ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

# The Transient X-Ray Sky

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*with inputs from*
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Black Hole Universe

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Time domain astrophysics: Studies of the variable sky

Following initial work, e.g., with Vela 5B monitors, significant progress since $\sim$1999 due to dedicated X-ray All Sky Monitors:

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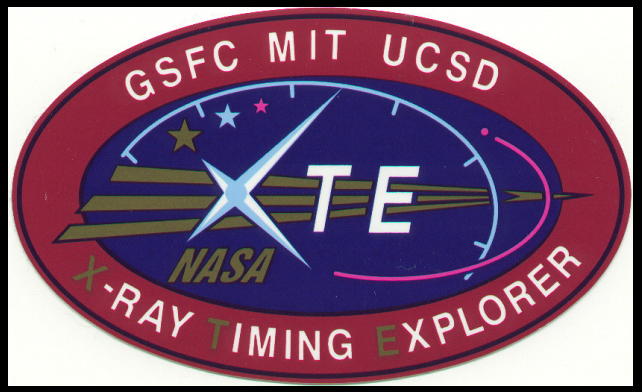
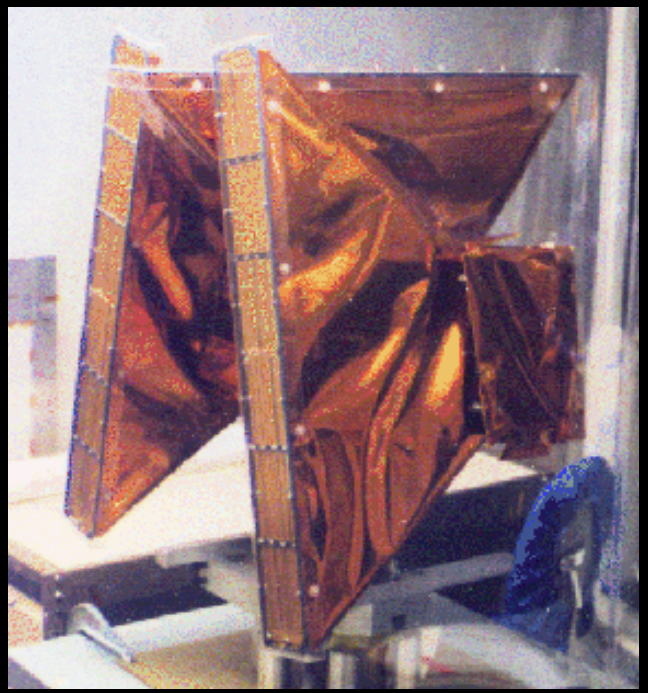
RXTE-ASM

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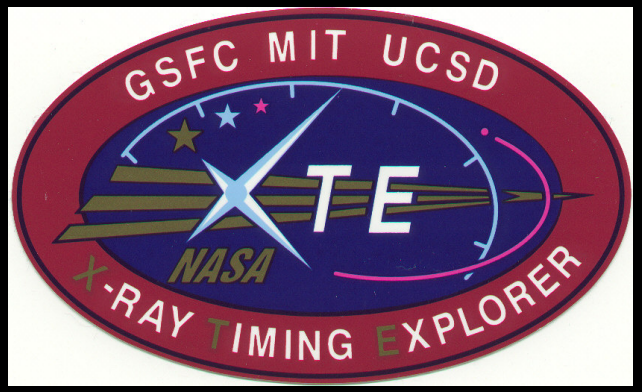
RXTE-ASM

Swift-BAT

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020





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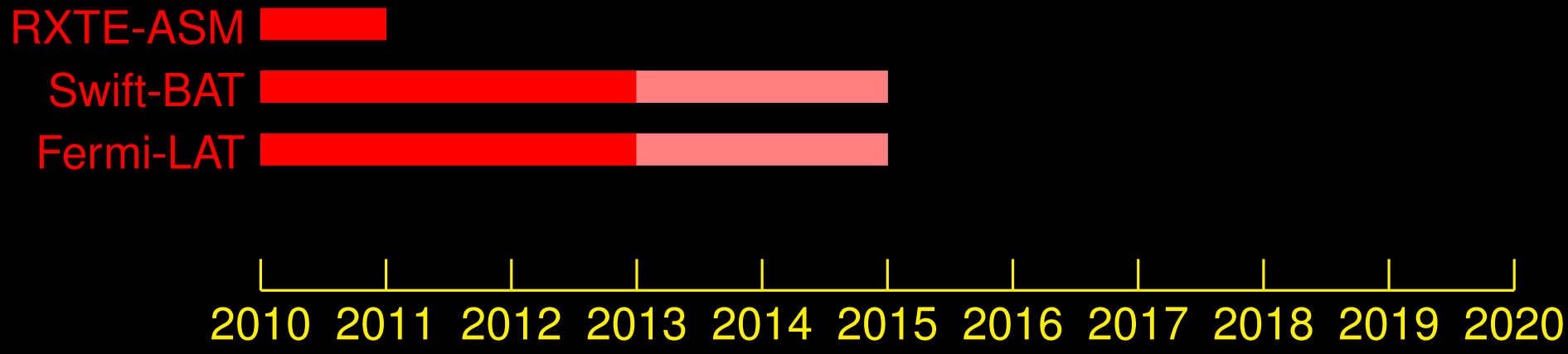


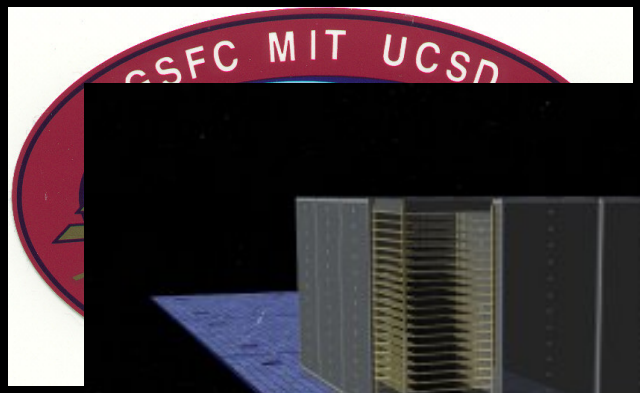



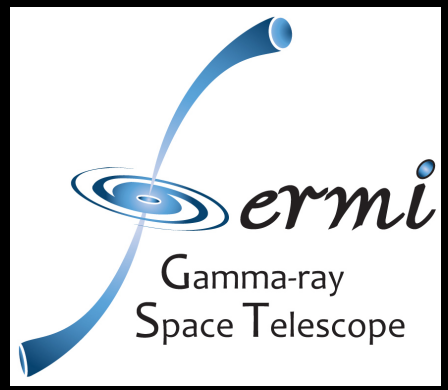

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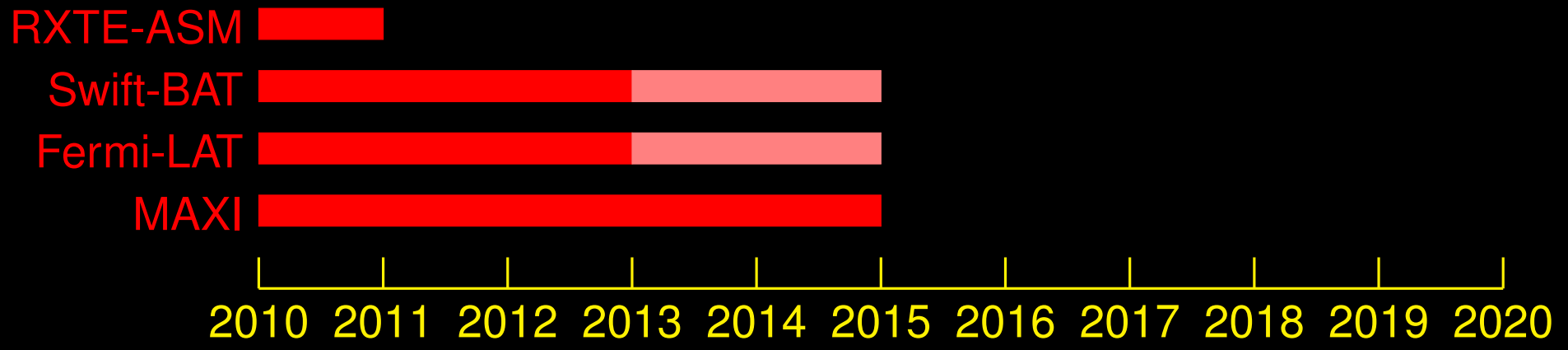


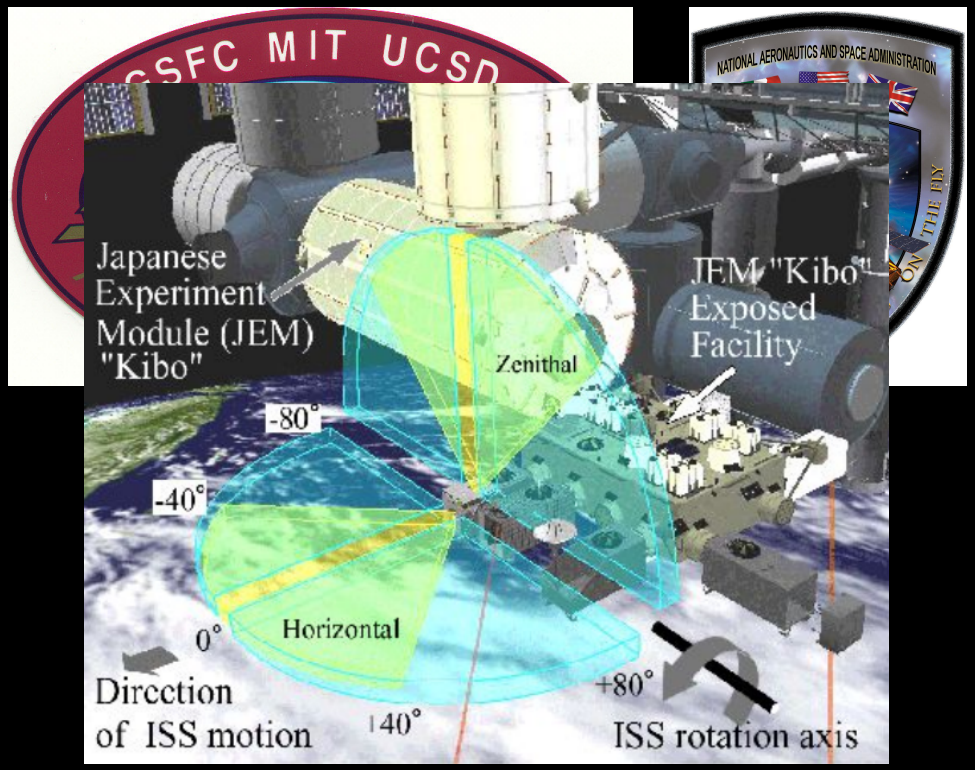


Gamma-ray Space Telescope

Monitor of All-sky X-ray Image

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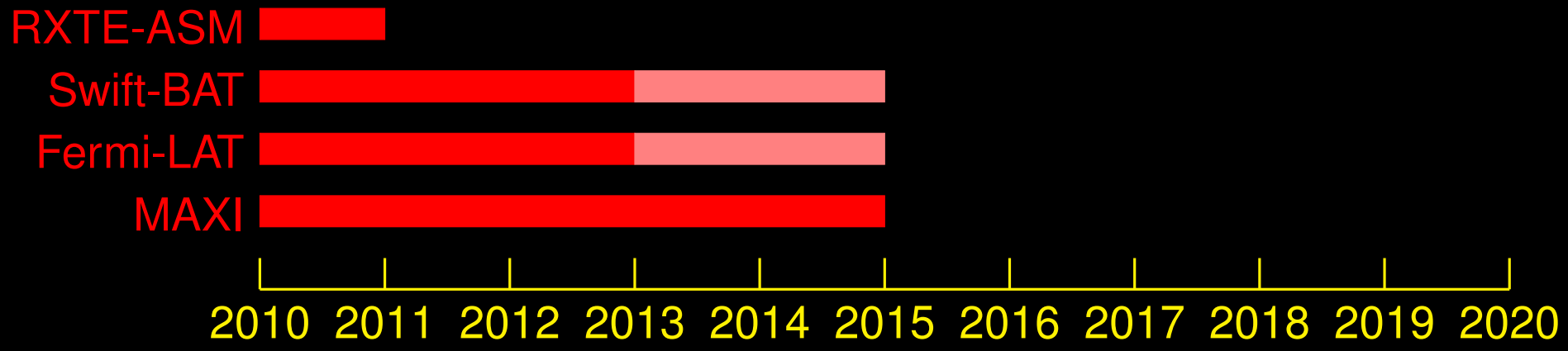
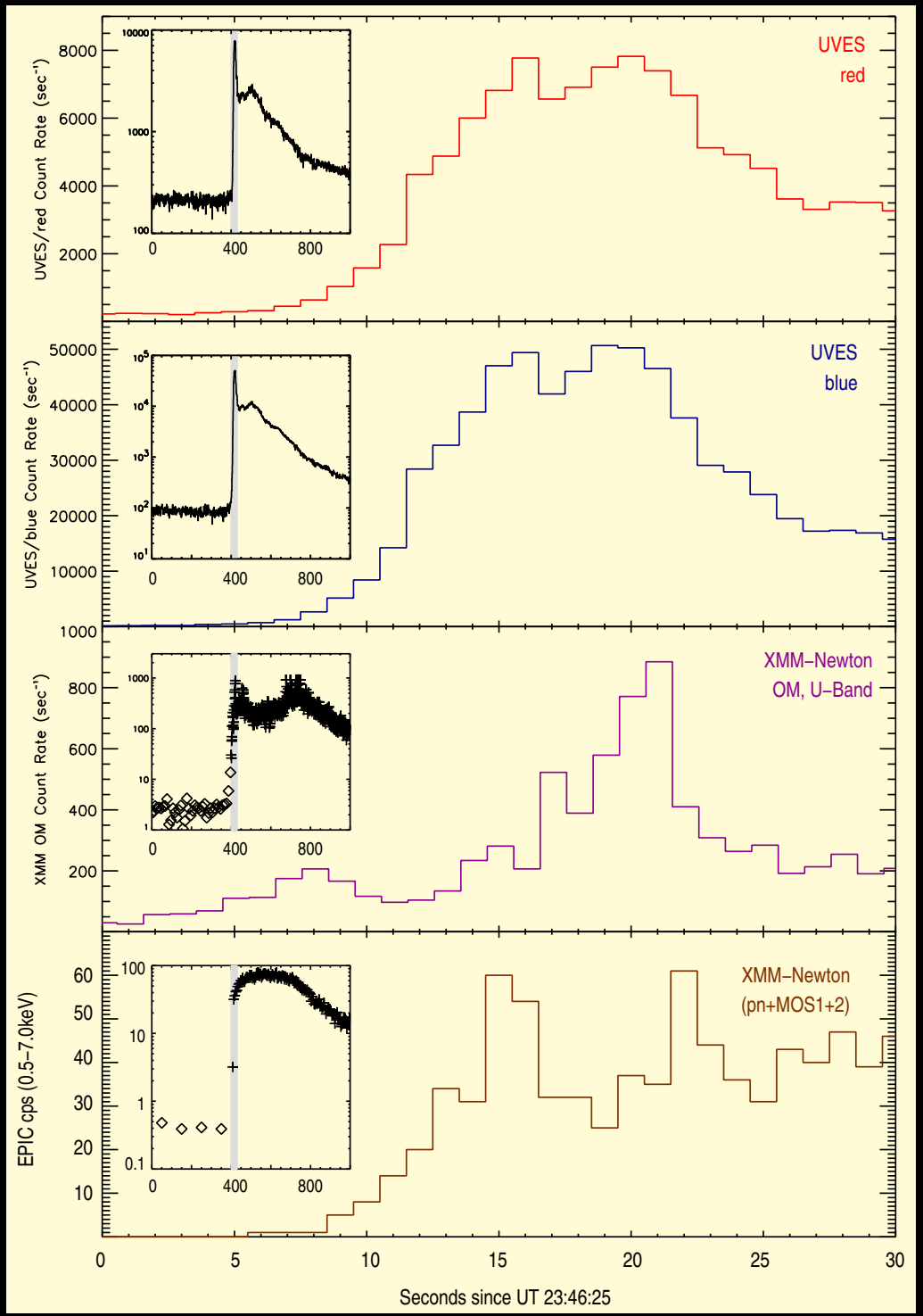



*Examples of potential interest for eROSITA:*

- Stellar flares
- Neutron star and black hole outbursts
- Long-term variability of Active Galactic Nuclei
- Galaxy Flares / Tidal Disruption Events
- Gamma-ray bursts

$\Longrightarrow$ Most sources that will be detected with eROSITA are variable.

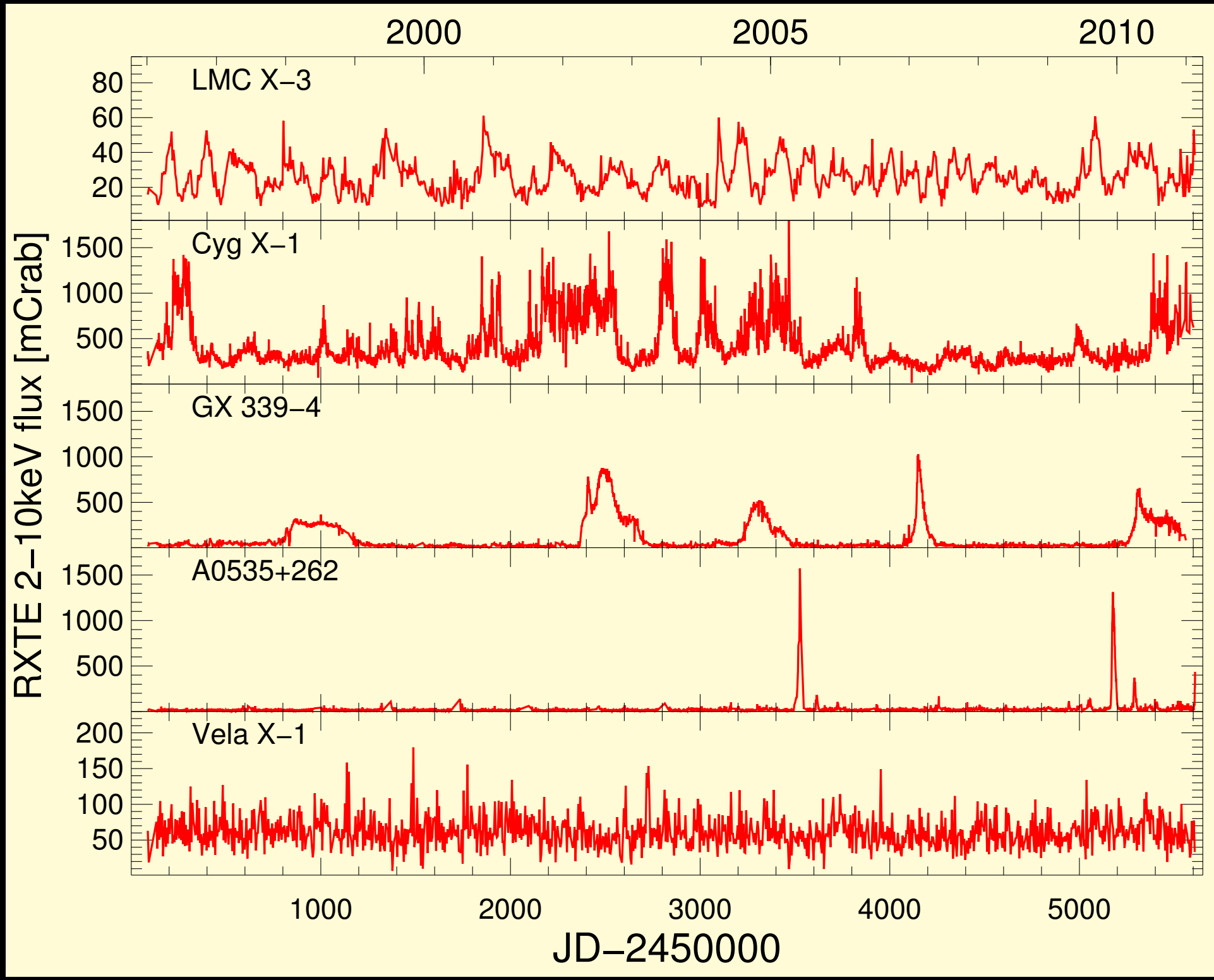



Stellar flares occur on timescales of seconds to weeks (Kürster & Schmitt, 1996)

Physics: reconnection in corona heats coronal plasma $\Longrightarrow$ soft X-ray emission

See talks tomorrow. . .

