing of the Fe line (disk:corona structure ; LFQPO origin)

Fast Timing in the NICER energy band

- HFQPO studies with deconvolution of disk and corona
- First Deep Exploration of Fast Timing in Soft X-rays

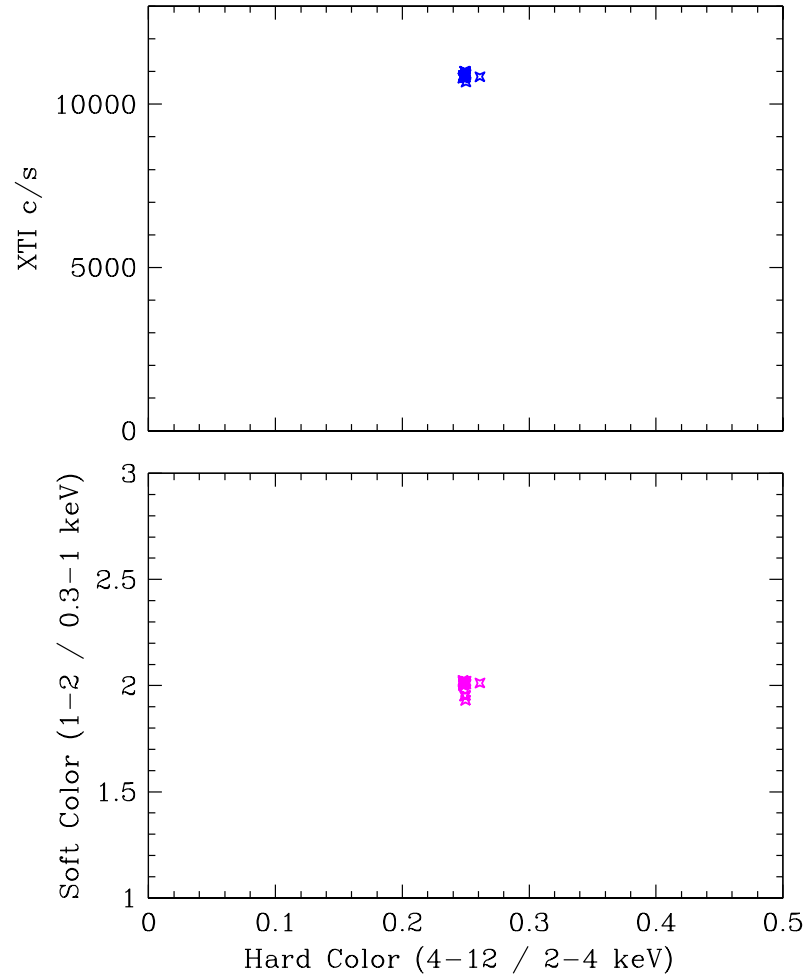
X-ray Partner for Time-Domain Astronomy

- New campaigns on MQ Jets
- Specialized investigations (e.g. NICER + fast-IR photometry with 10-m GTC, twice already)

Crab Nebula

Sum of 4 Energy Bands:
A+B+C+D

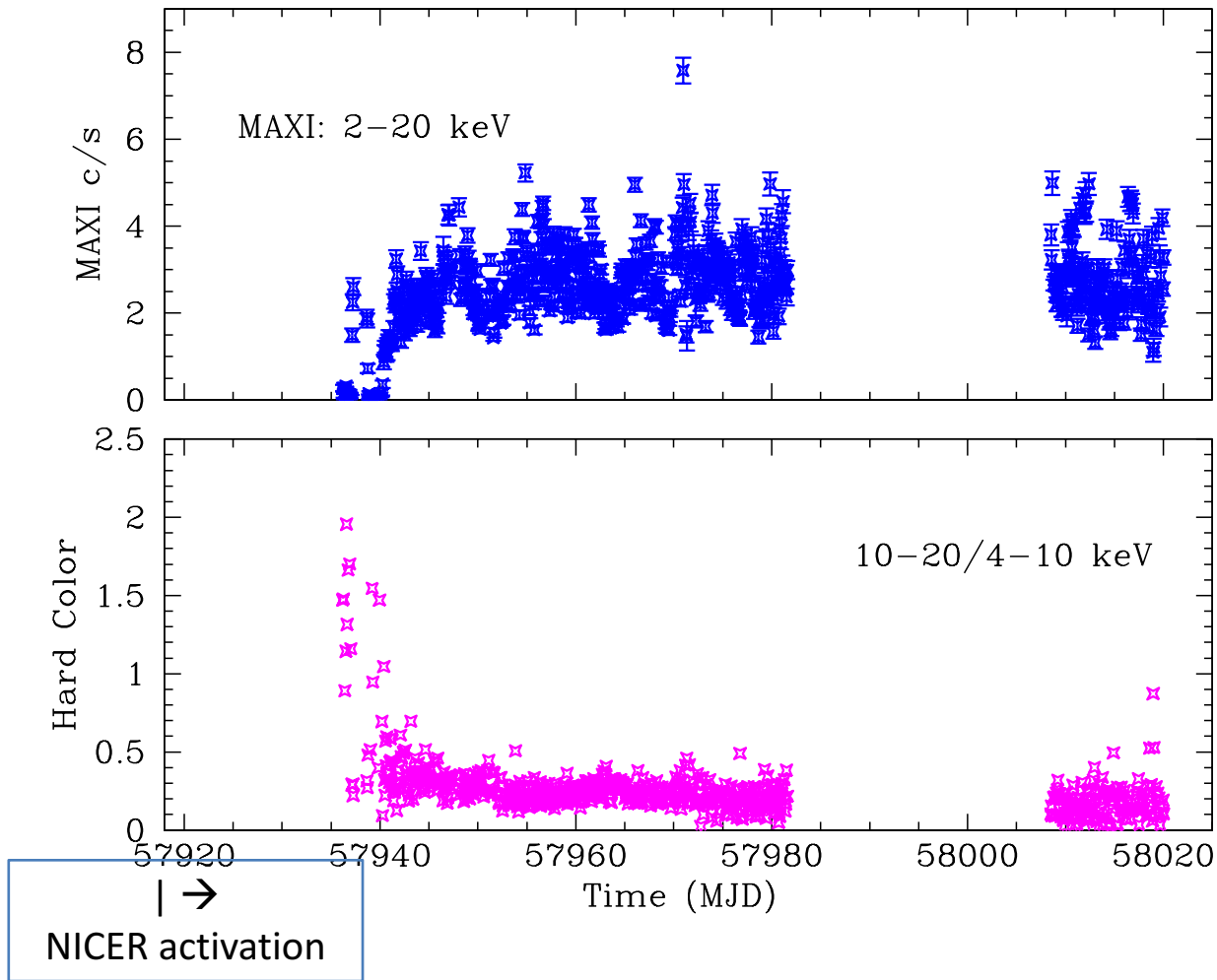
Crab: 20 obs.: 2017 Aug, Sep NICER HID & CD



