The long-lasting tail of a bright burst from the magnetar 1E 1547.0–5408: the effect of dust-scattering

Fabio Pintore

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

IASF

Co-authors: *Sandro Mereghetti, Andrea Tiengo, Giacomo Vianello, Elisa Costantini, Paolo Esposito*

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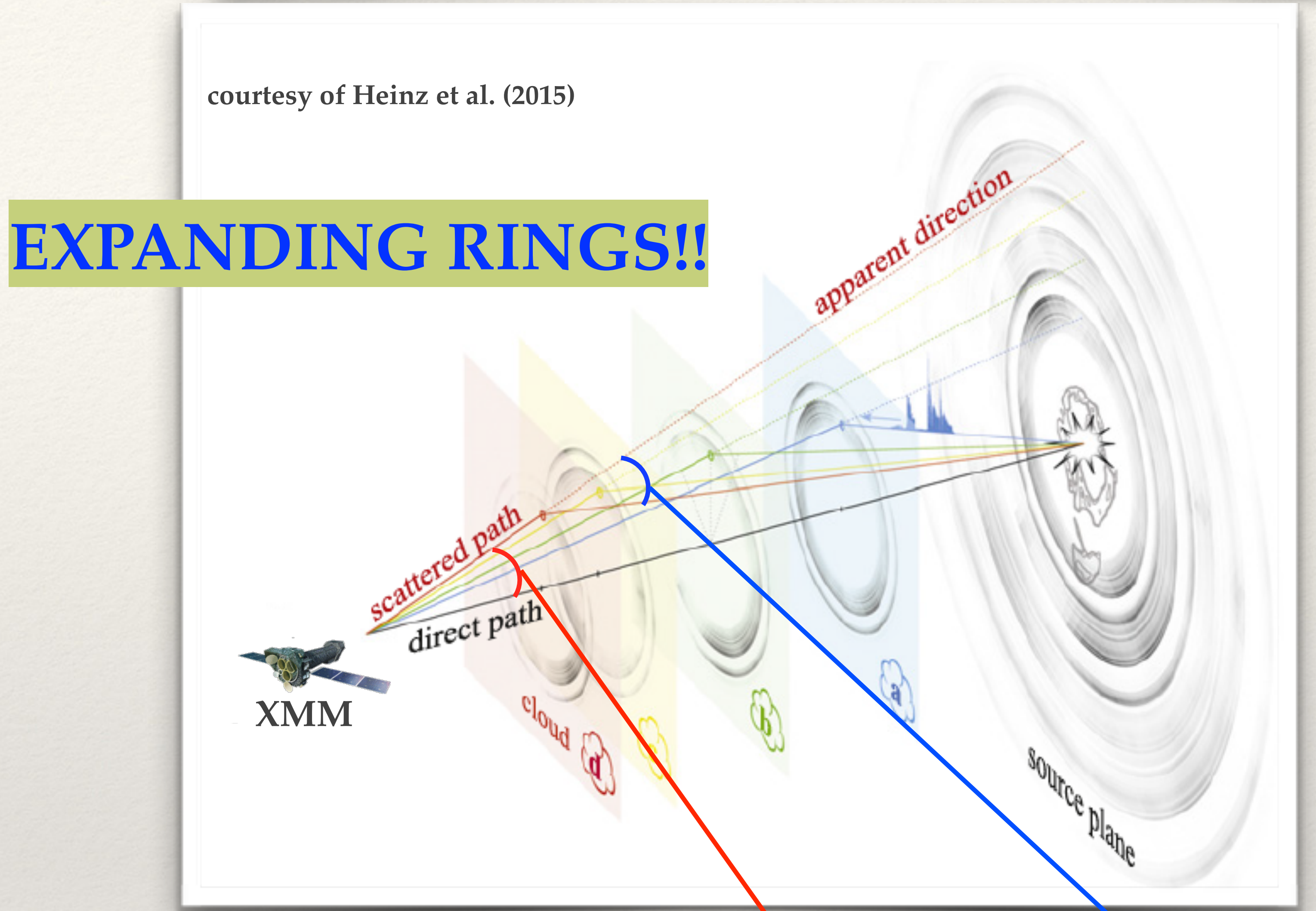
Introduction
- Dust-scattering
- 1E 1547-5408

1E 1547-5408
- Tail
- Burst
- Radial profiles
- Expansion law
- Ring spectrum
- Lightcurve

Conclusions

DUST-SCATTERING



$x = d/D$ $\theta = (1 - x)\theta_{sca}$

Intensity and cross-section dependent on:
- **grain size distribution, energy, scattering angle**
- ***burst fluence***
- **column density of the dust-cloud**