(CN Leo; Schmitt et al., 2008, Fig. 1)


2000
2005
2010
LMC X−3
80
60
40
20
Cyg X−1
1500
1000
500
GX 339−4
1500
1000
500
A0535+262
1500
1000
500
Vela X−1
200
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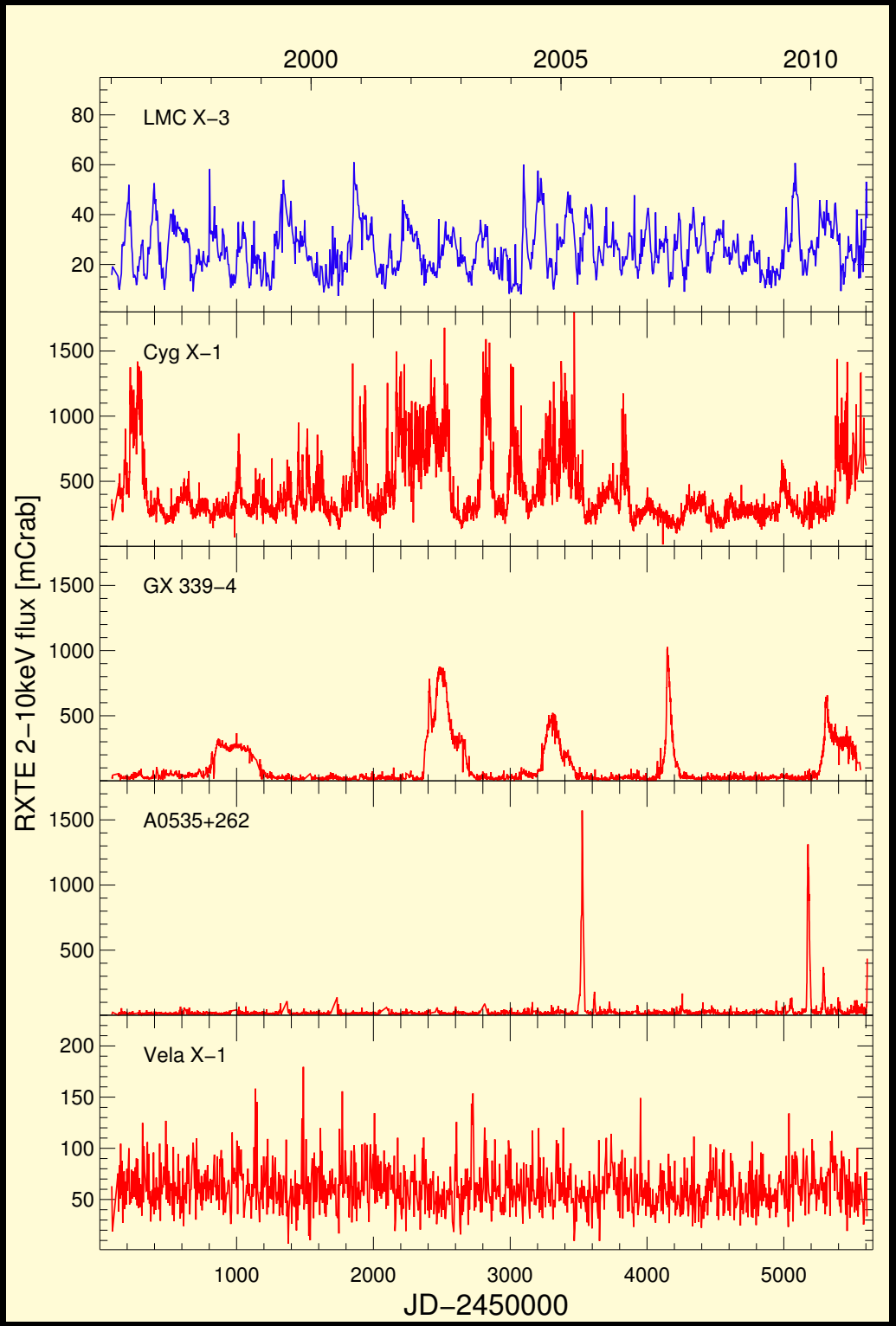
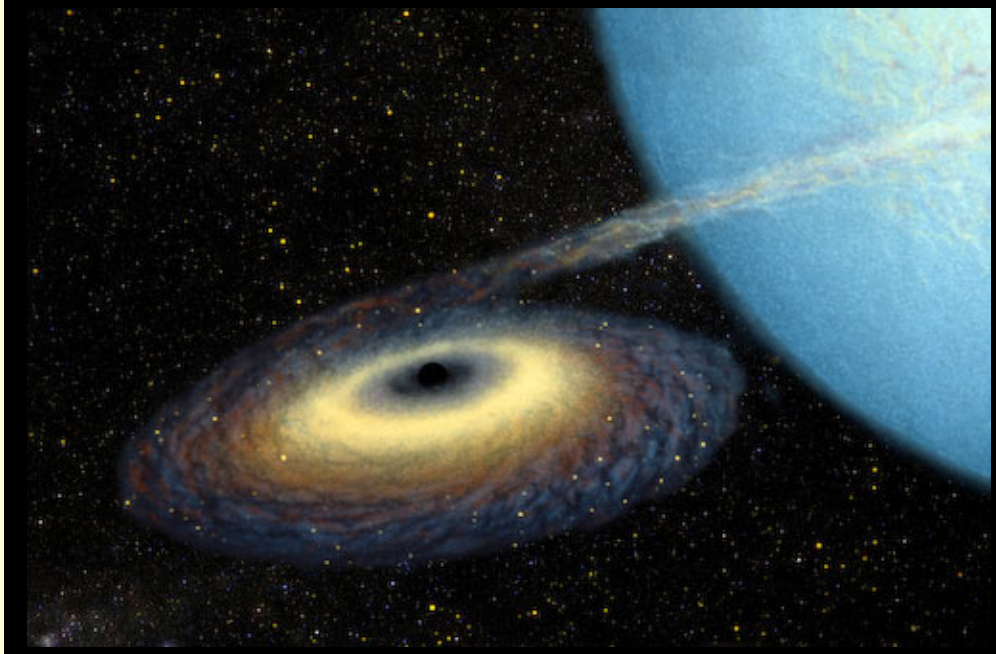
50
RXTE 2−10keV flux [mCrab]
1000
2000
3000
4000
5000
JD−2450000



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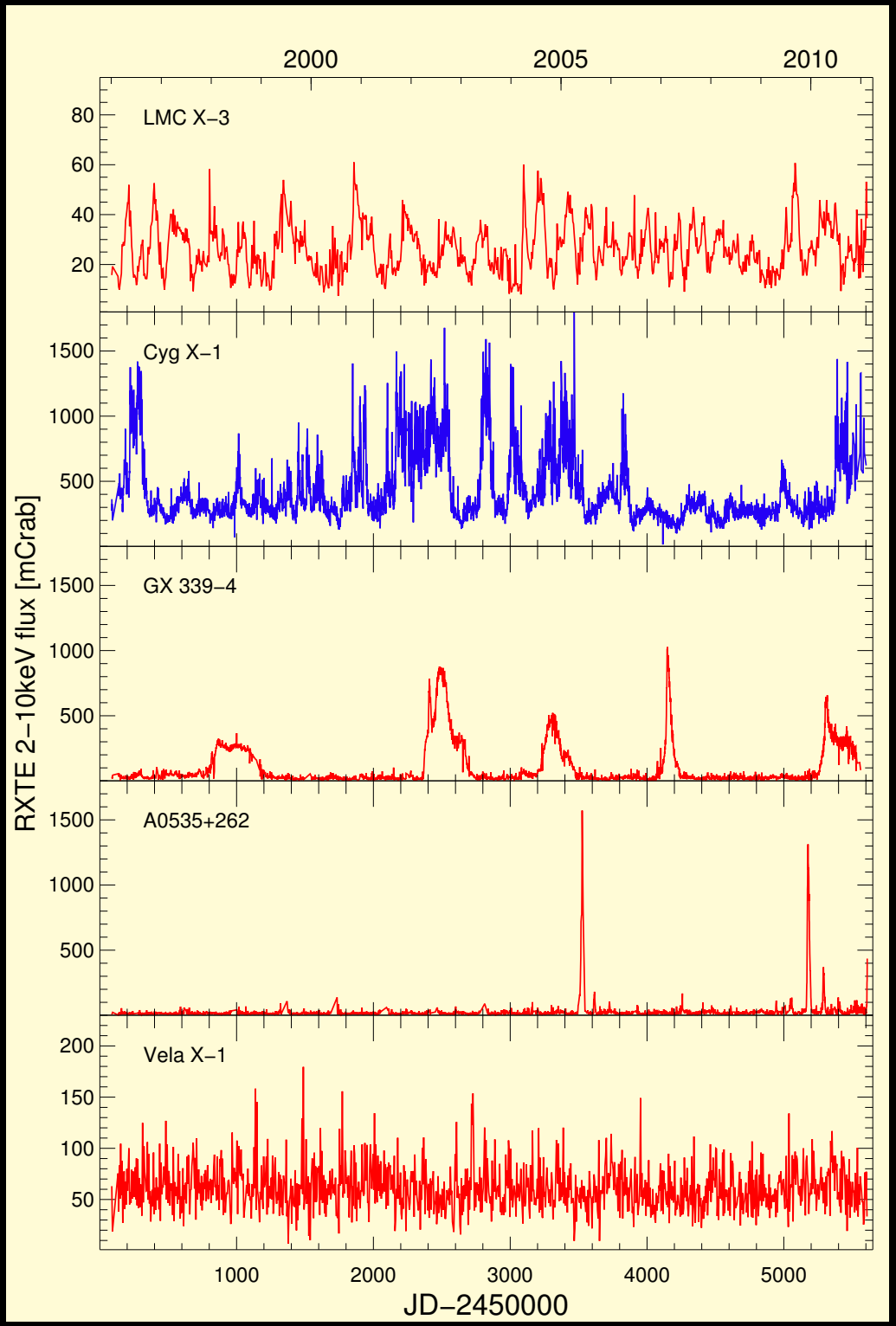
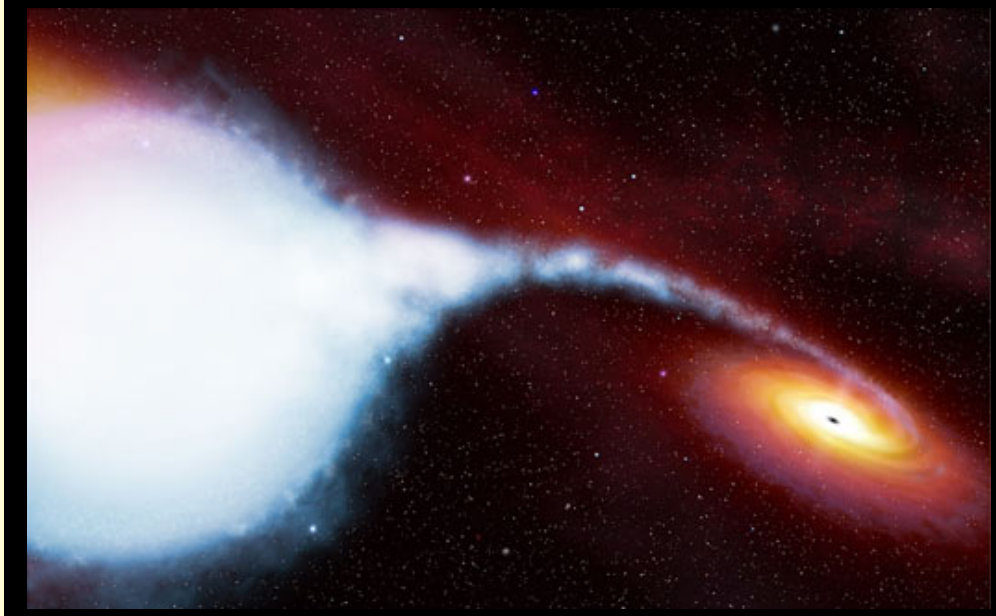
Black Holes in High Mass X-ray Binaries (intermediate systems such as e.g., LMC X-3 [B-star companion]): Variability due to modulation of $\dot{M}$ at inner Lagrangian point

(Wilms et al., 2001)

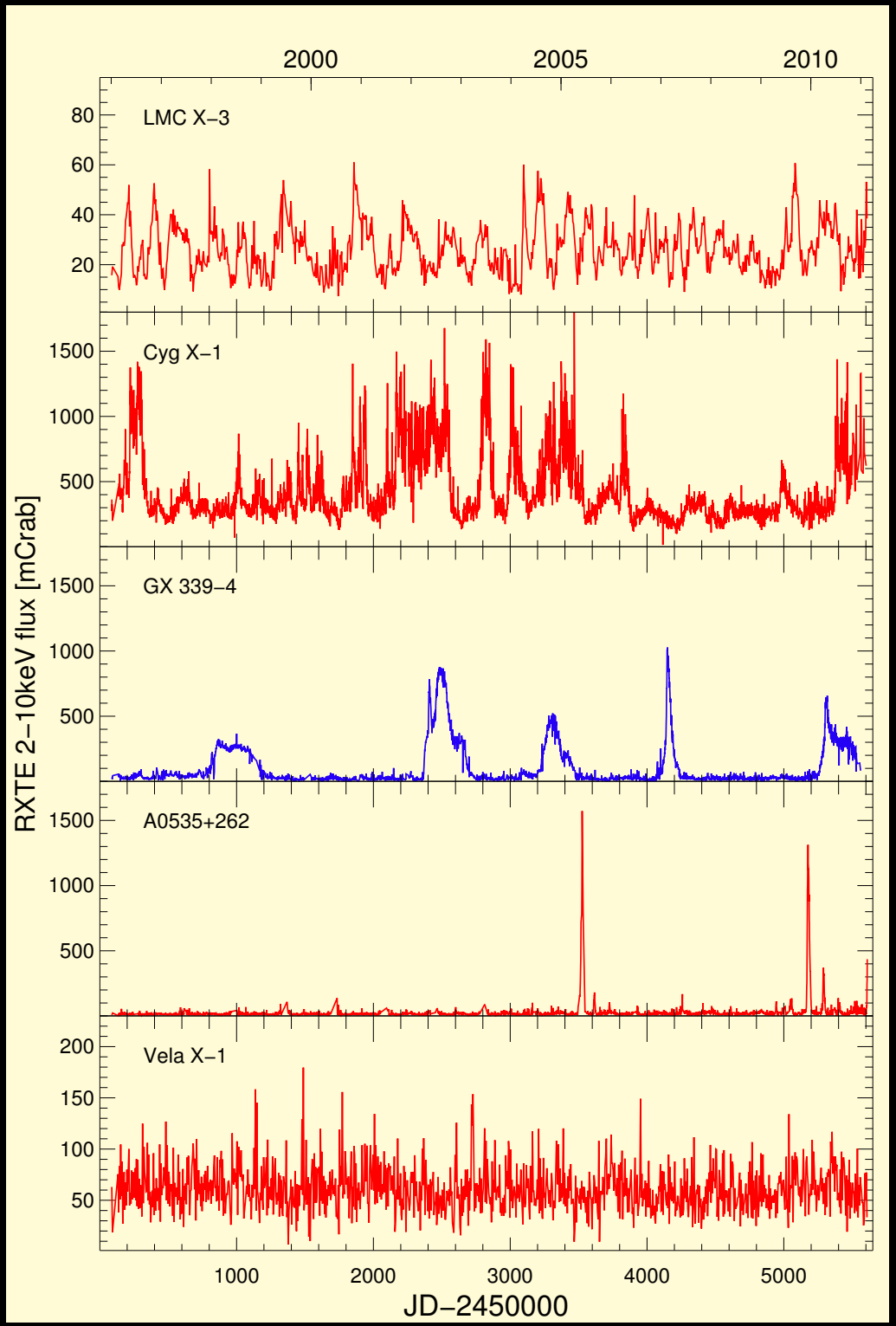


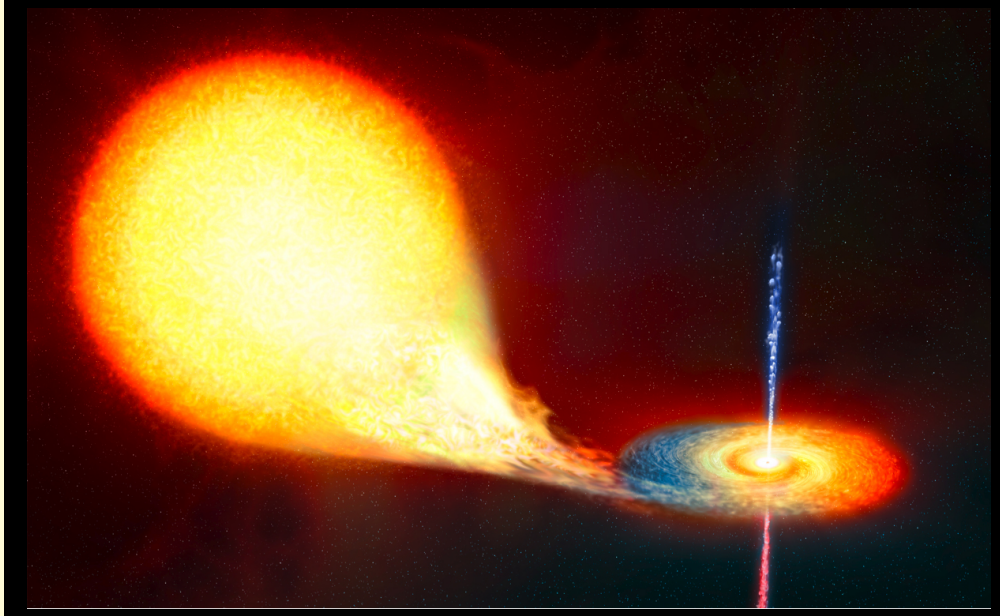



ESA

Black Holes in High Mass X-ray Binaries (e.g., Cyg X-1): Variability due to $\dot{M}$ variations due to photoionized stellar winds.

