Why are the Soft Proton Flares Such a Problem for XMM, Not a (significant) problem for Chandra, and Is there anything to be done about them?

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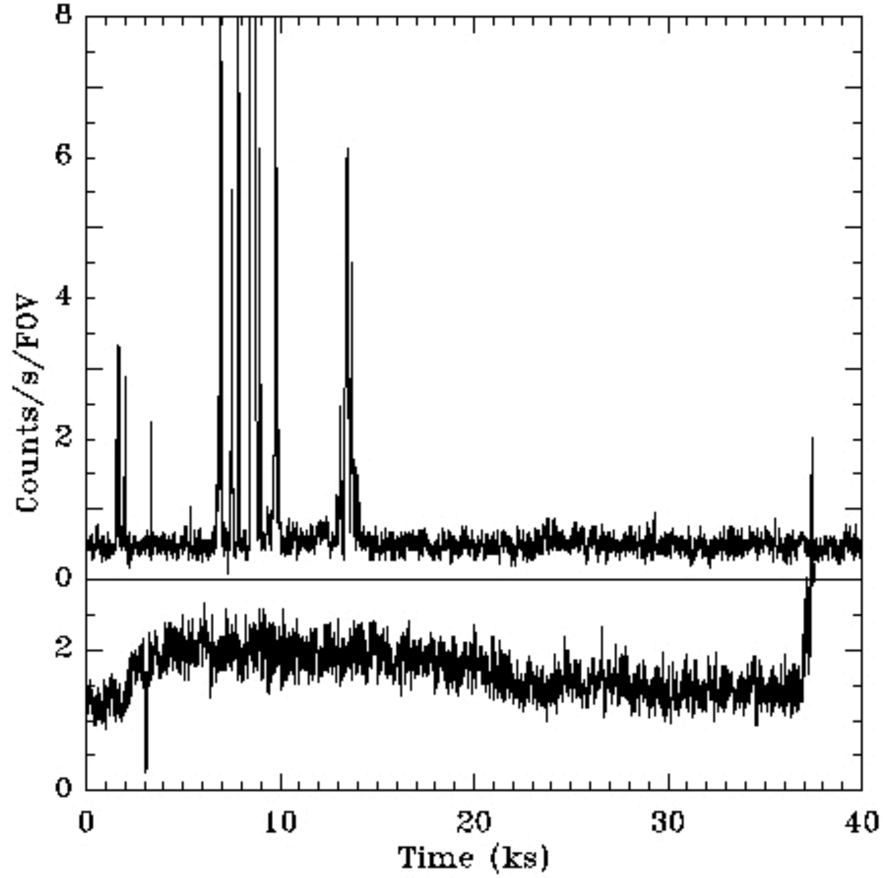
Setting the Problem



Soft Proton Flares (SPF)
- increase backgrounds by XXX
- duration scales: 10 s — 10^4 s
- variable at many frequencies
- not be detectable in short exp.
- affect 51% of exposure time

Soft Proton Flares (SPF)
- allow study of the lower energy population of energetic particles
- (and people who study such things are interested)

FLARING COMPONENT

- PAT 0-4 ONLY
  PAT 31 NOT SEEN ⇒ CONV. NEAR SURFACE OF CCD
- WHEN PRESENT, THE TOTAL BKG. INTENS. CAN INCREASE BY ORDERS OF MAGNITUDE
- SPECTRUM IS HARD (MEAS. IN LOW GAIN)
- FLARES ARE NOT SEEN IN RADIATION MONITOR (SHOULD BE IF PARTICLES WERE LOW ENERGY ($E \gtrsim 50$ keV) ELECTRONS)
- ENERGY LOSS THROUGH FILTERS IS CONSISTENT WITH EXPECTATIONS FOR SOFT PROTONS. ($E \lesssim 200$ keV)
- PARTICLES ENTER THROUGH TELESCOPE VIGNETTING IS SEEN IN ALL 3 UNITS
- LOW EN. ELECTRONS SHOULD BE REMOVED FROM MAGNETIC DEFL.

> FLARES ARE DUE TO SOFT PROTONS.

SOFT PROTONS

WHERE DO THEY COME FROM?

FLARES ARE SPATIALLY LOCALIZED AND TYPICALLY AWAY FROM APOGEE.

REPETITION OF L.C. STRUCTURE FROM REV 70 TO 71 IS NOT PERFECT.

MOS1 & MOS2 BEHAVIOUR IS ALMOST IDENTICAL.

[illegible]

S.P. ARE MOST LIKELY STRUCTURED IN CLOUDS WHICH ARE SLOWLY MOVING THROUGH THE MAGNETOSP.

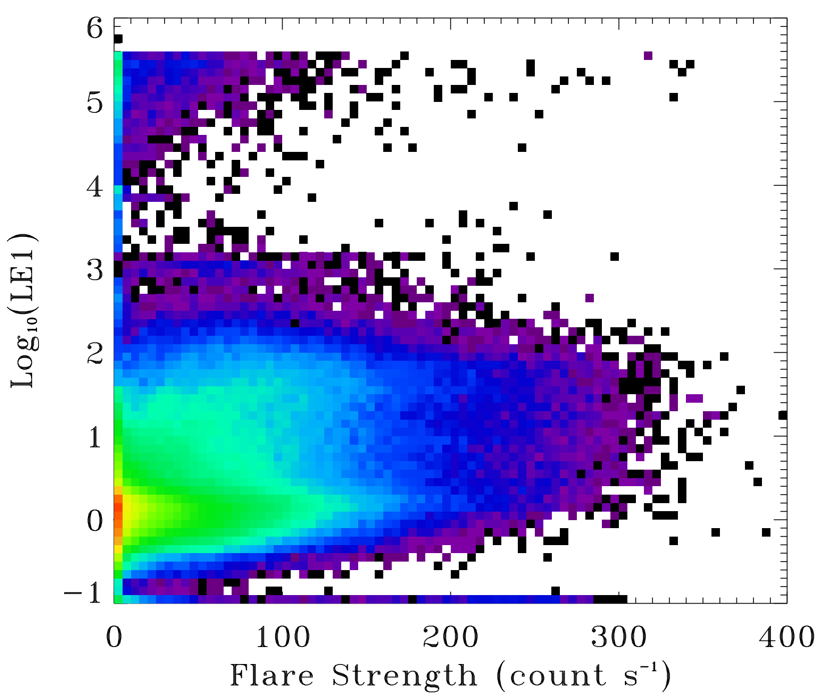
Silvano Molendi ca. 2000

Summary of Standard Wisdom

Background flares are due to "soft" protons

- from XMM patterns - deposit energy near surface → low E
- sweeping magnets
  - remove e^- below 20 keV and
  - reduce by ~10^5 e^- in 20 keV-100 keV range
- not correlated with EPIC Radiation Monitor (ERM) measures
  - thus not these particles in these Energy Ranges
- modulated by filters
- vignetted