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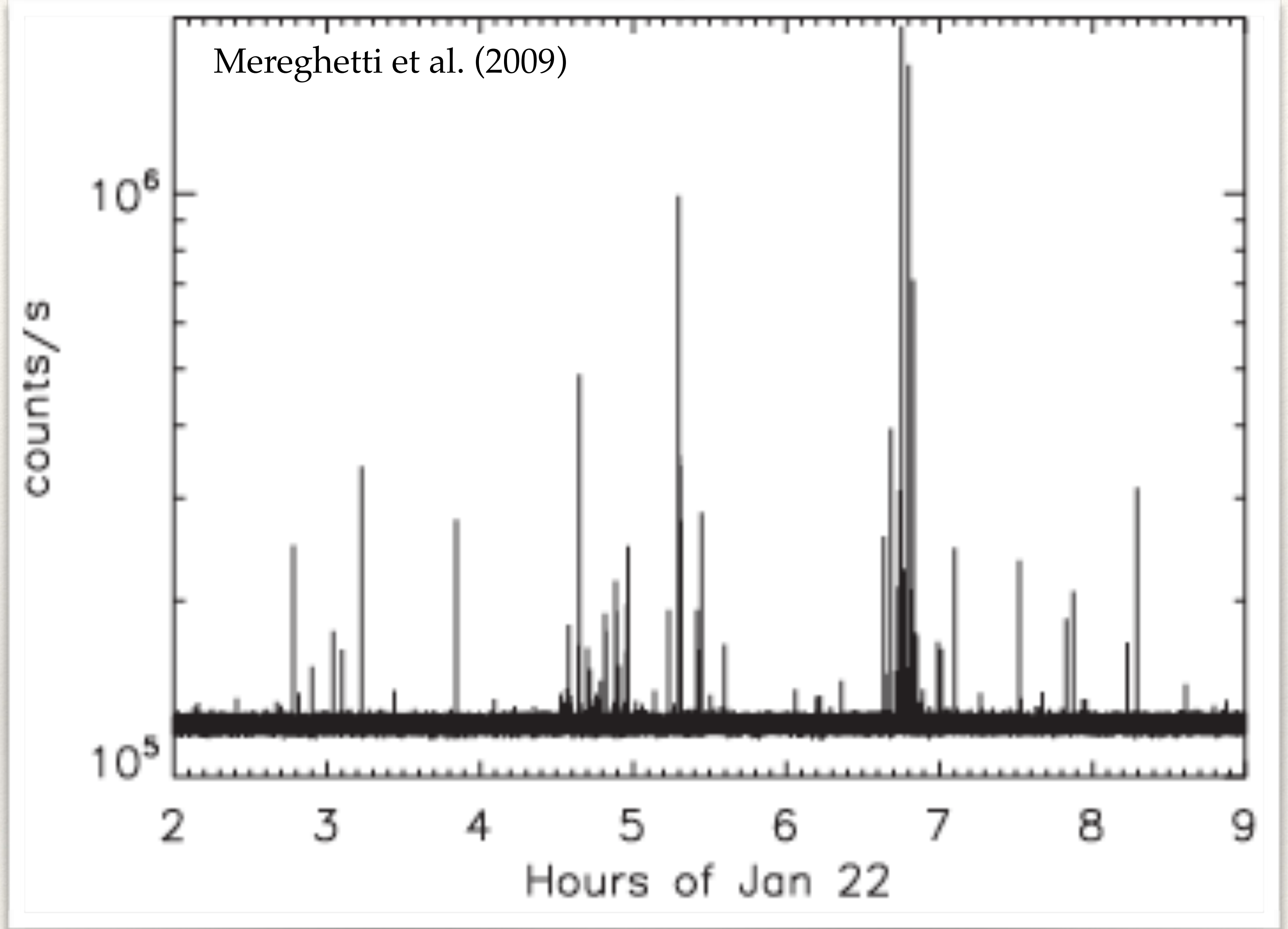
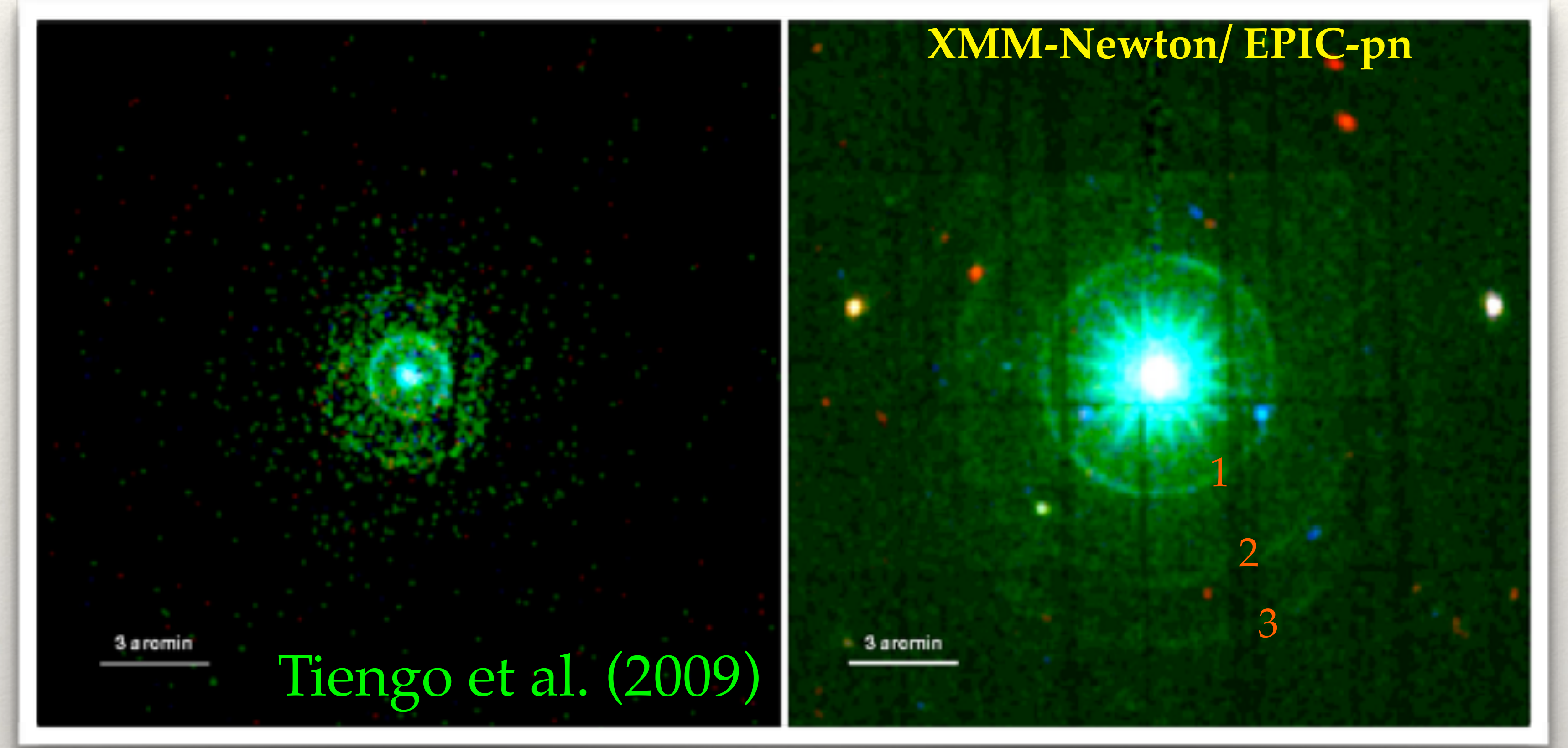
1E 1547-5408



- **Period of strong bursting activity on 2009 January 22**
- **233 bursts were detected from 18:11 UT of January 21 to 4:27 UT of January 23**

DUST-SCATTERING



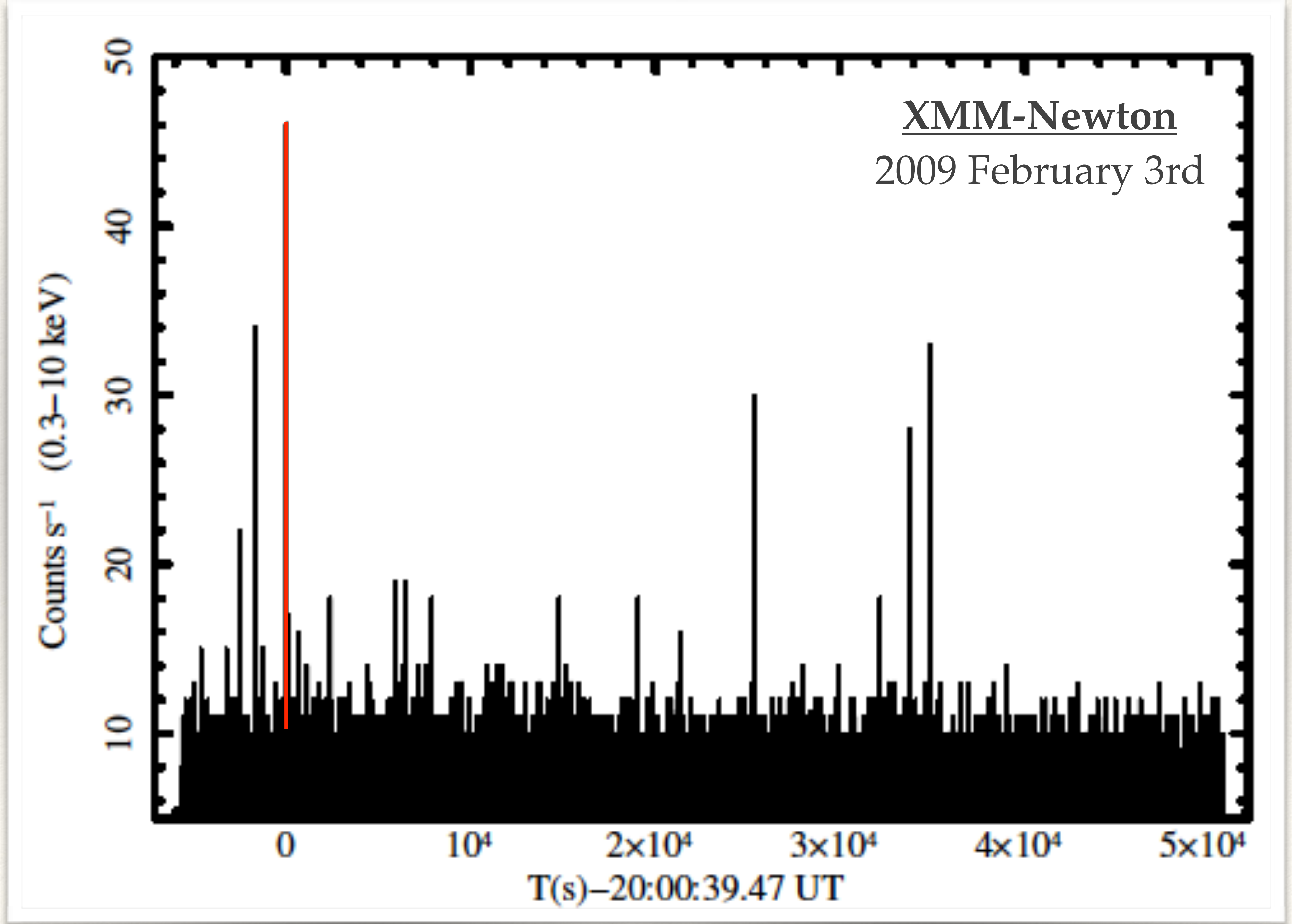
- **Expanding rings around the source due to dust-scattering**