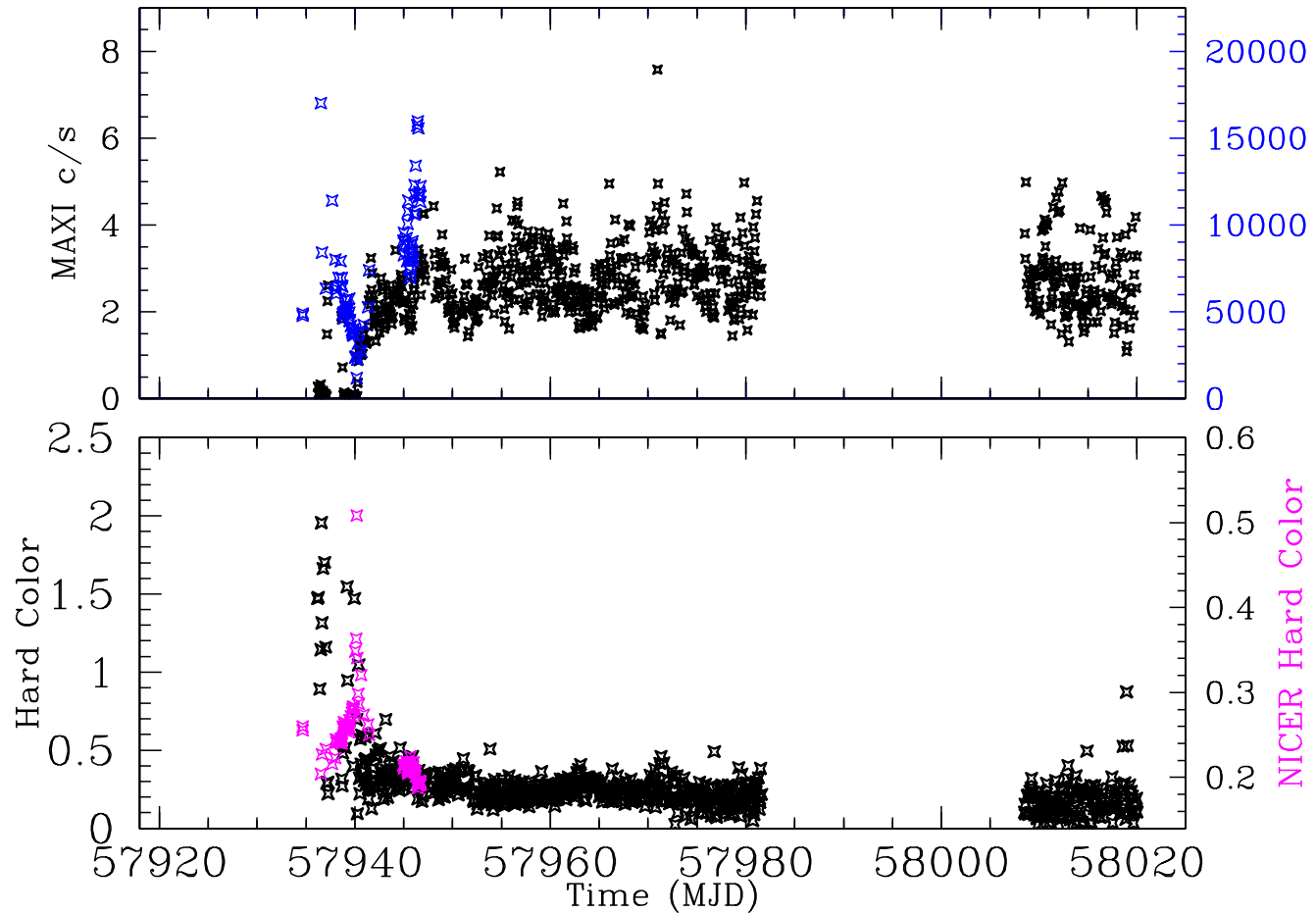
B/A

D/C

MAXI Light Curve: Cyg X-1 2017 Jun 14 (NICER Activation) to present



MAXI Light Curve: Cyg X-1 2017 Jun 14 (NICER Activation) to present

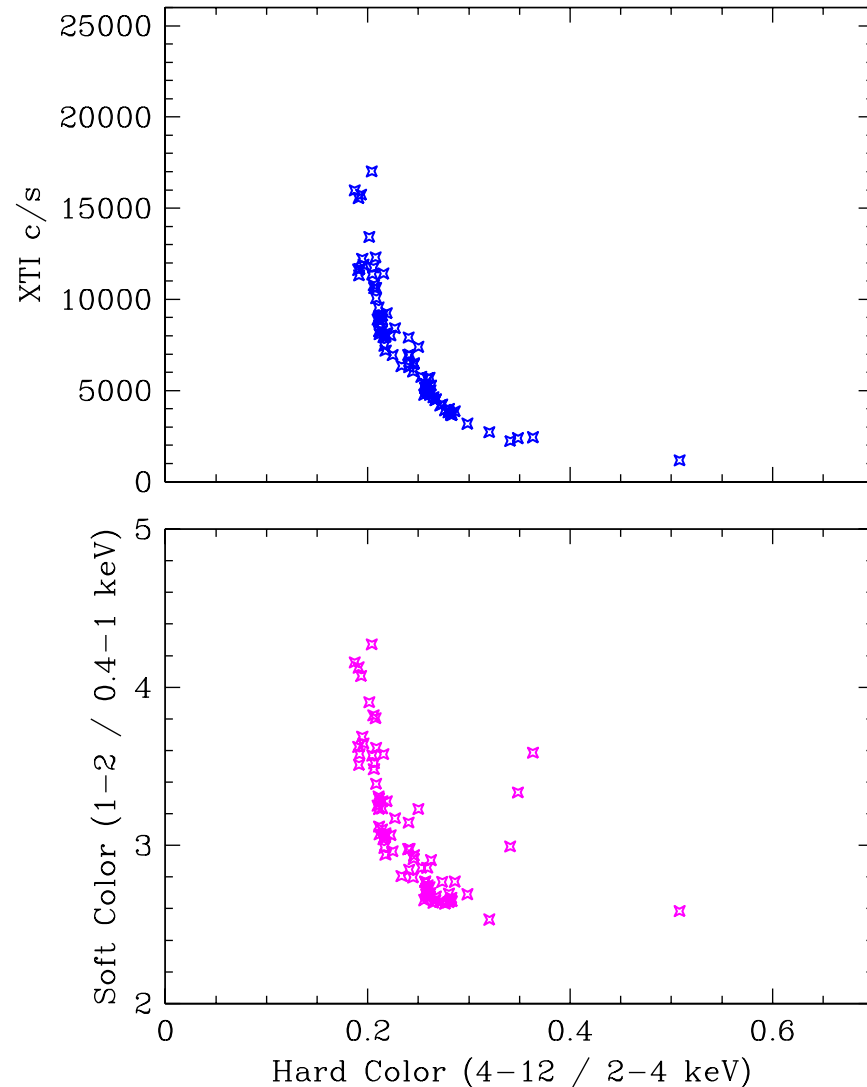


Cyg X-1 2017 Jun 30 – Jul 12

