Suzaku Observations of SNR RX J1713.7-3946 in the Energy Range up to 40 keV

Takaaki Tanaka (SLAC/KIPAC, ISAS/JAXA)
Yasunobu Uchiyama, Tadayuki Takahashi (ISAS/JAXA),
Felix Aharonian (MPIK) and Suzaku RX J1713 team

17 Oct. 2007 Five Years of INTEGRAL @ Chia Laguna

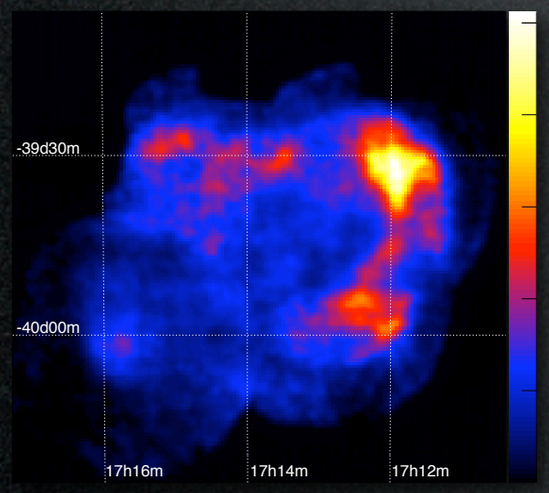
SNR RX J1713.7-3946

Best Object for Study of Particle Acceleration

- Non-thermal X-ray emission dominates
- Bright & Large (d ≃ 1°)
- Studied well also in TeV gamma-rays with H.E.S.S.

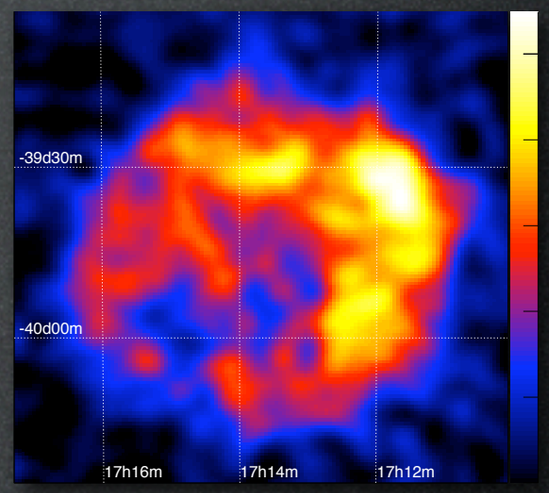
Cutoff ? Detailed Morphology ? → Suzaku

X-ray (ASCA)



Uchiyama et al. (2005)

Gamma-ray (H.E.S.S.)

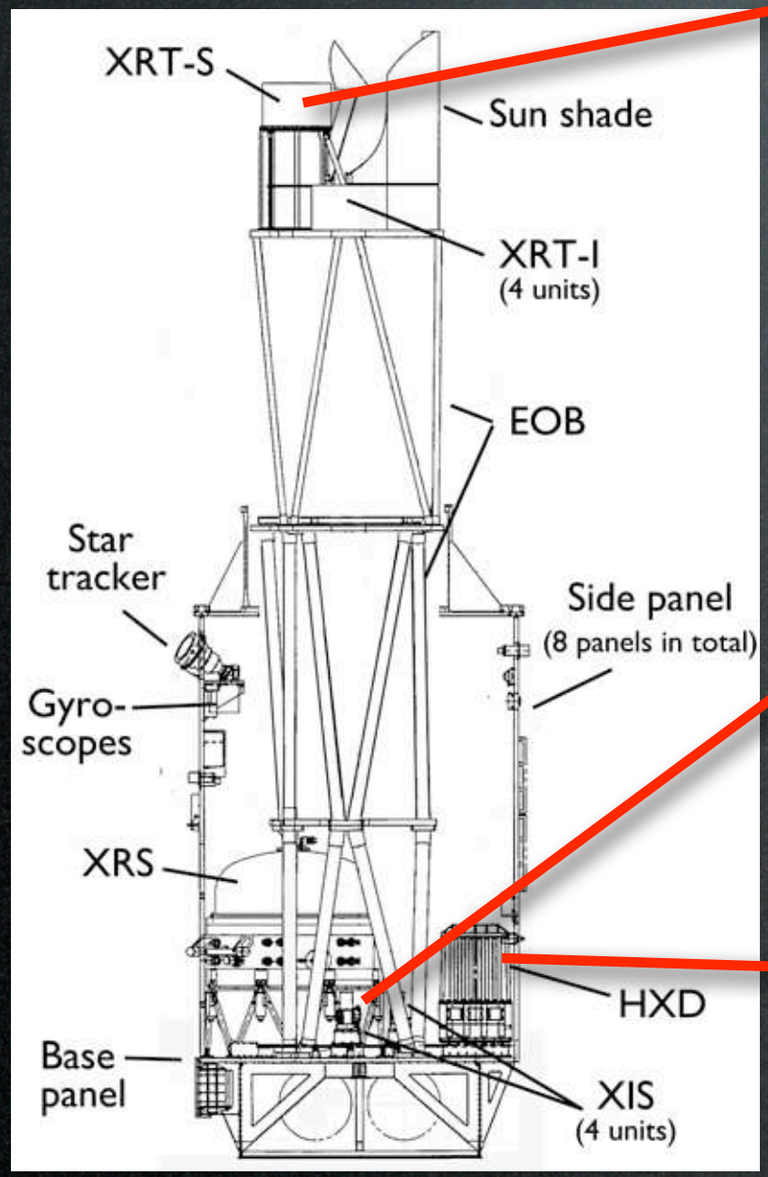


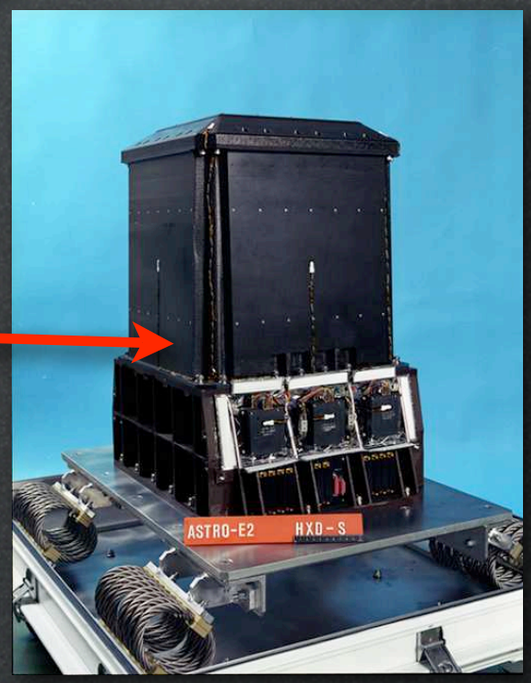
Aharonian et al. (2006)

Distance: 1 kpc
Age: 1600 yr

Suzaku Observatory

Launched on 07/10/2005





XIS + XRT

(0.2 – 12 keV)

Low Bgd.