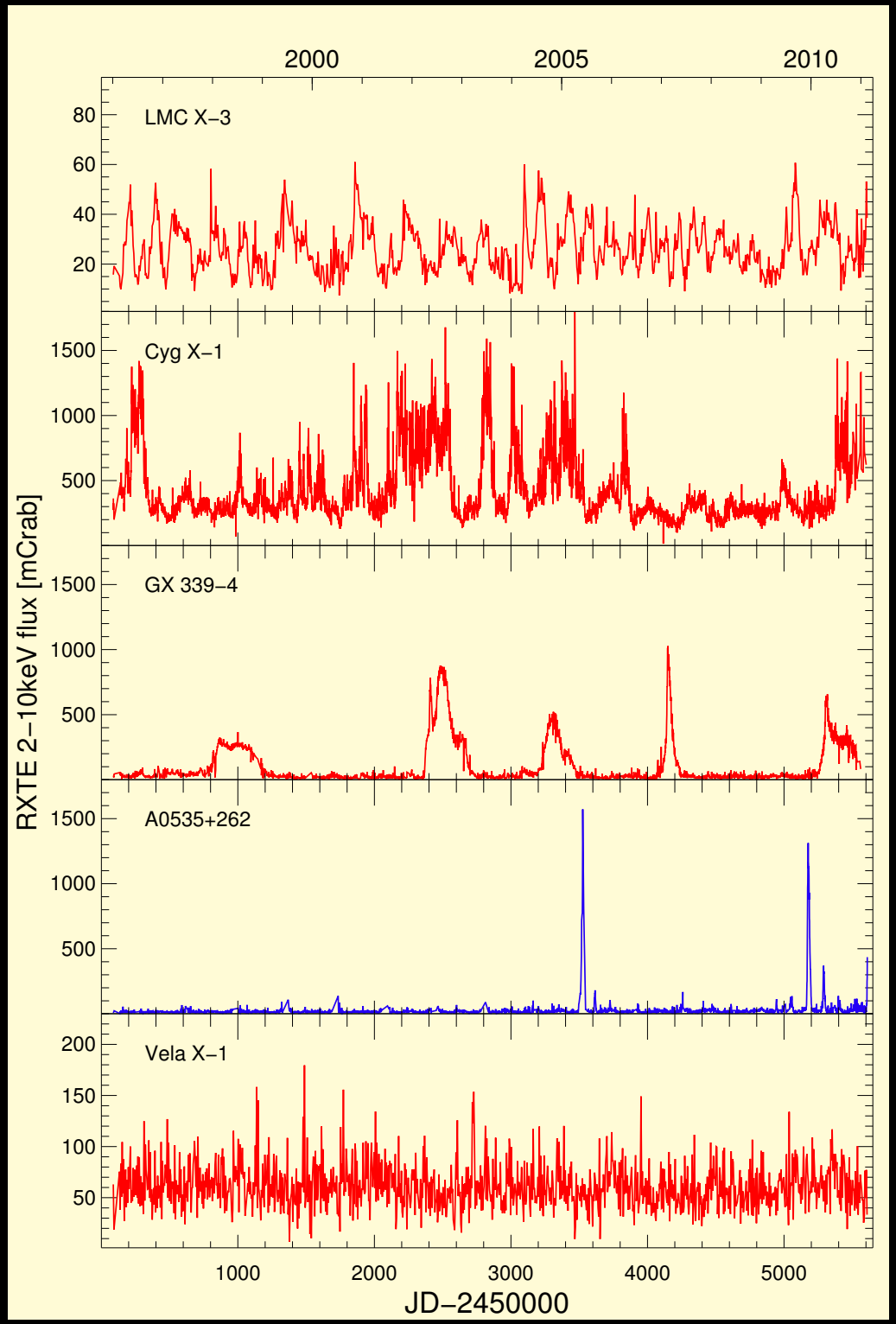
(e.g., Gies et al., 2008, and therein)

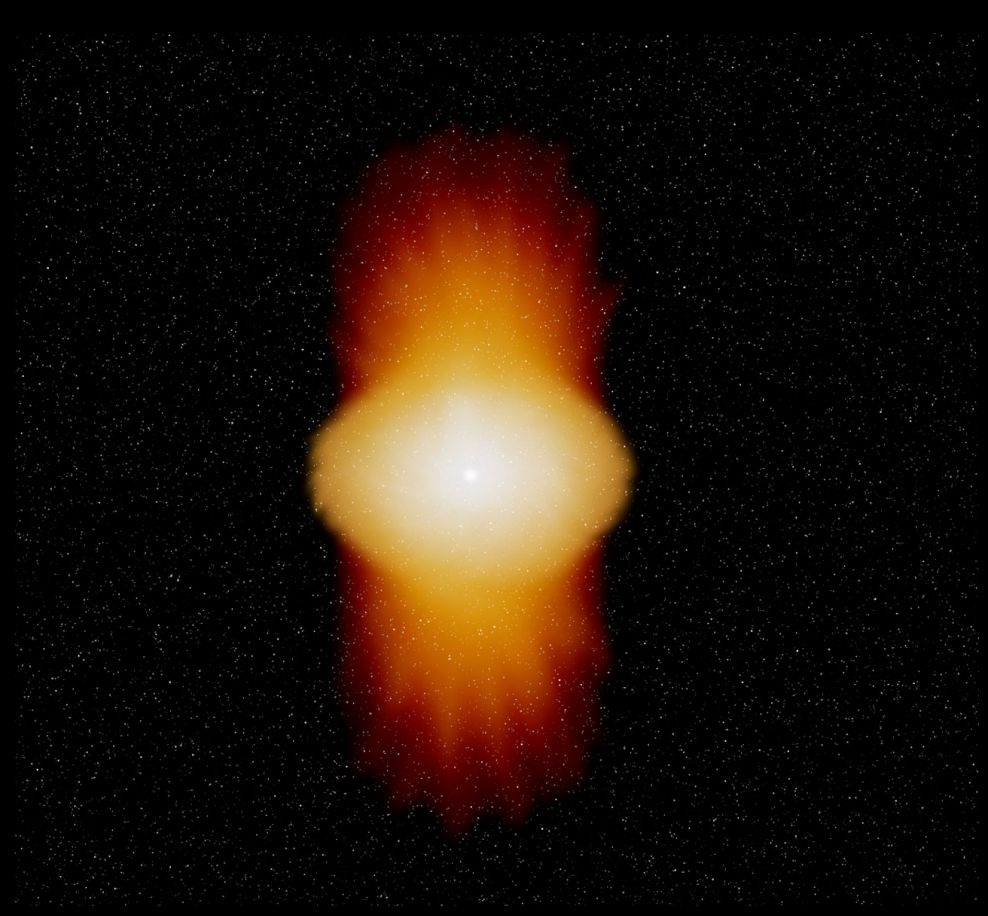


Black Hole Transients in Low Mass X-ray Binaries: Strong $\dot{M}$ changes due to instabilities in the accretion disk (e.g., ionization dependence of viscosity)

(e.g., Cannizzo et al., 1995)

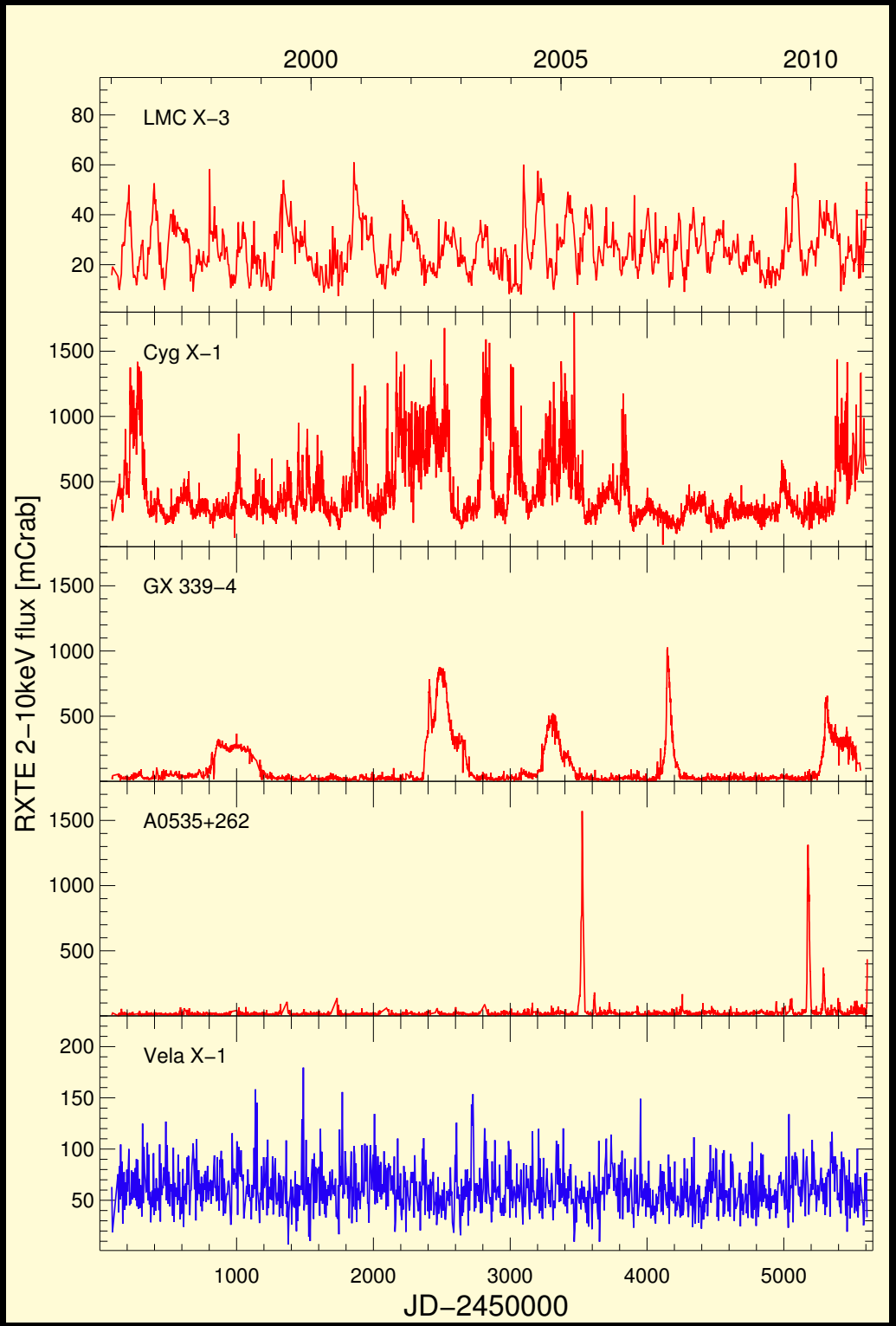


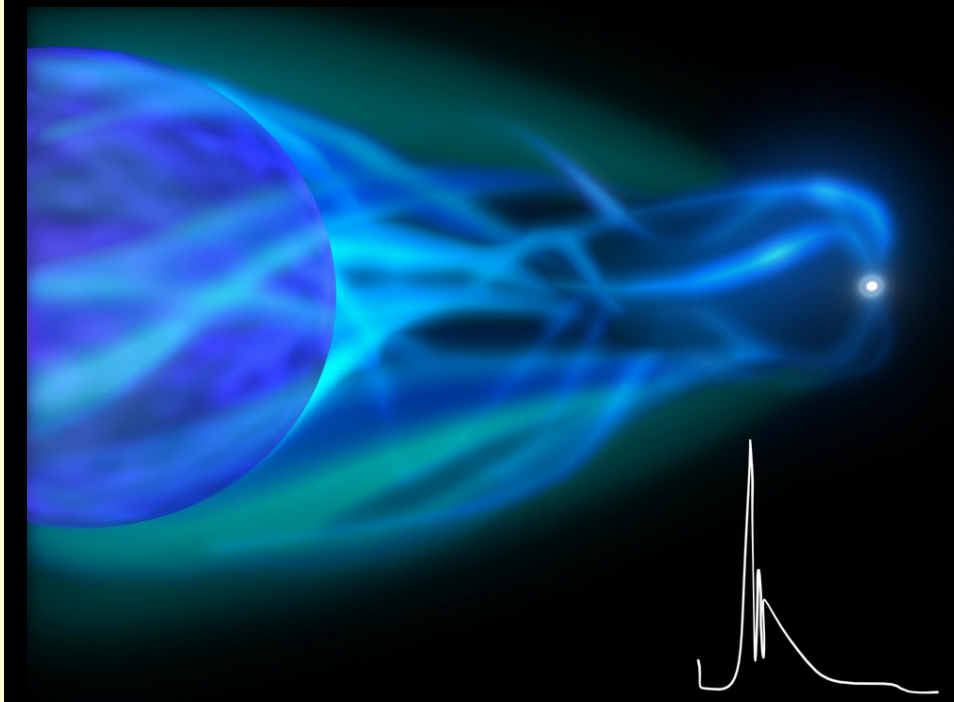



ESO

Neutron Stars in Be-Systems: Extreme outbursts due to interactions with the Be-disk

(A0535+262 can go up to $>$1 Crab!)



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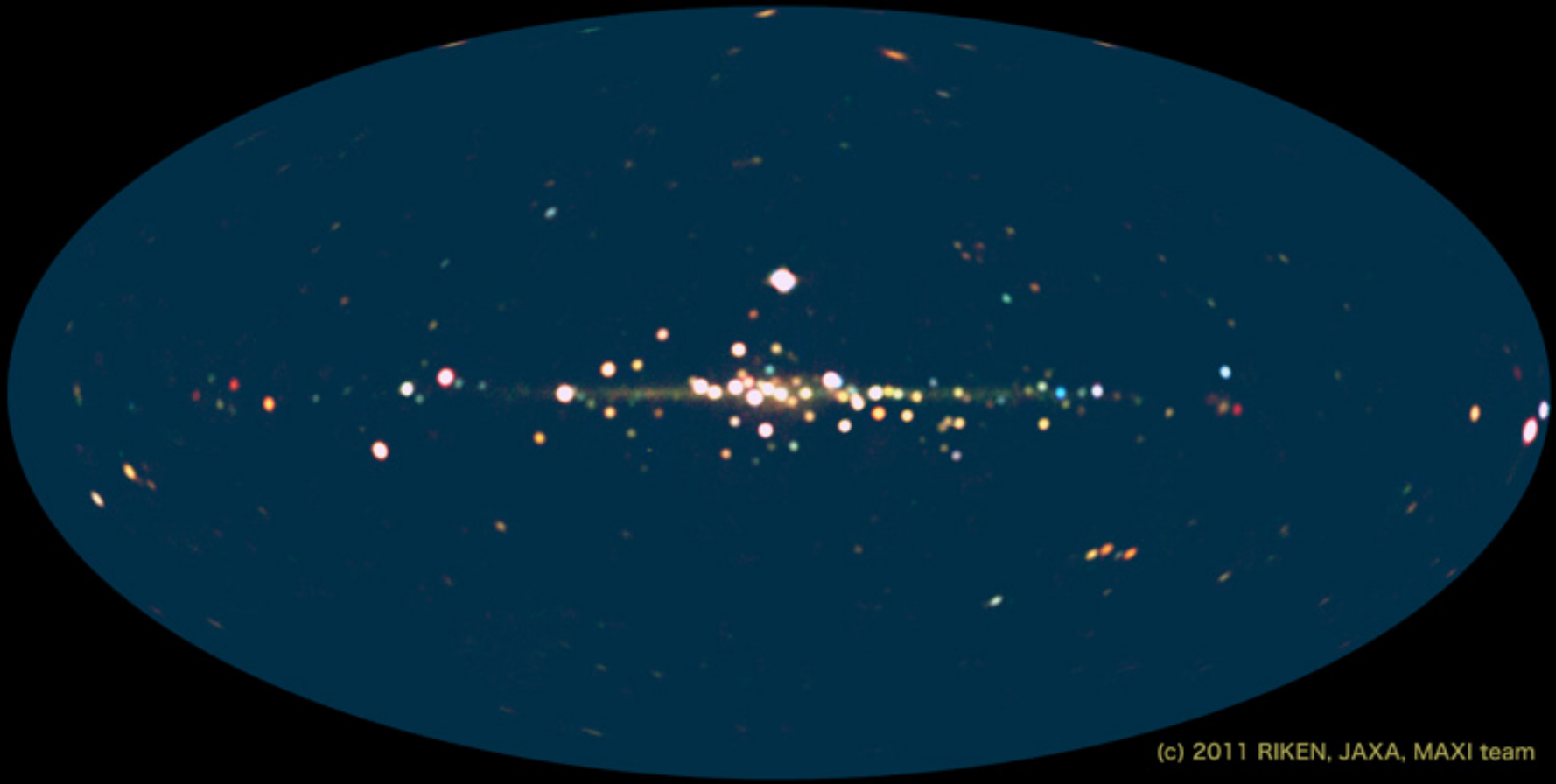
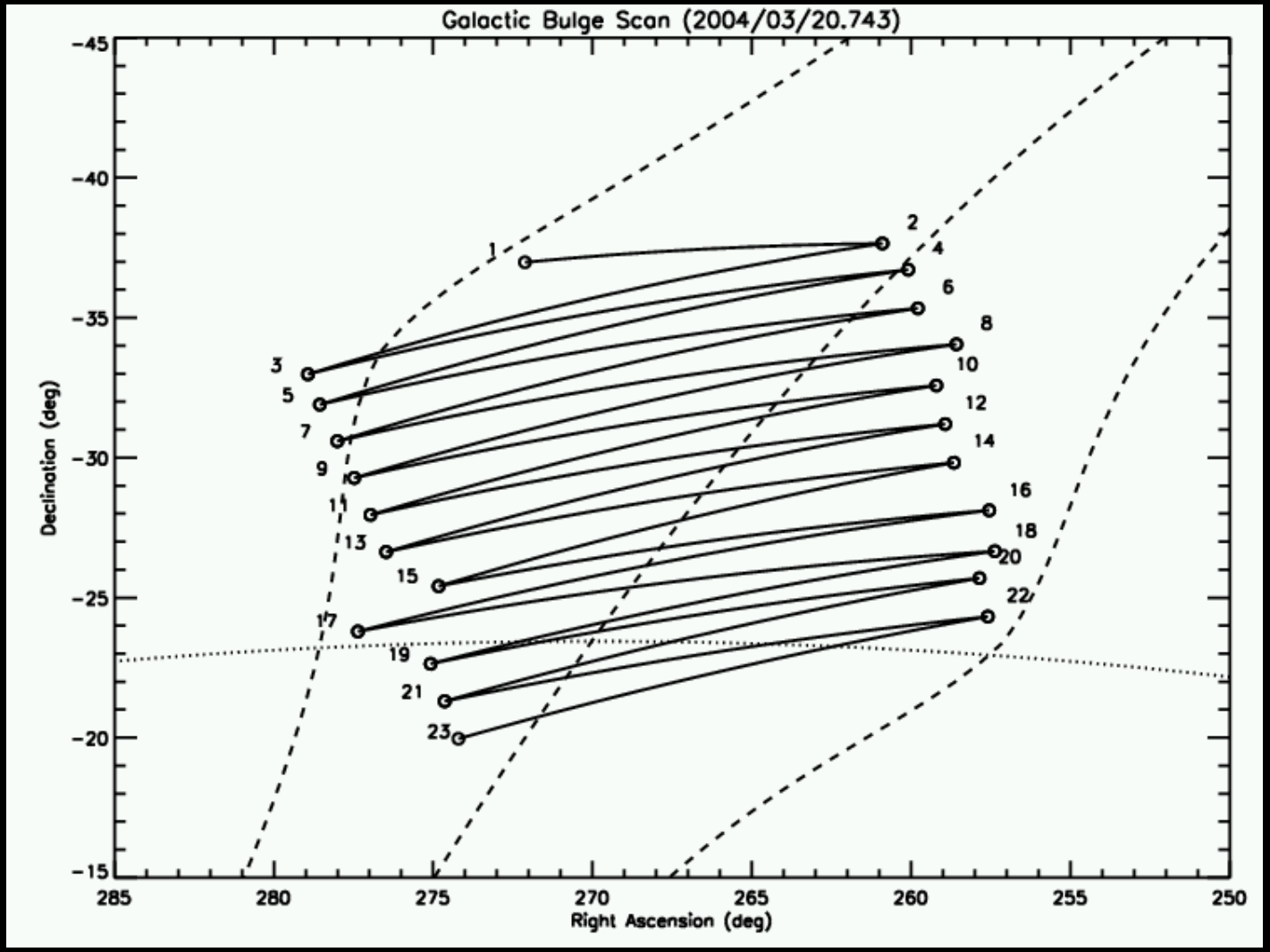
Neutron Stars in High Mass X-ray Binaries: Strong variability due to the stellar wind and eclipses

(Fürst et al., 2010; Kreykenbohm et al., 2008)