	e^-	p^+
LE	0.13-1.5 MeV	1.0-4.5 MeV
HE	1.0-1.75MeV	8-40 MeV



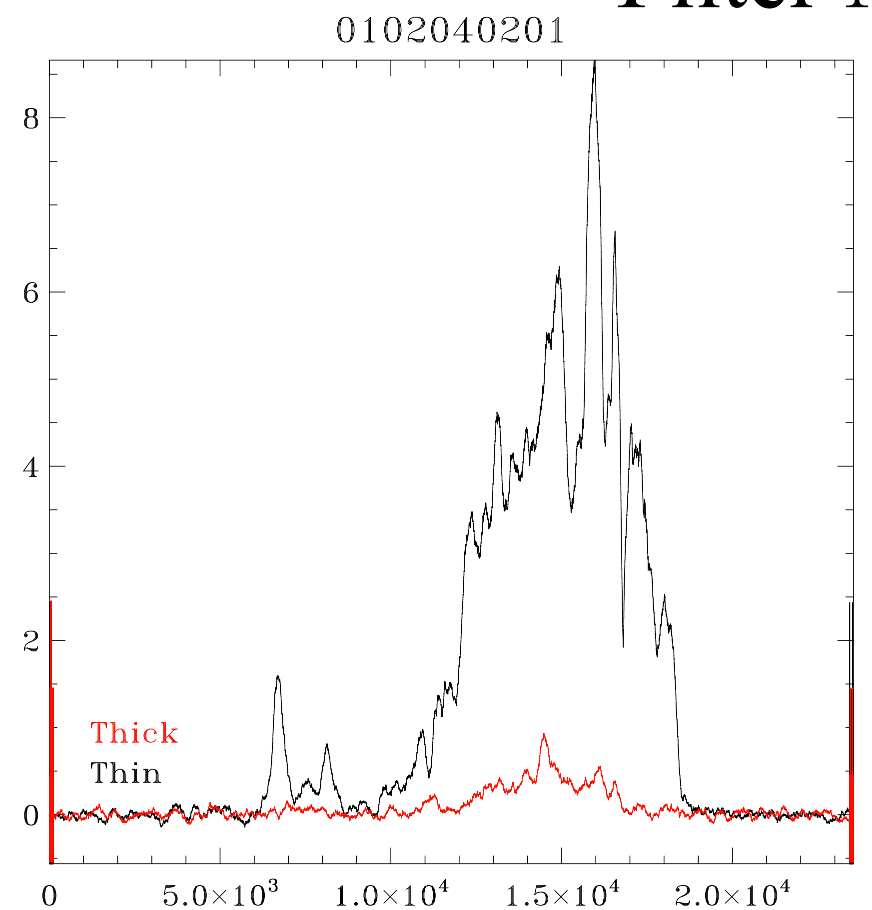
Filter Modulation

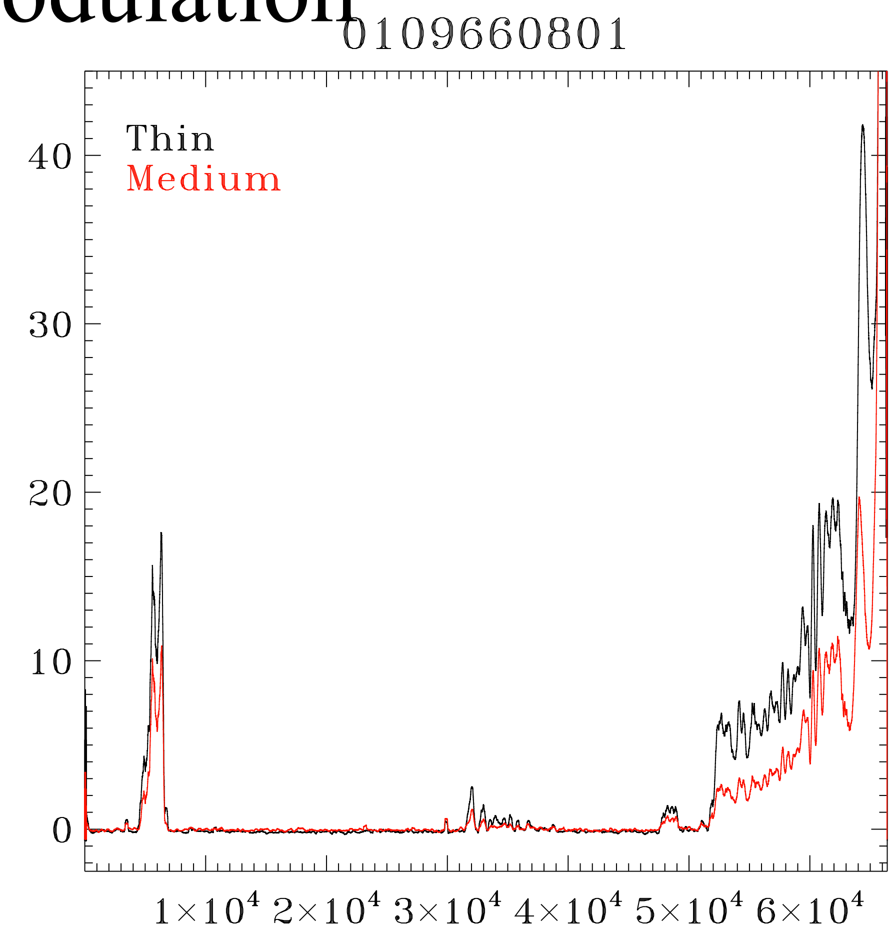
Each MOS camera has identical filter sets:

Filter	polyimide	Al	Sn	Stopping Power (100 keV)
Thin	160 nm	40 nm		8 keV
Medium	160 nm	800 nm		100 keV
Thick	330 nm	160 nm	40 nm	59 keV

Stopping power calculations were very roughly done.
Expect reduction of 6-12X between Thin and the other filters

Filter Modulation

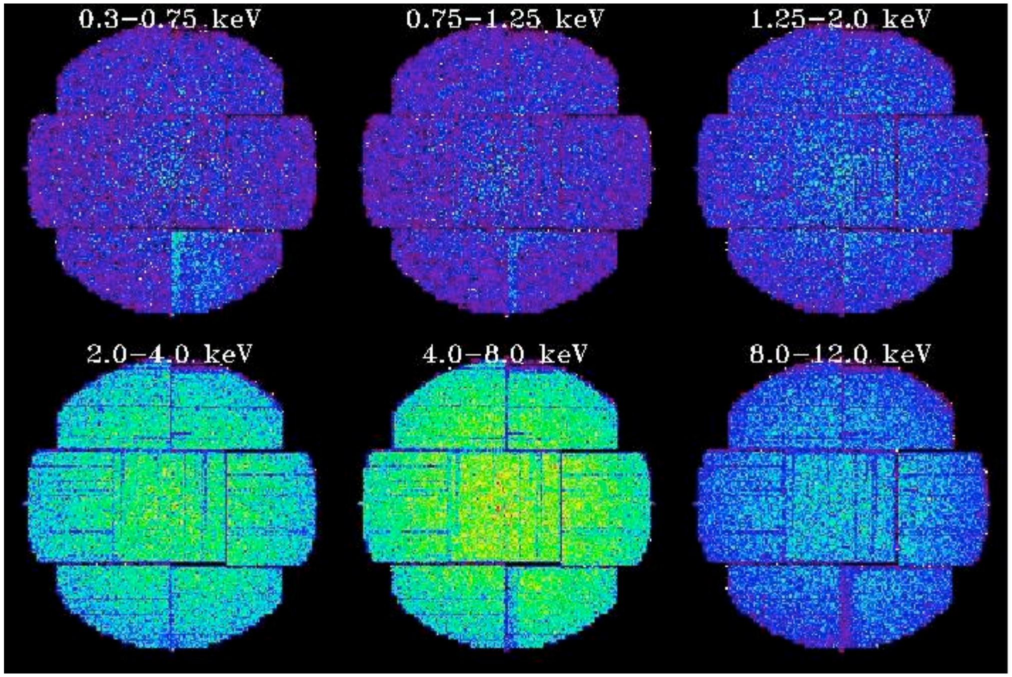




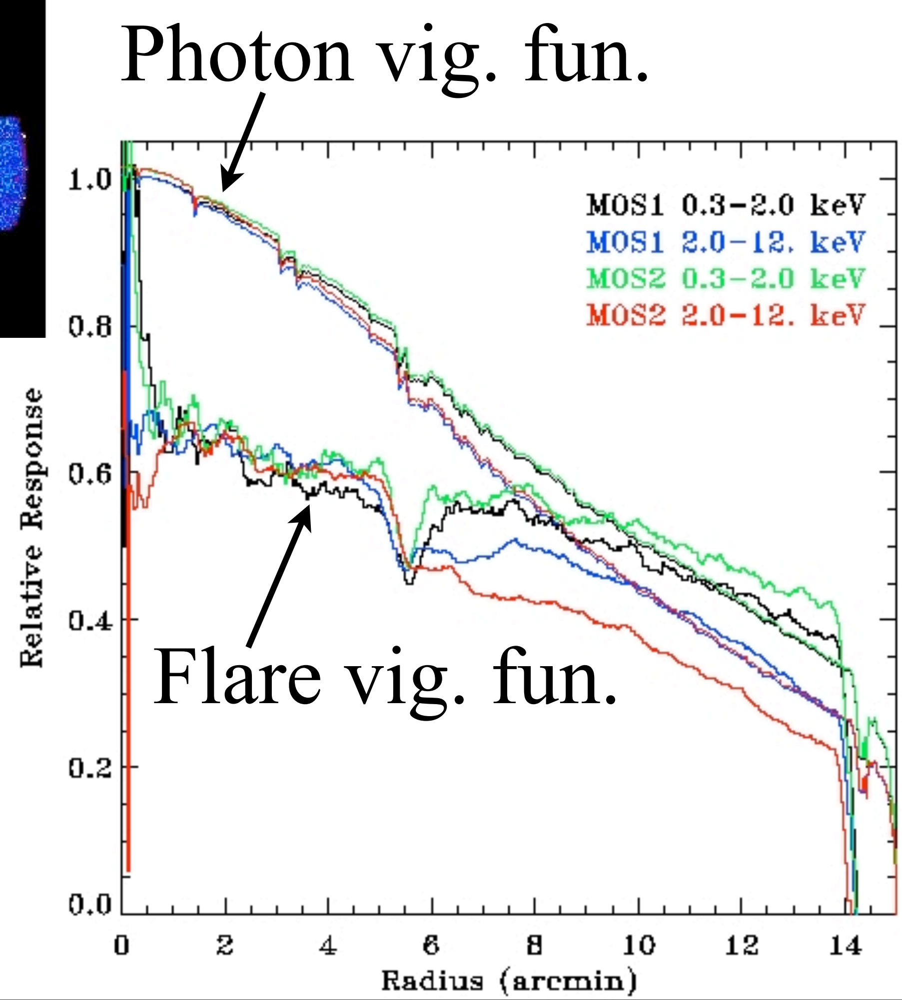
Two examples

- filter to filter ratios vary with time (thus p+ energies varying)
- ratios aren't quite those expected - but in the right range

Vignetting



Vignetting → particles interaction with the mirrors
Flare vignetting measured for use in XMM-ESAS as f(E)