Large Eff. Area

Good ΔE

HXD

(10 – 600 keV)

Well-type

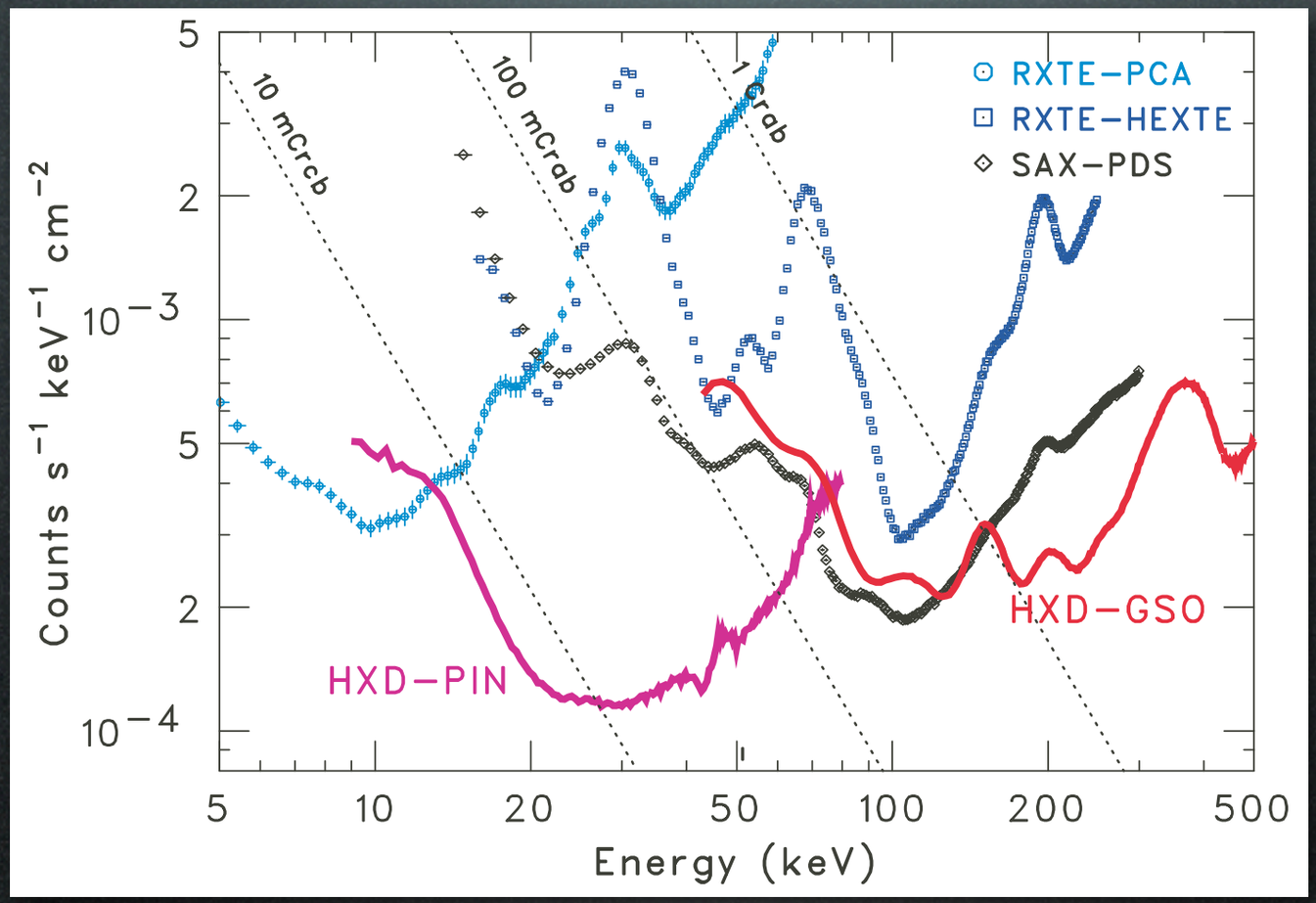
Active Shield

↓

Low Bgd.

Hard X-ray Detector (HXD)