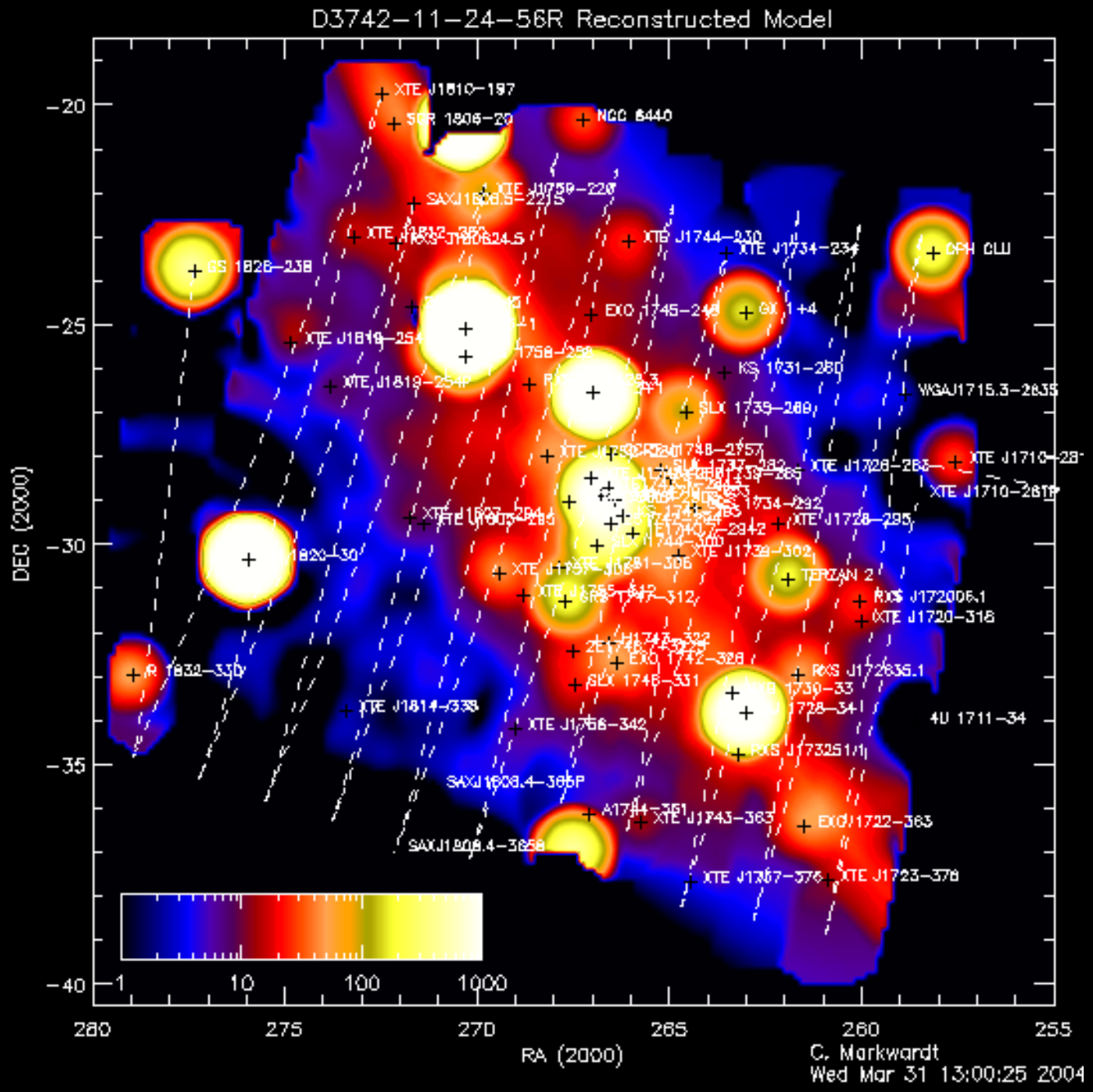

MAXI 1.7 year map

Most bright transients located in the Galactic center region




Good statistics on transient source behavior from *RXTE* Galactic Bulge Scans (C. Markwardt):

- since 1999
- twice weekly
- $\sim$20 s of on-source exp., 2000–4000 $\mathrm{cm}^2$ eff. area in 2–10 keV

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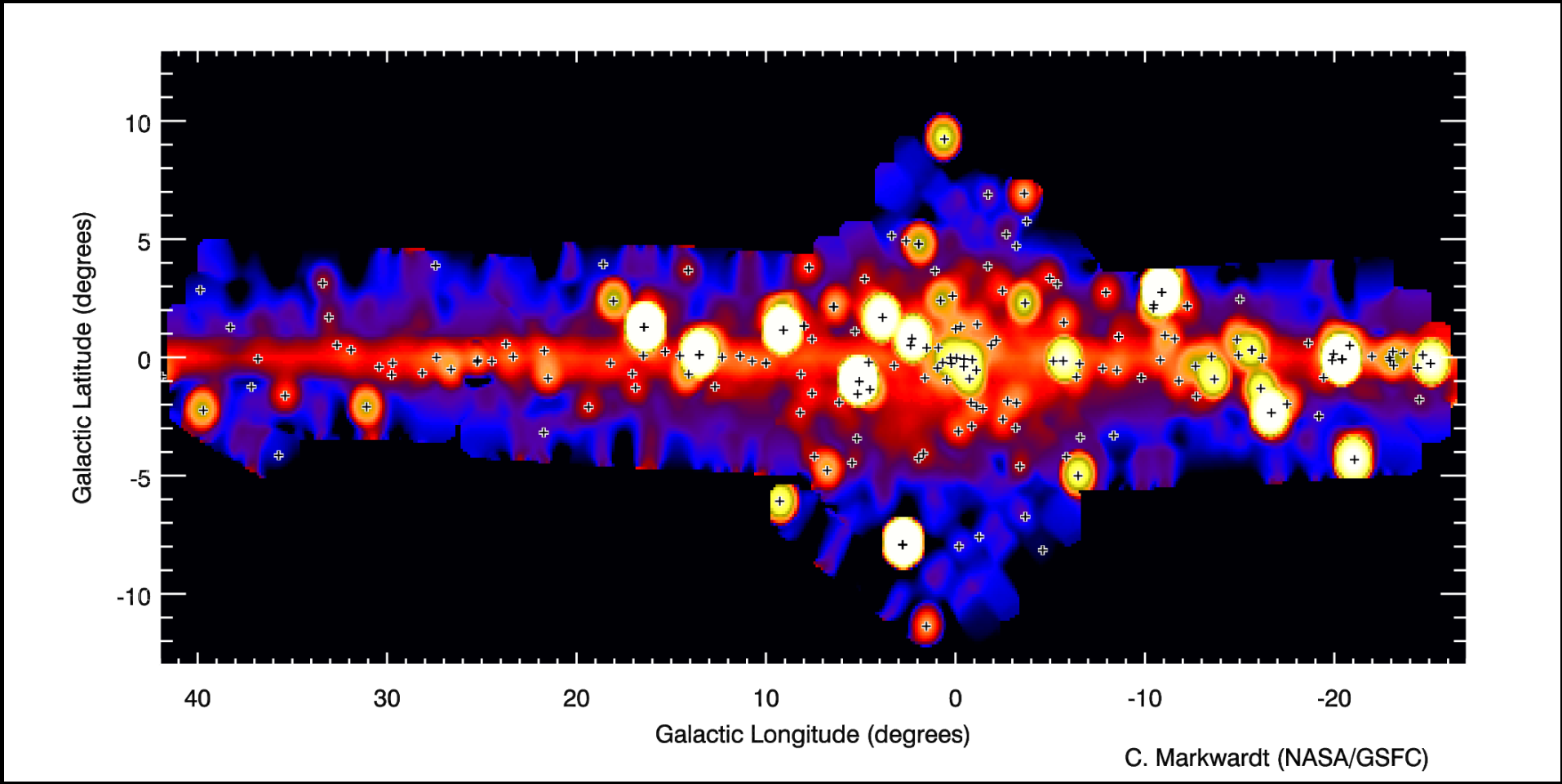
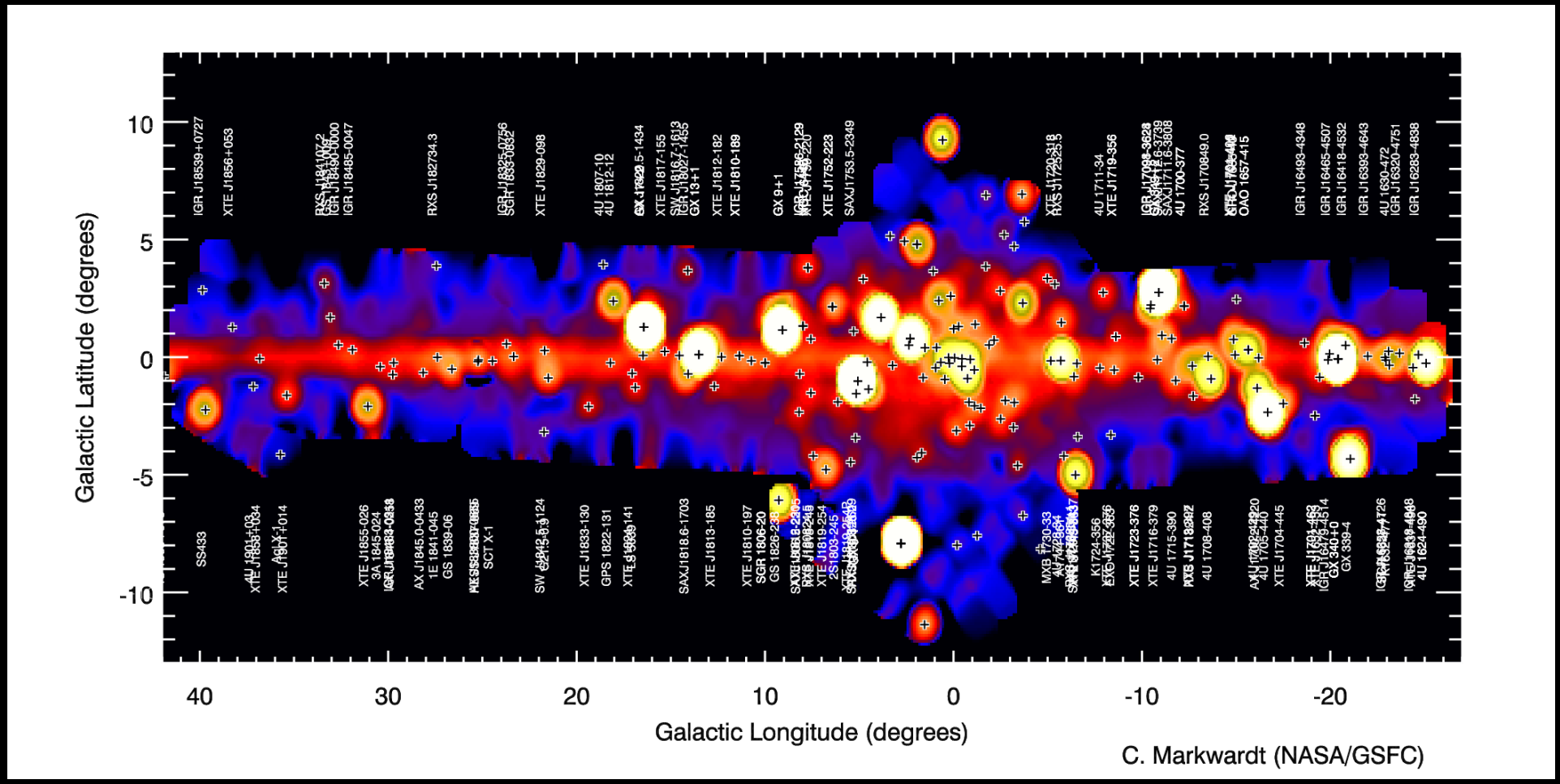



C. Markwardt

- Results: http://lheawww.gsfc.nasa.gov/users/craigm/galscan/
- since 1999: 250 sq. deg.
- since 2004: 500 sq. deg.
- since 2008: 625 sq. deg.
- 50 new sources discovered

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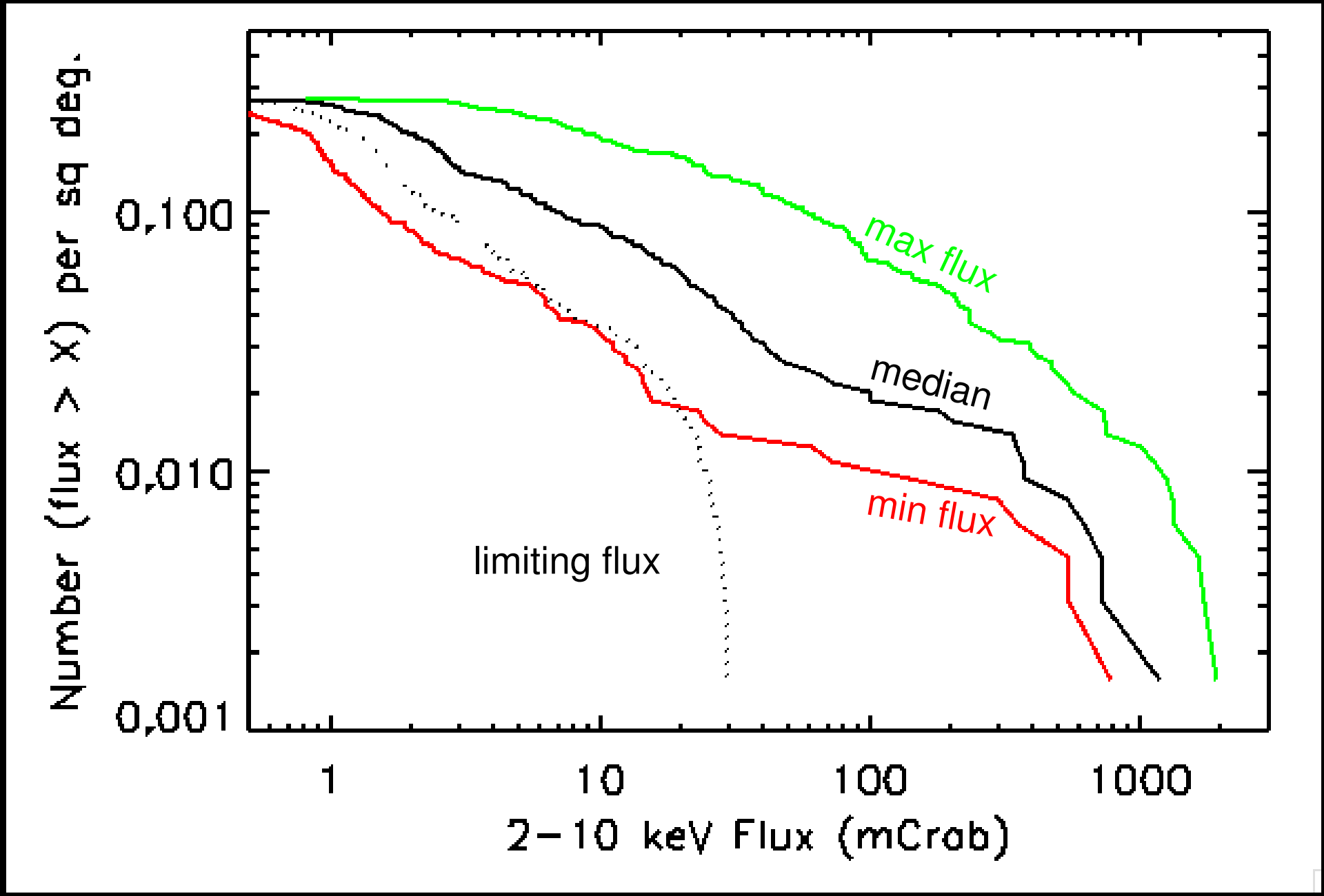
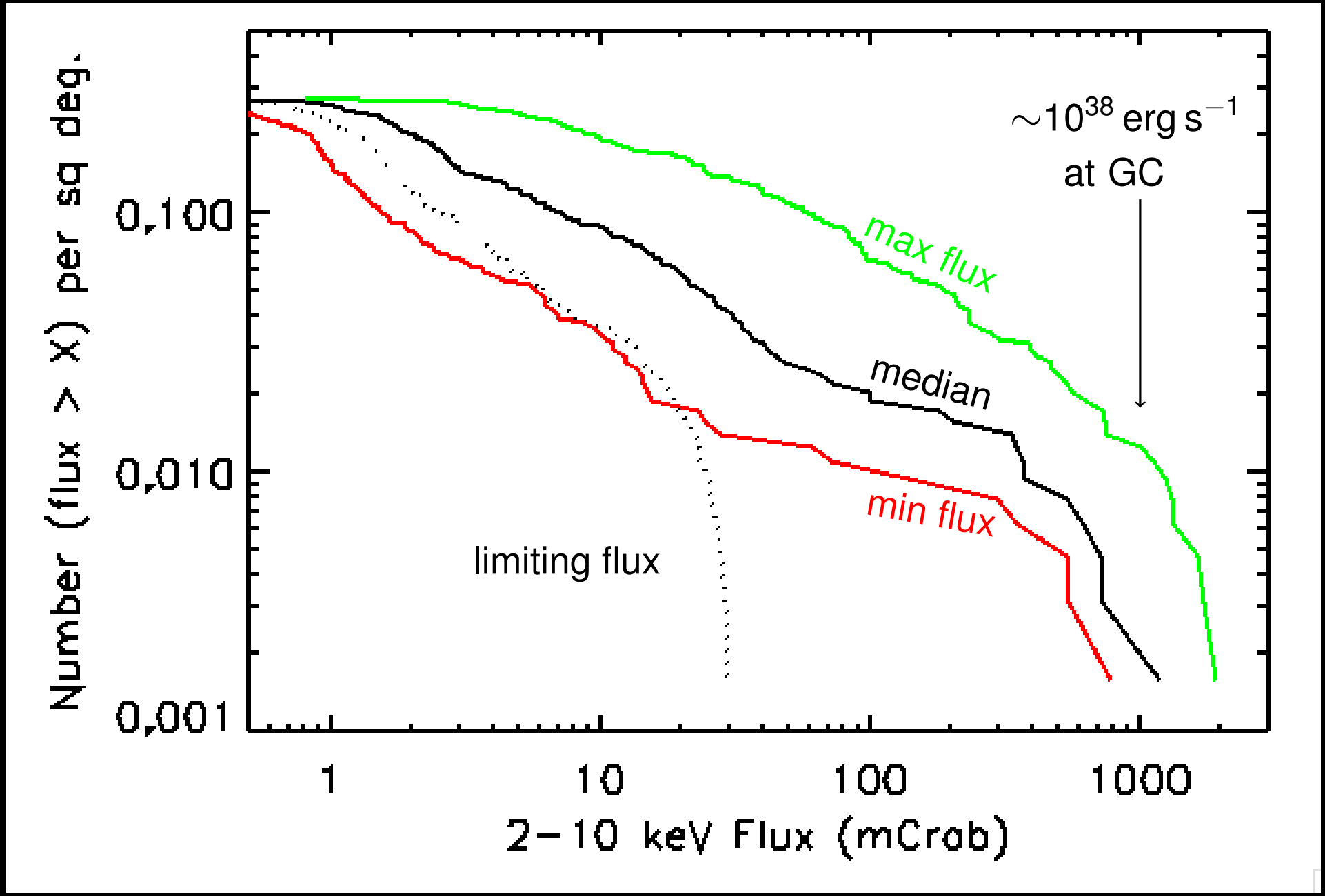



after C. Markwardt

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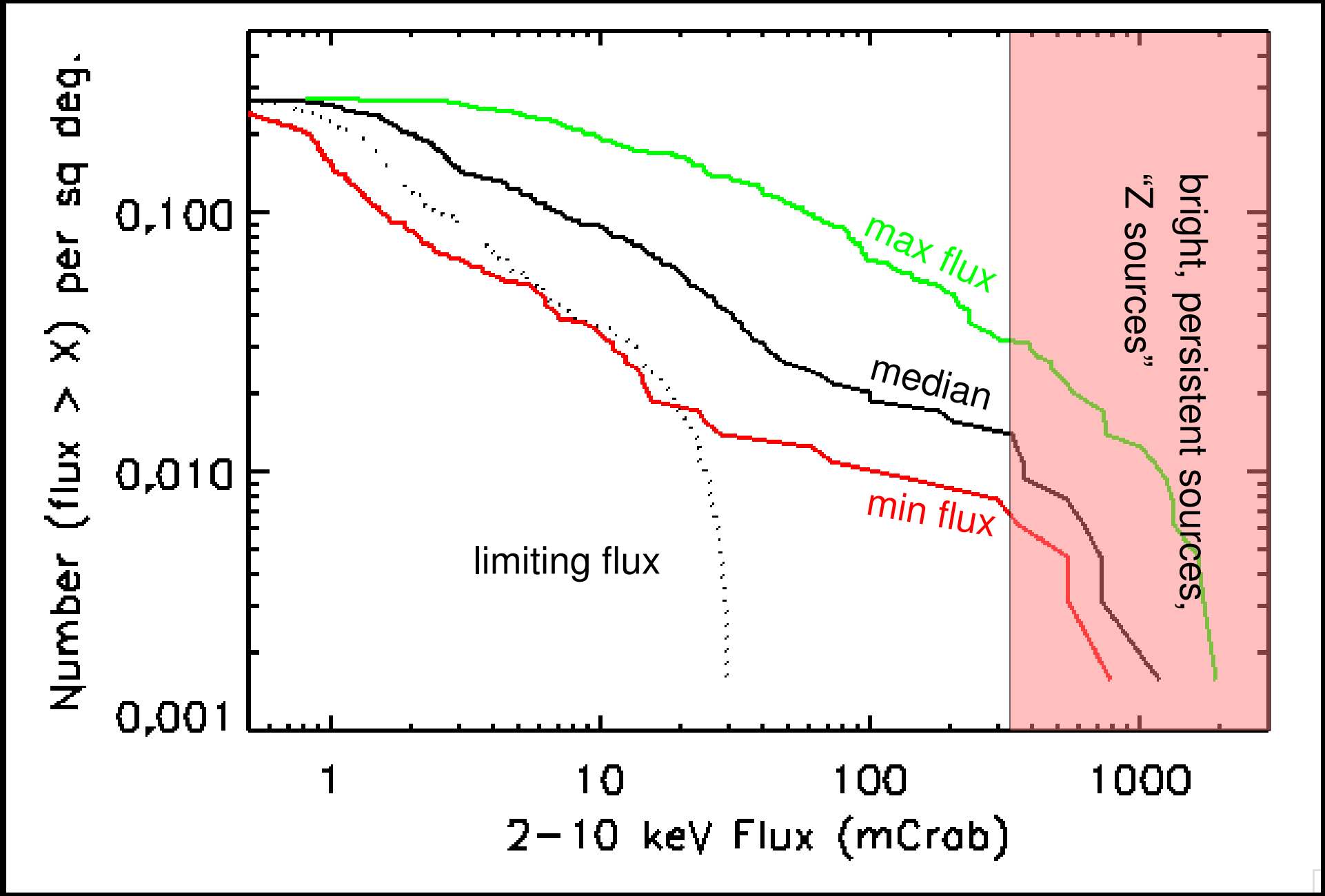