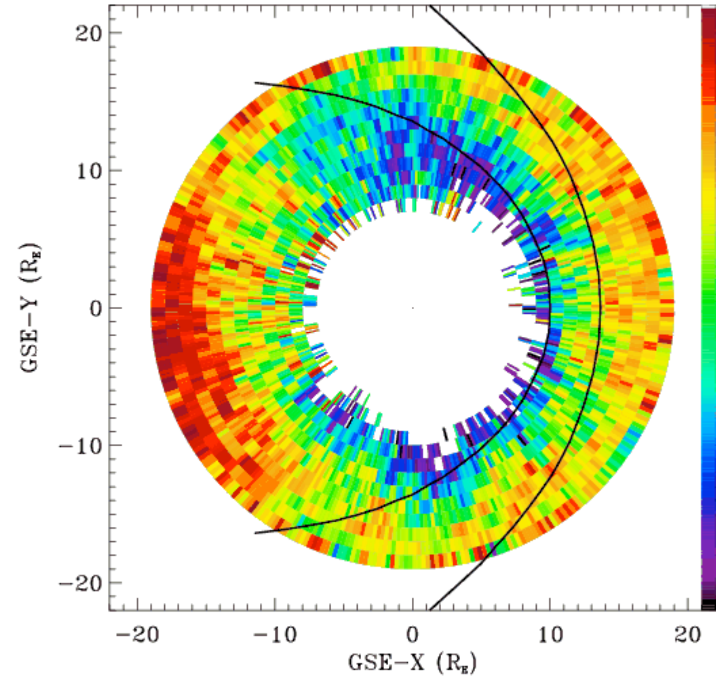
Old News

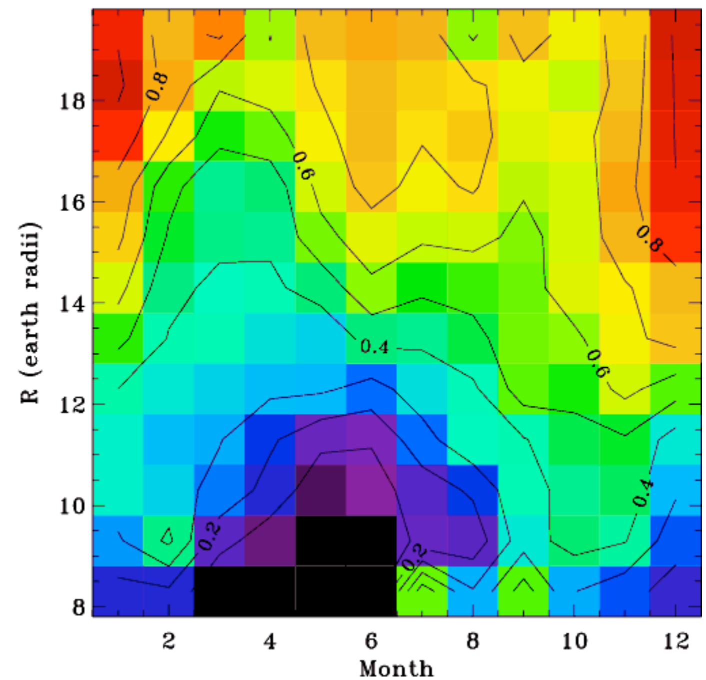
- SPF are worse closer to the Earth
- no orbit-to-orbit repetition
- SPF occur preferentially at certain times of year (Kuntz & Snowden 2008)

→ soft protons related to particular parts of the magnetosheath

→ the magnetopause particularly problematic

- Tools too crude to go further

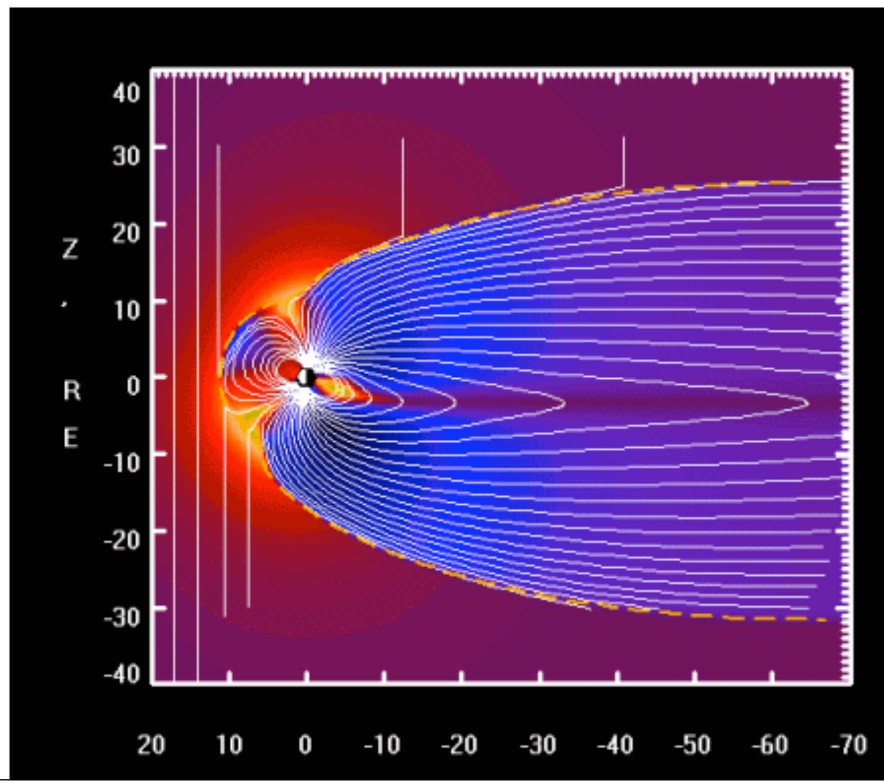


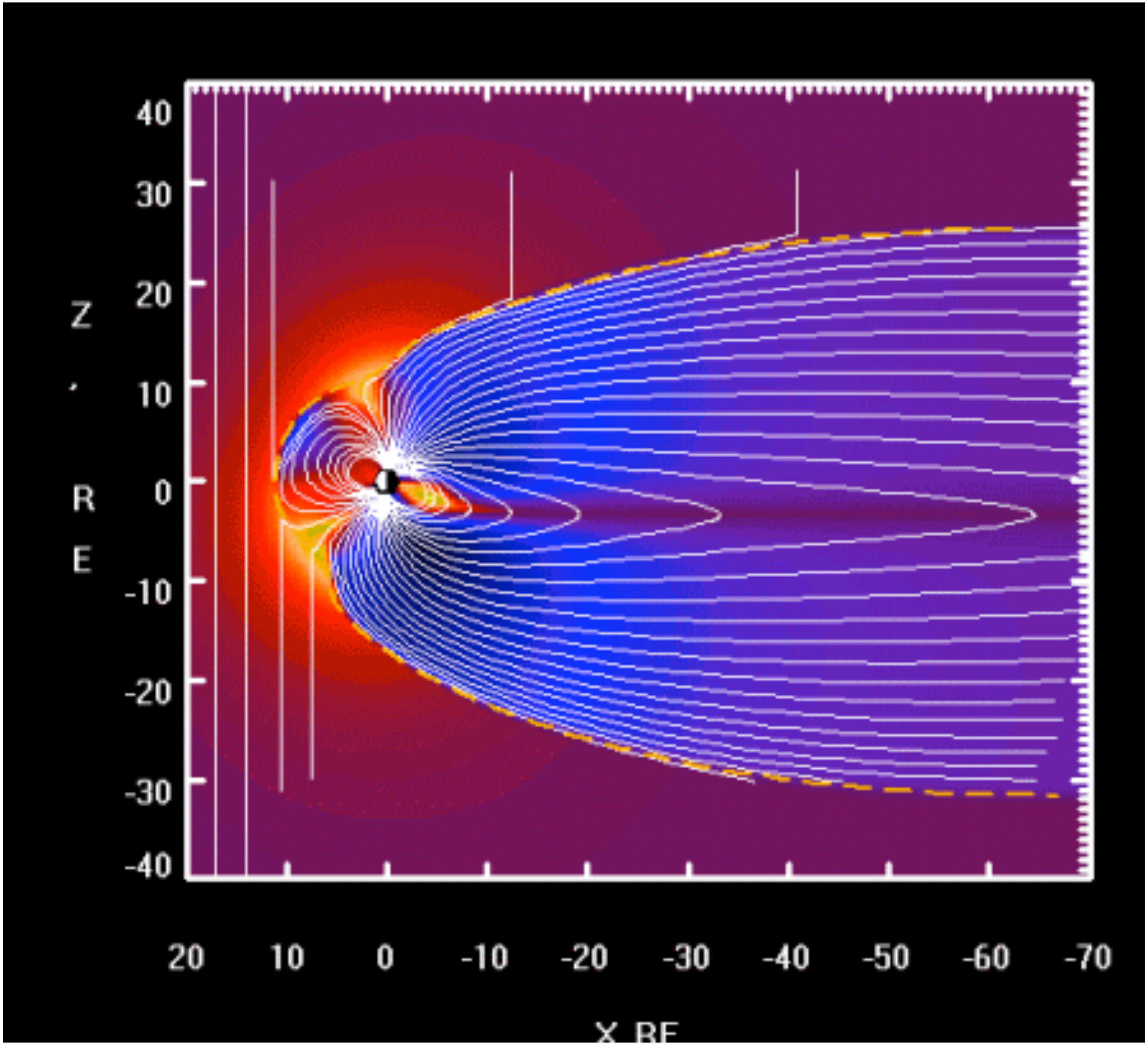


Renewed Efforts

- The XMM Trend data
  - contains flare data, spacecraft data, solar wind data
  - aligned to the same time steps
  - currently being upgraded (again)
- (Acceptable) model of the Earth’s B field
  - depends on solar wind flux and IMF
  - allows one do determine local field geometry