Distances are well known:
- **3.9 kpc ---> 1E 1547-5408**
- **3.4 kpc ---> farthest cloud**
- **2.6 kpc ---> intermediate cloud**
- **2.2 kpc ---> closest cloud**

Unfortunately, uncertain on burst fluence ---> dust cloud column densities

1E 1547-5408

However, in the same observation a bright burst followed by a long-lasting tail (~10 ks) was seen!



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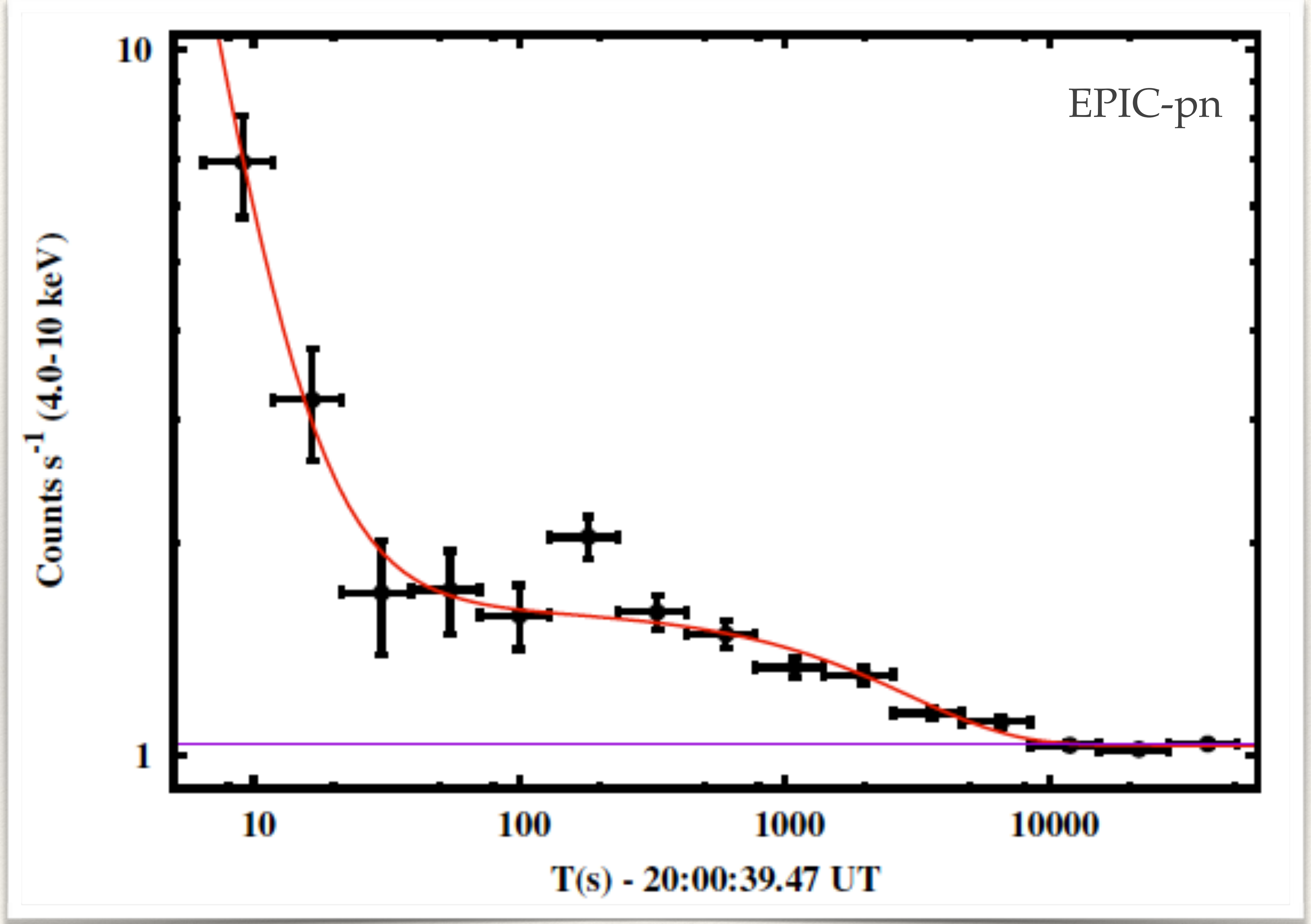
TAIL



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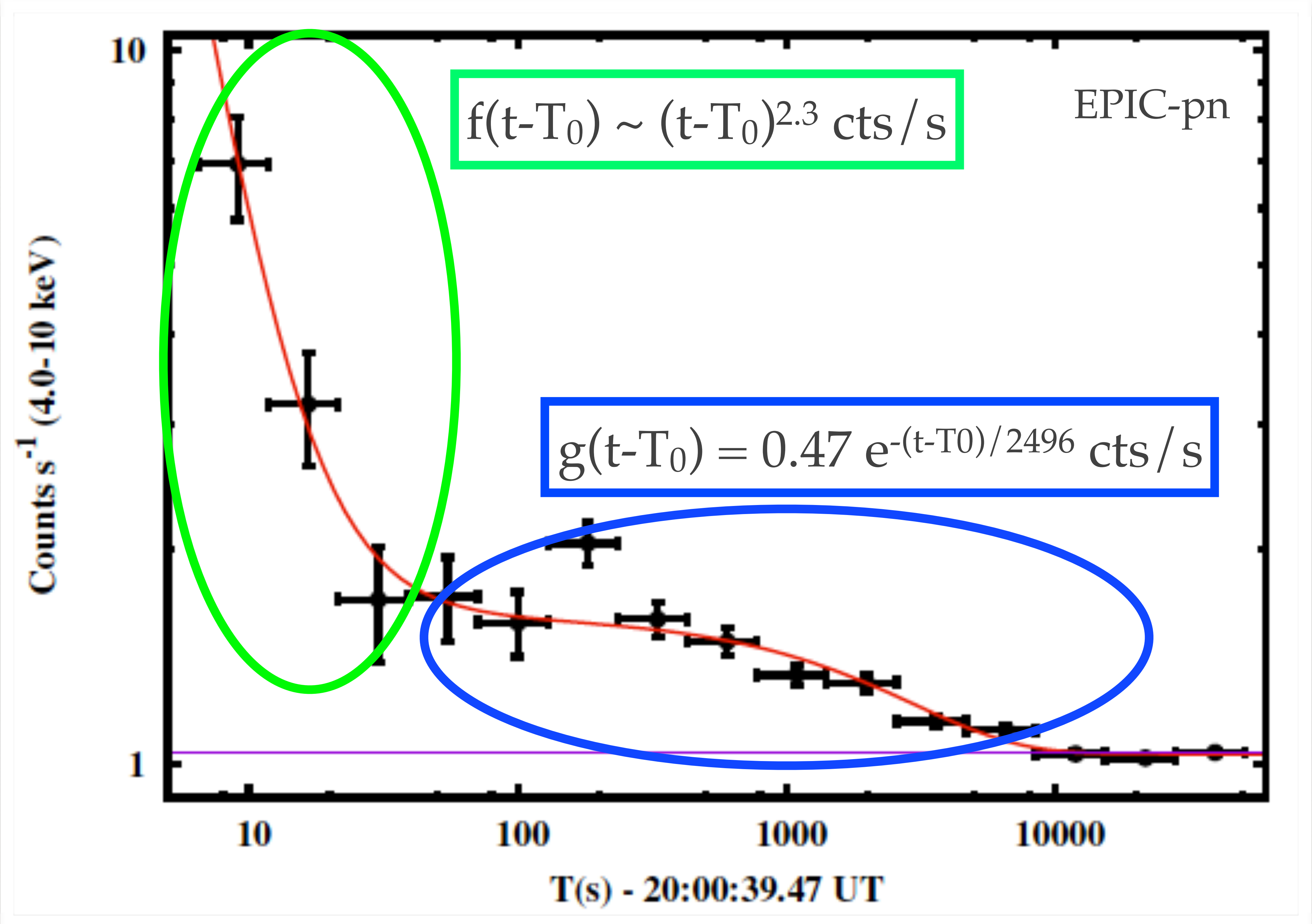