① Low Detector BGD



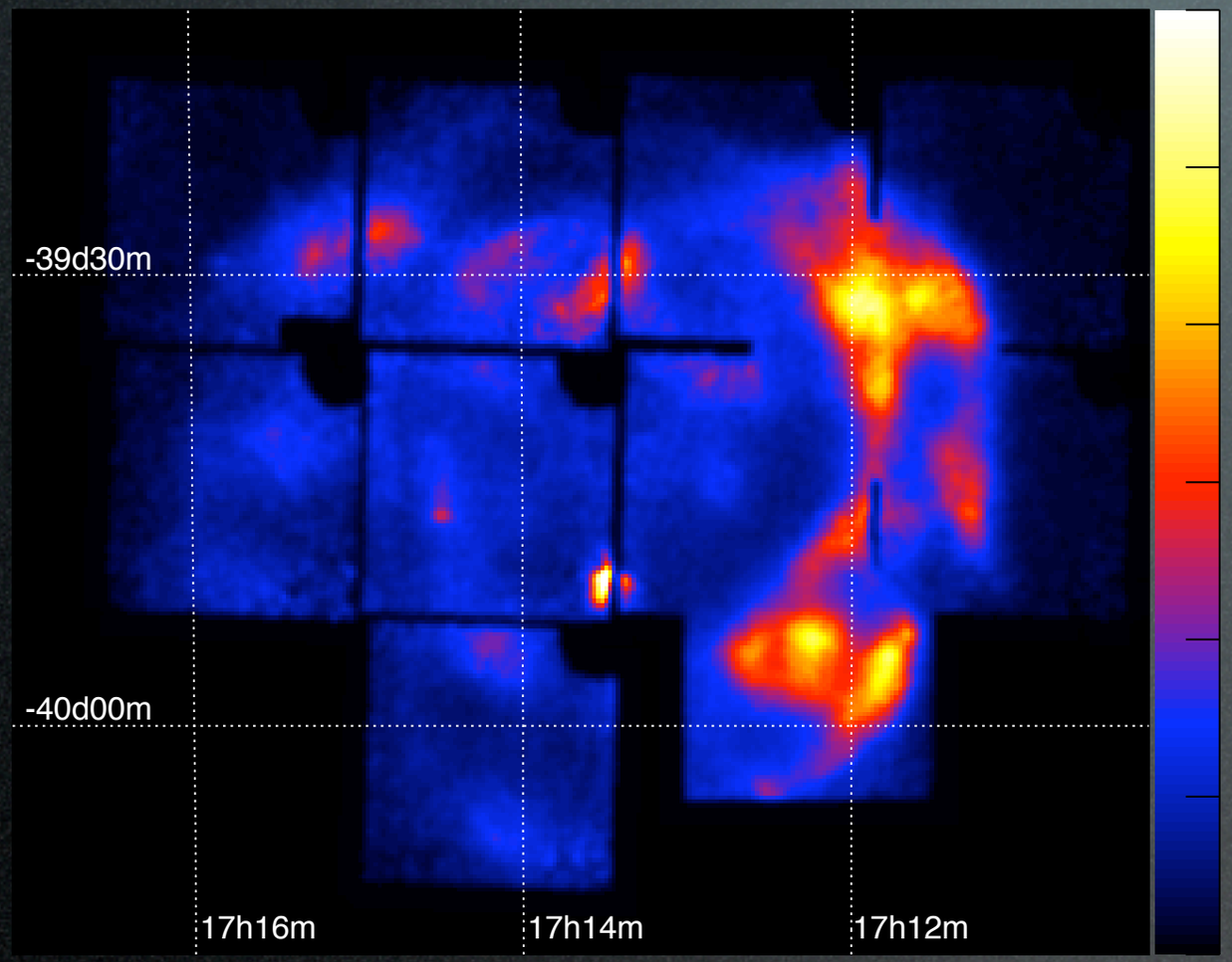
② Narrow FoV

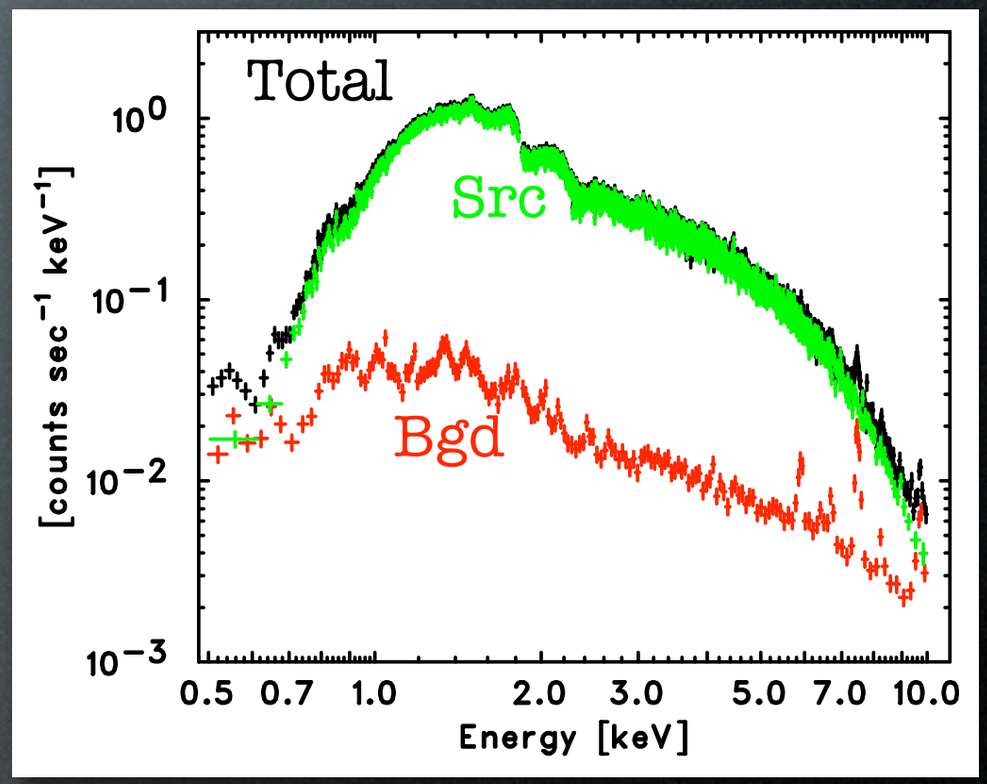
HXD-PIN　SAX-PDS

Reduces X-ray BGD
ex) CXB, GRXE
Suitable for study of
RX J1713.7-3946
(d ≃ 1°)

XIS Data (0.4–12 keV)

1–5 keV





Power-law type spectra (No line features)