Nikolai Tsyganenko



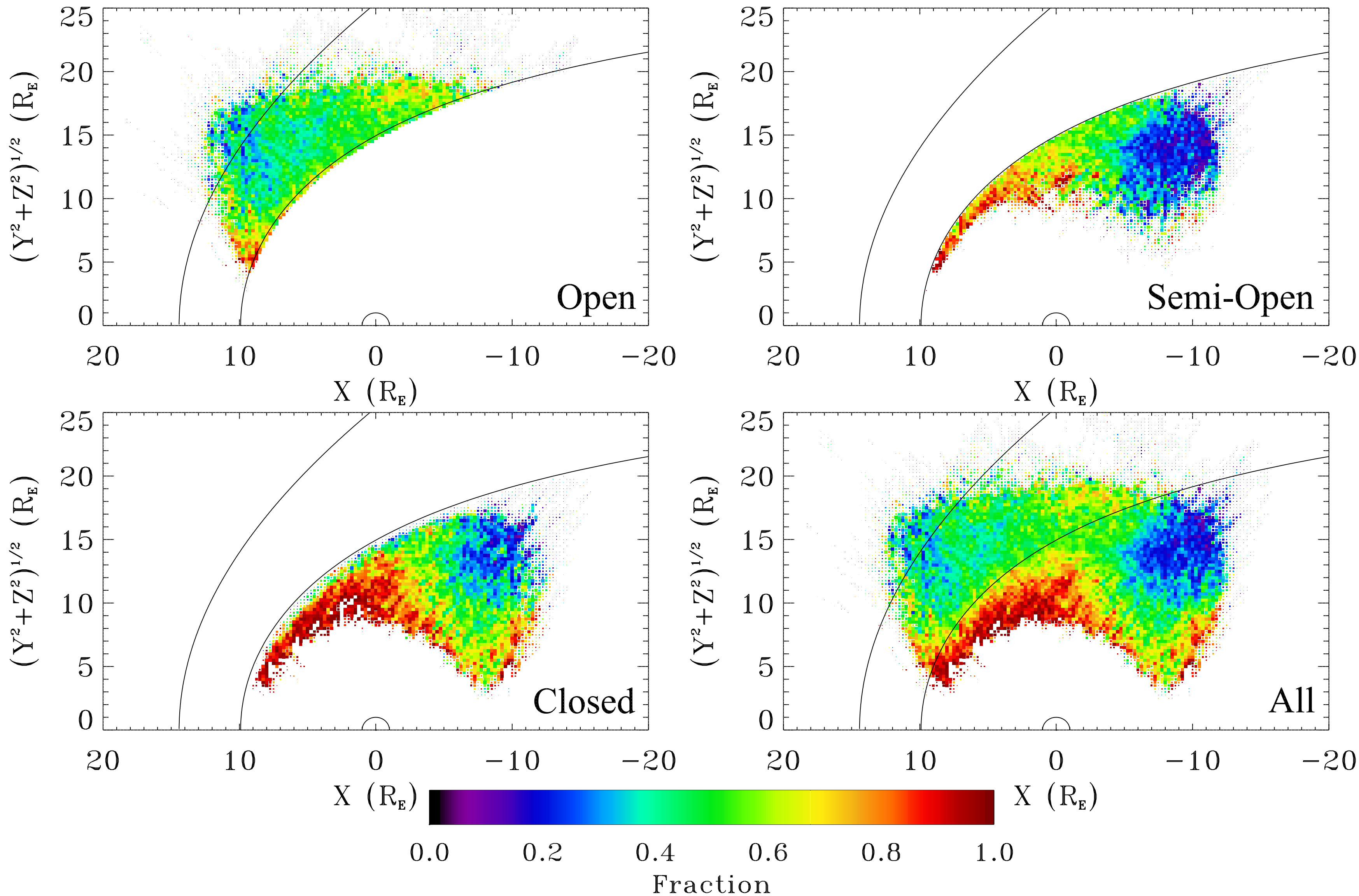

40
30
20
10
0
-10
-20
-30
-40
Z , R E
20 10 0 -10 -20 -30 -40 -50 -60 -70
X RE

Renewed Efforts

- Reconstructed the soft proton flare filtering for PN (espfilt)
  - with manual checking of all 6241 public obsids
- Used OMNIdata for the solar wind (multi-mission)
  - more complete coverage than ACE
  - more uniform calibration
- Used TS05 model in geopack for $\vec{B}$
- Used Shue (1998) model for magnetopause
- Used Bennet et al (1997) model for bowshock

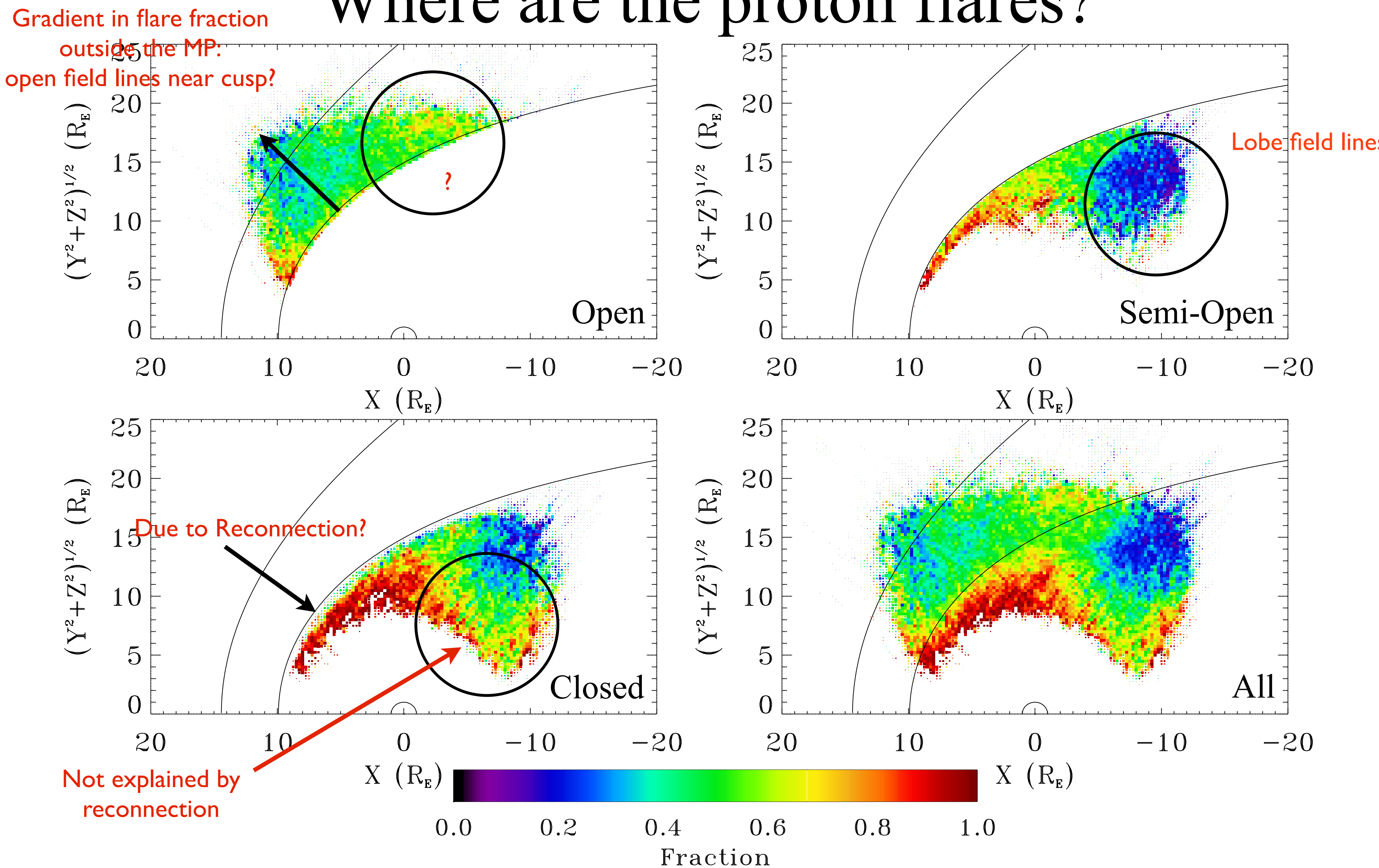
- Determined flare incidence rate ("flare fraction") as function
  - s/c distance from earth/current distance to MP (same Iλ)
    - as a function of magnetic geometry
  - angle of look direction from velocity
  - angle of look direction from $\vec{B}$

Where are the proton flares?



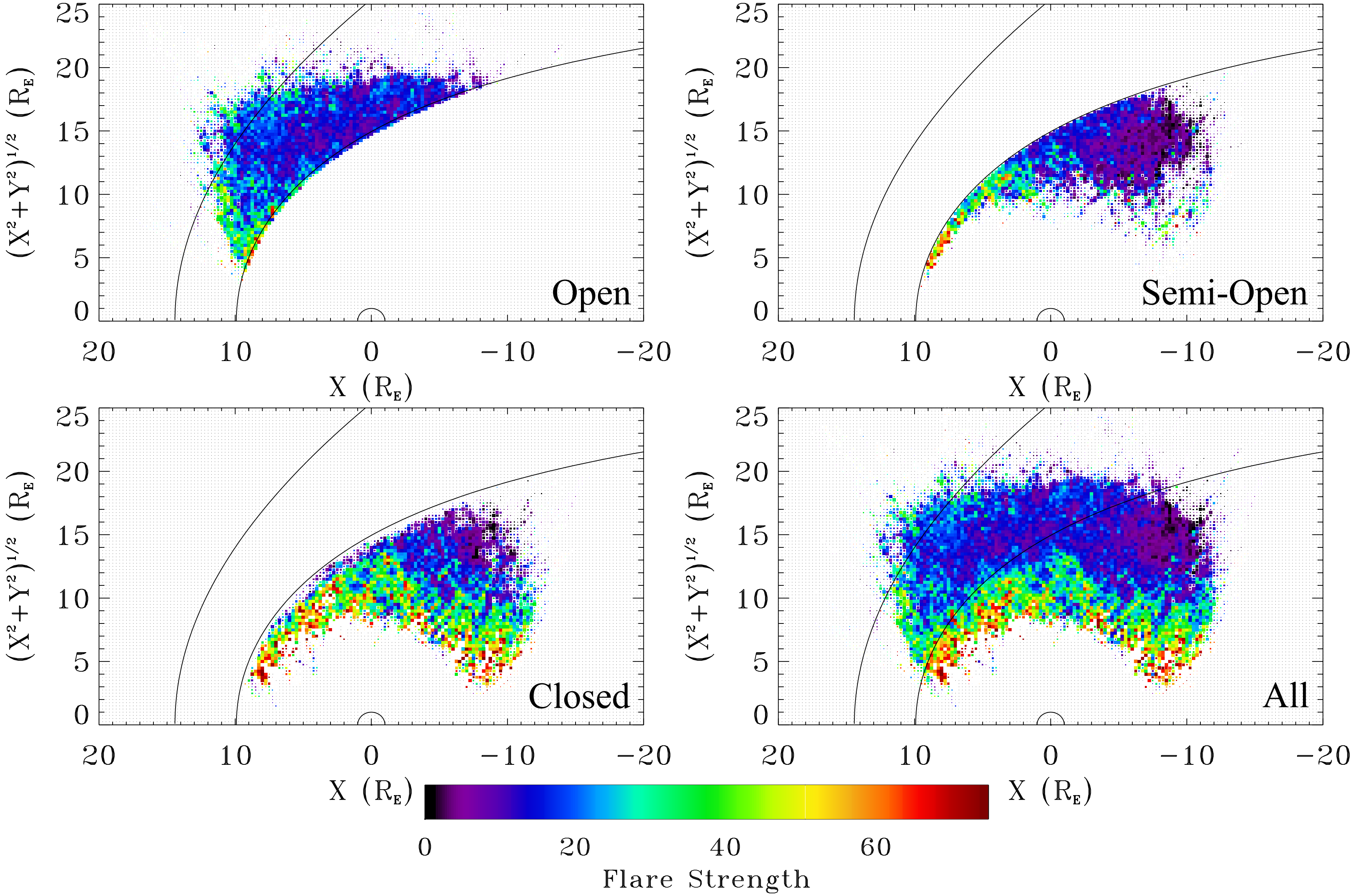
The flare fraction is the highest on closed field lines.
The “hot zone” is just inside the magnetopause.