- **steep powelaw decay in the first 20-30s**
- **exponential function for the next ~10 ks**

TAIL

DUST-SCATTERING ORIGIN!

We know:

- ***burst fluence***
- ***distances (well known, Tiengo et al.2009)***

We can find:

- ***dust-cloud column density***

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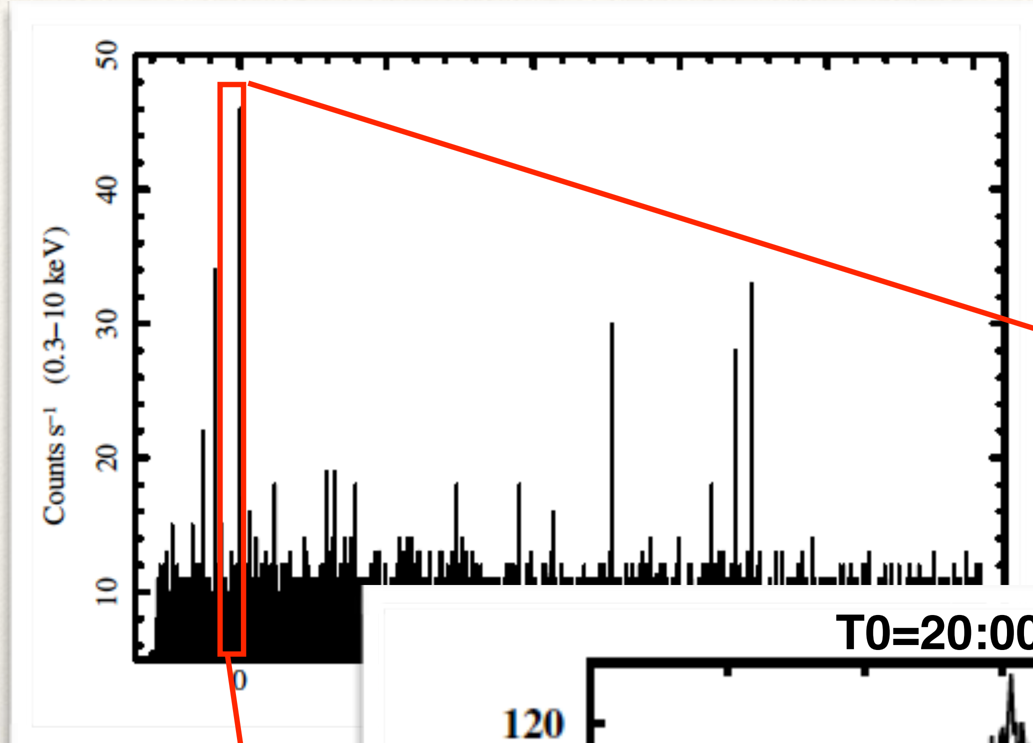
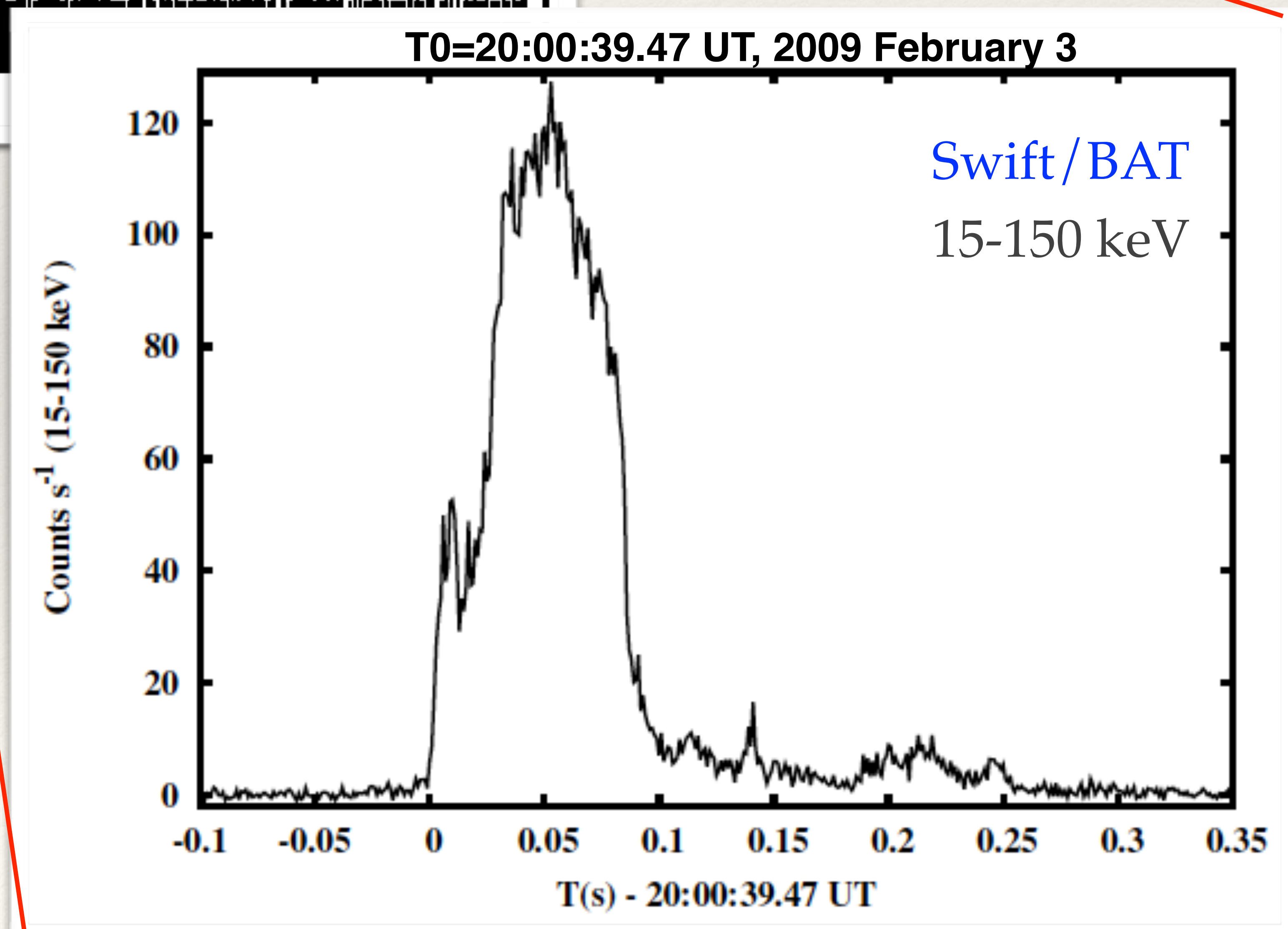
BURST