- 80 exposures: avg. 600 s
- Data from Spectra
(background subtracted)
- Fortunate sampling:
 - * factor ~ 8 in brightness
 - * state evolution

Cyg X-1: (30 Jun to 12 Jul)

NICER HID & CD

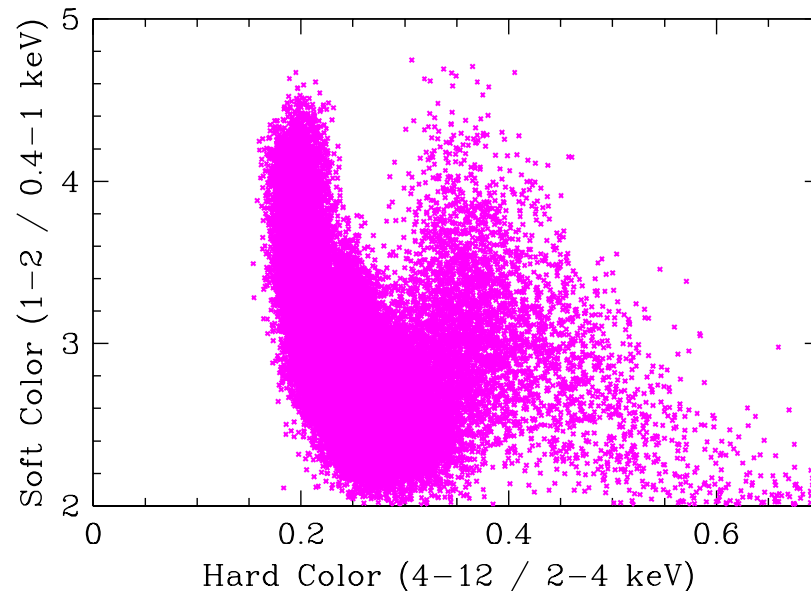
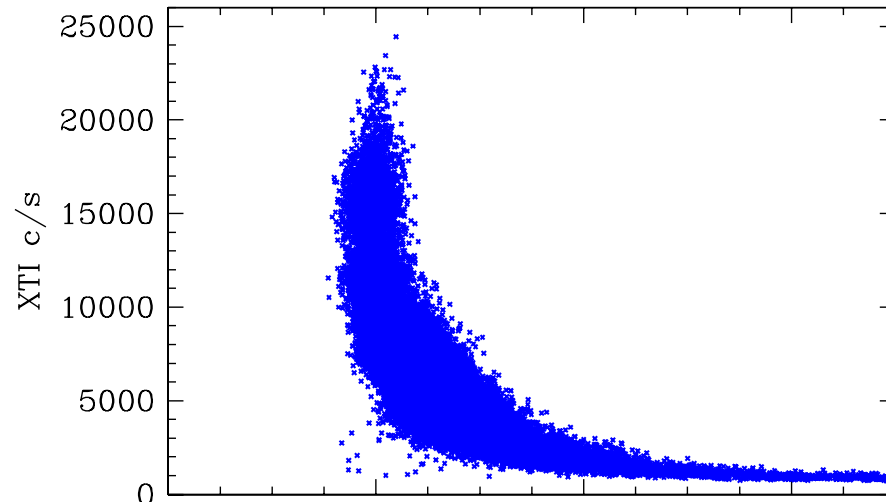