Where are the proton flares?



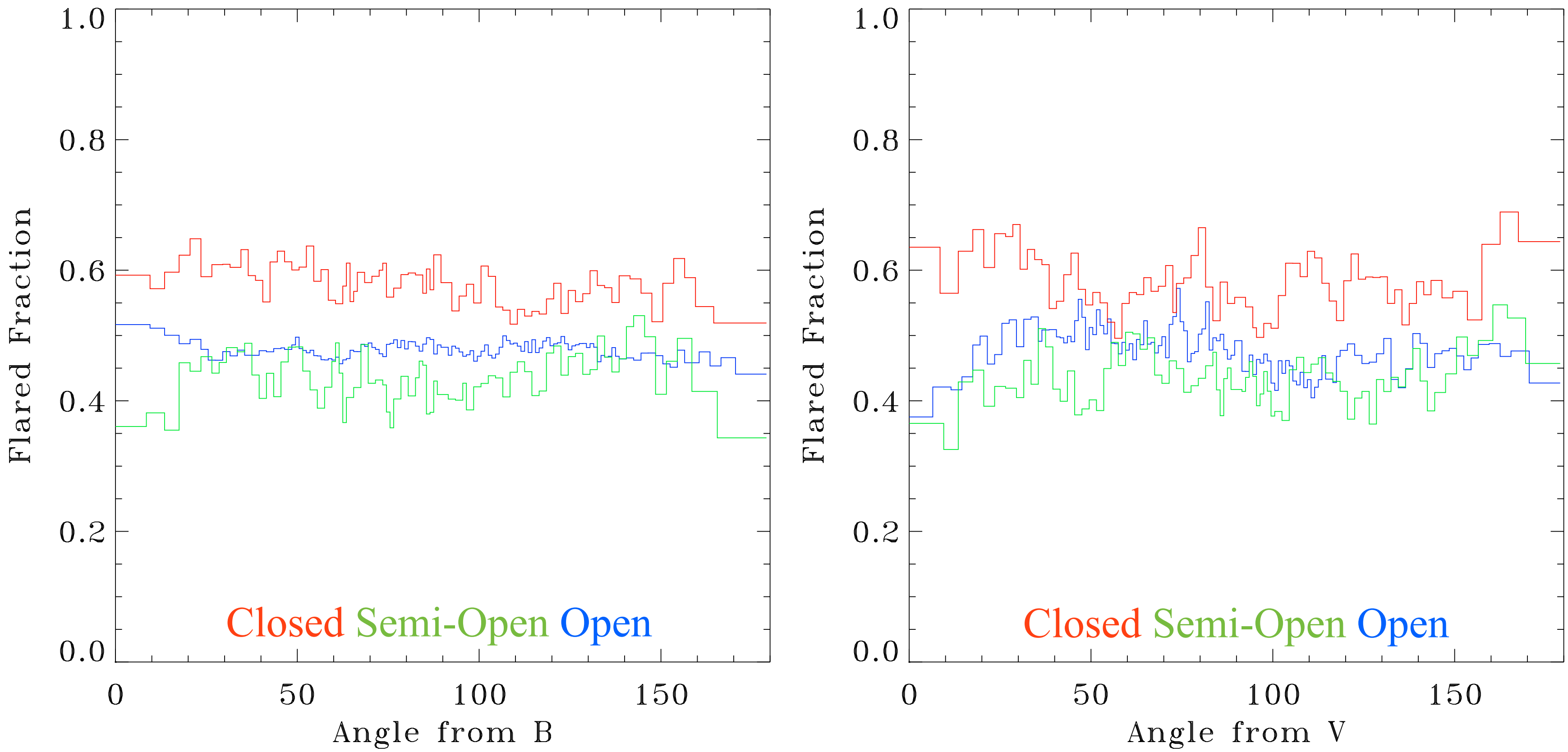
Caveat: the placement of the magnetopause is uncertain, so the interpretation of events near the magnetopause is equivocal.

Where are the strongest flares?



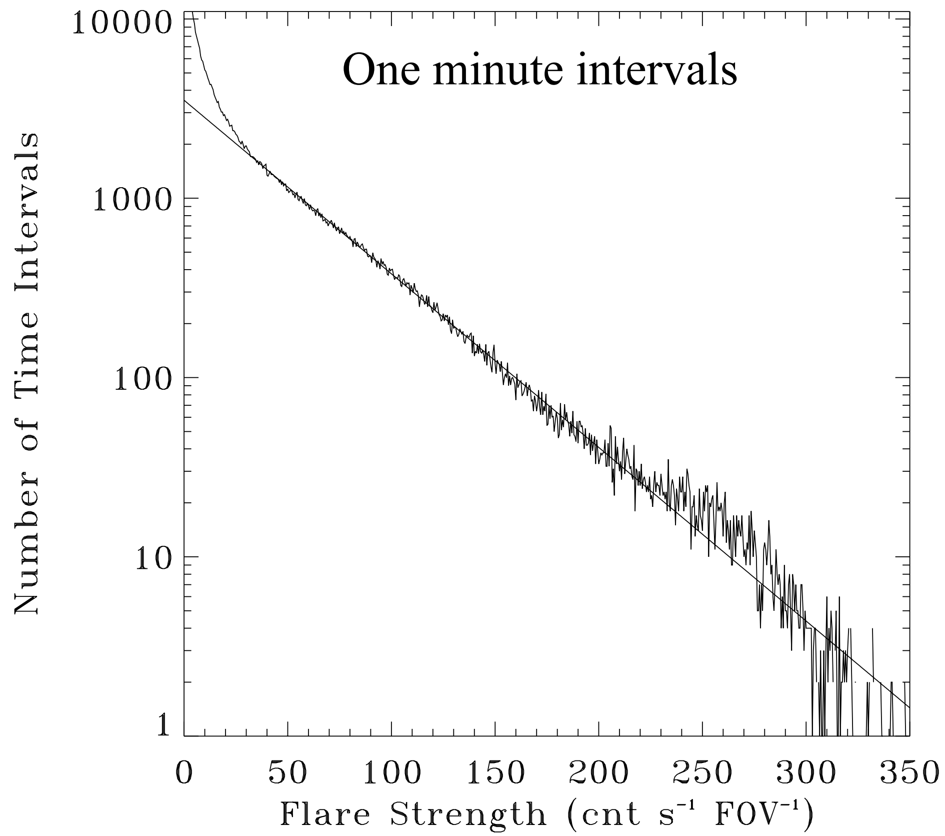
As expected, strongest flares are closest to the Earth.
(Some confusion with particle belts?)

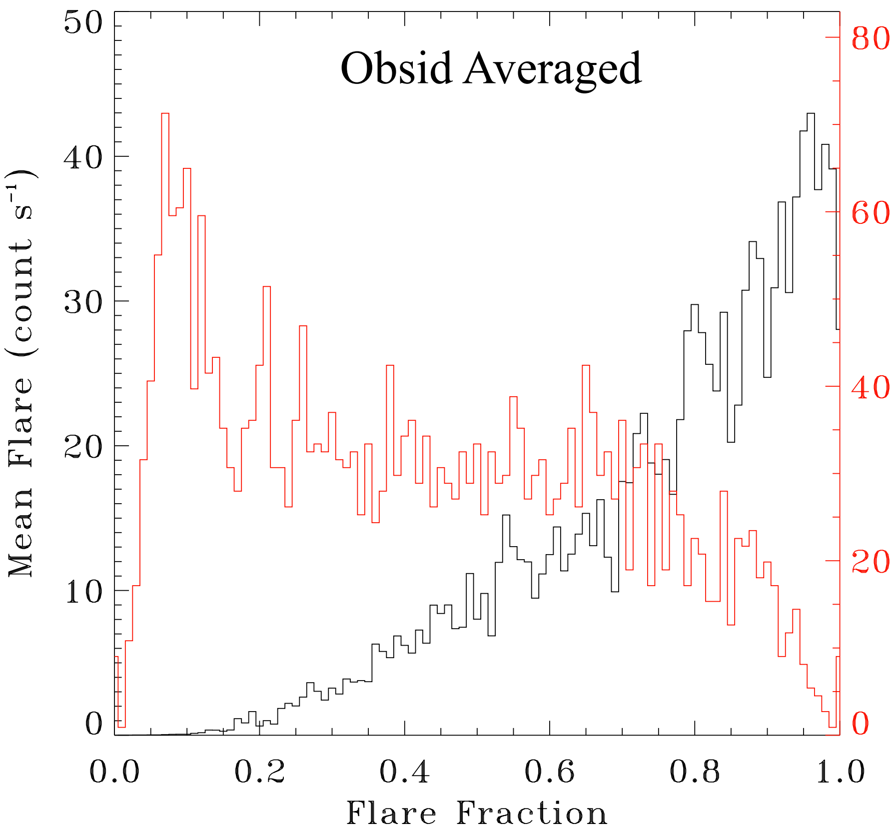
Dependence on Look-Direction?