Bright peak lasting 0.1 s, followed by fainter emission lasting about 0.2 s

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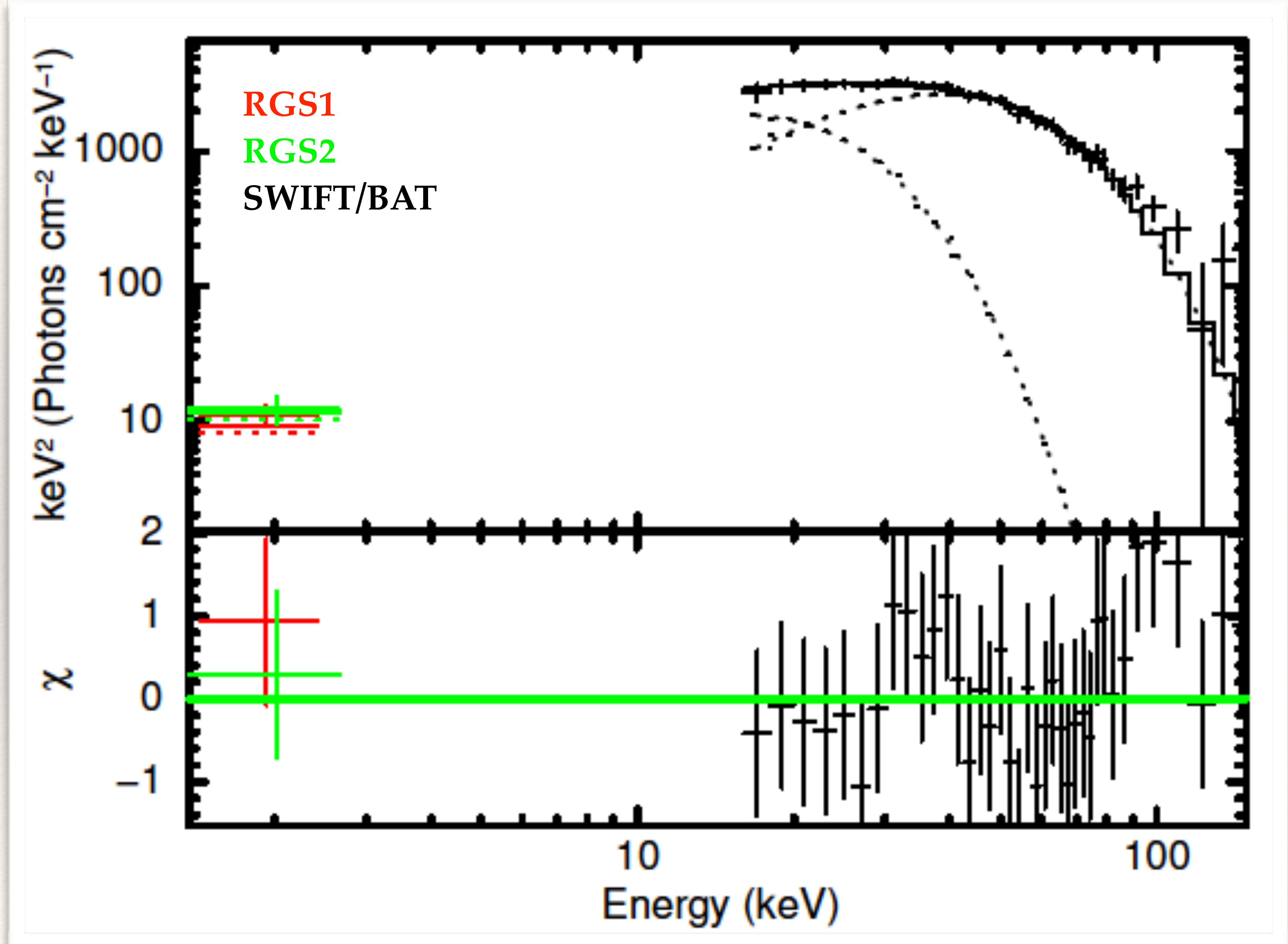
- EPIC- pn/MOS were saturated
- RGS1 and 2 NOT SATURATED!
- RGS+Swift/BAT spectra: best-fit with two blackbodies

$kT_1 \sim 4$ keV ---> $R_1 \sim 15 d_{4kpc}$

$kT_2 \sim 10$ keV ---> $R_2 \sim 3.1 d_{4kpc}$



Fluence (0.3-150 keV) ~10^{-5} erg cm^{-2} s^{-1}

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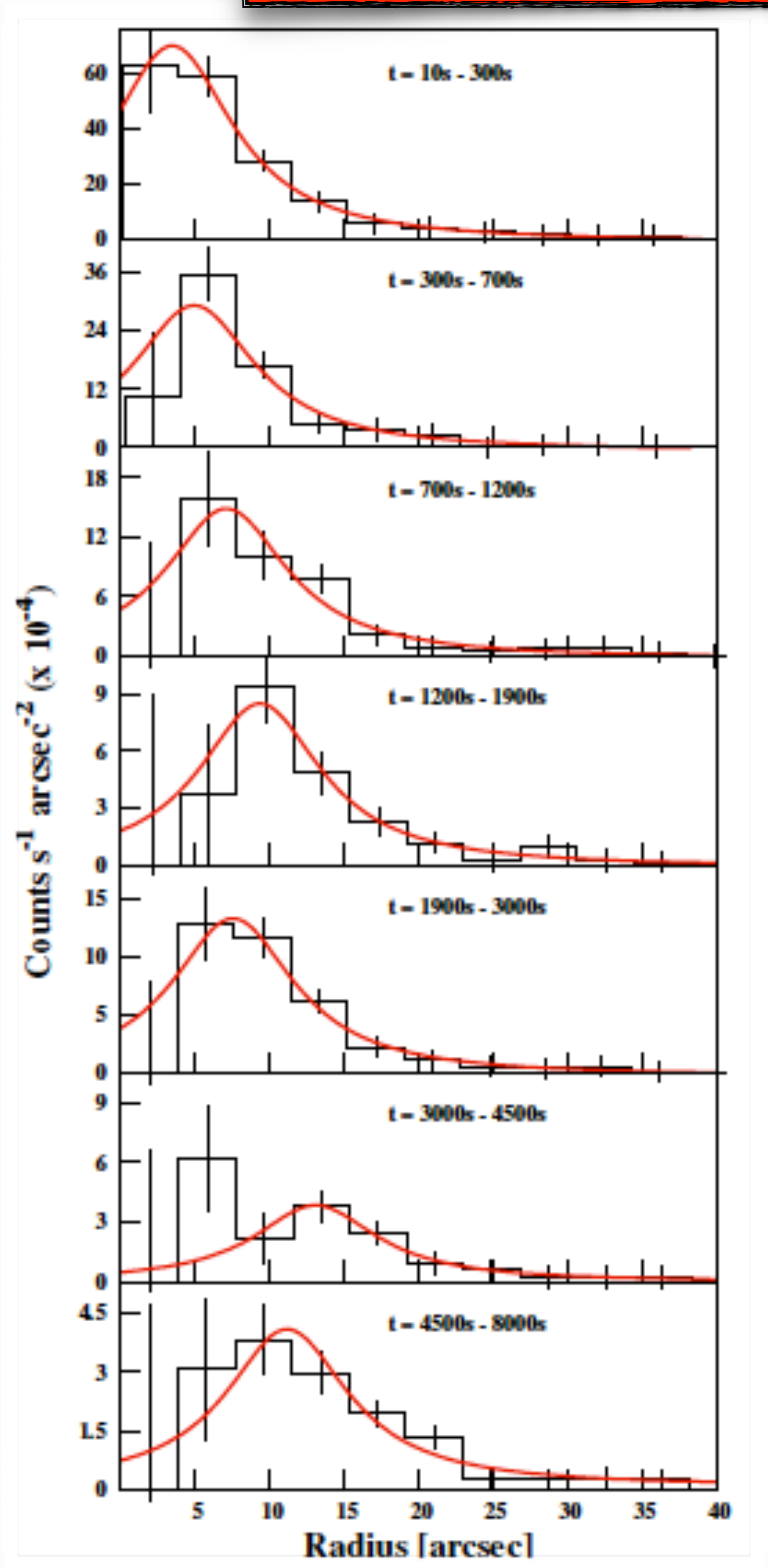
RADIAL PROFILES