Γ = 2.2–2.7

Consistent with previous studies

by ASCA, Chandra and XMM-Newton

Cutoff around 10 keV

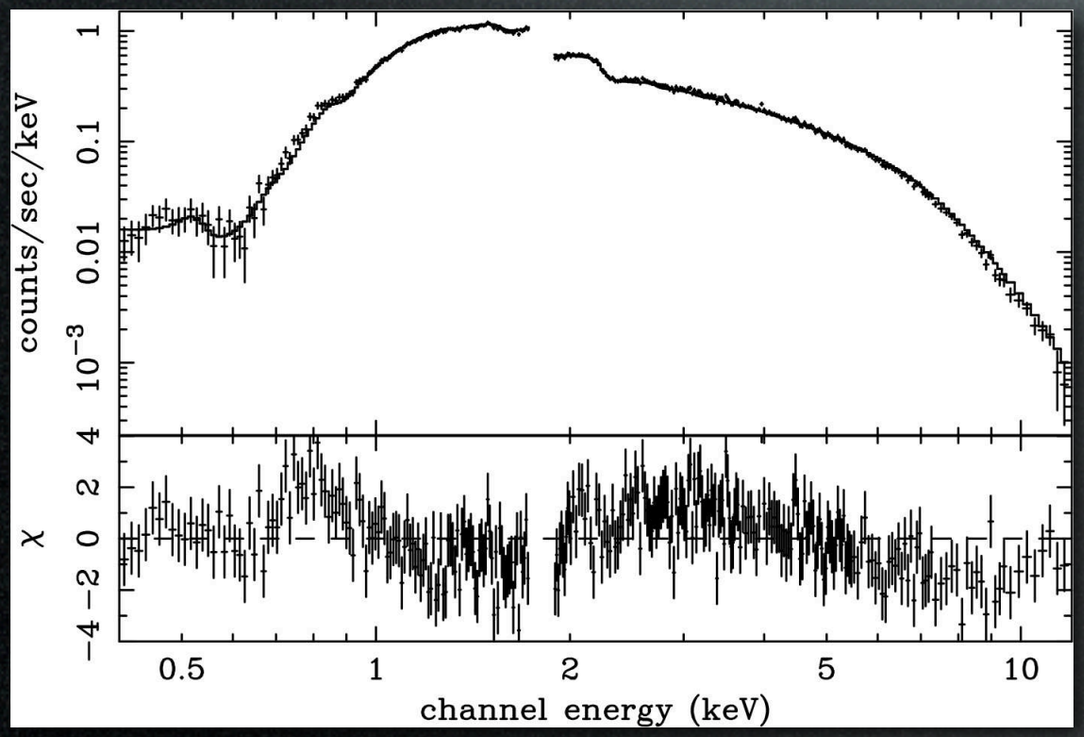
Spectrum of SW rim

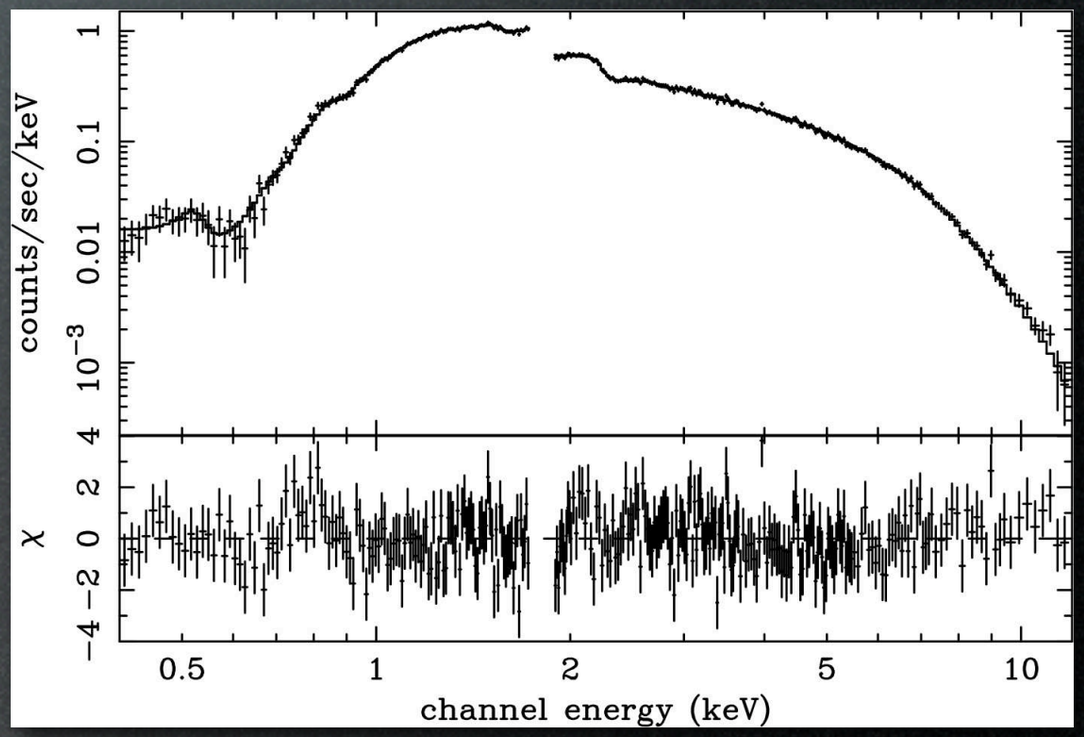
Simple Power Law

$$\frac{dN}{d\varepsilon} \propto \varepsilon^{-\Gamma}$$

Power Law with an Exponential Cutoff

$$\frac{dN}{d\varepsilon} \propto \varepsilon^{-\Gamma} \exp\left[-\left(\frac{\varepsilon}{\varepsilon_c}\right)\right]$$