No strong trends in flare fraction seen as a function of the angle between the look direction and $\vec{B}$ (or $\vec{V}$).

And the Usual Statistics



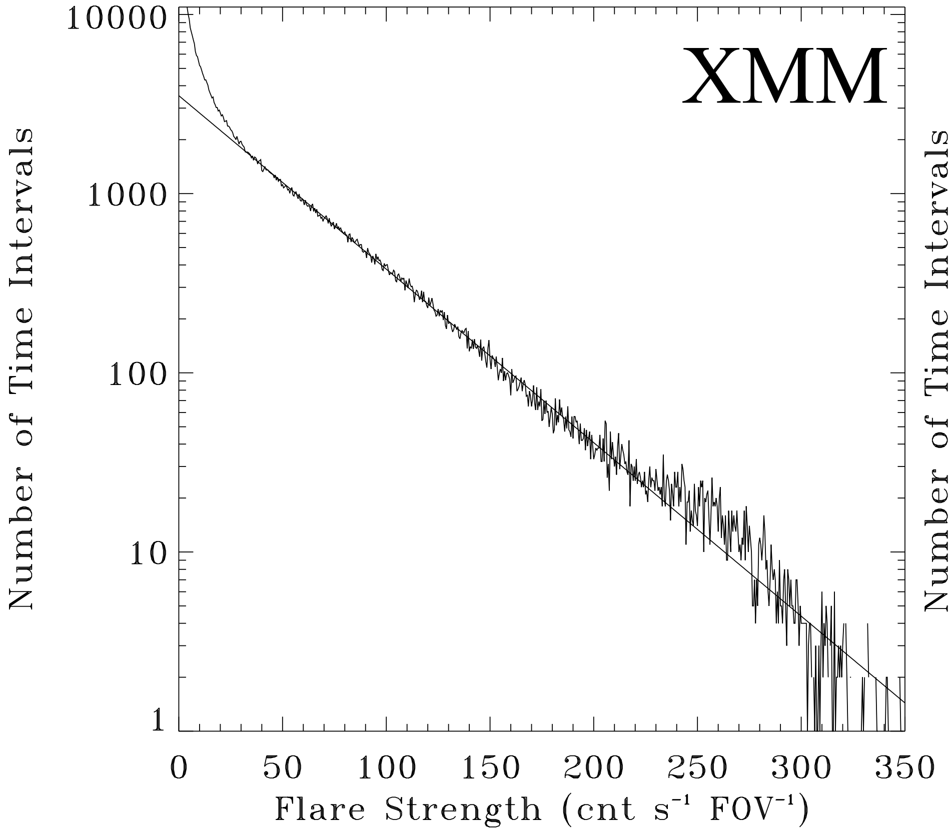


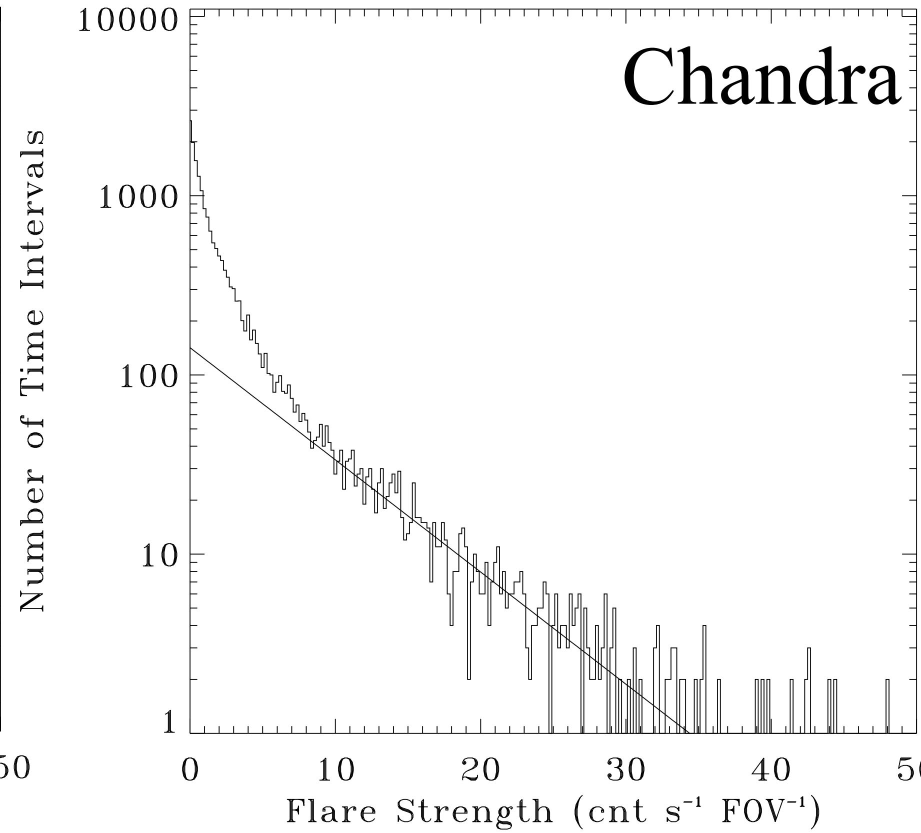
Why Not Chandra?

Roughly 51% of XMM time is flared, but only 8% for Chandra.
Several suggestions have been made for the difference:

- Different orbits
  - Chandra, i=28.5, a=25.4 R_E, e=0.80 (launch)
  - XMM, i=-40.0, a=21.0 R_E, e=0.79 (launch)
- Different mirror/optical train efficiencies
  - At 100 keV ACIS/MOS~2 (Nartallo et al 2000)
  - At 200 keV ACIS/MOS~3
  - $\eta \equiv \Omega A_{source} N_{detect}/(4\pi A_{detect} N_{incident})$
- Different detector sizes
  - Chandra S3, 6.03 cm^2, 70.5 $arcmin^2$
  - XMM PN, 30 cm^2, 706 $arcmin^2$
- Different detector designs
  - ???

Chandra Comparison

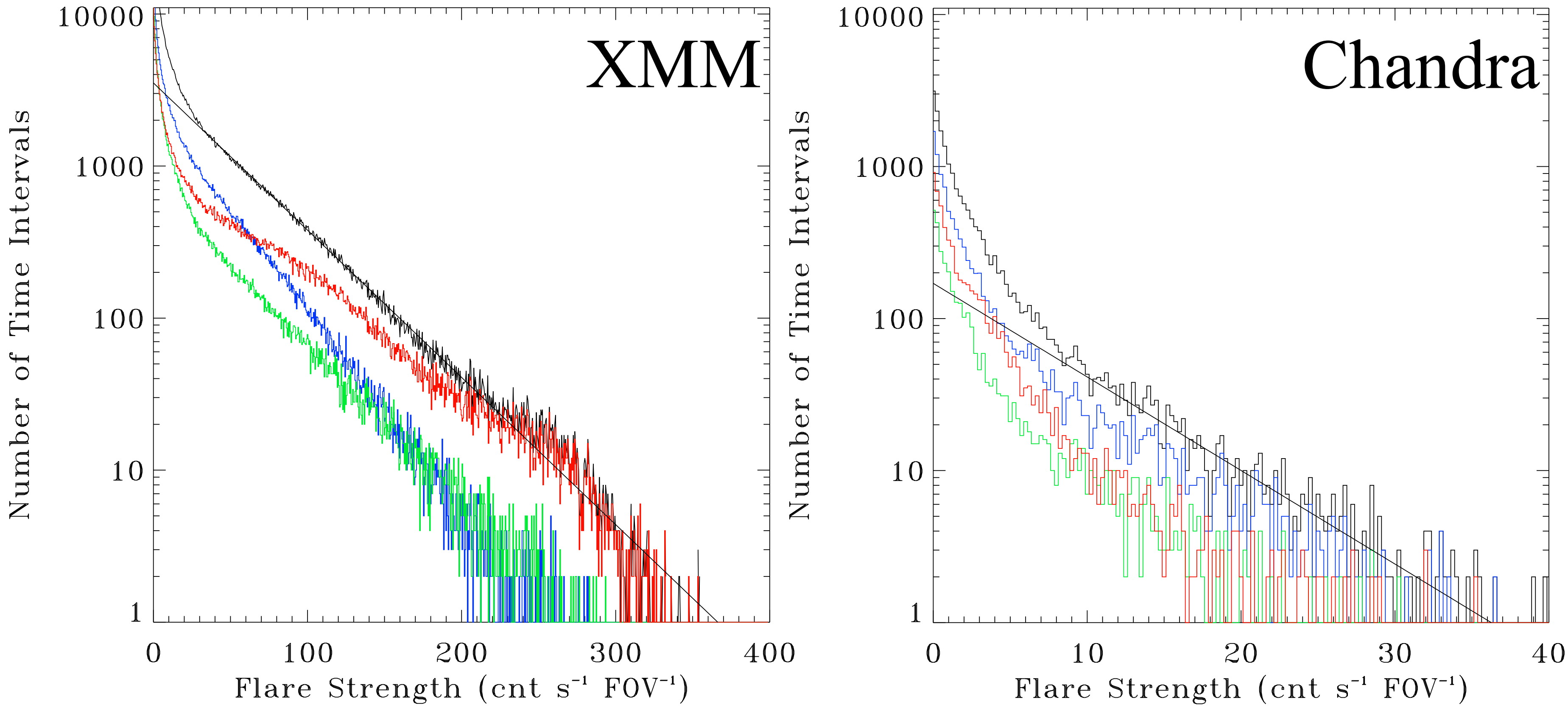




Maximum flare strength for Chandra is ~1/10 that of XMM

- makes it more difficult detect flares at low levels
- since low amplitude flares are more common
  - can significantly reduce the number of flares