- **PN + MOS radial profiles;**
- **the persistent emission is subtracted to the radial profiles;**
- **A fit with a simple King function was not acceptable;**
- **Best-fit with a Lorentzian + costant;**

EXPANSION LAW

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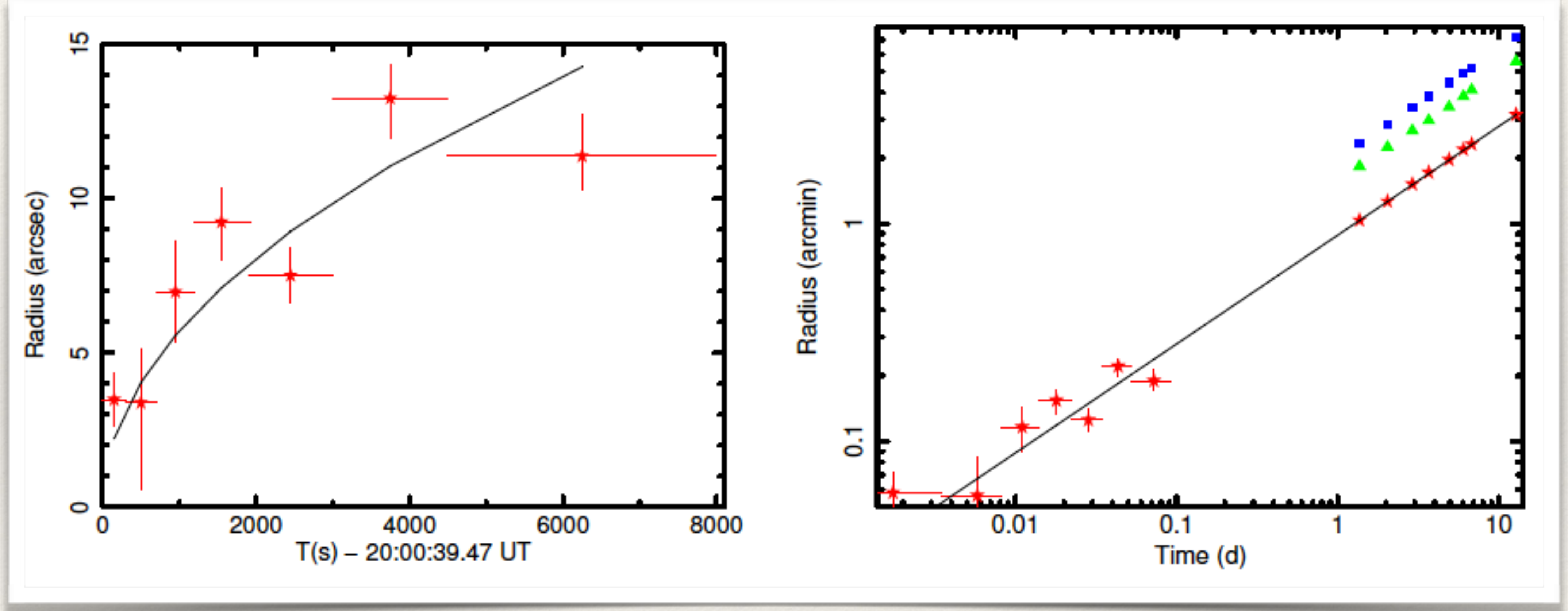
$$\theta(t) = K(t - T_0)^{0.5}$$

$$K = 0.884 \pm 0.045 \, \text{arcmin day}^{-0.5}$$



Fully consistent with the value reported in Tiengo et al. (2009)

$$K=0.8845 \pm 0.0008$$

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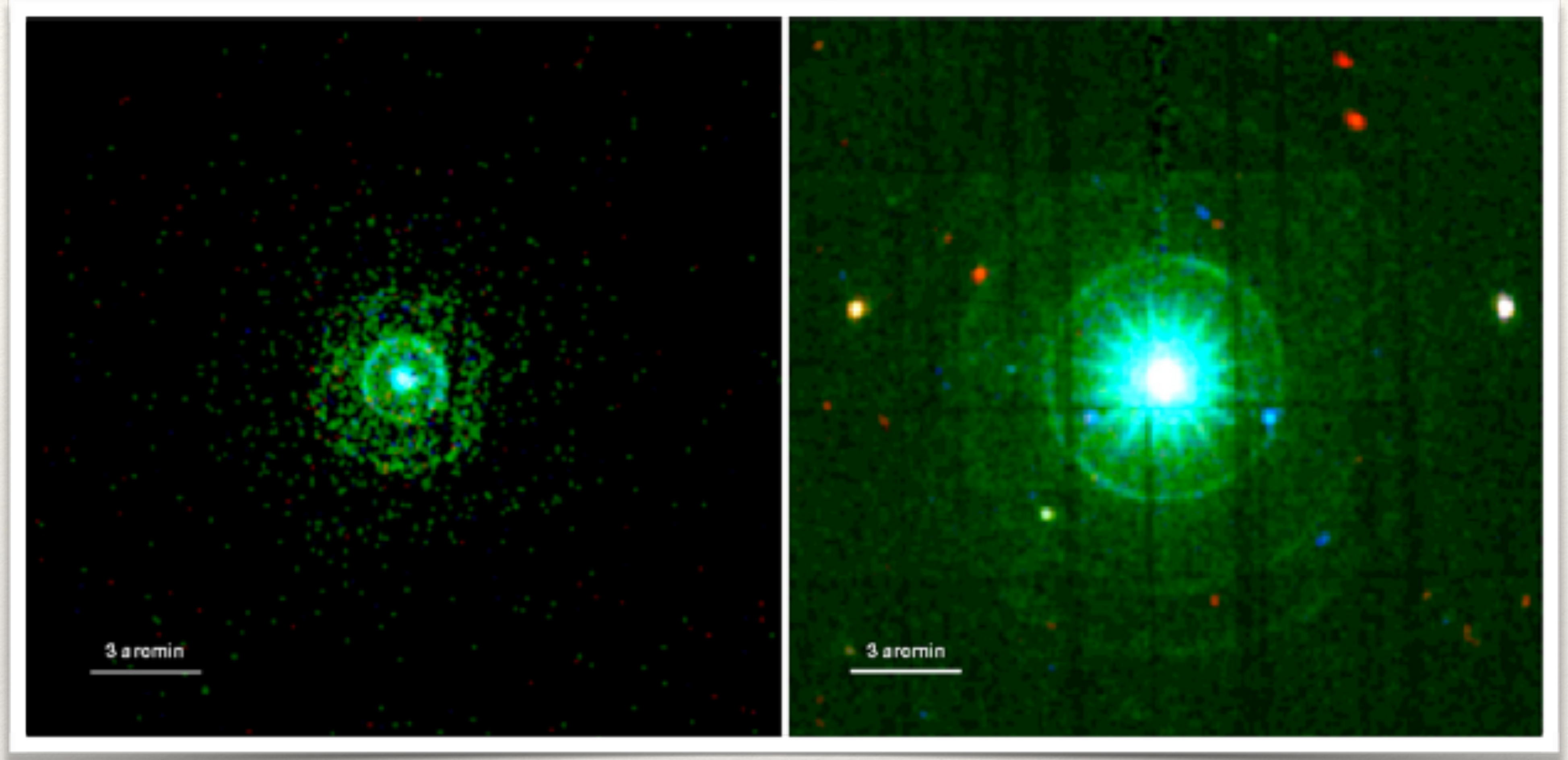
IT CORRESPONDS TO THE INNER RING