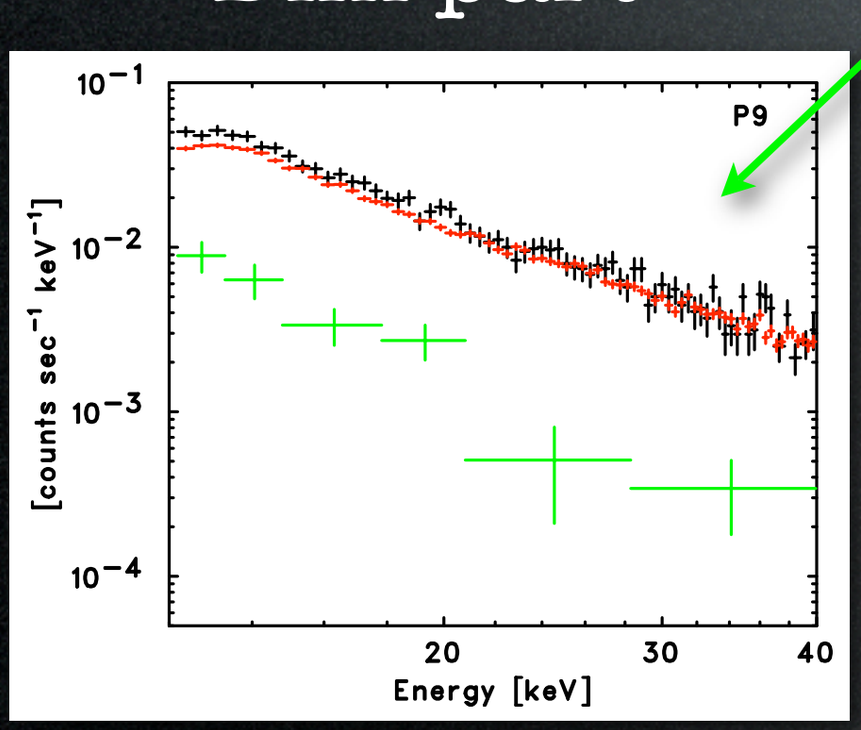


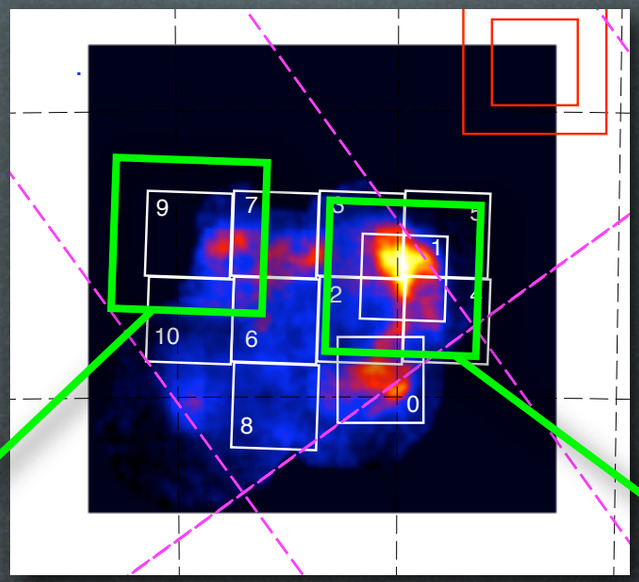
Spectral steepening even below 10 keV

HXD: Spectra above 10 keV

Detected up to ≃ 40 keV from all pointings

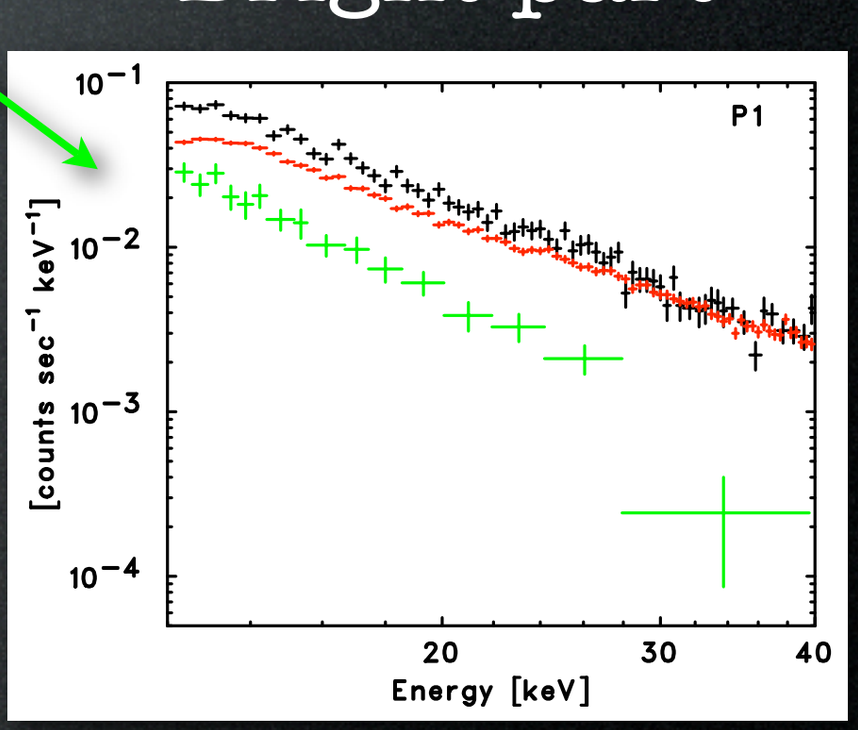
Dim part





Total
Bgd
Bgd sub

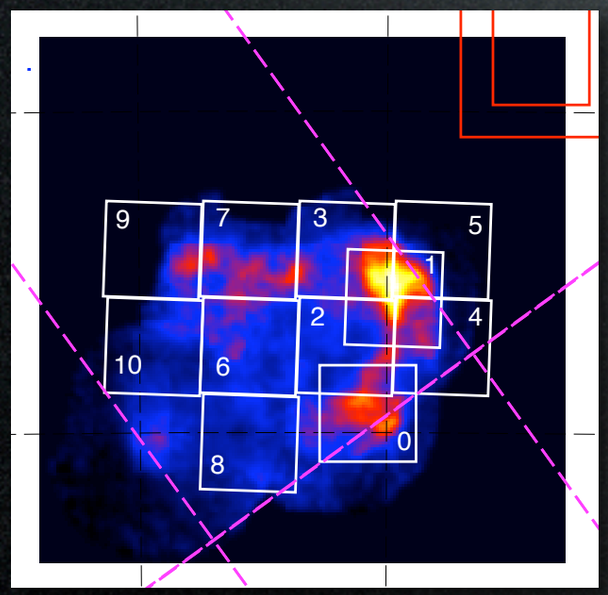
Bright part

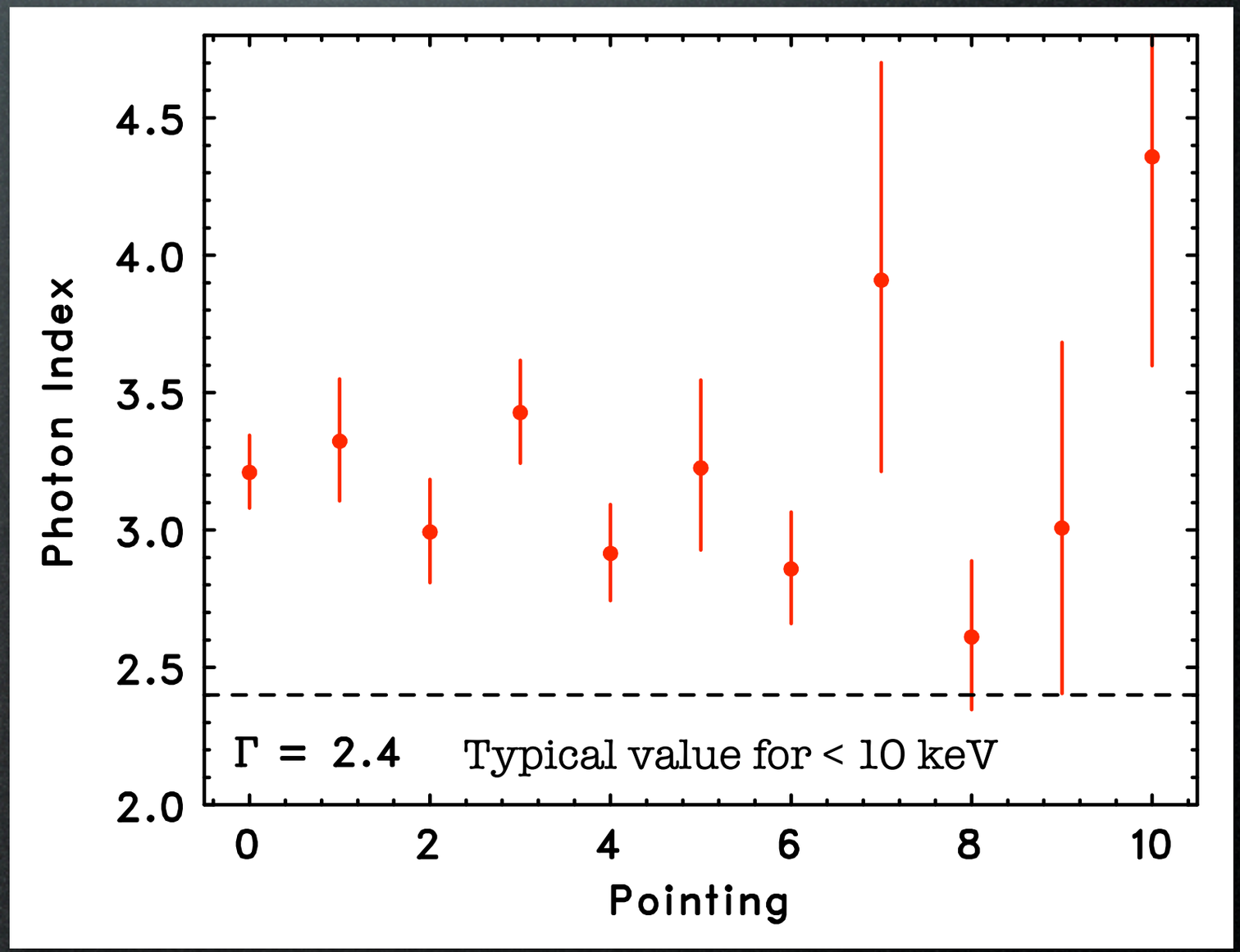


HXD: Spectral Fitting

power-law fit → $\Gamma \simeq 3.2$

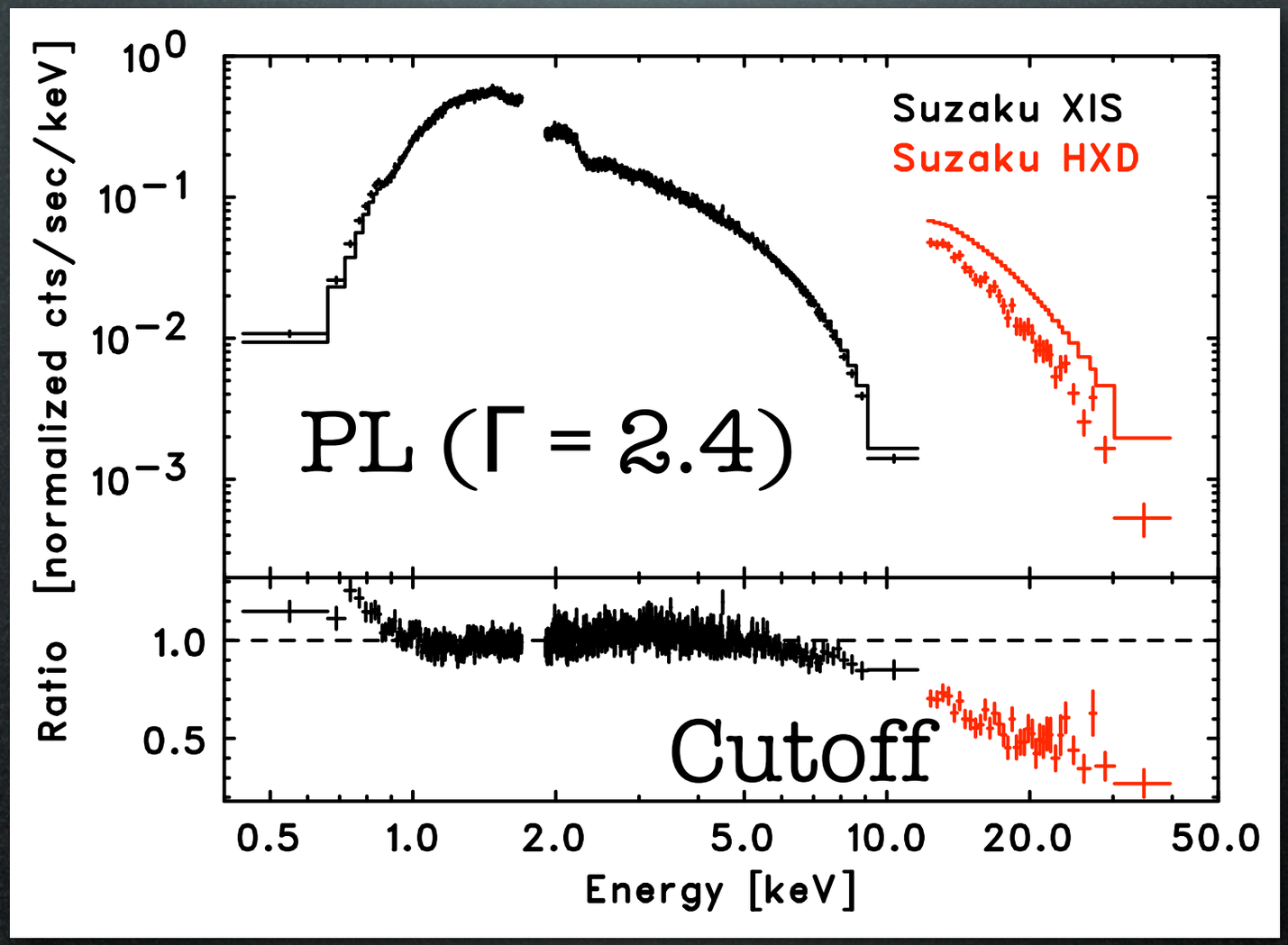