Cyg X-1: (30 Jun to 12 Jul) NICER 1s HID & CD

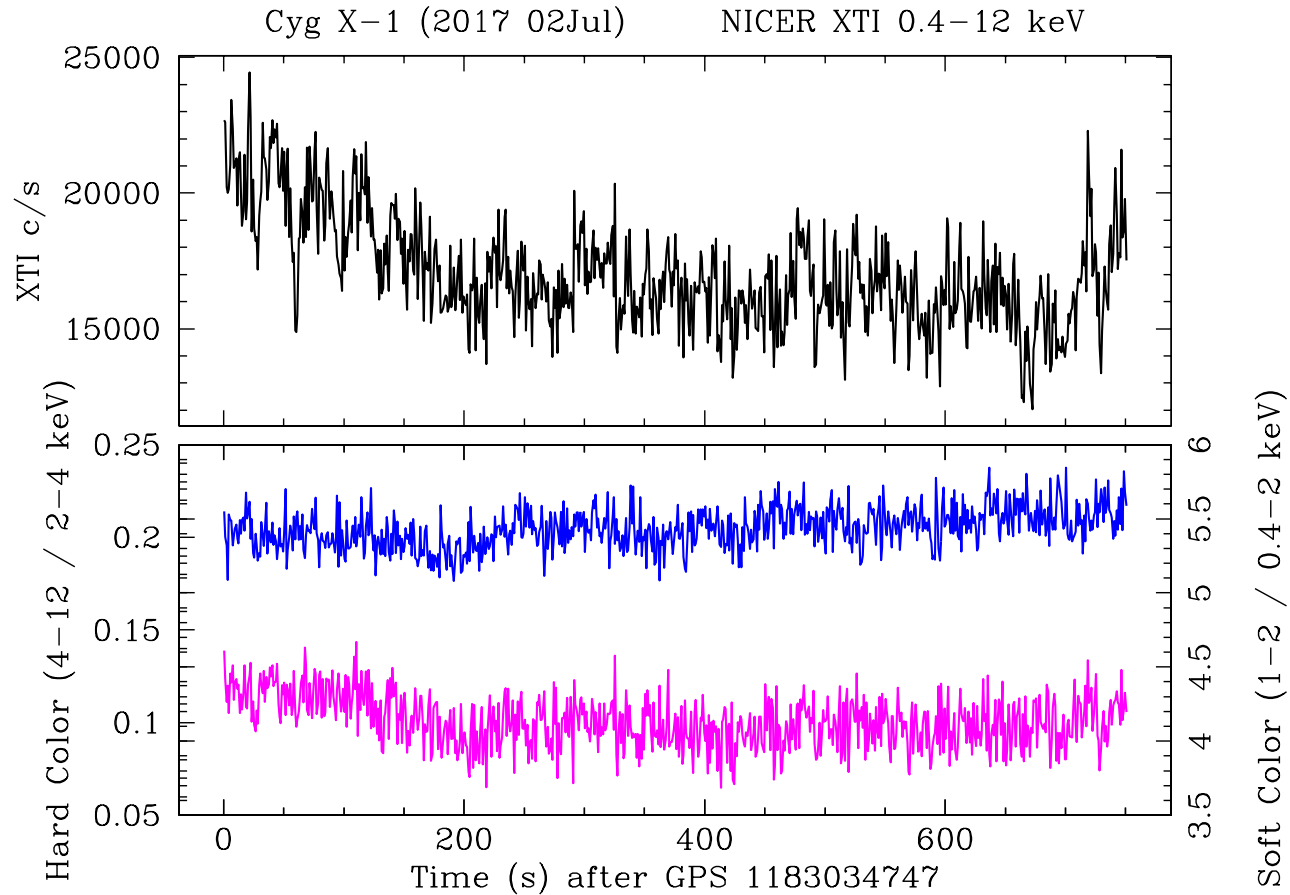
Cygnus X-1:

Same obs. But from light curves, in 1-s time bins (instead of ~600 s)

- Much higher count rates (up to 25k c/s vs. 17k c/s) in previous plot
- Suggests fast flaring
- High rates are clustered in obs. #003 and #080



Cyg X-1: 1-s Light curve from Obs #3 (2017 02 Jul)