(i.e. the farthest dust-layer)



IN OUR CASE, NOT RESOLVED IN XMM!!

Hereafter, we consider a **distance of 3.9 kpc for the source and 3.4 kpc for the dust cloud** (as in Tiengo et al. 2009)

RING SPECTRUM

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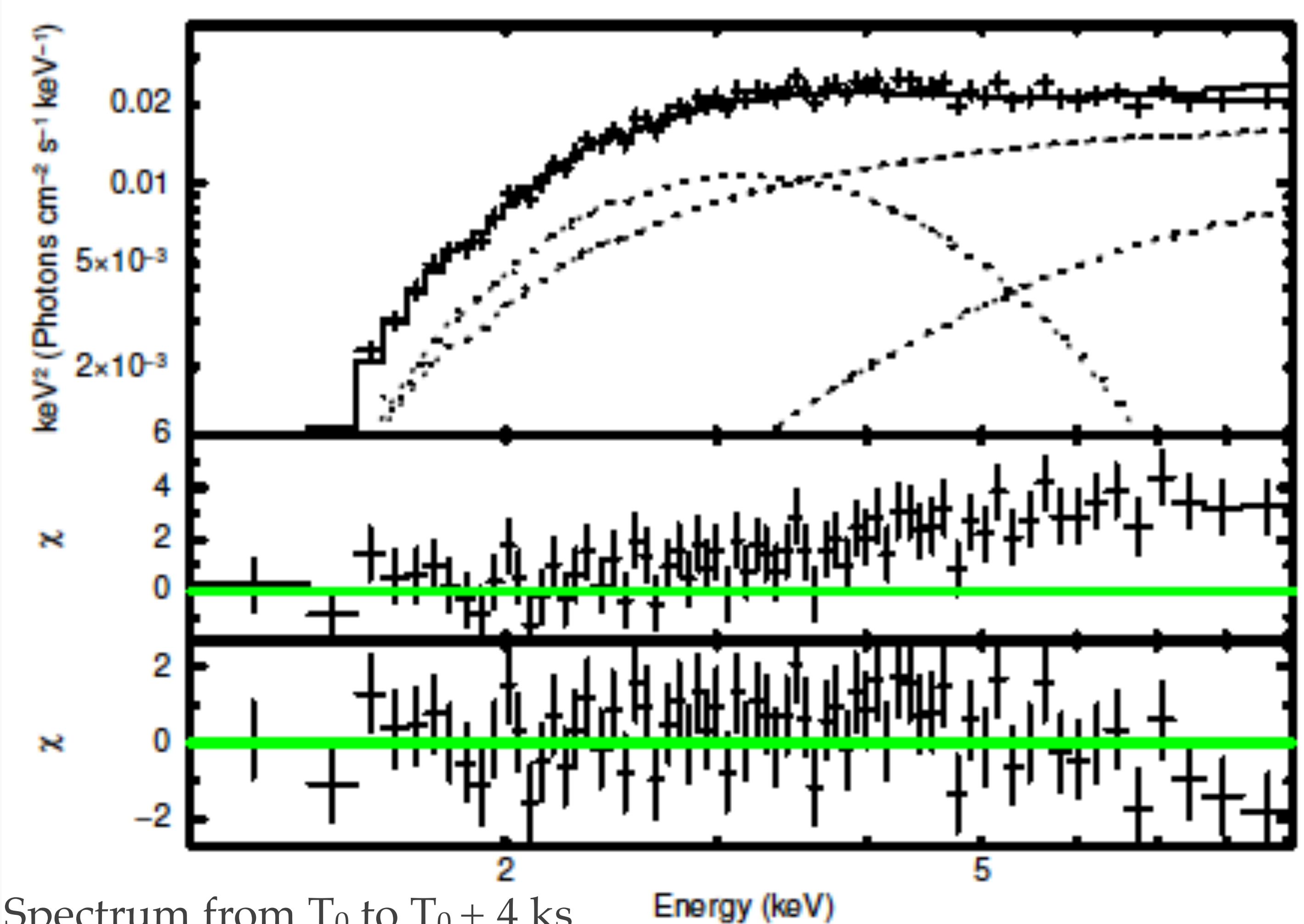
- We created a dust-scattering model, considering the contribution of the three dust-layers found in the Tiengo et al. (2009);
- We assumed the dust-distribution of the BARE-GR-B (Zubko et al. 2014);