significantly larger than those in soft X-ray band





Wide-Band Spectrum

From 0.4 keV to 40 keV



Detection up to 40 keV
→ Clear spectral cutoff

Cutoff Energy

Cutoff Energy →

Acceleration rate = Synchrotron loss rate

Zirakashvili & Aharonian (2007)

Predict rapid cutoff which agrees with Suzaku spectrum

$$\varepsilon_0 = 0.55 \left(\frac{v_s}{3000 \text{ km s}^{-1}} \right)^2 \eta^{-1} \text{ keV}$$

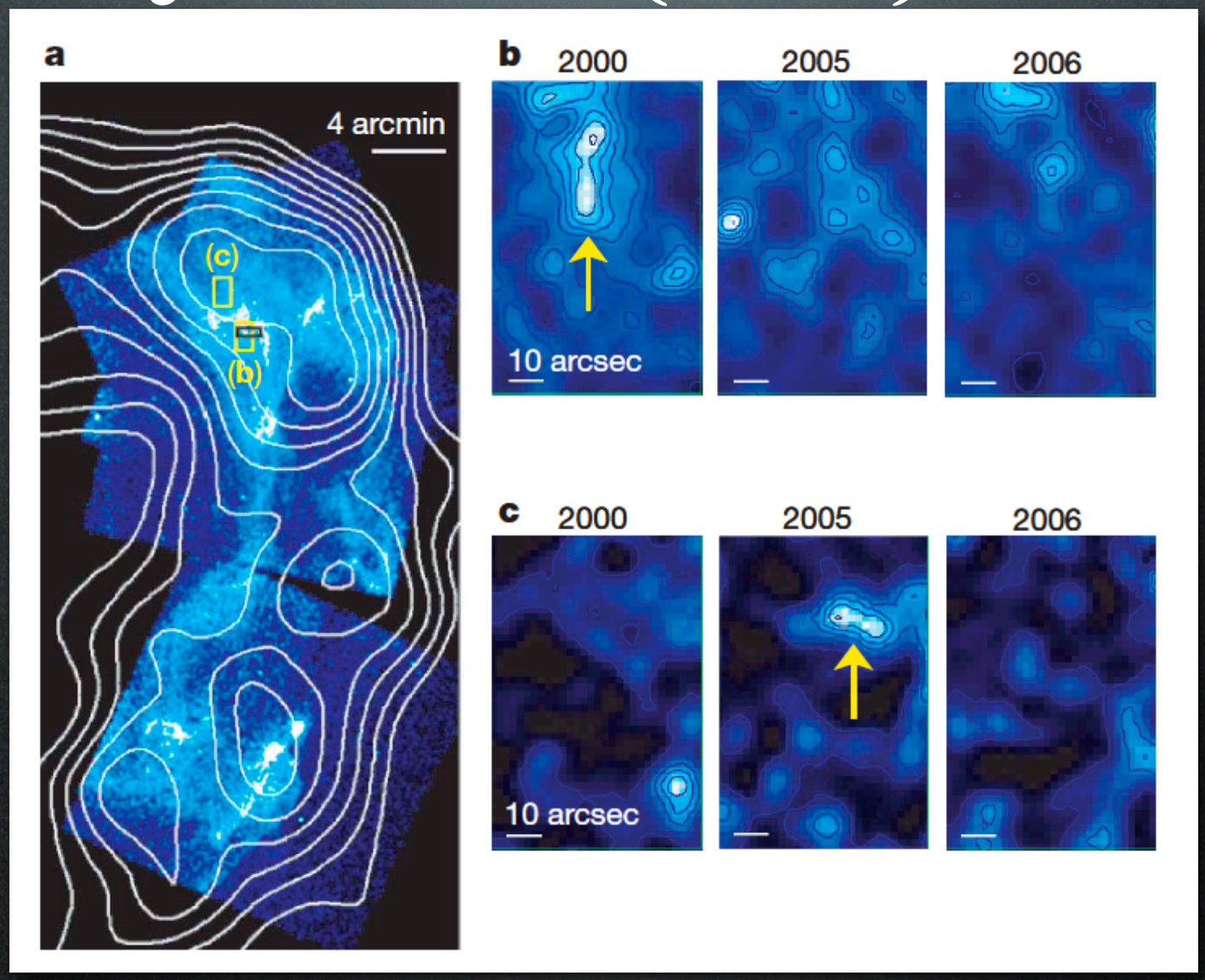
Suzaku Spectrum → $\varepsilon_0 = 0.67 \pm 0.02$ keV