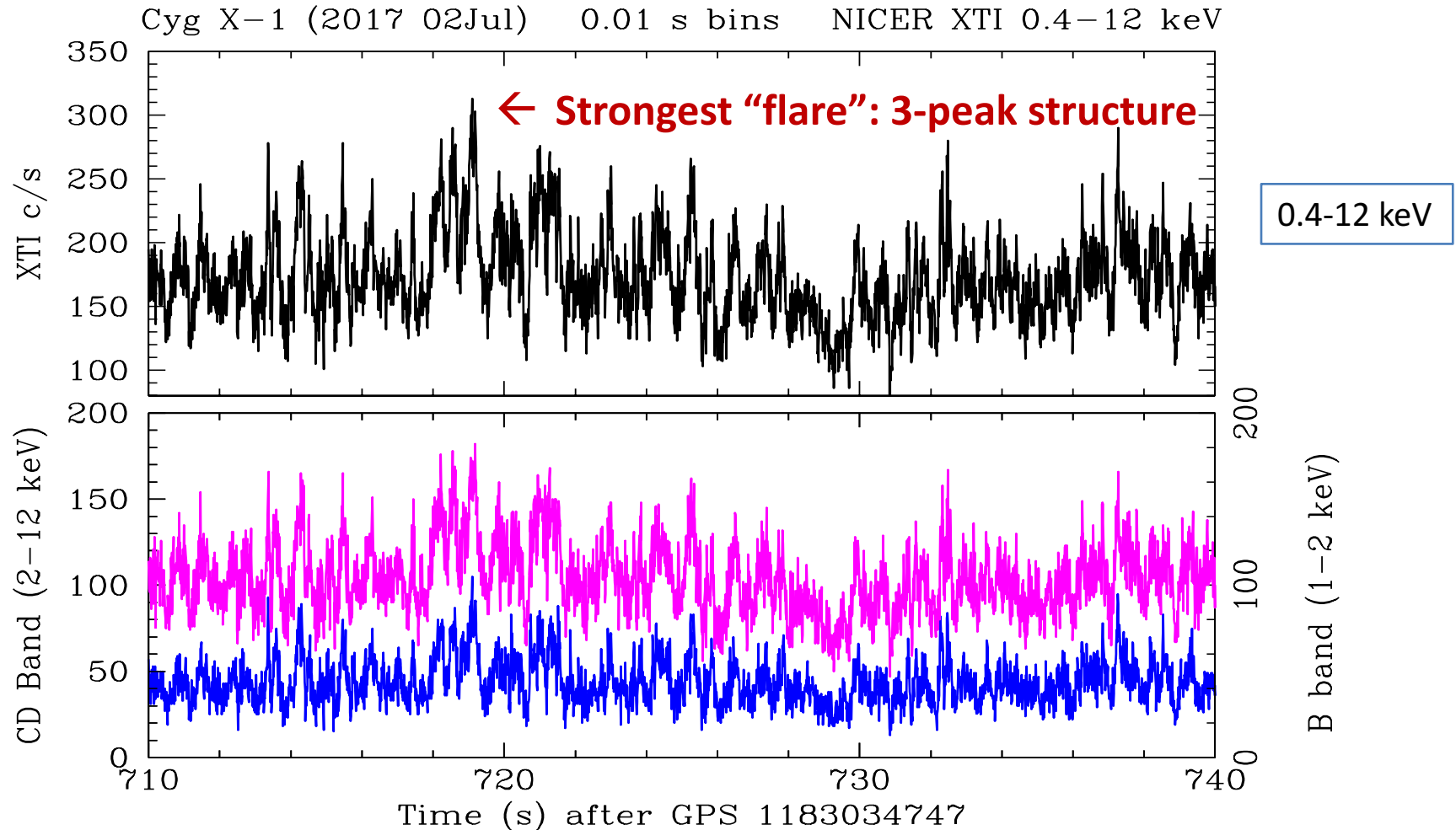


← Example of fast flare at 716 s

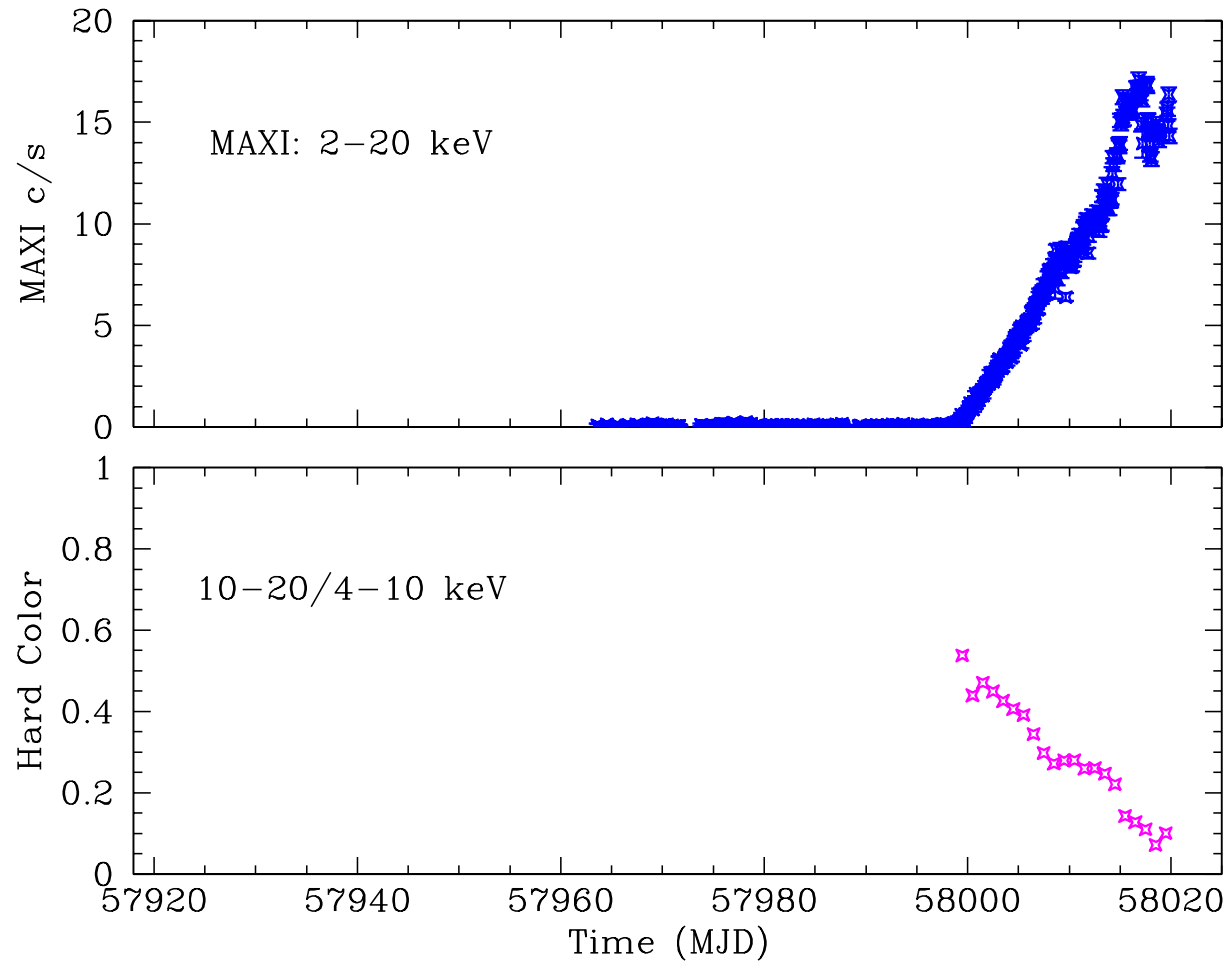
← Little change