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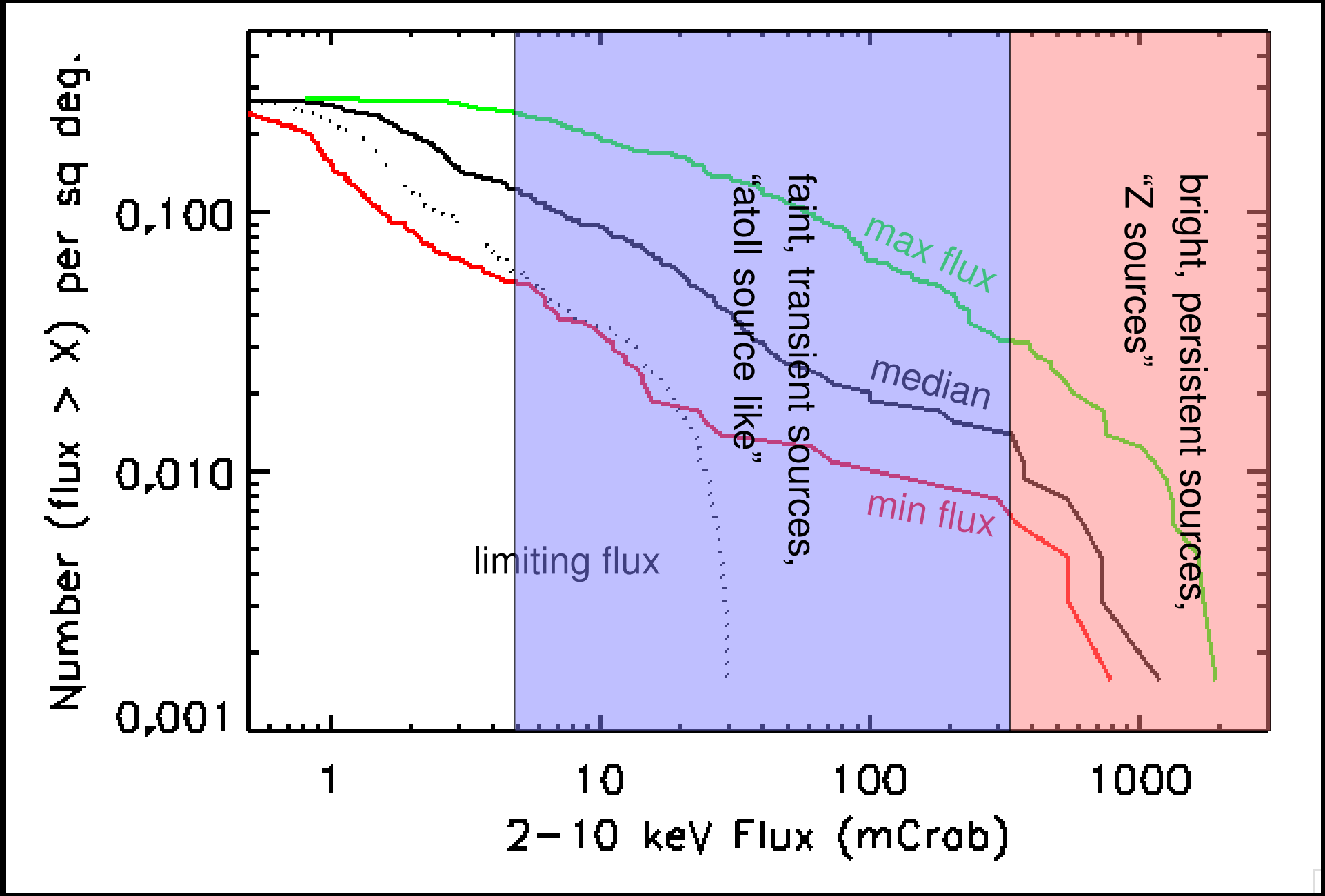


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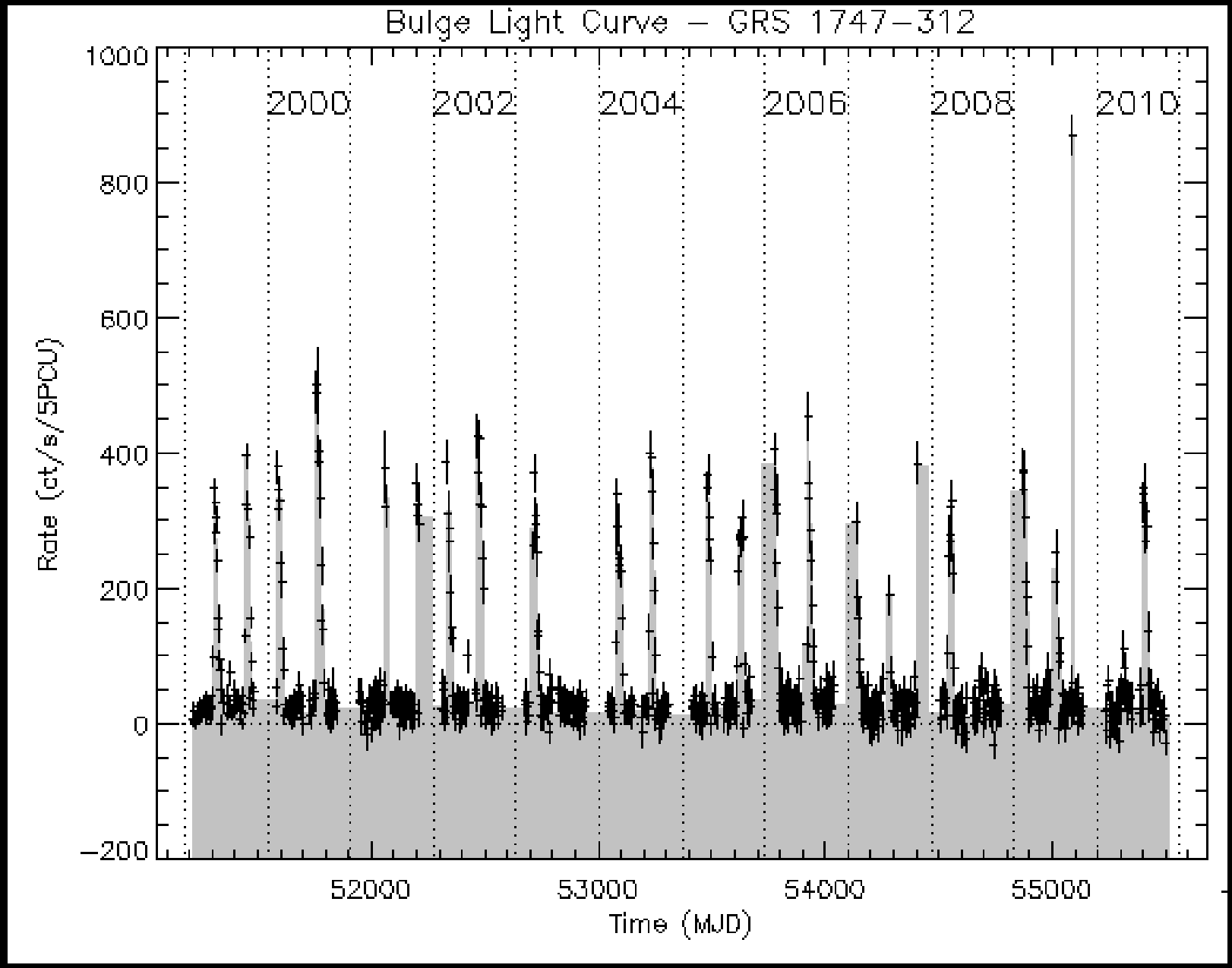
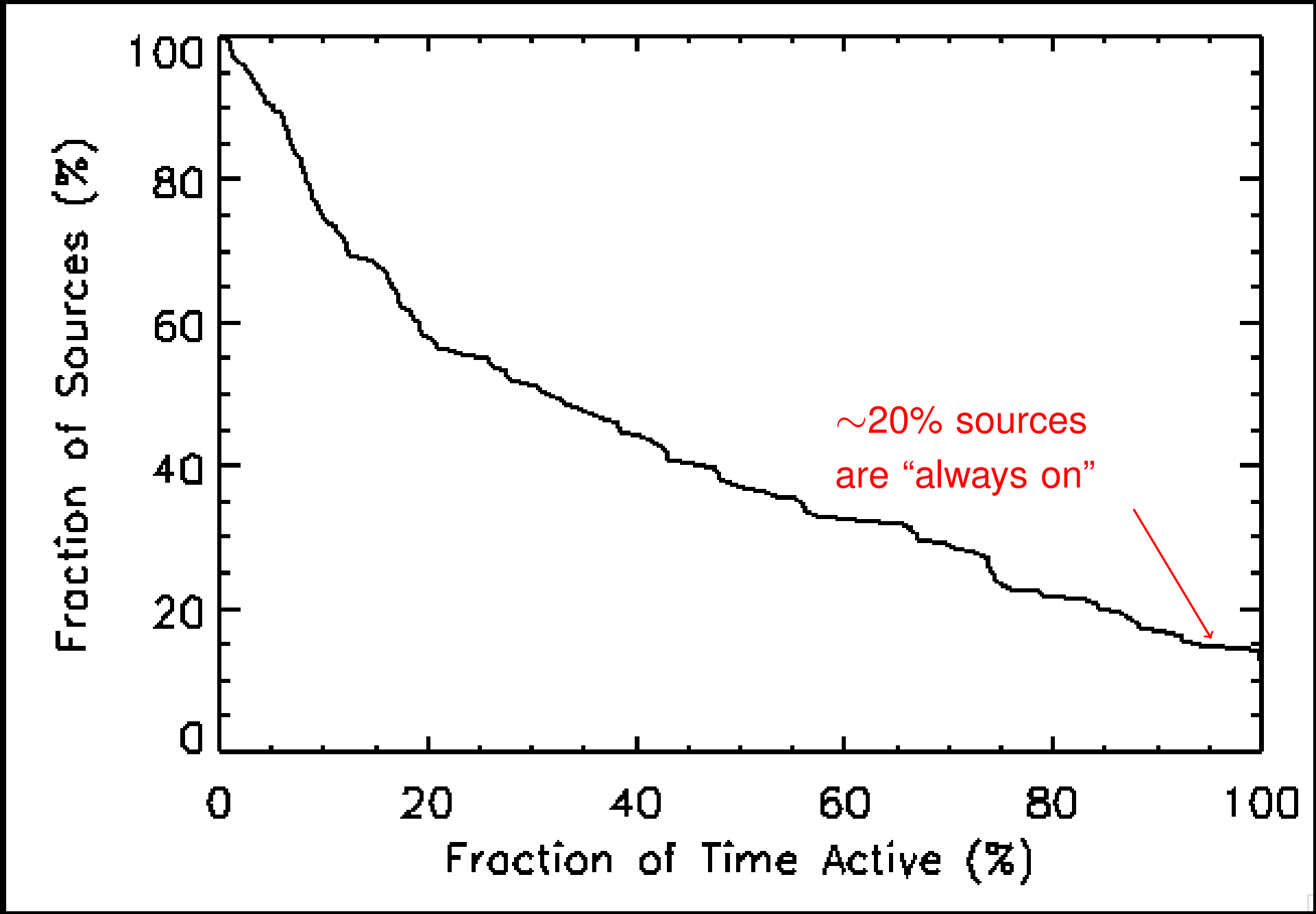



C. Markwardt

Many GC sources are strongly variable

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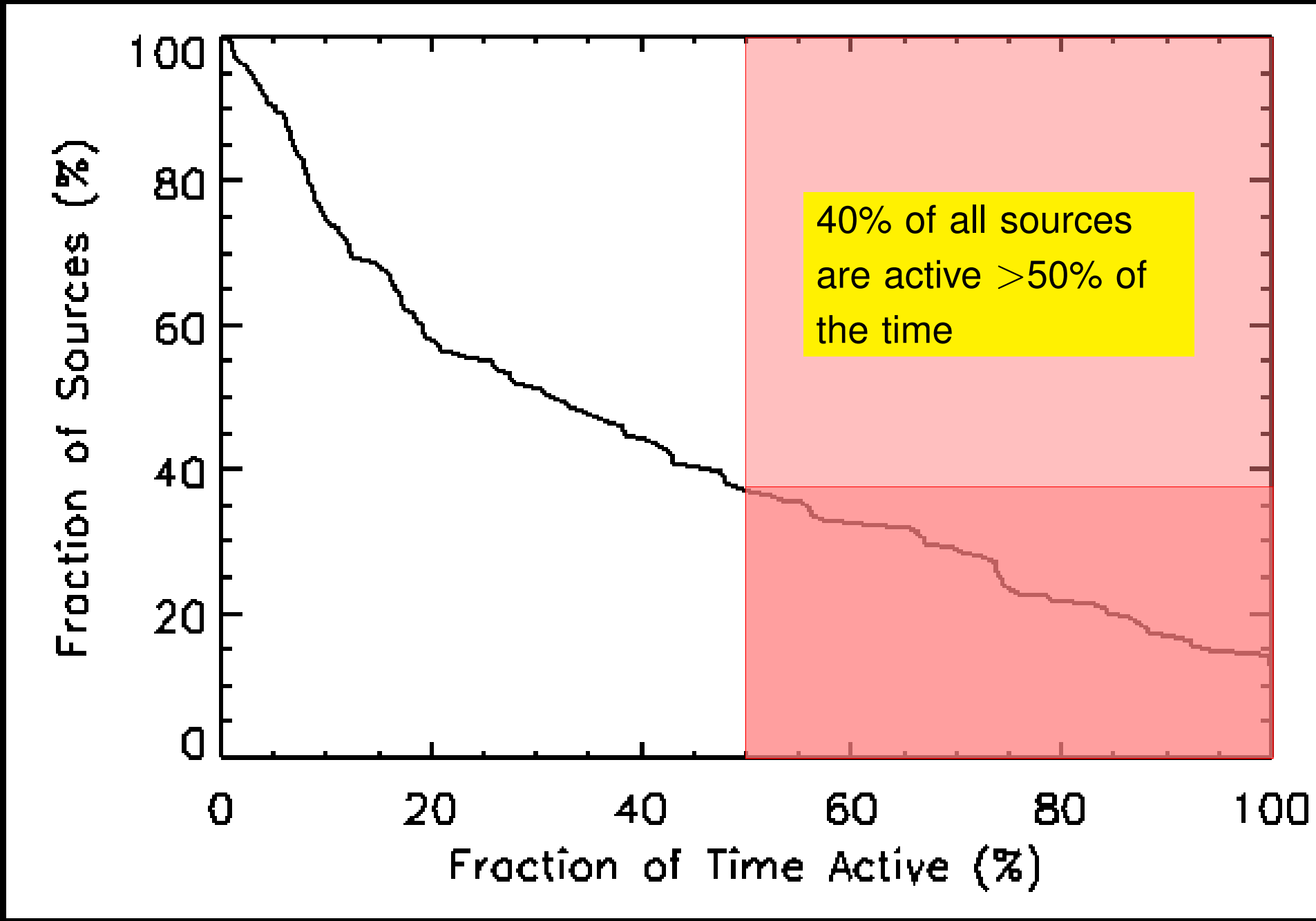


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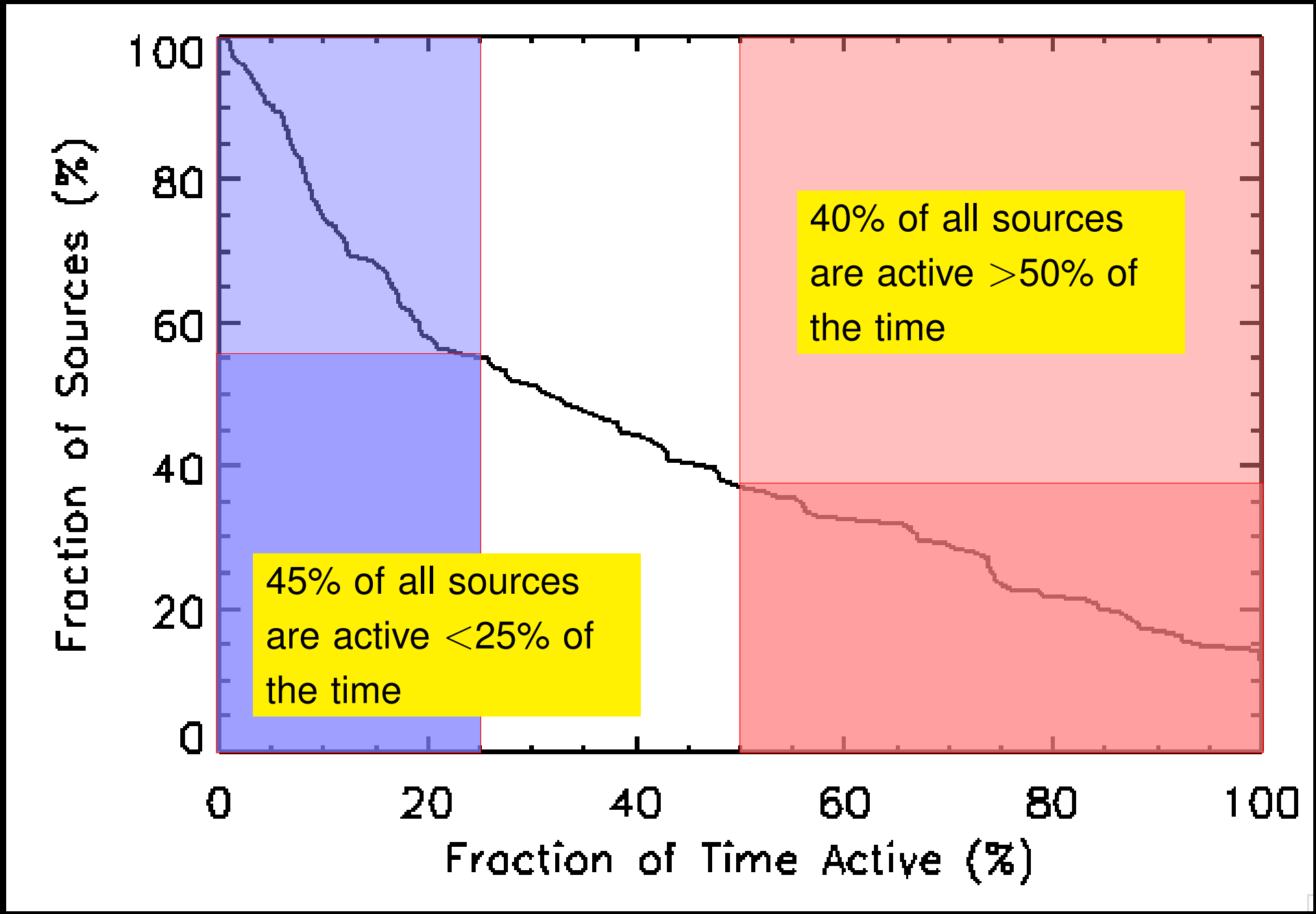


