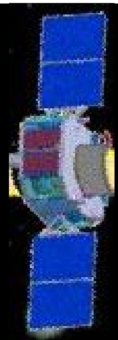
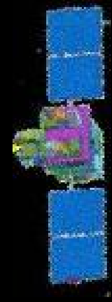


Workshop SIMBOL−X
2004, March 11−12



Particle acceleration in the supernova remnant G347.3−0.5

- 1, Introduction to SNR G347.3−0.5
- 2, SNR G347.3−0.5 observed by XMM−Newton
- 3, SNR G347.3−0.5 observed by SIMBOL−X

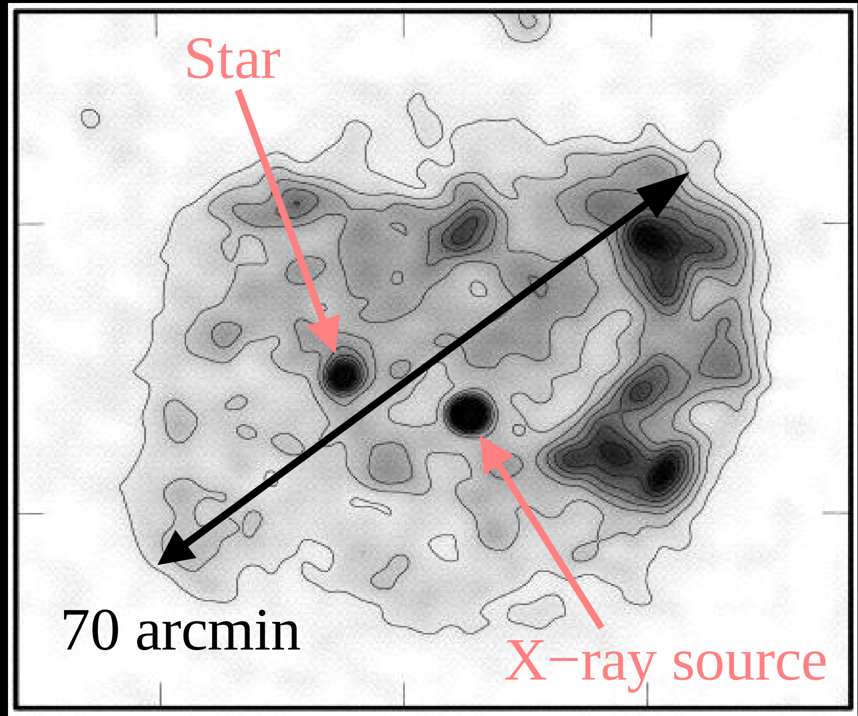
Presented by Gamil CASSAM−CHENAÏ
CEA−Saclay, Service d’Astrophysique
FRANCE

Collaborators: A. **DECOURCHELLE**, J. **BALLET**, J.−L. & G. **DUBNER**

Previous X−ray observations of G347.3−0.5

ASCA observation:

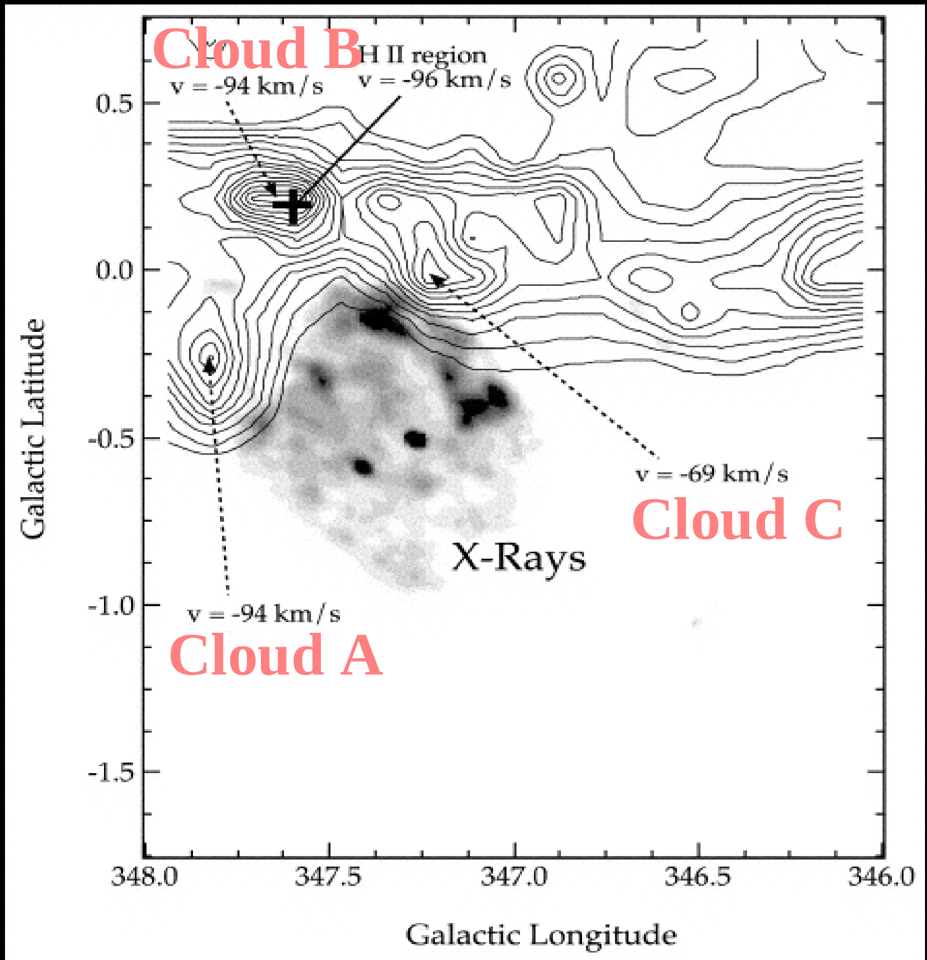
- X−ray spectrum with no line emission and well fitted by a power law model ($\Gamma \sim 2.4$) => X−ray flux dominated by synchrotron radiation
- SNR shock accelerating particles to very high energies. 10 keV photons => electrons with energies of 300 TeV assuming $B \sim 10\ \mu G$
- No thermal emission is detected anywhere in the SNR
- Detection of a point source consistent with neutron star properties => type II SN