← in either X-ray color

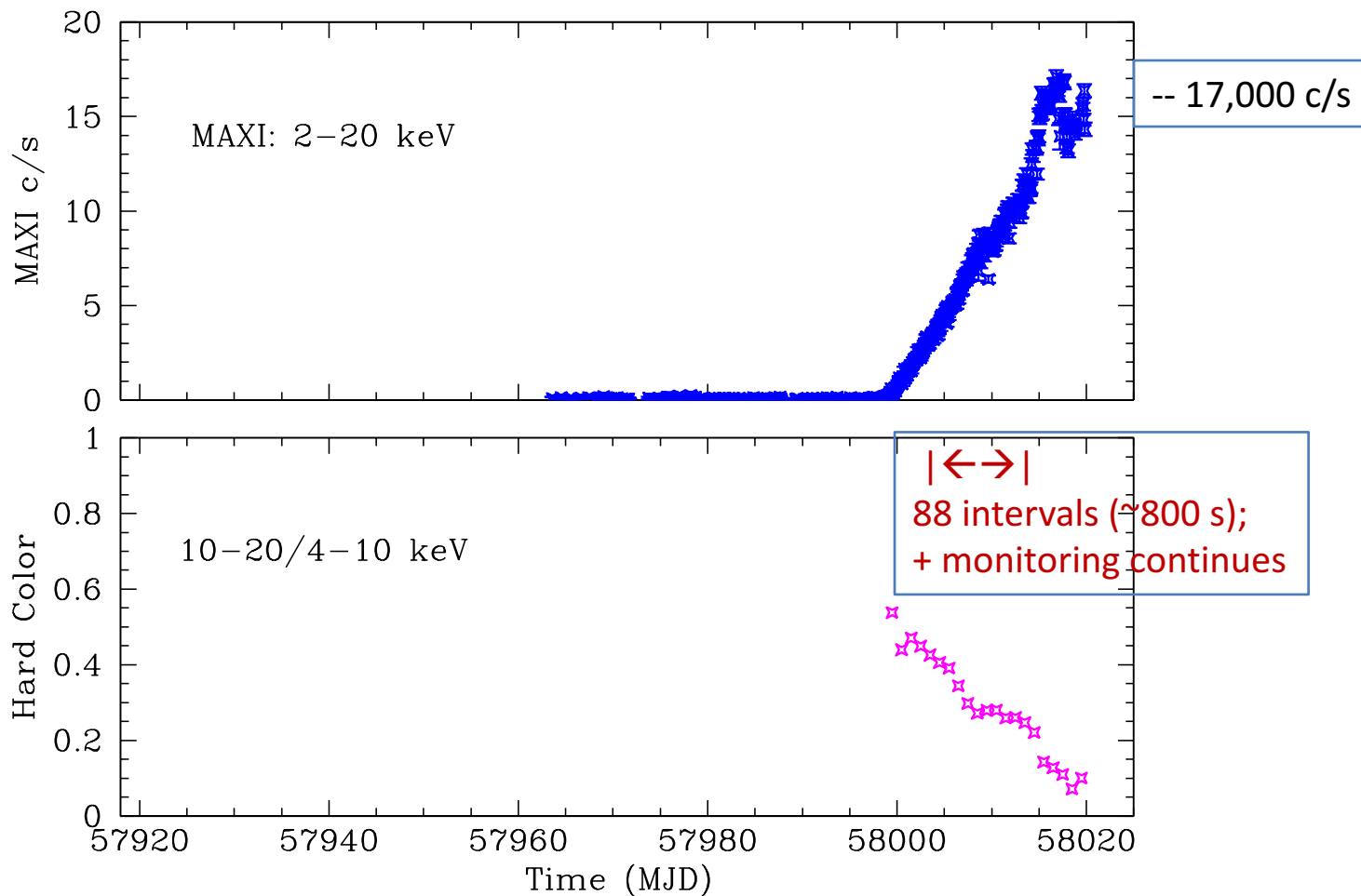
Light curve from Obs #3 in 0.01 s bins: structure!