Chandra Image
Uchiyama et al. Nature (2007) → $v_s < 4500 \text{ km s}^{-1}$

$\eta \approx 1$ Almost the Bohm limit
Very Efficient Acceleration

Magnetic Field

Uchiyama et al. (2007) Nature

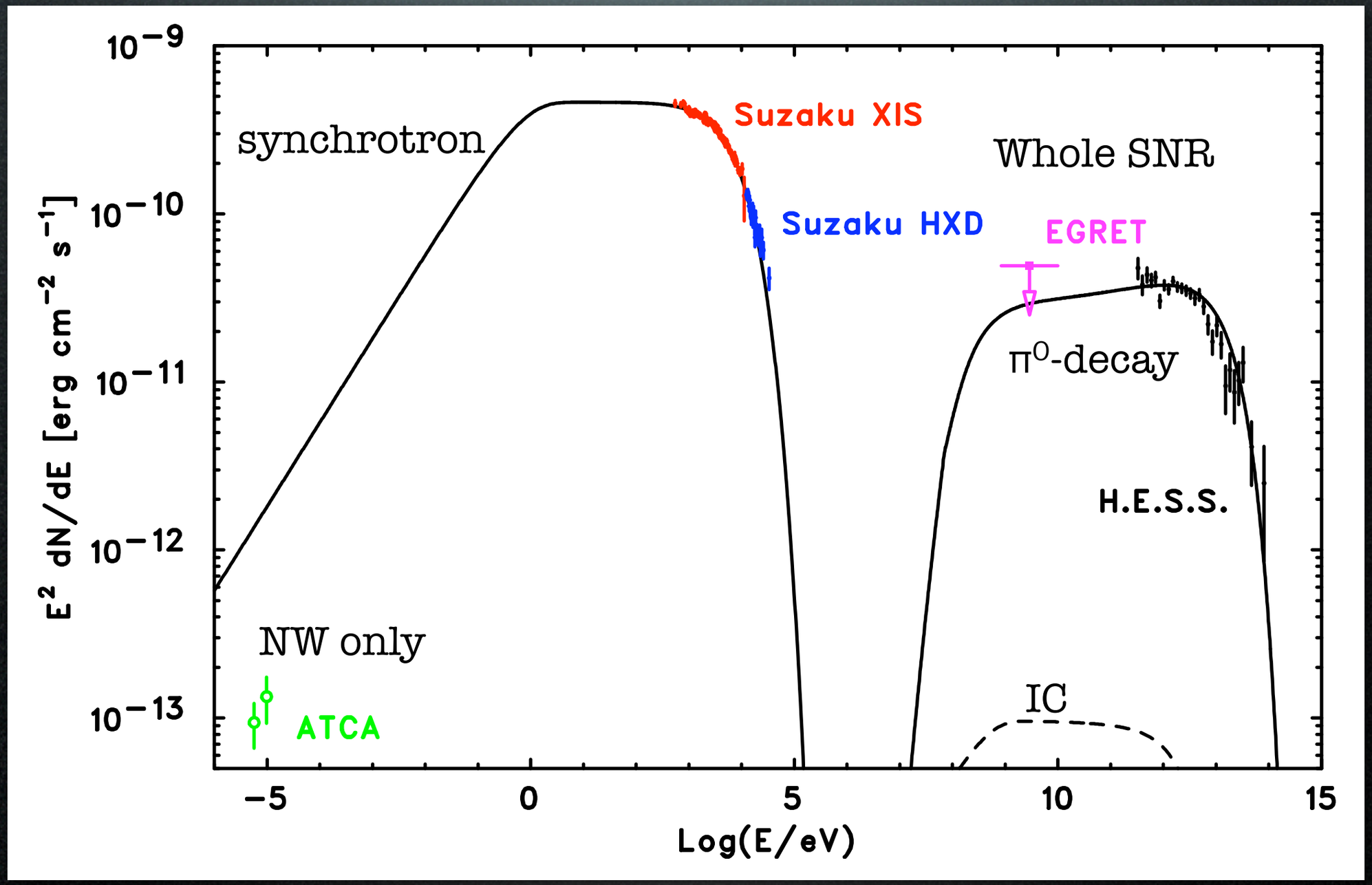


Year-scale Variability detected with Chandra

→ Acceleration & Cooling in year-scale

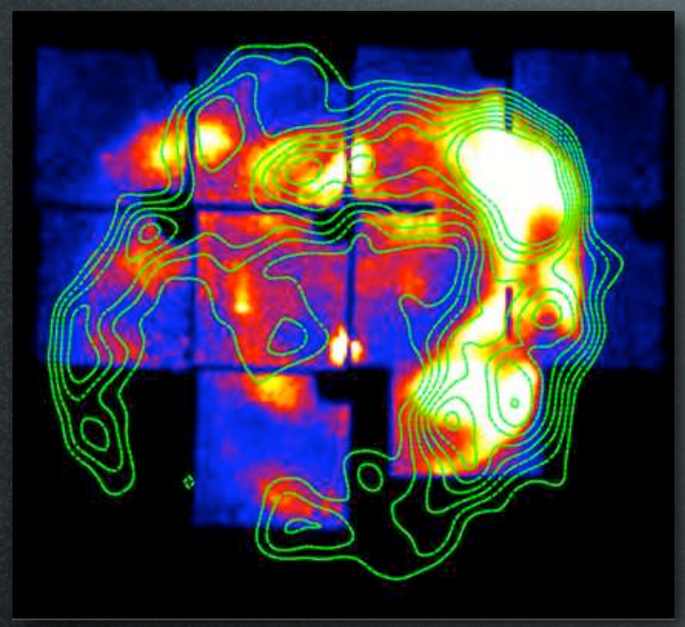
→ High Magnetic Field: 1 mG

Multi-Wavelength Study



B = 200 μG, t_0 = 1000 yr, s = 2.0 (for e^- and p)