ROSAT image of G347.3−0.5

Pfeffermann & Aschenbach 1996
Koyama et al. 1997, PASJ, 49, L7
Slane et al. 1999, ApJ, 525, 357

G347.3−0.5 and its environment



CO contours intensity with the ROSAT image (CfA−Chile 1.2m telescope, at 115 GHz)

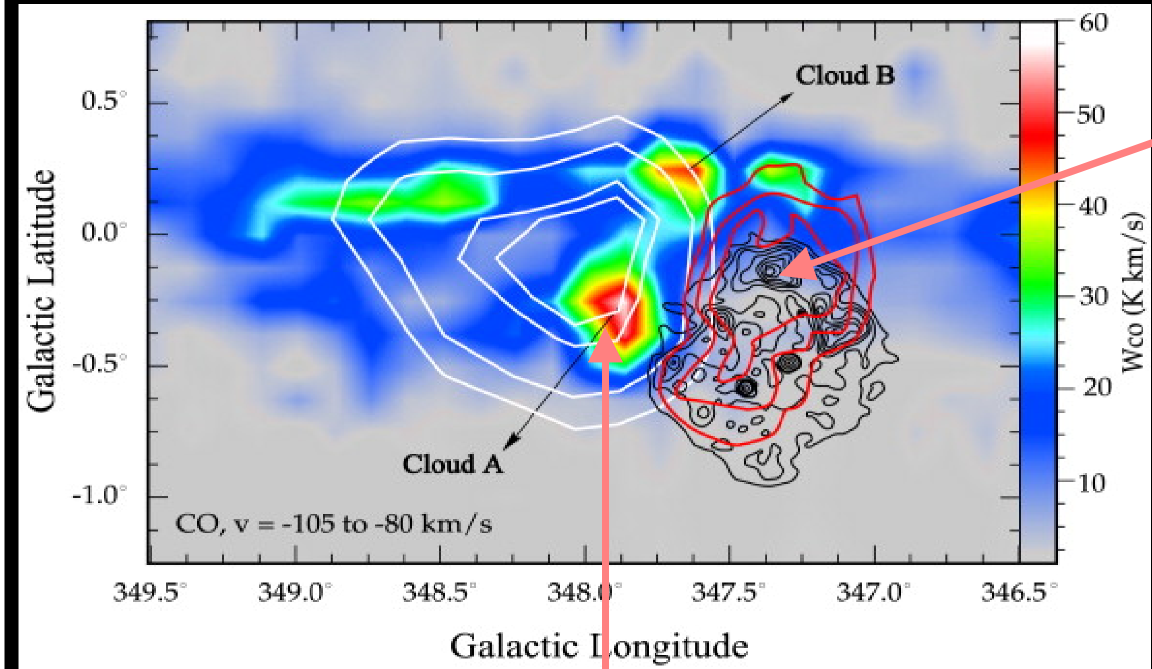
CO observation:

- CO is the best large−scale tracer of interstellar molecular gas
- 3 dense and massive clouds (**A, B, C**) seem to be associated with the SNR (based on the morphology)
- These 3 clouds are part of the same molecular complex of a Galactic arm located at ~ 6 kpc
- Enhancement of the CO(2−1)/CO(1−0) line ratio for **Cloud A** => the shock front of the SNR is interacting with **Cloud A**