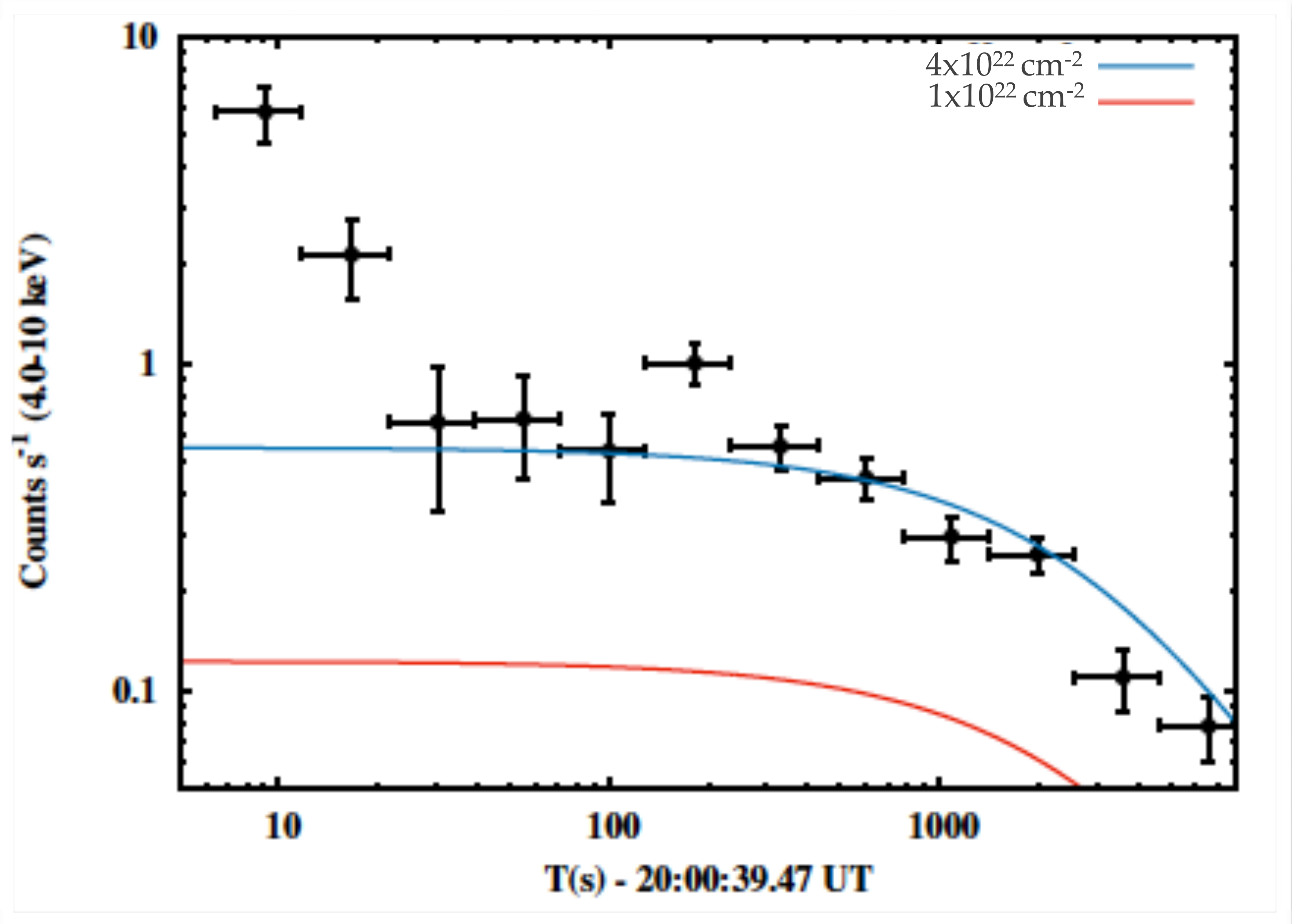


Spectrum from T_0 to $T_0 + 4$ ks

- Tail EPIC-pn spectrum
- Persistent emission only
- Persistent emission + dust-scattering model

1. nH1 = $4x10^{22}$ cm^{-2}
2. total dust column density along the line of sight of $6x10^{22}$ cm^{-2}
3. 40% larger than hydrogen nH from the persistent emission

D-S LIGHTCURVE

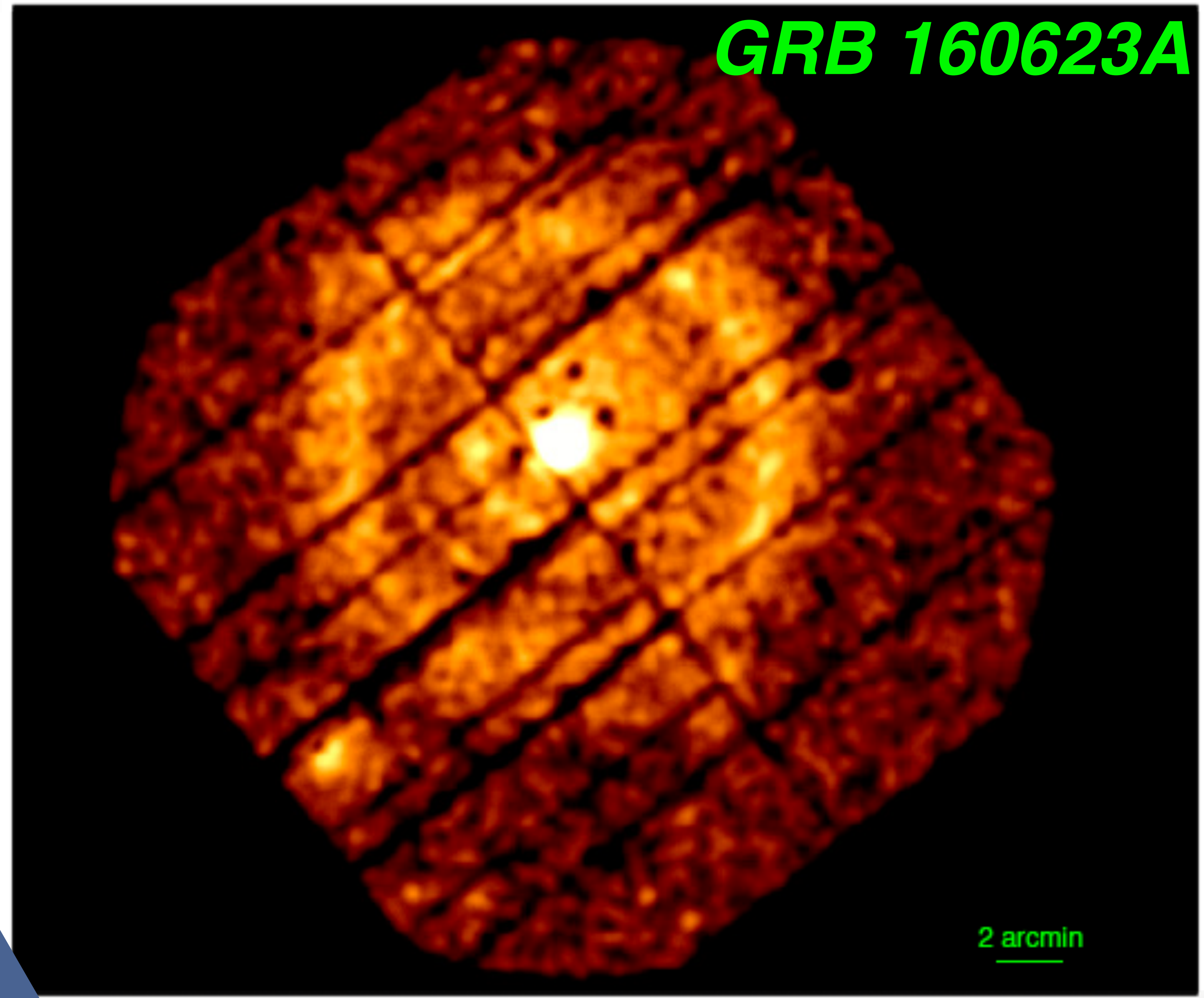


- The dust-scattering lightcurve can explain most of the tail, except for the first 20-30 sec;
- Probably intrinsic magnetar emission;

CONCLUSIONS

- **The dust-scattering can well explain the long-lasting tail of the bright burst of 1E 1547;**
- **We were able to put constraints on the dust-layers column density along the line of sight;**
- **More information on Pintore et al. (2017)**
- **Tails observed also in other magnetar bursts;**
- **When pulsations are observed, the emission comes from the NS;**
- **However, for unpulsed emission tails, intrinsic NS cooling or dust-scattering effects can both be important;**
- **The two effects can be distinguished in bright bursts if timely follow-up with good imaging and sensitivity are carried out to study the X-ray halo evolution;**

Soon on the screens!



Six expanding rings!

SPOILER

Extremely precise measurements of the dust-cloud distances and column densities!

Thanks for the attention!