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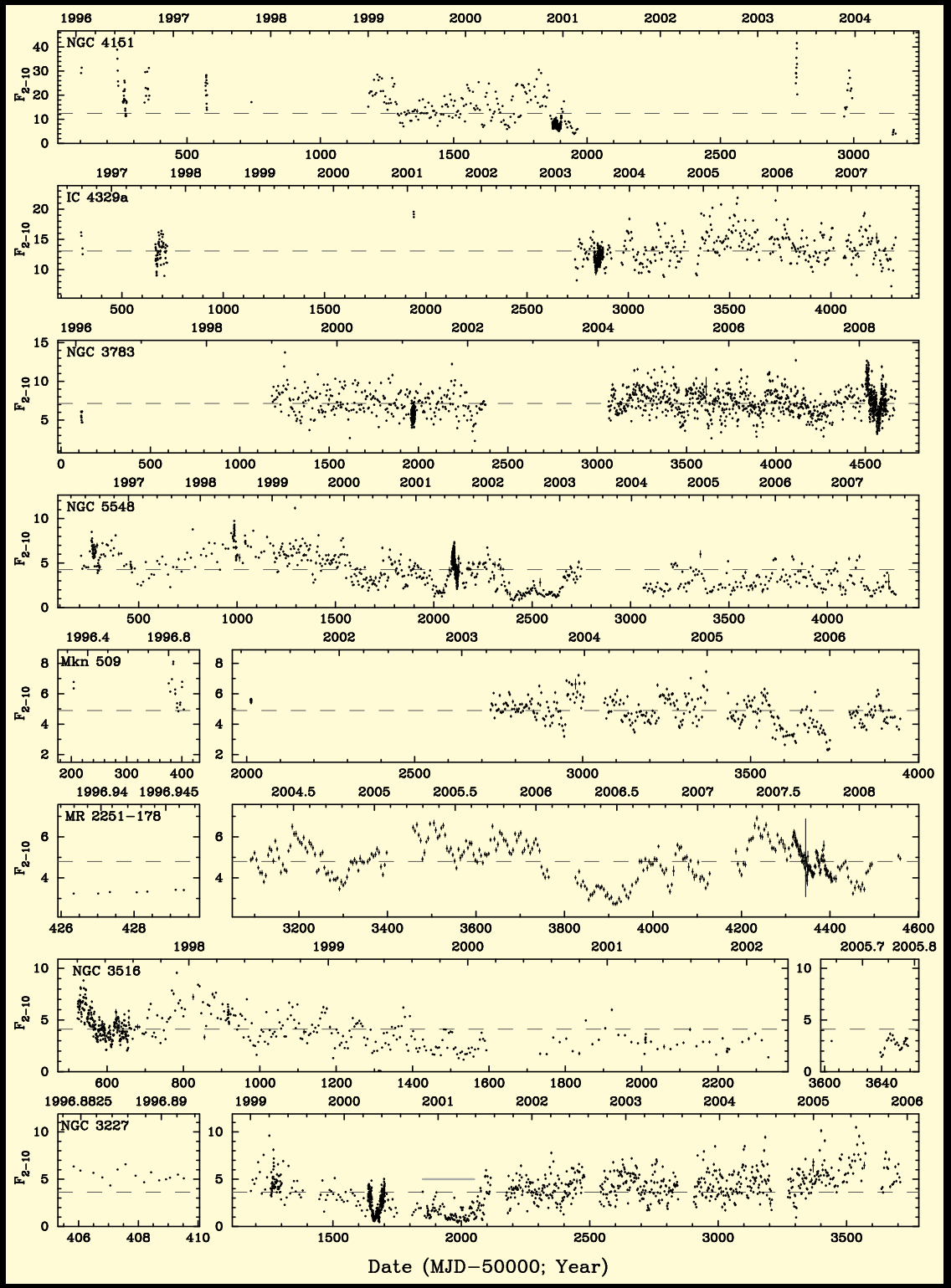
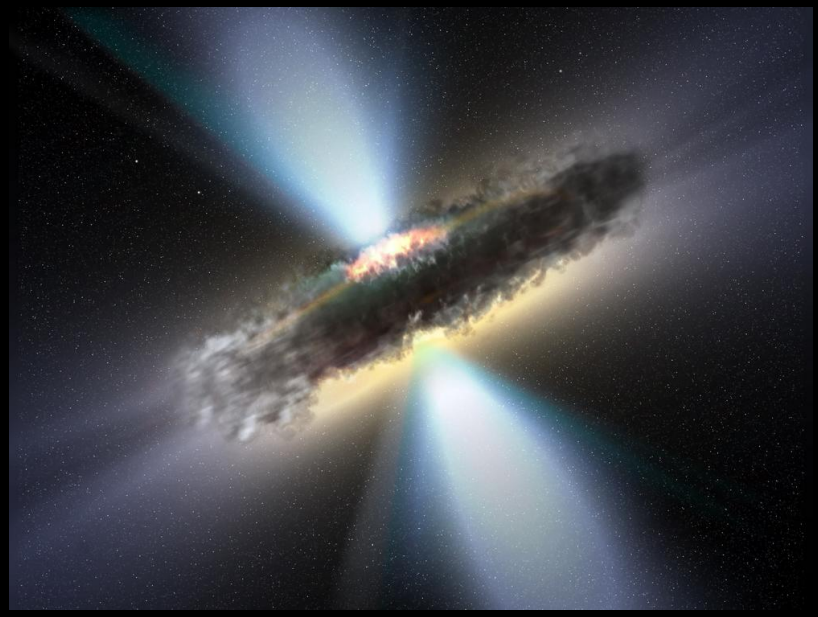
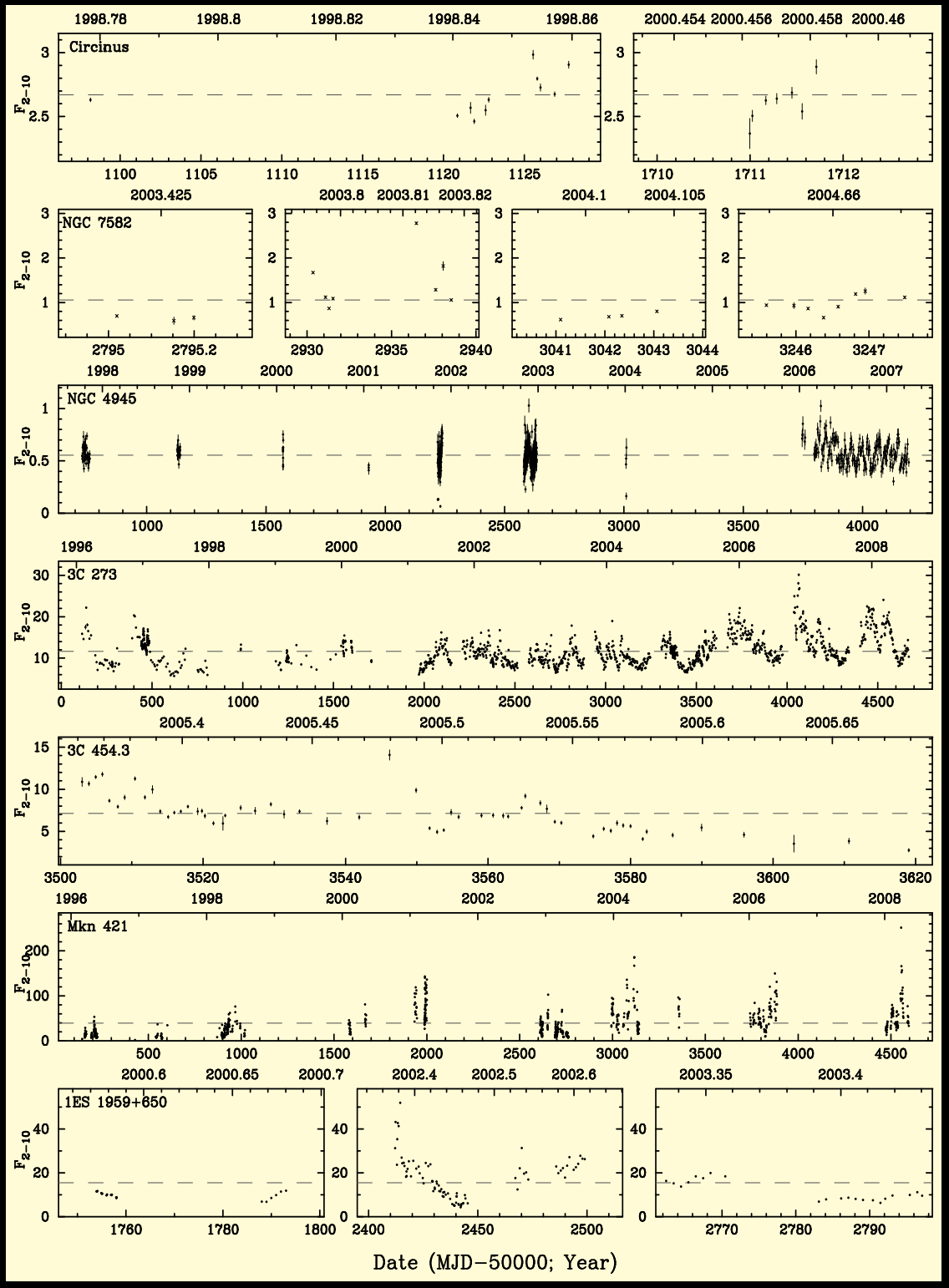


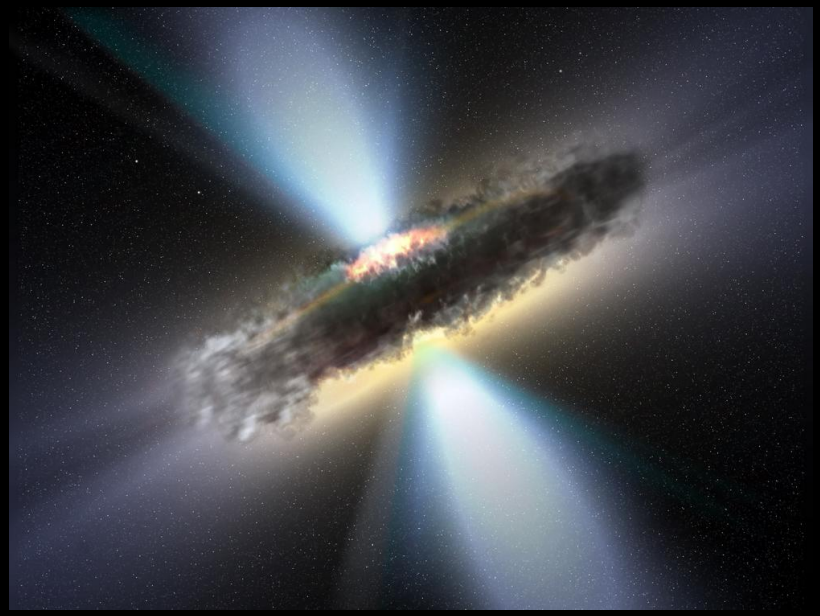



ESA

All Active Galactic Nuclei are strongly variable on long timescales ($\dot{M}$ variations?)

(AGN monitoring with *RXTE*-PCA, pointed observations; Rivers et al., 2011)



ESA

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eROSITA: monitoring will have coverage similar to, e.g., NGC 4945

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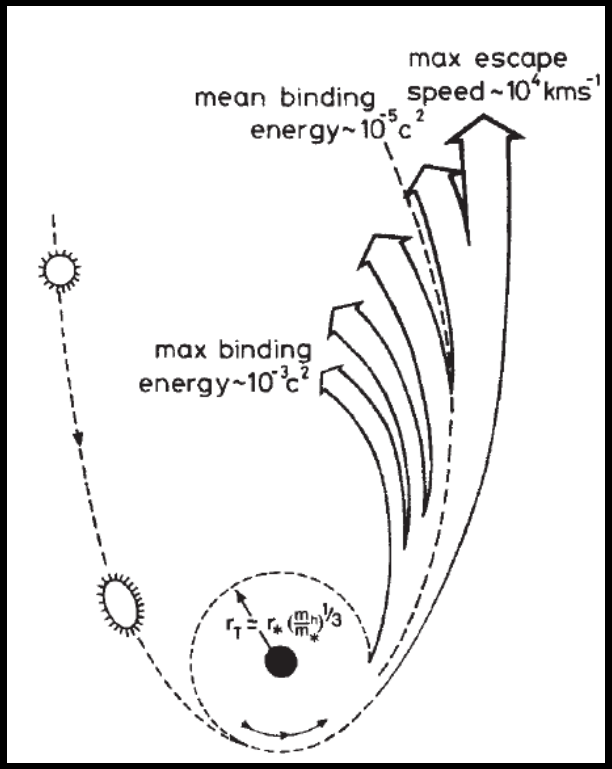
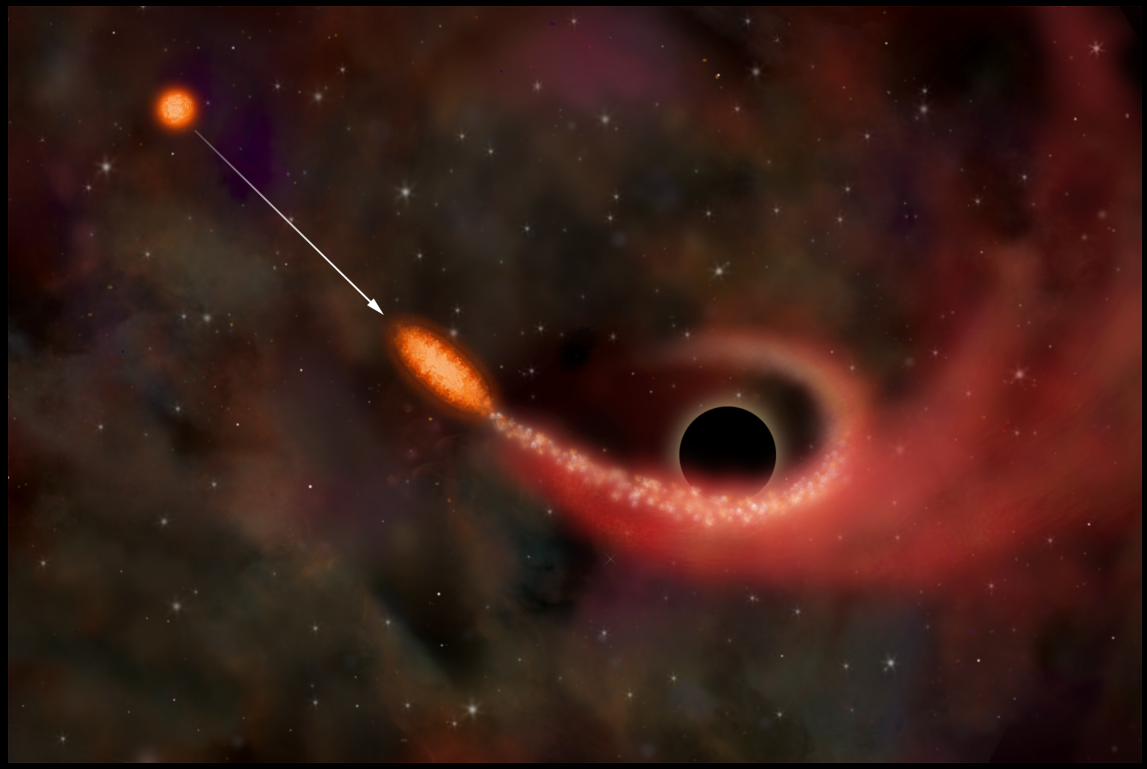


## tidal disruption events:

Star is tidally disrupted it gets too close to black hole (e.g., Rees, 1988):

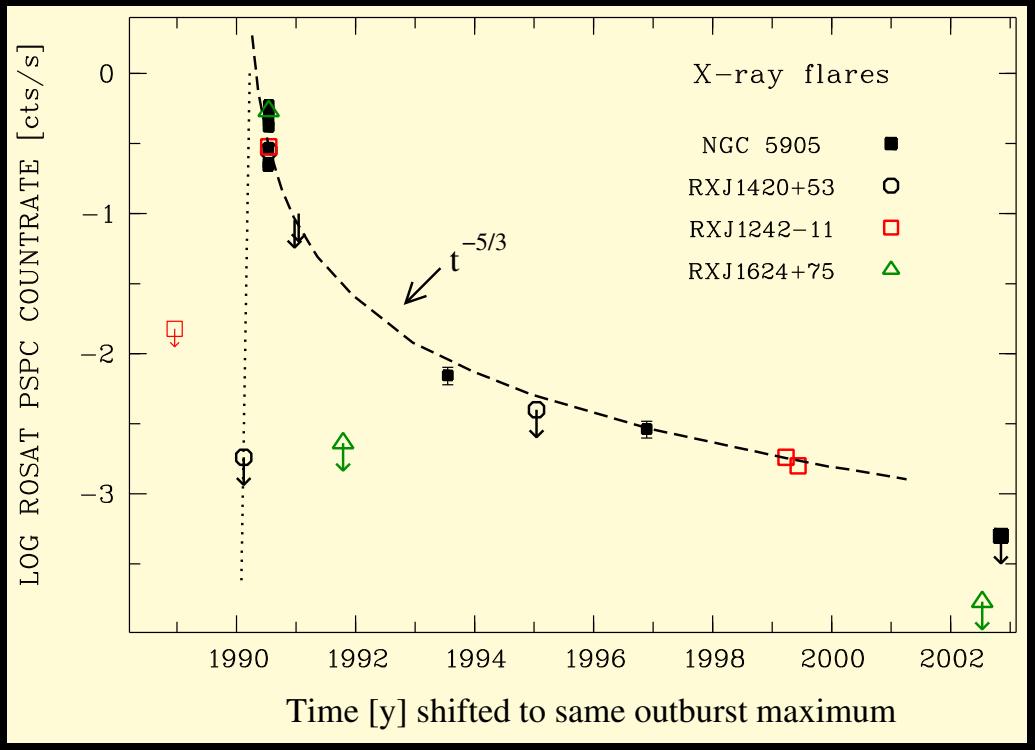
$$R_\mathrm{T} = 0.7\,\mathrm{AU}\cdot\frac{R_*}{R_\odot}\left(\frac{M_*}{M_\odot}\right)^{-1/3}\left(\frac{M_\mathrm{BH}}{10^7\,M_\odot}\right)^{1/3} > R_\mathrm{S}\ \text{for}\ M_\mathrm{BH} \lesssim 6\times10^7 M_\odot \qquad (1)$$