=> D_{SNR} ~ 6 kpc

Slane et al. 1999, ApJ, 525, 357

High energy γ–ray emission



TeV emission (CANGAROO):

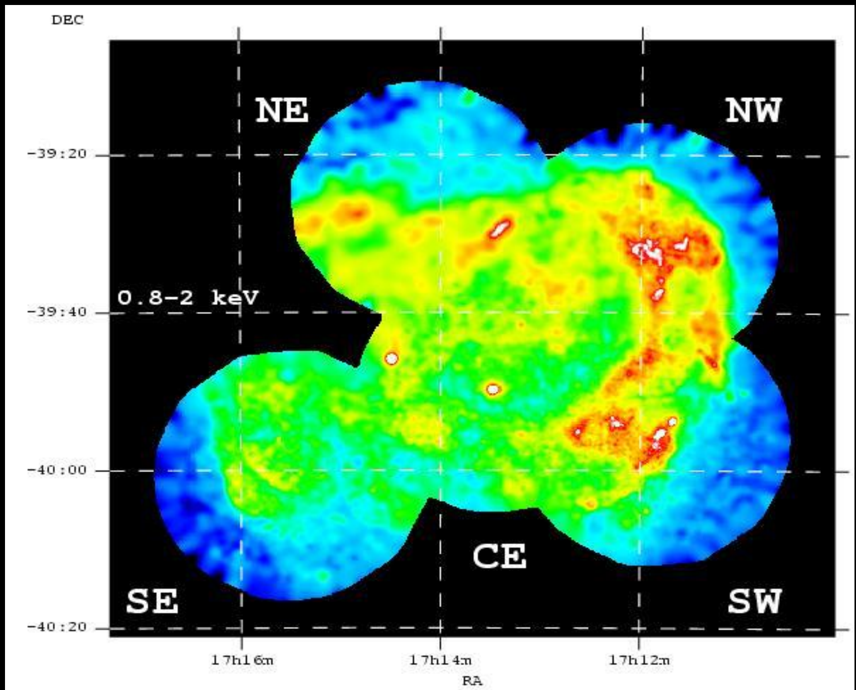
- Found in the brightest NW rim of G347.3−0.5
- First, explained as arising from accelerated electrons through the IC process
- Afterwards, the TeV γ–ray spectrum was shown to be consistent with the π^0 decay process and any other mechanisms => TeV CR protons acceleration in SNRs!

GeV emission (EGRET):

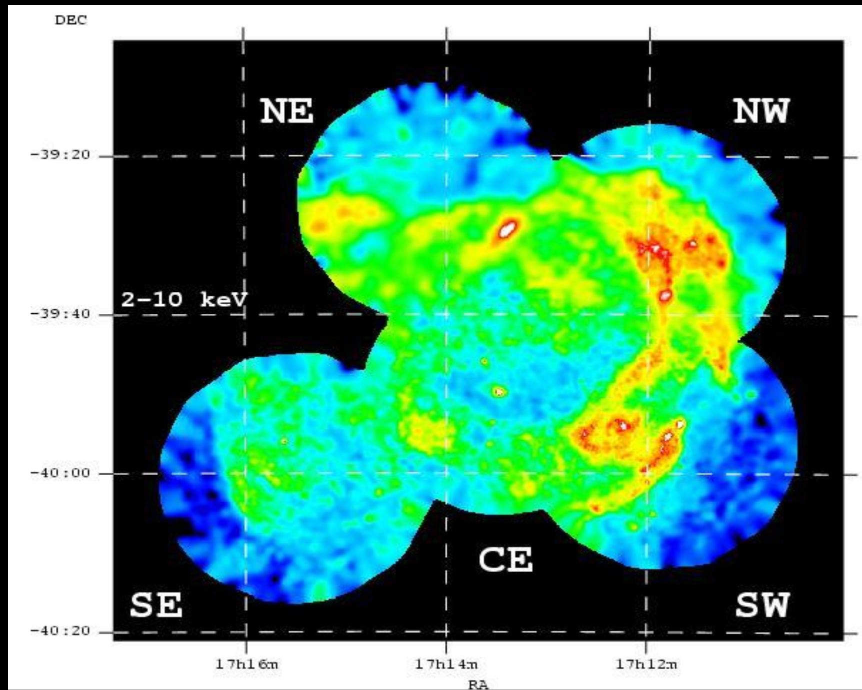
- Coincident with Cloud A
- Attributed to the interaction of nuclei with the ambient interstellar gas producing GeV γ–ray via the decay of neutral pions
=> G347.3−0.5 is a CR protons accelerator

Butt et al. 2001, ApJ, 562, L167
Muraishi et al. 2000, A&A, 365, L57
Enomoto et al. 2002, Nature, 416, 25
Reimer & Pohl 2002, A&A, 390, L43