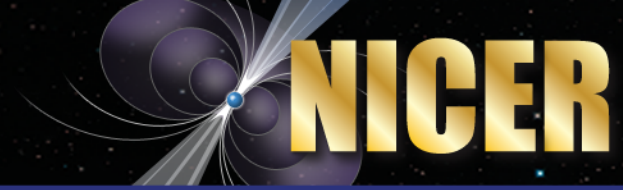
MAXI Light Curve: MAXI J1535-571 2017 Jun 14 (NICER Activation) to present



MAXI Light Curve: MAXI J1535-571 2017 Jun 14 (NICER Activation) to present



HID and CDs with NICER

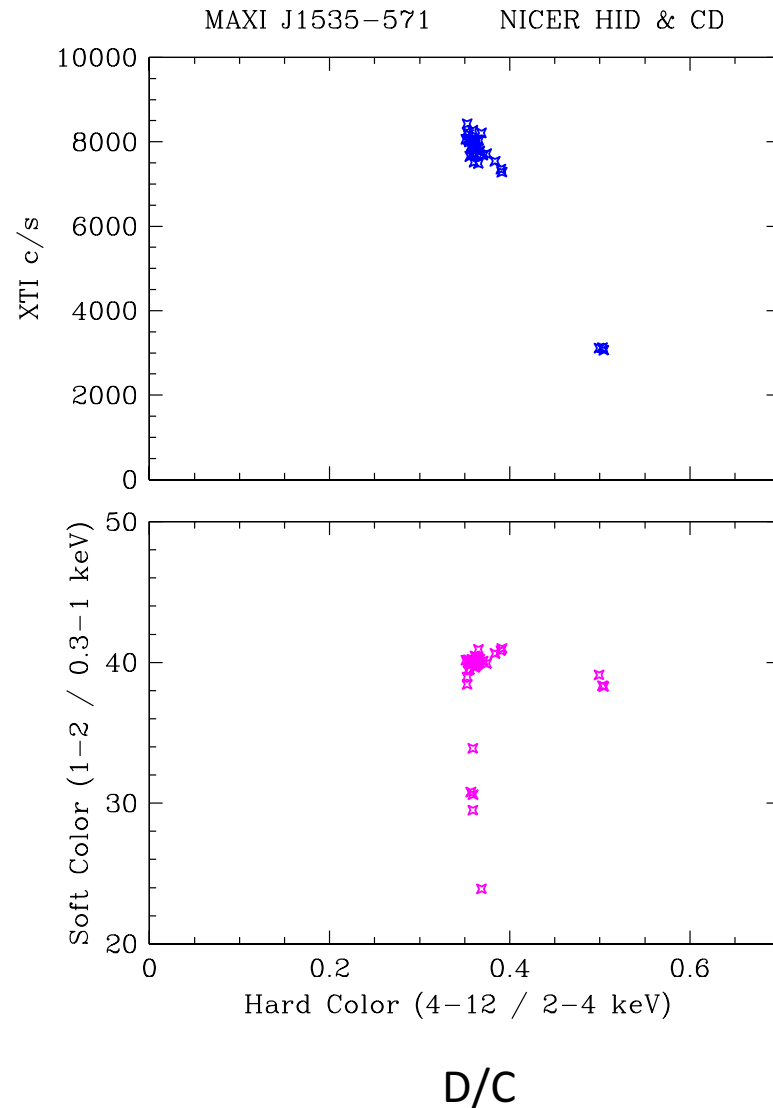


MAXI J1535-571

Obs. to Sept. 13

Sum of 4 Energy Bands:
A+B+C+D

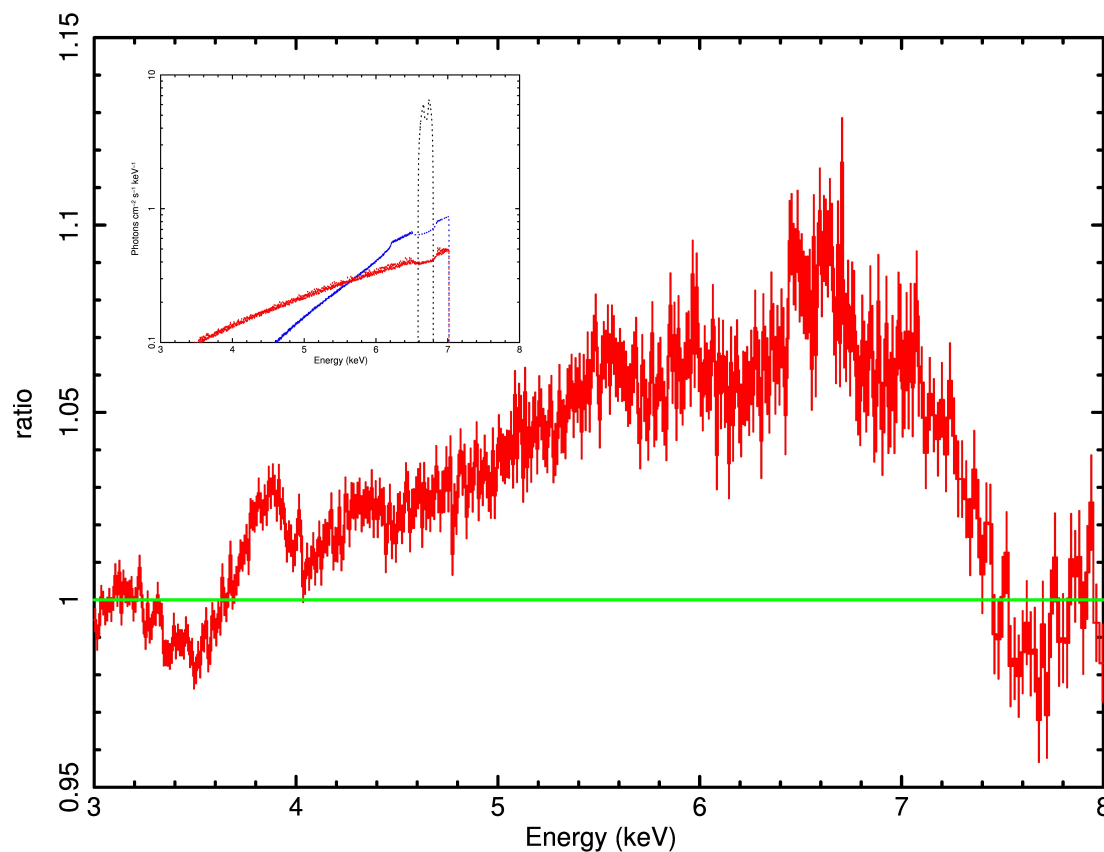
B/A



First NICER Report: Atel #10768 (2017 22 Sep)

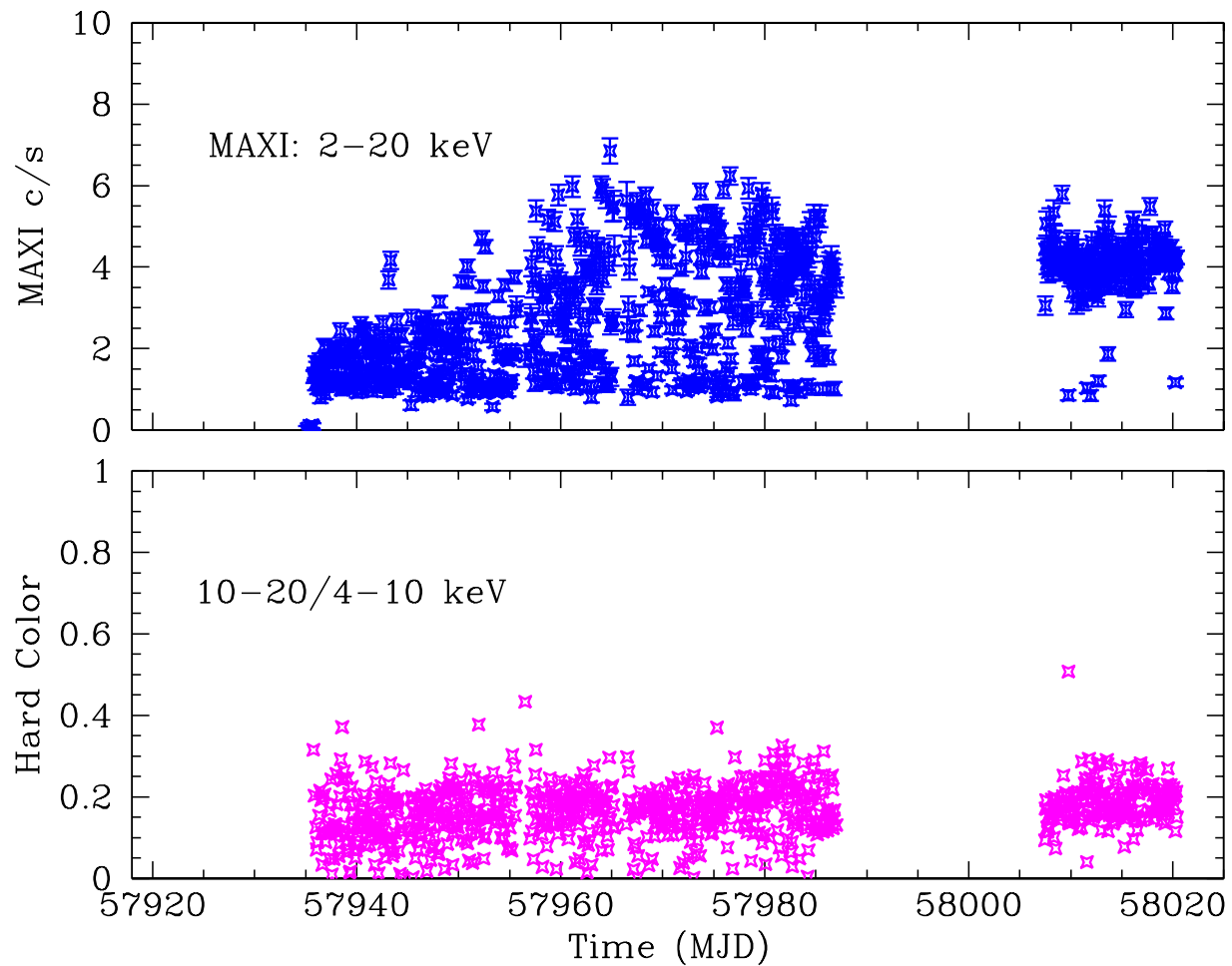
MAXI J1535-571 (Gendreau et al. 2017)

Broad Fe line $\rightarrow a_* = 0.88 (+0.1, -0.2)$



Credit: Jon Miller,
U MI

MAXI Light Curve: GRS1915+1-5 2017 Jun 14 (NICER Activation) to present



- NICER energy range & measurement capabilities will provide major advances for BHBs/MQs & other high-energy sources: **accretion physics ; jets ; physical properties of BHs**
- Mother Nature (and Father Poisson): extremely cooperative in early transients and activity in persistent sources

NICER is an Invitation

- Explore the Public Archive Release in Winter 2018
- Submit GO Proposals in Spring 2018
- Help NICER to Achieve Extension and Status as a GO Facility via NASA Senior Review