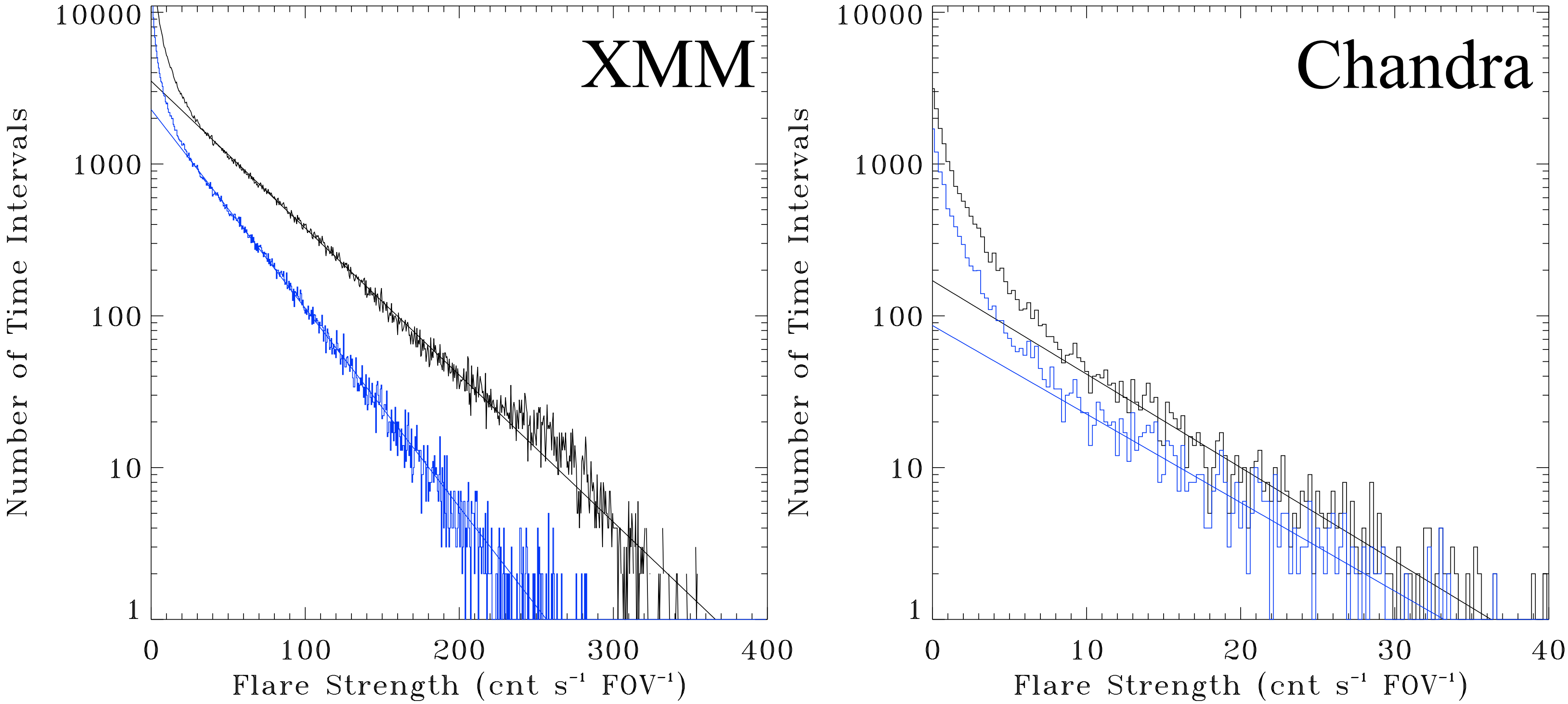
Chandra Comparison



Comparing the total distribution is a bit unfair

- Divide the distribution by local $\vec{B}$ geometry
- XMM shows broader variety of behaviors

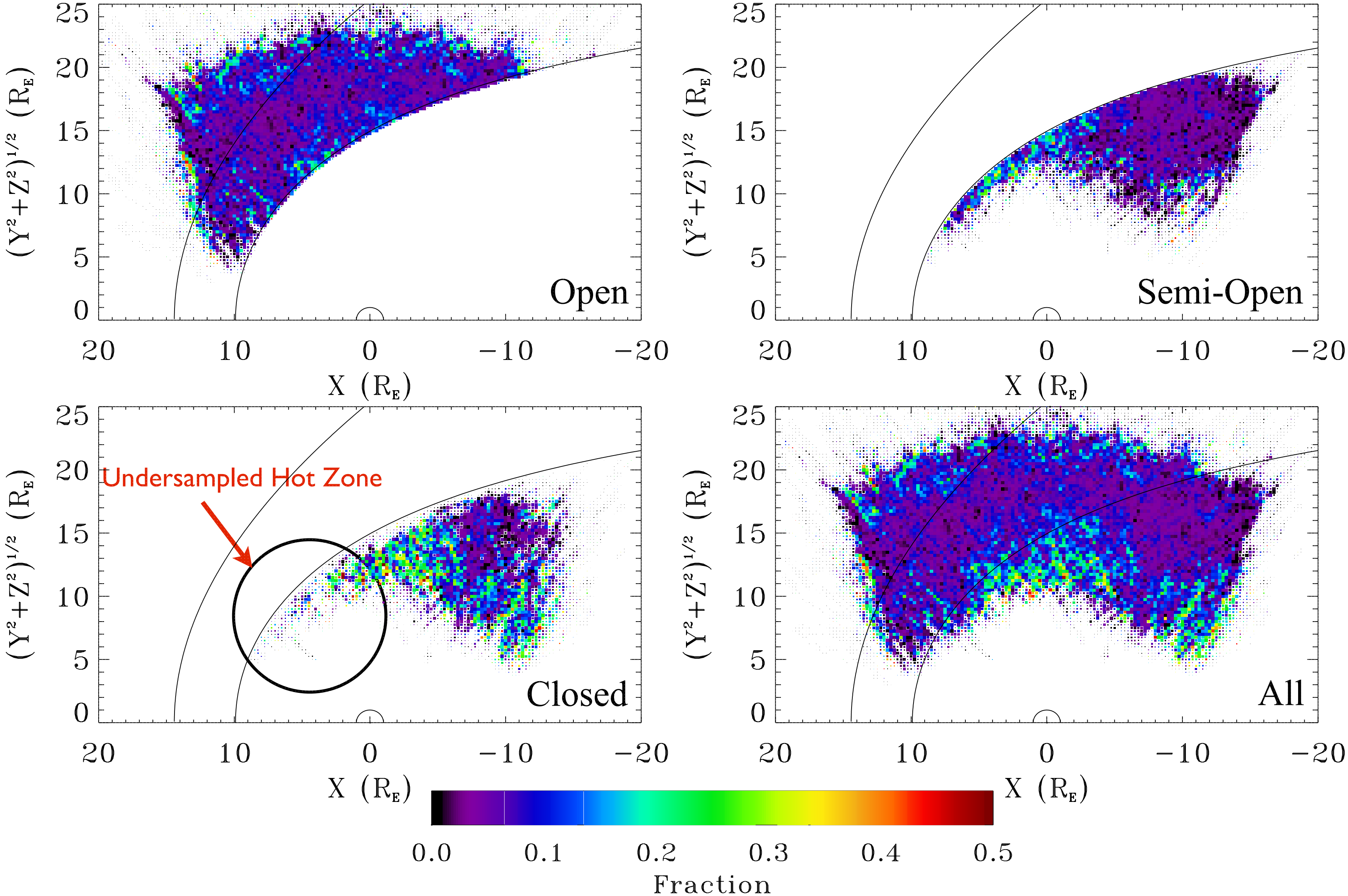
Chandra Comparison



Maximum flare strength for Chandra is ~1/8 that of XMM

- comparing only flares on open field lines
- slopes dissimilar (not clear why)

Chandra Comparison



Same flare fraction pattern as XMM (but lower amplitude)

Chandra does not spend as much time (on) in the “hot-zone”

Chandra Comparison

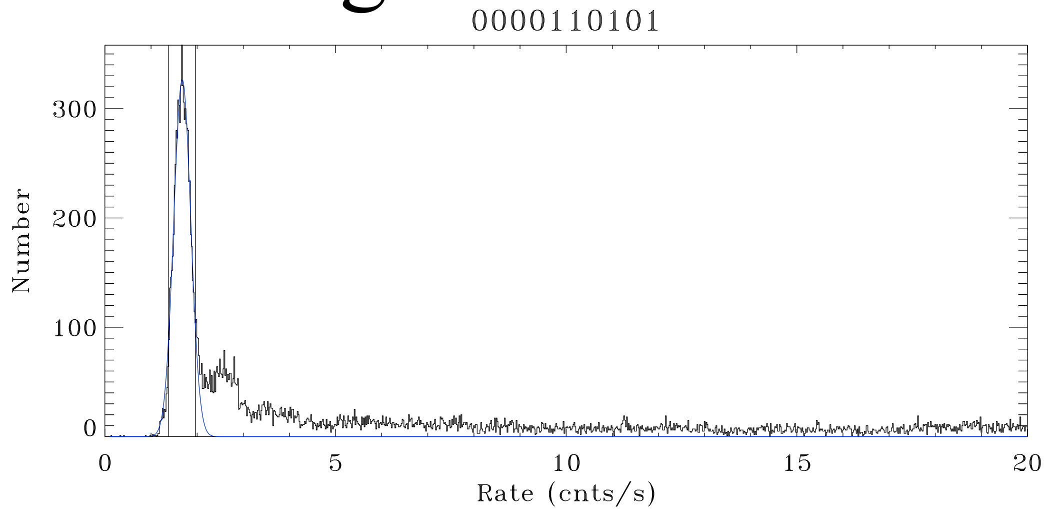
The "hot zone" is just inside the magnetosheath and has
- highest incidence of flares
- strongest flares