XMM−Newton observations of SNR G347.3−0.5



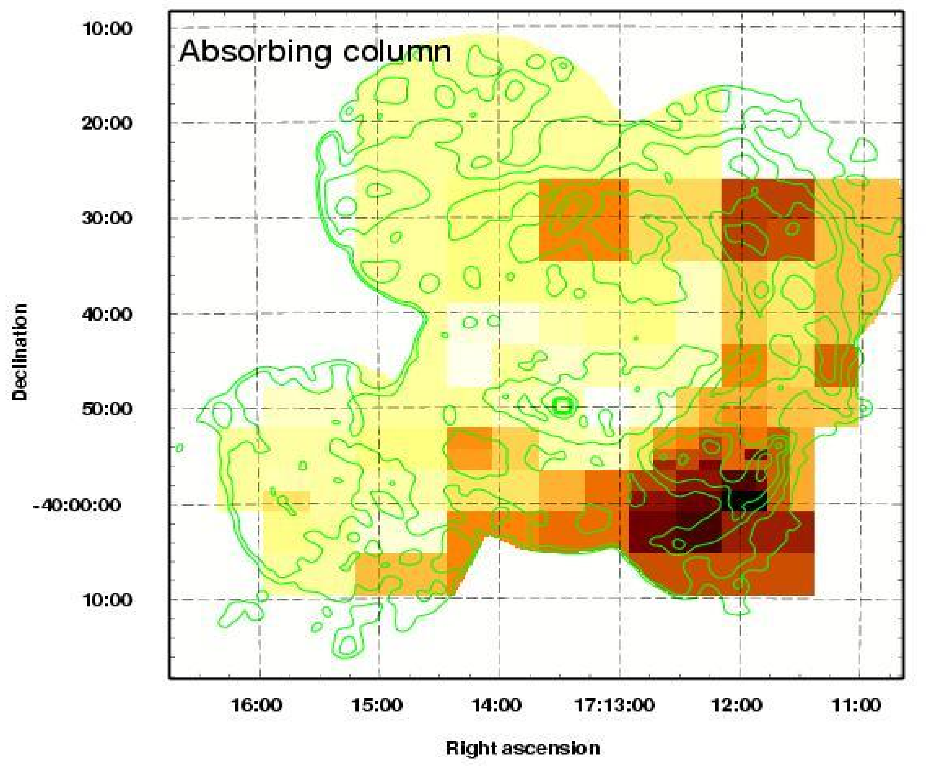
0.8−2 keV



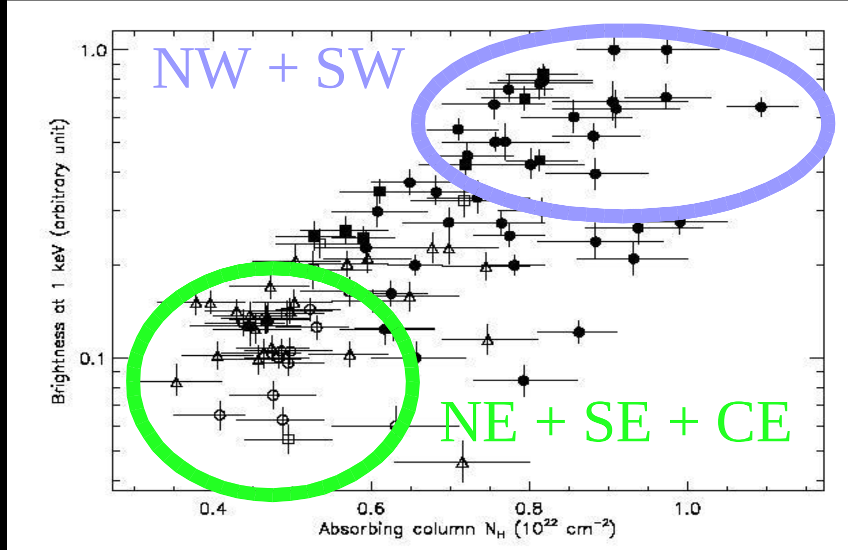
2−10 keV

- 5 pointings of 15 ks each observed by the 3 EPIC cameras (MOS1, MOS2, pn)