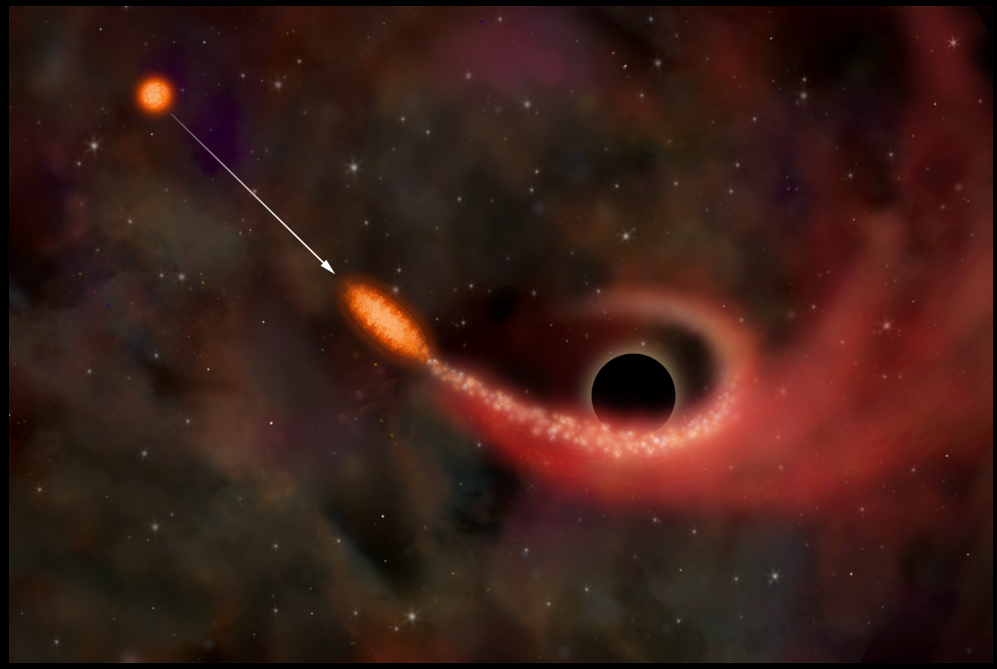
Disruption leads to ejection of ∼50% material, rest remains bound to BH and is accreted. Typical temperatures in soft X-rays:

$$T(3r_\mathrm{S}) = 7\times10^5\,\mathrm{K}\cdot\left(\frac{M_\mathrm{BH}}{10^6\,M_\odot}\right)^{1/4} \sim 60\,\mathrm{eV} \qquad (2)$$

and flux declining $\propto t^{-5/3}$

(Rees, 1988; Komossa, 2004; Esquej et al., 2010, and therein)



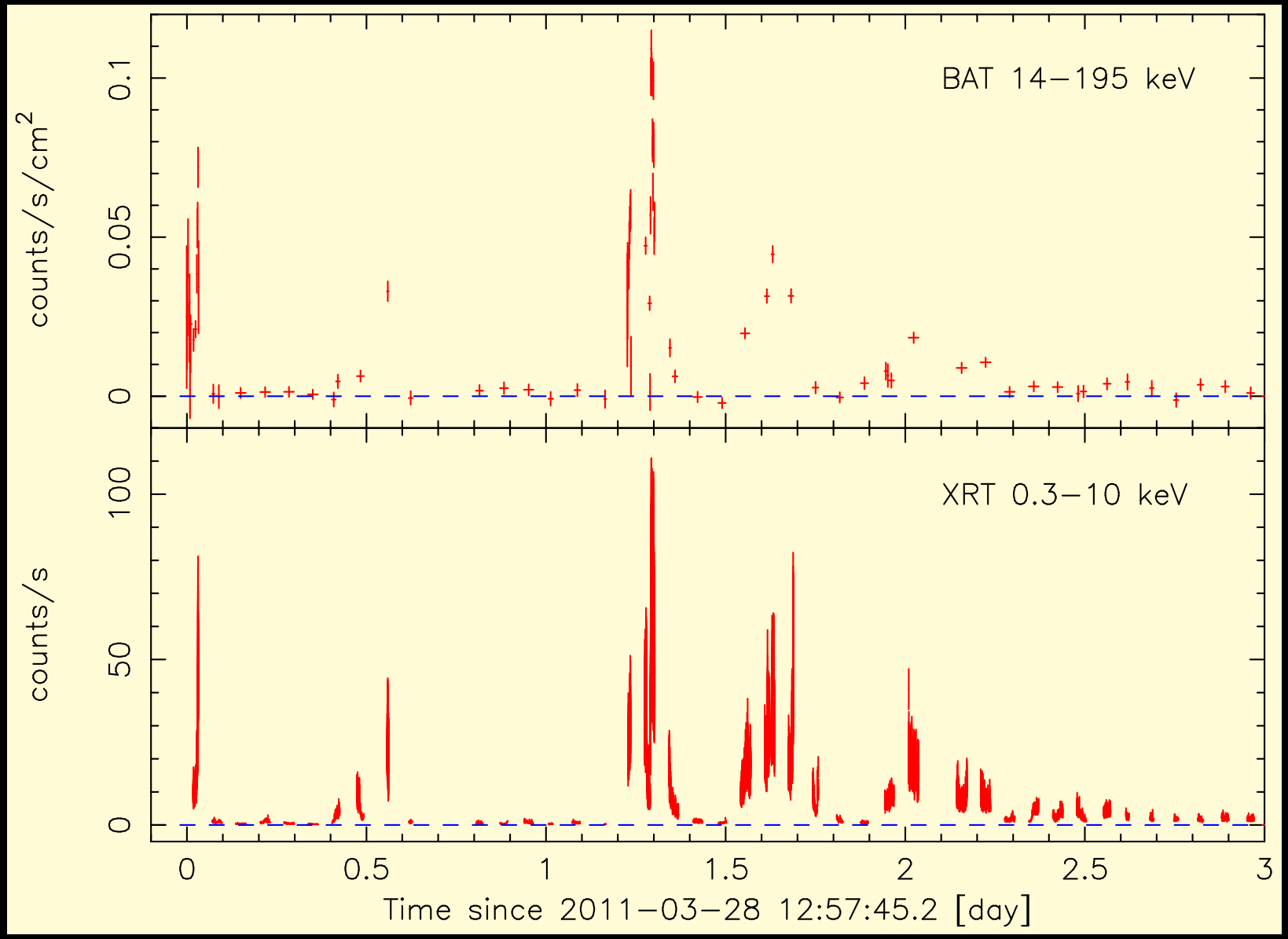
(Komossa, 2004, Fig. 1)

Example: $L_X \sim 9 \times 10^{43}$ erg s$^{-1}$ in RXJ 1242−1119 (Komossa & Greiner, 1999)

Tidal disruption events already seen in *ROSAT* All Sky Survey, and all later missions

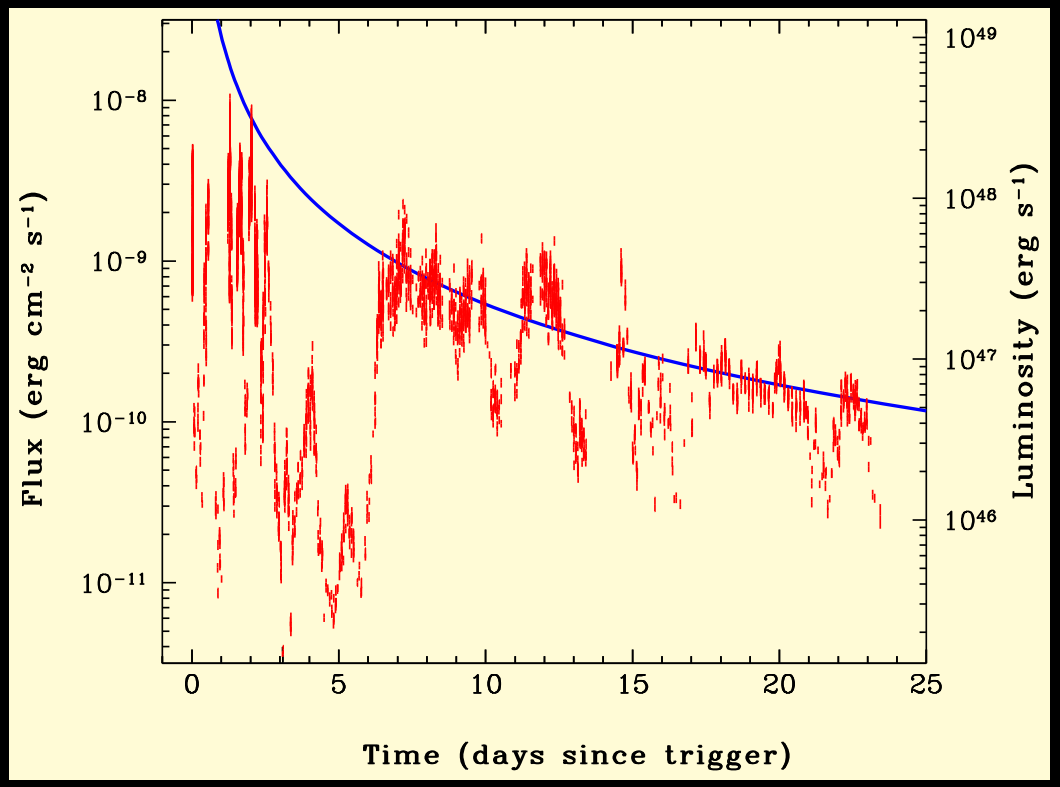
A handful events seen in RX J1242.6−1119 (Komossa & Greiner, 1999), RX J1624.9+7554 (Grupe et al., 1999), NGC 5905 (Komossa & Bade, 1999), RX J1420.4+5334 (Greiner et al., 2000), TDXFJ134730.3−325451 (in Abell 3571; Cappelluti et al., 2009), 3 unnamed GALEX sources at $z \sim 0.3 \ldots 0.4$ (Gezari et al., 2009), and 2 events from *XMM-Newton* slew survey data (Esquej et al., 2010)

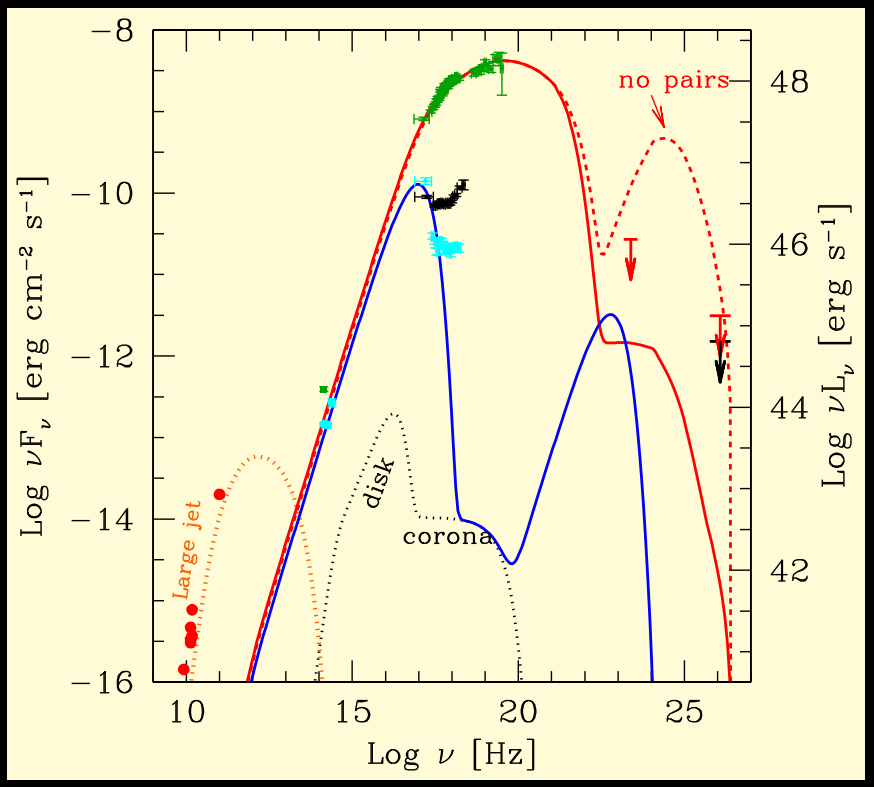
LSST expects 7 events per year.




(Burrows et al., 2011)

28 March 2011: Swift discovers very peculiar “Gamma Ray Burst”: GRB 110328A



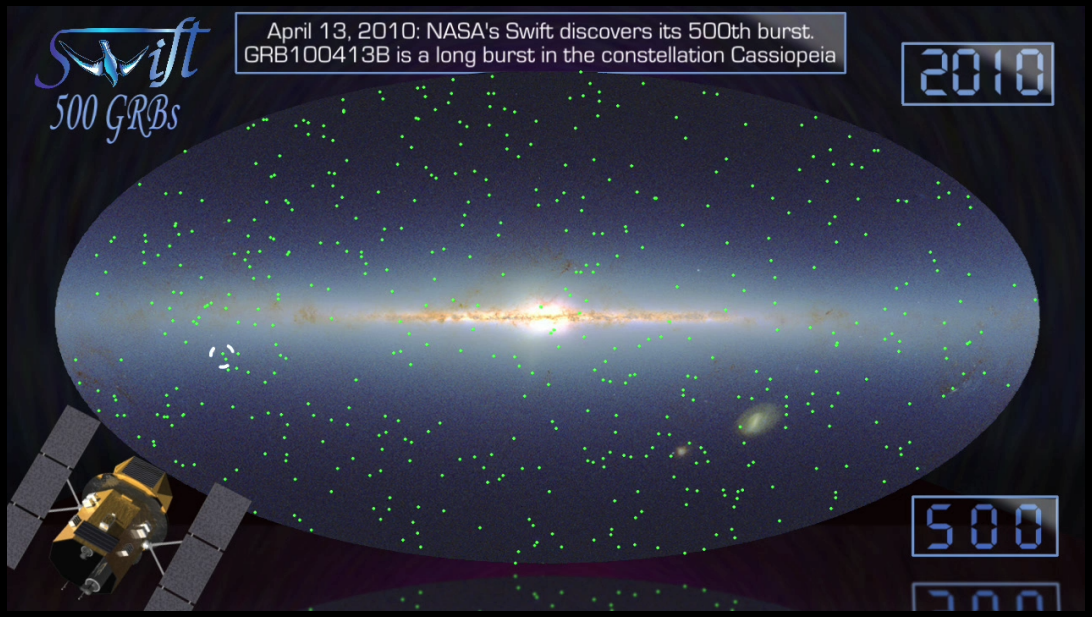




(Burrows et al., 2011)

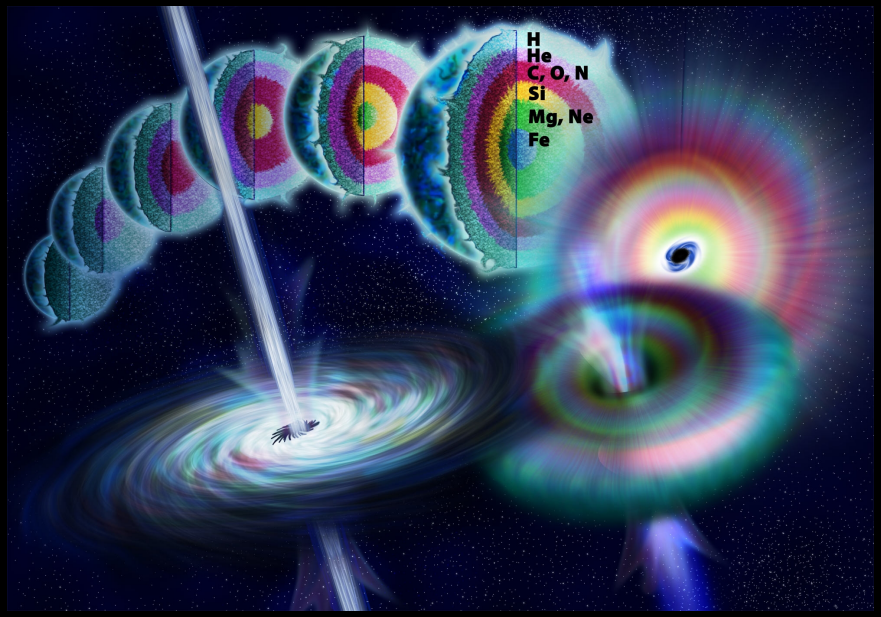
GRB 110328A is a tidal disruption event: Swift J164449.3+573451

Measurements in J1644 show relativistic jet activity caused by the violent accretion.

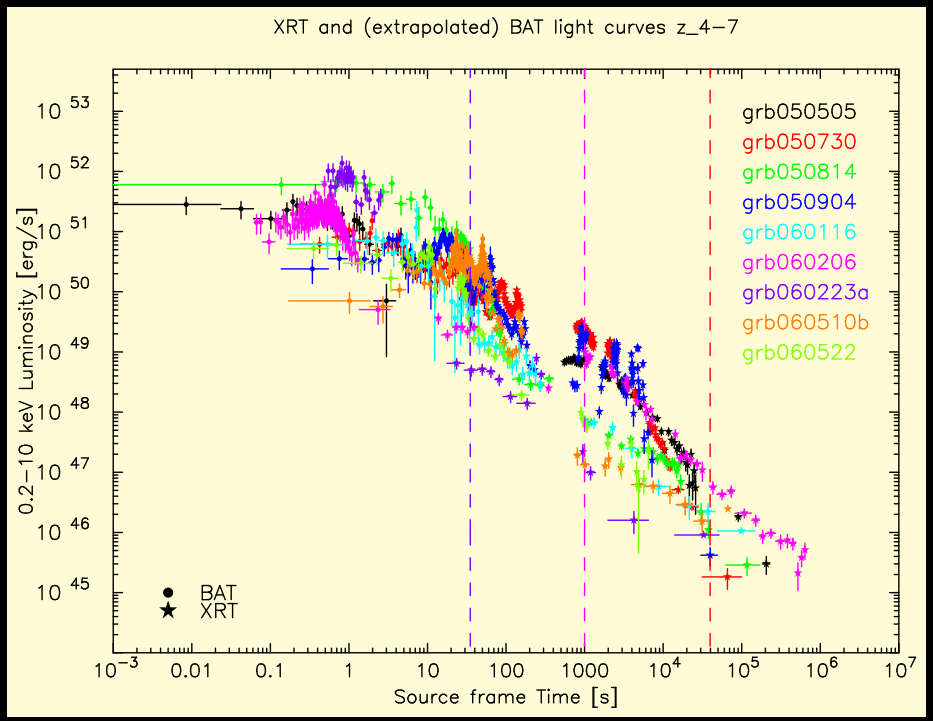
Some contribution from instant jet, plus more extended jet; suppression of highest energies by photon-photon pair production.