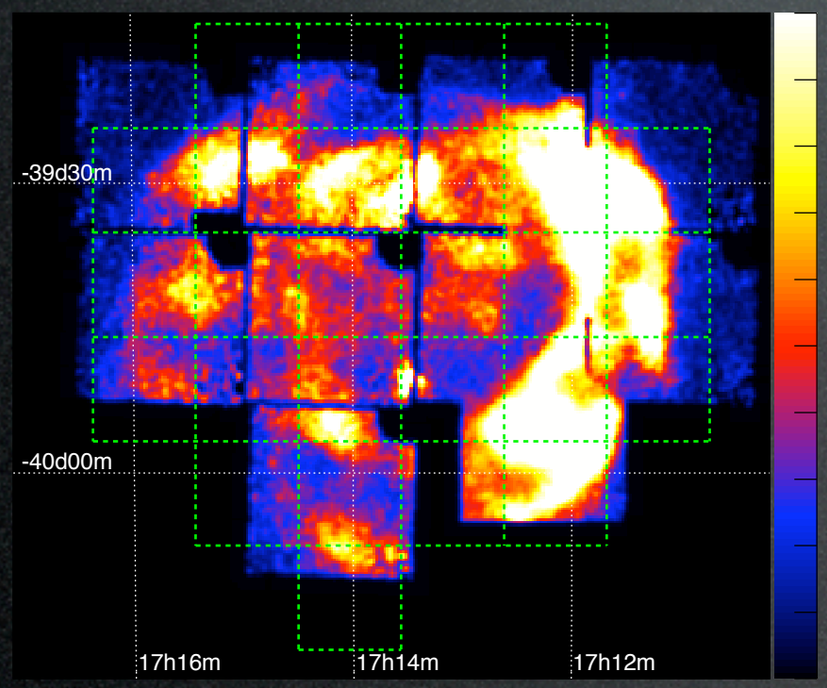
keV Image vs TeV Image



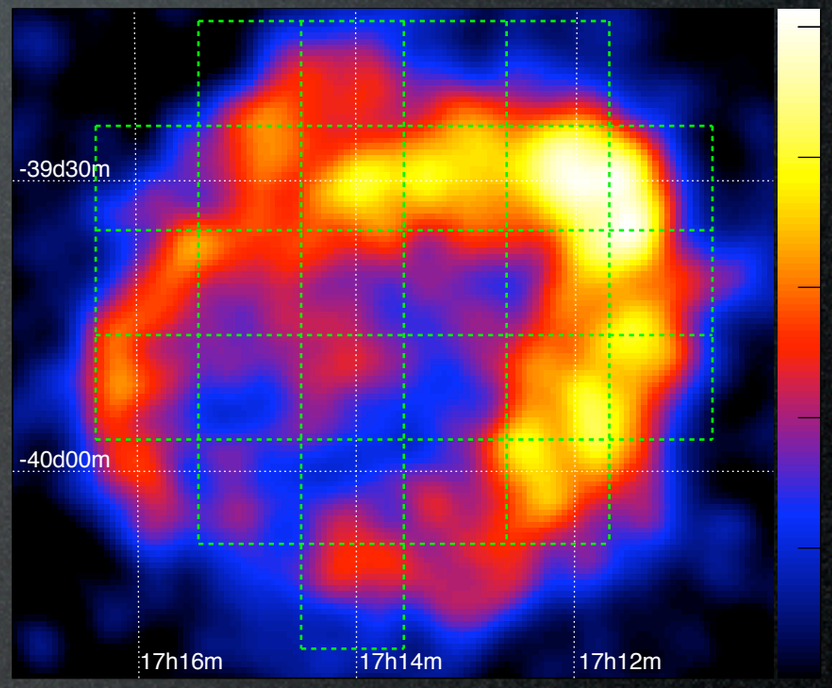
Color: Suzaku XIS (1-5 keV)
Contour: H.E.S.S.

Similar morphology also
in the dim parts
(Low BGD and large effective
area of Suzaku XIS)

Suzaku XIS



H.E.S.S.



Compare flux for the each square region

keV Image vs TeV Image

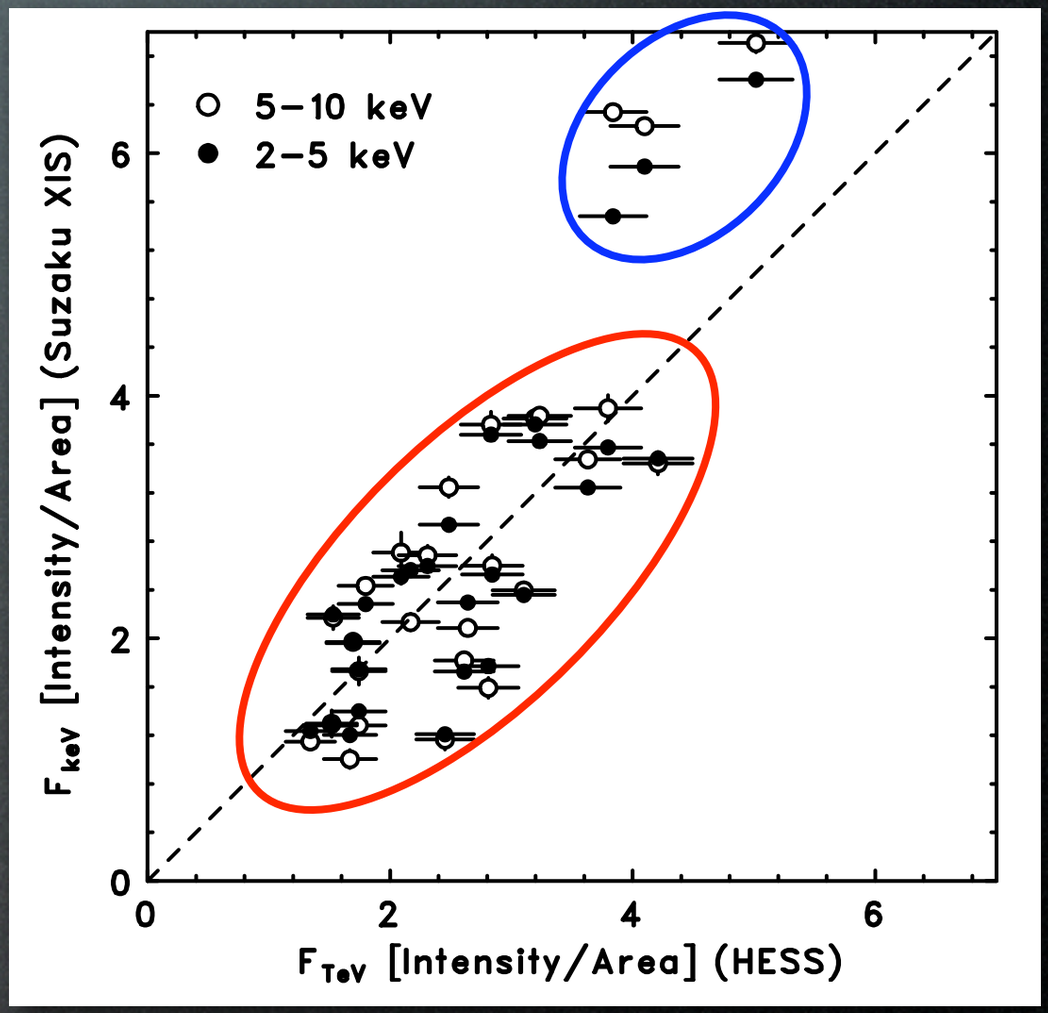
Tight Correlation

Homogeneous matter distribution ?
(Inconsistent with NANTEN)

Synchrotron emission correlate with matter distribution ?

“keV” excess

Large e/p ratio ?
Recent acceleration at the bright spots ?



Conclusions

- We observed RX J1713.7-3946 with Suzaku
- We have detected hard X-rays up to 40 keV from RX J1713.7-3946, for the first time
- We have clearly detected cutoff structure around 10 keV
- Cutoff energy indicates very efficient acceleration (almost in the theoretical limit)
- Multi-wavelength spectrum can be well modeled with hadronic scenario.
- Tight keV-TeV correlation & “keV excess” in the brights spots