Variation of absorbing column over the SNR

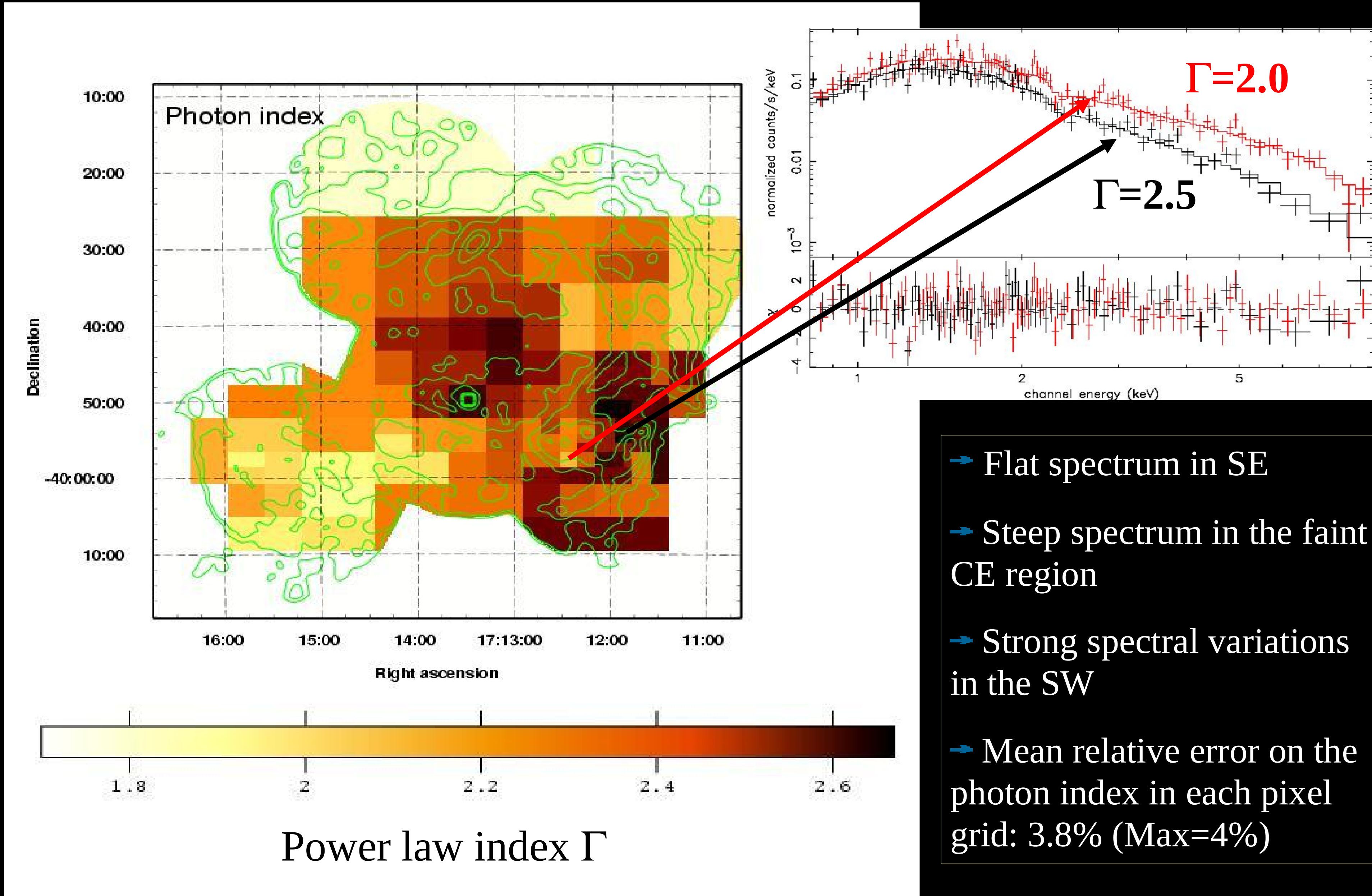


N_H in units of 10^{22} cm^{-2}



- Adaptive grid
(point sources removed)
- Extraction of the EPIC spectra
- Fit using a simple power law
- Mean relative error on the absorbing column in each pixel grid: 9% (Max=16%)

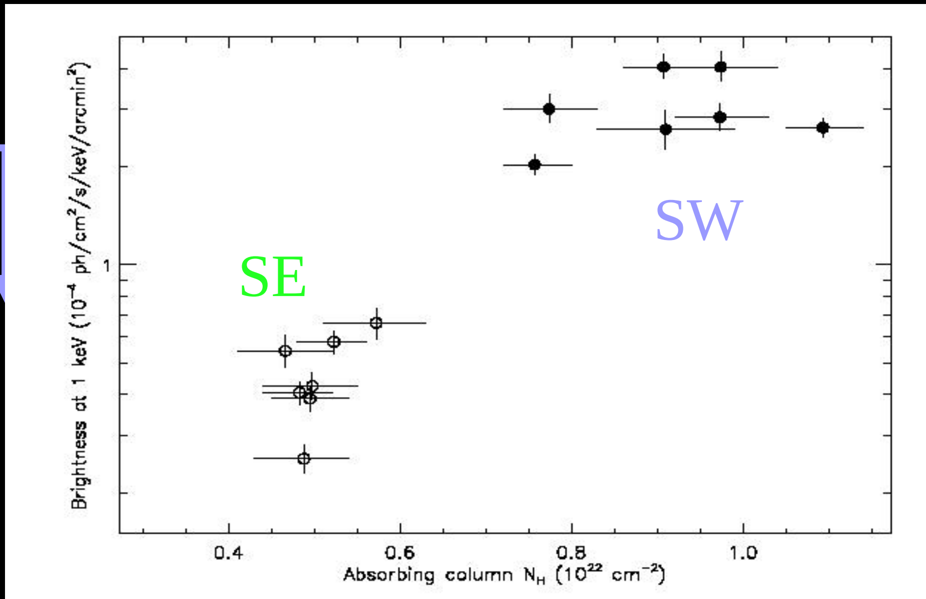
Variation of the Photon Index over the SNR