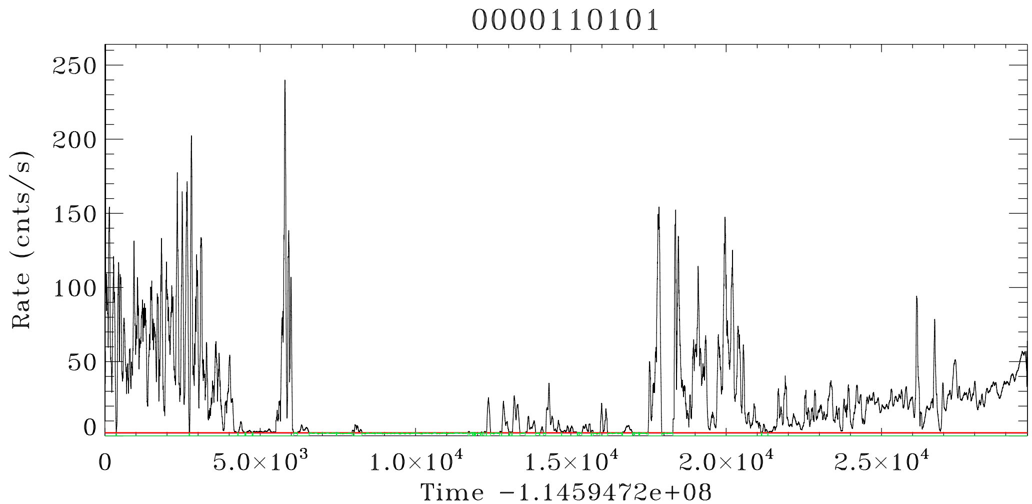
Two reasons why the Chandra is lower:
- it does not observe as much in the "hot zone"
- over-all response to flares is lower so less obvious
- not obvious why the response is lower

Quod Erat Demonstrandum

XYZ

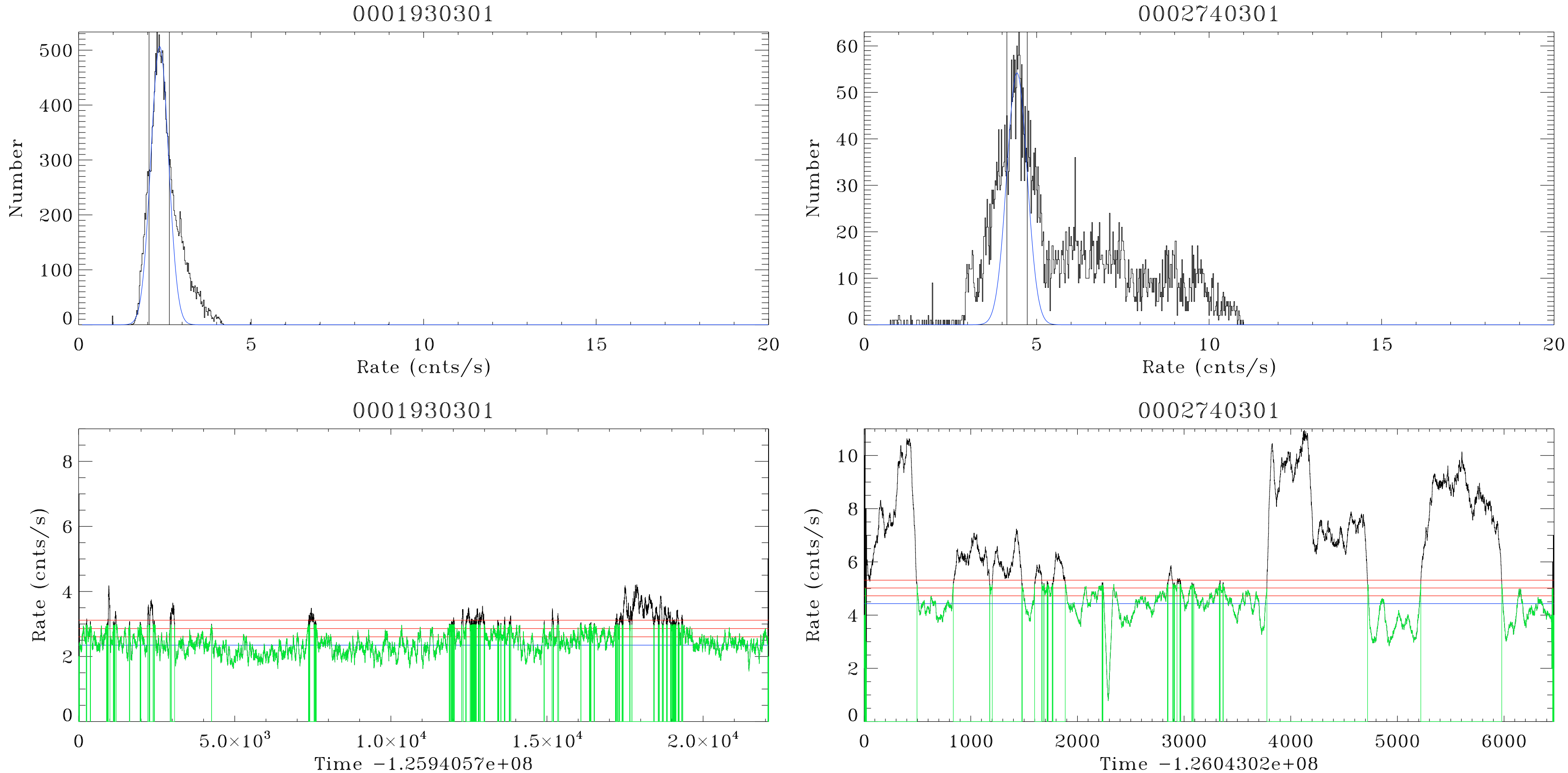
Determining the Flare Times/Rates





Create a histogram of the light-curve,
Fit a Gaussian to the lowcount-rate peak
Set threshold over which emission is considered “flare” ~3σ

Determining Flare Times/Rates



Fully automated fitting doesn’t always work:

By eye categorization as good, bad, or indifferent

- good: can get flare intervals and strengths
- indifferent: can get flare intervals but not strengths
- bad: can’t get info about flares

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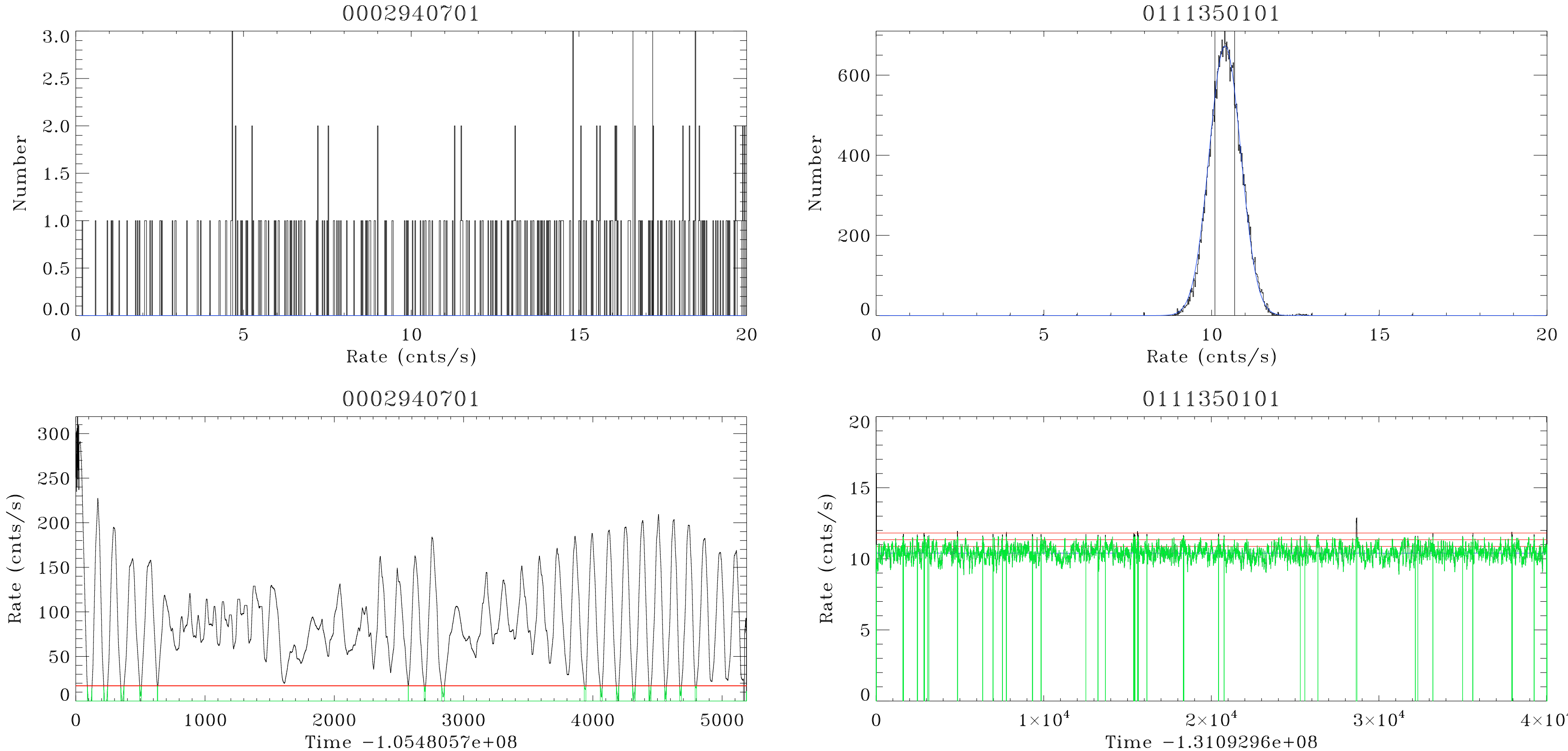

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XYZ