NASA



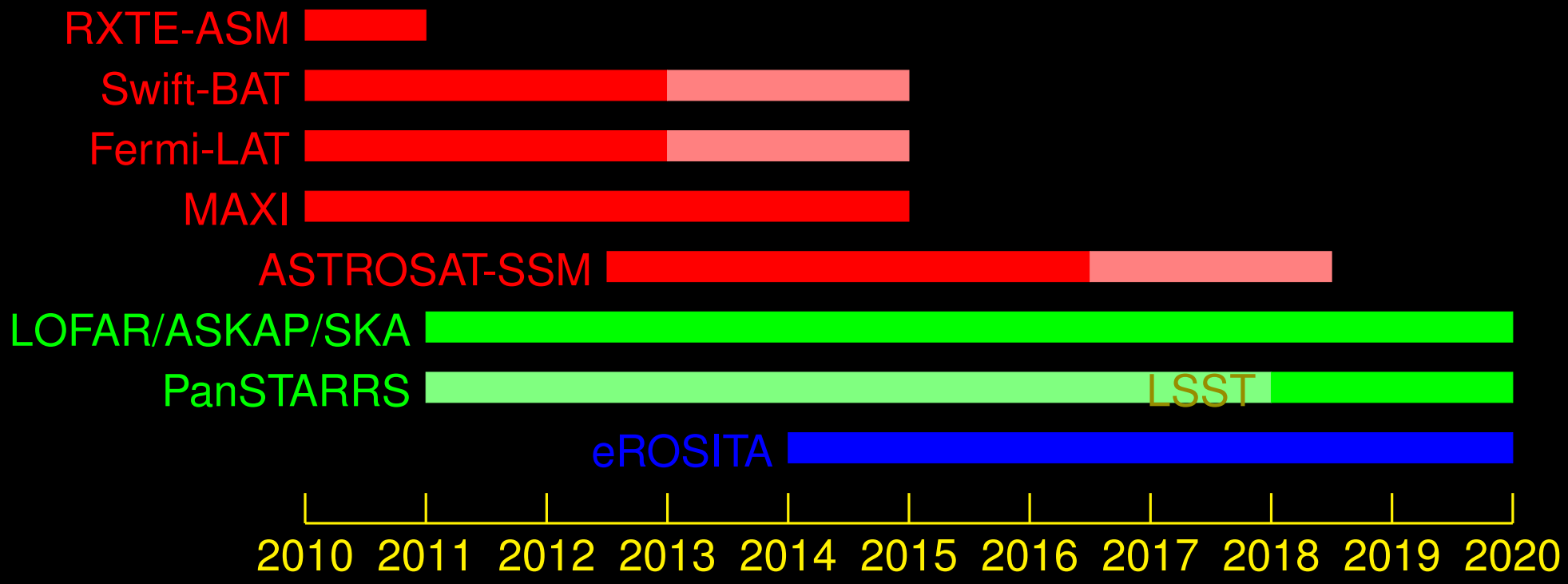

NSF




Gamma-Ray Bursts: We expect to be able to see a handful of GRBs(-afterglows) with eROSITA

(Mangano et al., 2006)

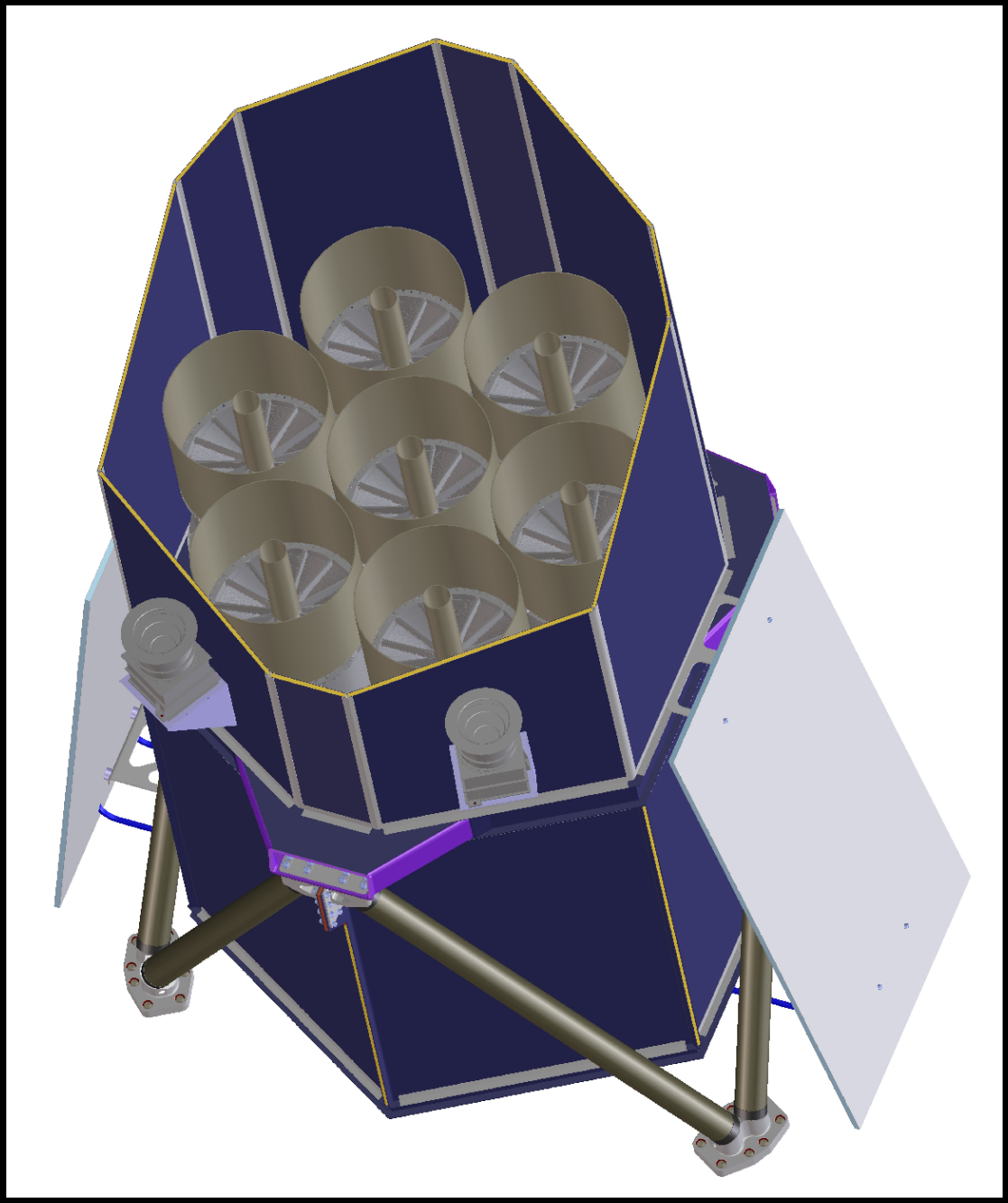
The future of transient monitoring observations:




In the next 10 years:

- multi-wavelength monitoring routine: LOFAR, LSST,. . .
- probably *max. 1* X-ray ASM (a shame!)

$\Longrightarrow$ what can eROSITA do?



## What will eROSITA bring?

- Sensitivity during individual source observations is in the mCrab range

  $\Longrightarrow$ Sensitivity on 30 s scales is better than *RXTE*-ASM or MAXI, comparable to *RXTE*-PCA slews

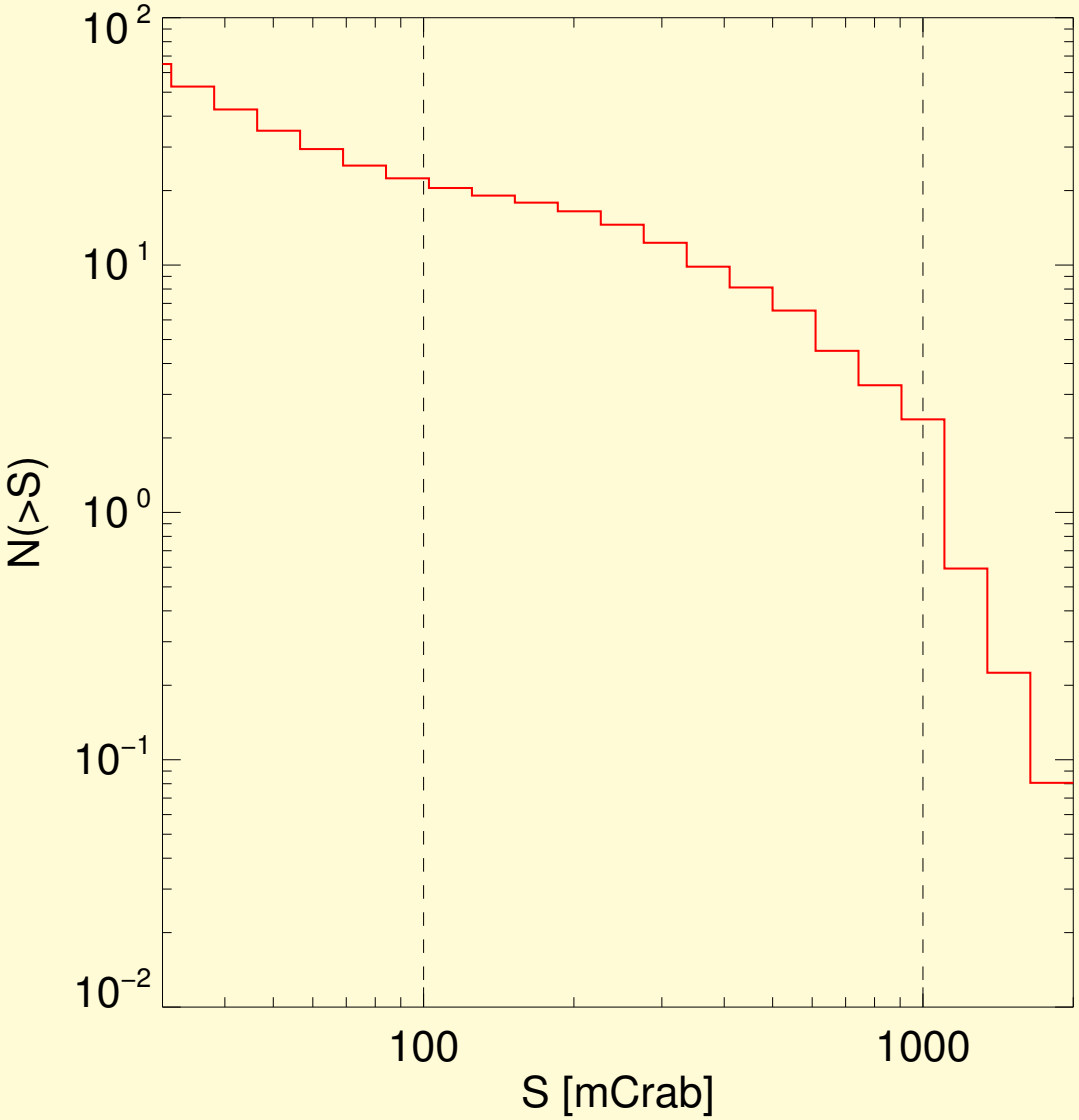
- However, survey strategy results in much lower duty cycle

  Good coverage:

  $\Longrightarrow$ Variability between individual scans (one “ero-day” to the next)

  $\Longrightarrow$ Variability on 0.5 yr scales

  $\Longrightarrow$ Variability during survey phase



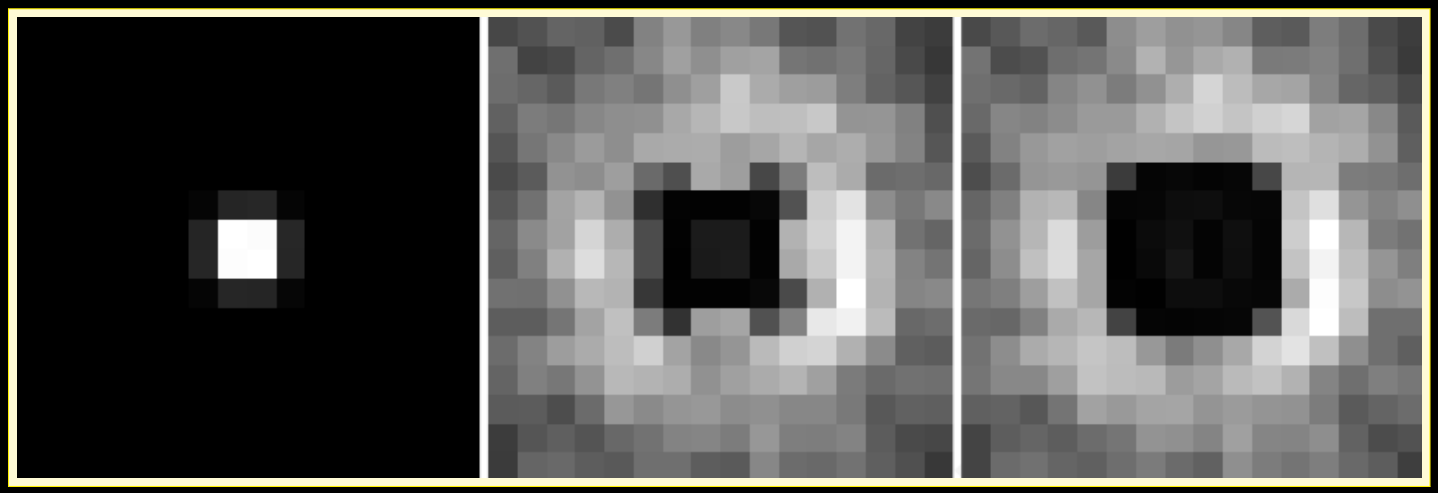

Bright source statistics: number of *RXTE*-ASM sources brighter than flux $S$ during $\Delta t = 0.5$ d averaged over 14 y of *RXTE*-ASM lifetime.

complete above a few 10s mCrab

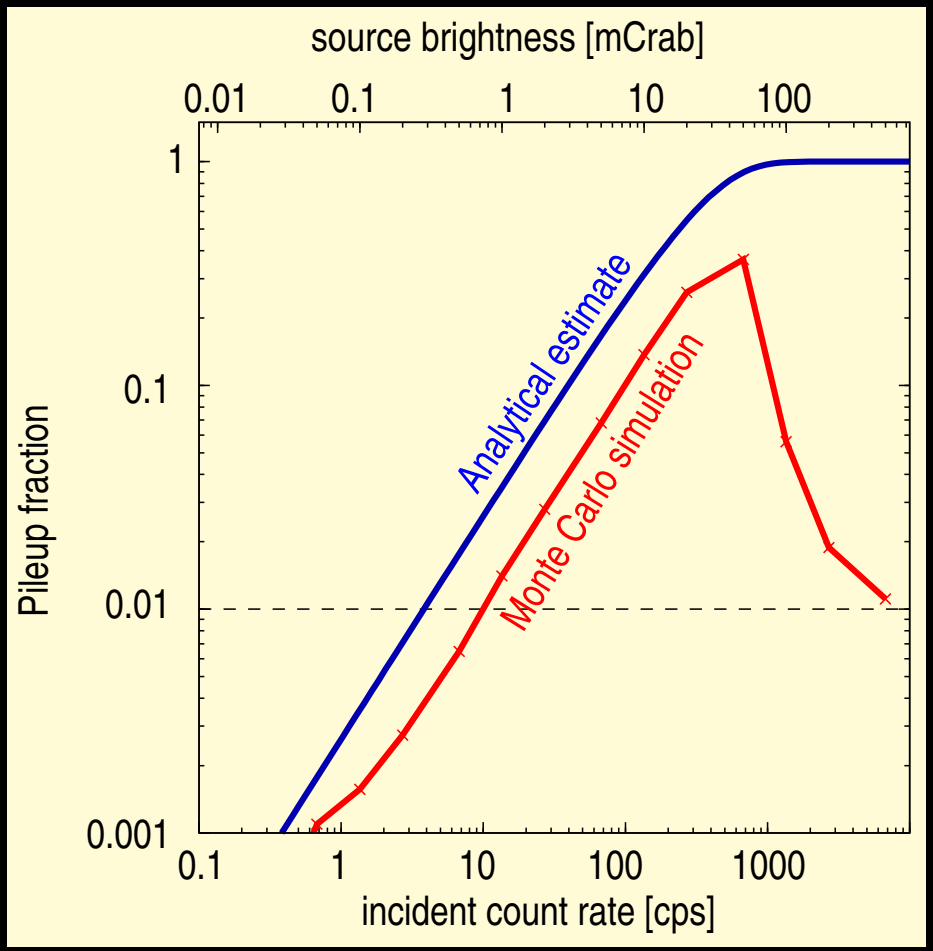
Detailed study of detection probabilities in progress (C. Grossberger).

eROSITA will see a bright source in every few scans.

Publish those fluxes immediately?



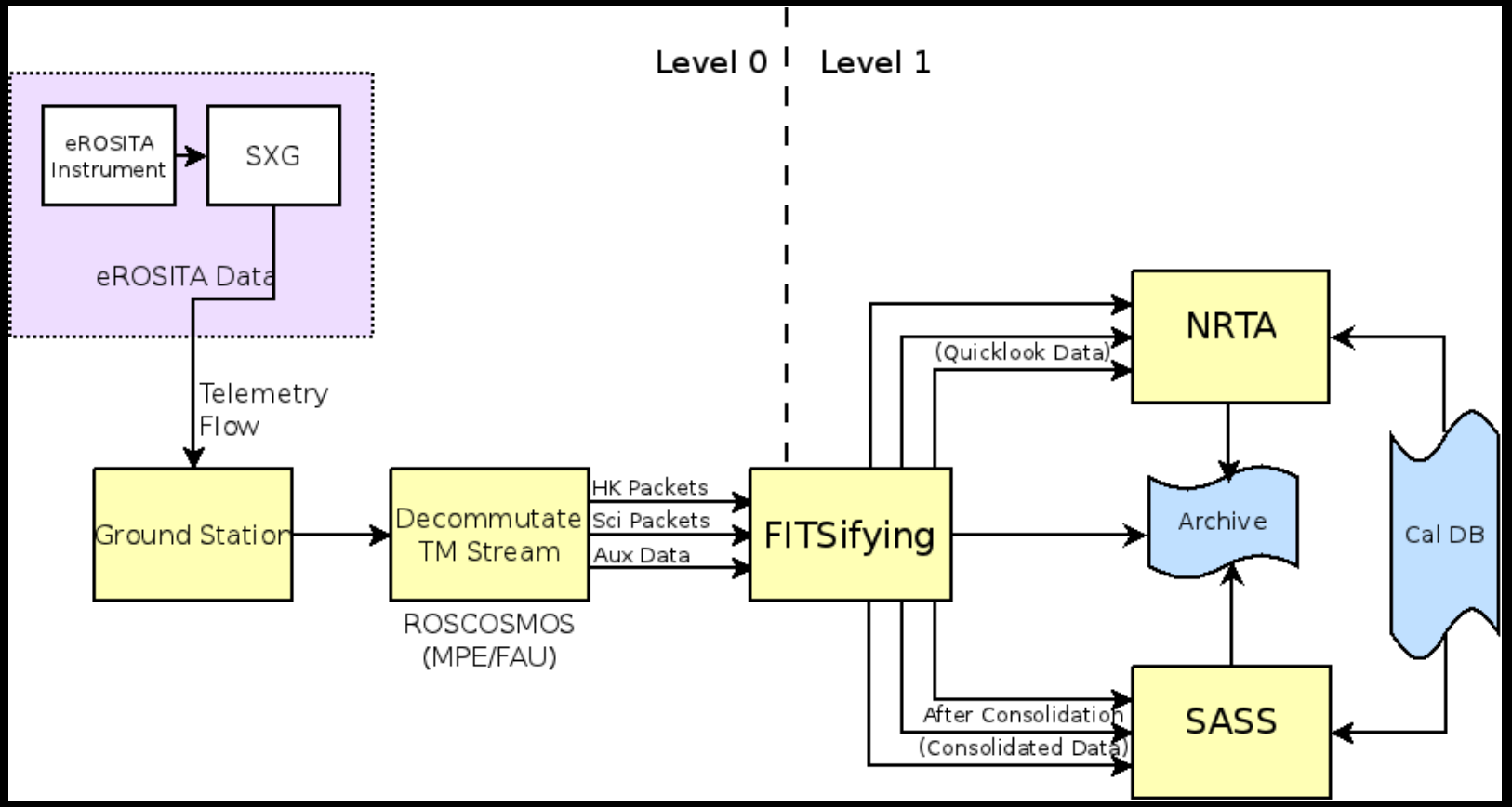
1 mCrab 200 mCrab 500 mCrab




One caveat, however: In the current design, eROSITA is severely piled up above 10 mCrab $\Longrightarrow$ bright source datamodes are *required* for the pointed phase!

Due to slews, less of a problem during survey phase, but final estimates are still required [work ongoing, C. Schmid].

eROSITA bright source report, Schmid et al.




Current strategy for variability detection during survey phase:

1. Directly after downlink: Near Real-Time Data Analysis (NRTA)
2. NRTA will produce SASS-compatible raw data
3. Special version of SASS will run on these new data
4. New bright sources and strong changes in source luminosity will be flagged

   e.g., comparison with earlier eROSITA observations of this field, catalogues,. . .
5. If phenomenon interesting: ATEL and/or special email lists

*Summary:*

1. Most *eROSITA* sources will be variable.
2. In bright Galactic sources, *eROSITA* will measure variability on hour, 180 d, and multi-year timescales
3. For bright variable sources, immediate detection and multi-wavelength monitoring is crucial

*The next steps:*

1. Study of bright transient detection probabilities and strategies

   ongoing, C. Grossberger (Remeis/ECAP)

   We need your input $\Longrightarrow$ lightcurves, source catalogues, spectra,. . .

2. Simulation of full survey, including simple transient sources

   ongoing, C. Schmid, T. Brand (Remeis/ECAP); first survey simulations available

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