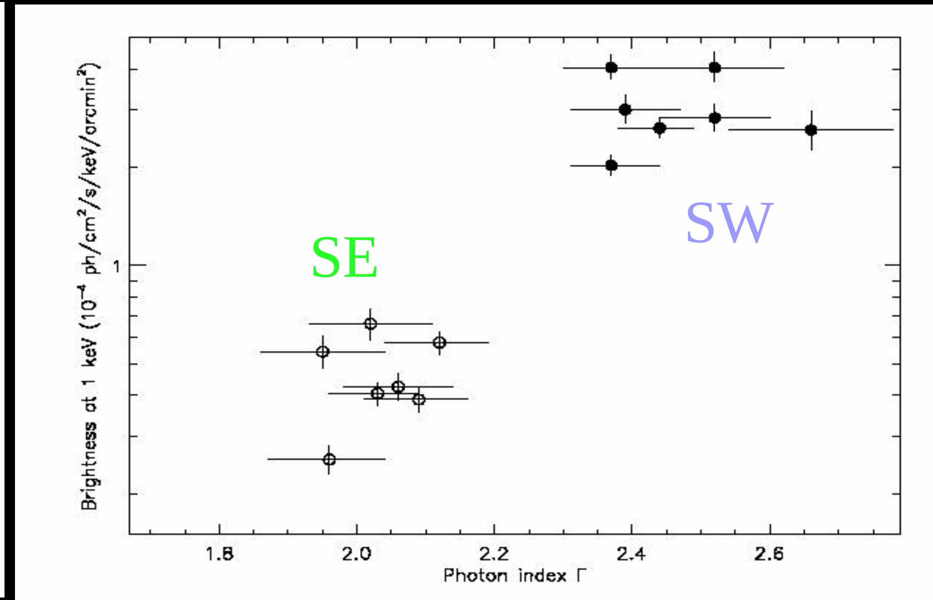


- Flat spectrum in SE
- Steep spectrum in the faint CE region
- Strong spectral variations in the SW
- Mean relative error on the photon index in each pixel grid: 3.8% (Max=4%)

Interaction with molecular clouds

X−ray brightness at 1 keV



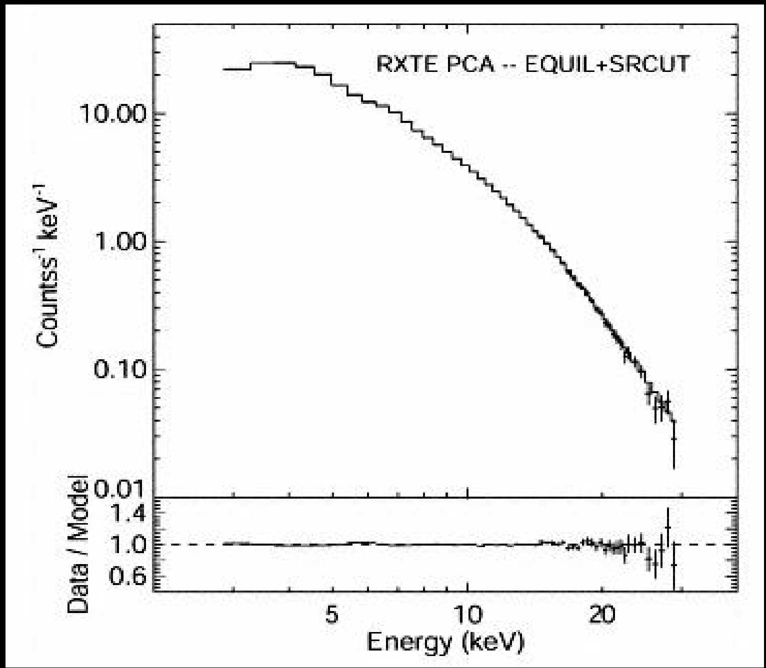


Absorbing column

Photon Index

- Conversely to SN 1006, the brightest regions have the steepest spectrum
- These regions are those where the SNR shock front impacts molecular clouds

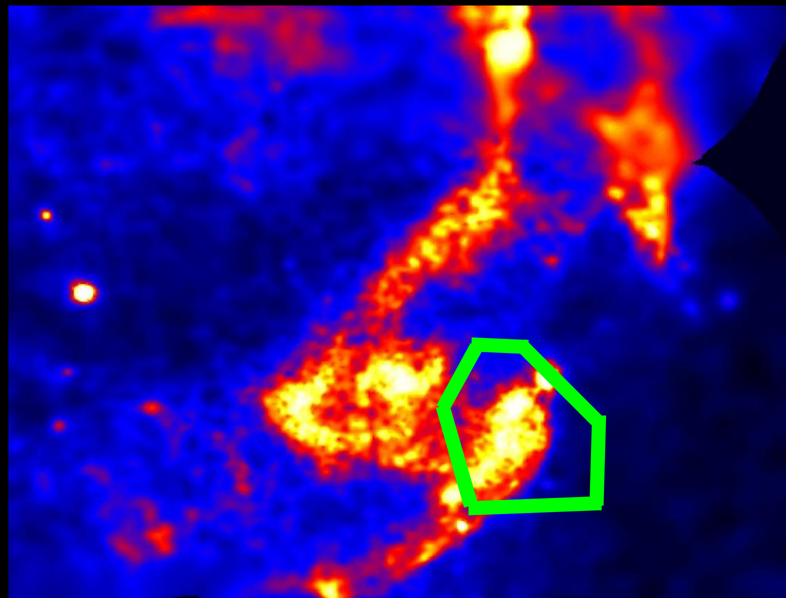
G347.3−0.5 above 10 keV



RXTE PCA spectrum of G347.3−0.5 integrated over the entire SNR

Pannuti et al. 2003, ApJ, 593, 377

- X−ray emission observed till 30 keV with RXTE but spectrum integrated on very large areas
- No (spectro−) imaging available
- Blend of regions with strong spectral index variations

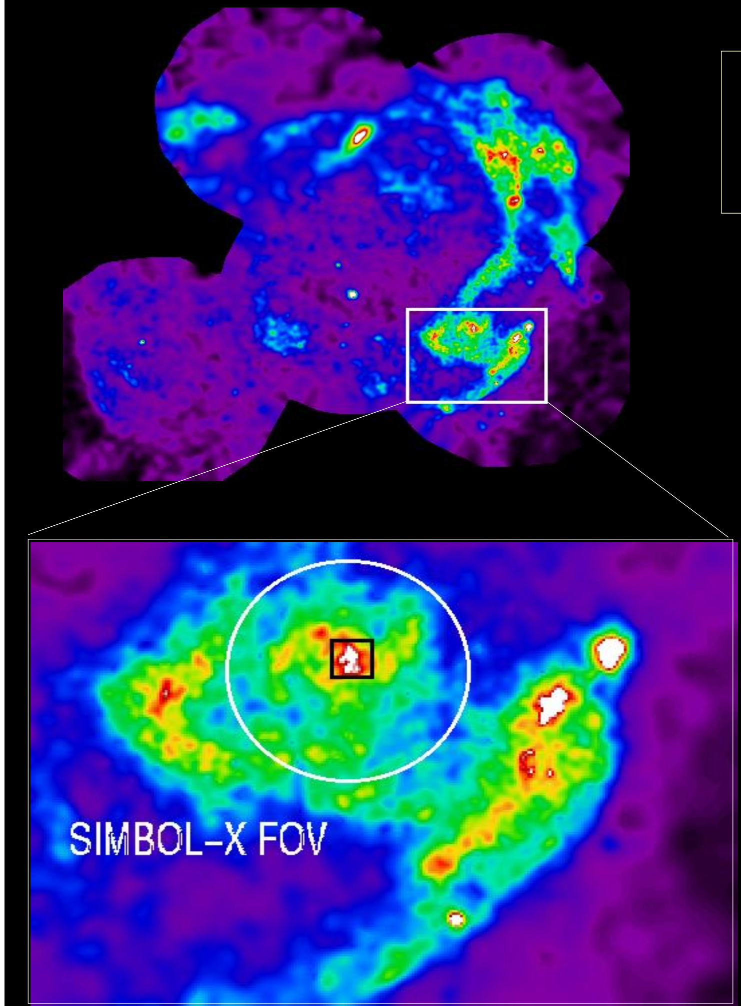


INTEGRAL contours (**20−40 keV**) superimposed on the XMM−Newton image (**2−10 keV**) of G347.3−0.5

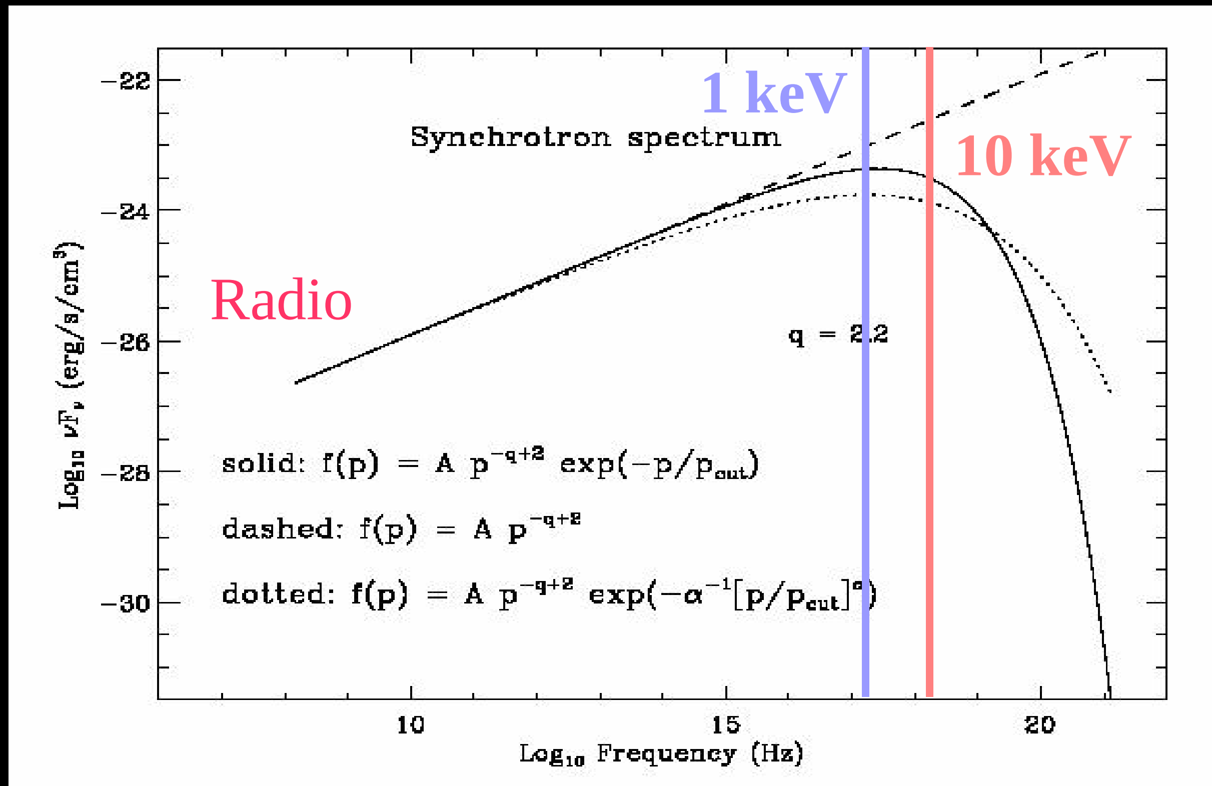
Courtesy of R. Terrier

- Detection with INTEGRAL: could be a point source...

SIMBOL−X simulated spectra



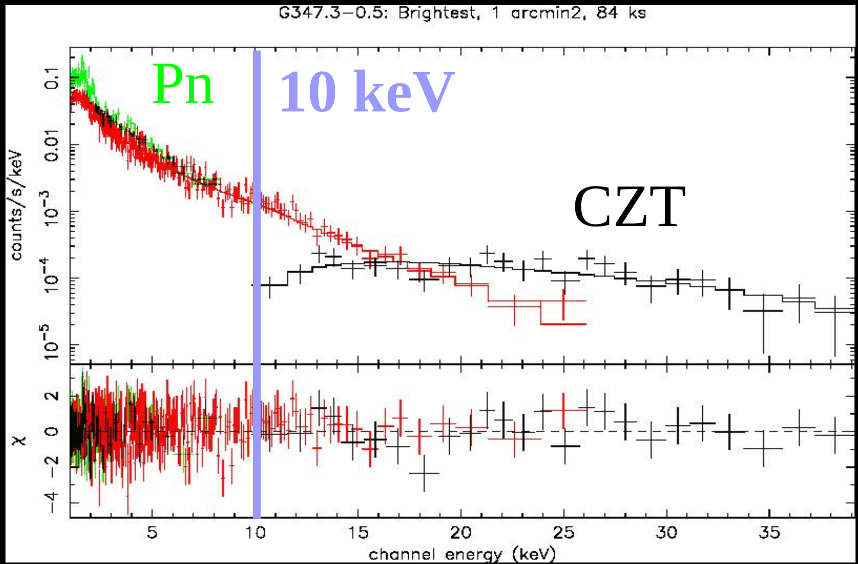
- By exploring the X−ray emission above 10 keV, we obtain constraints on the most energetic electron population



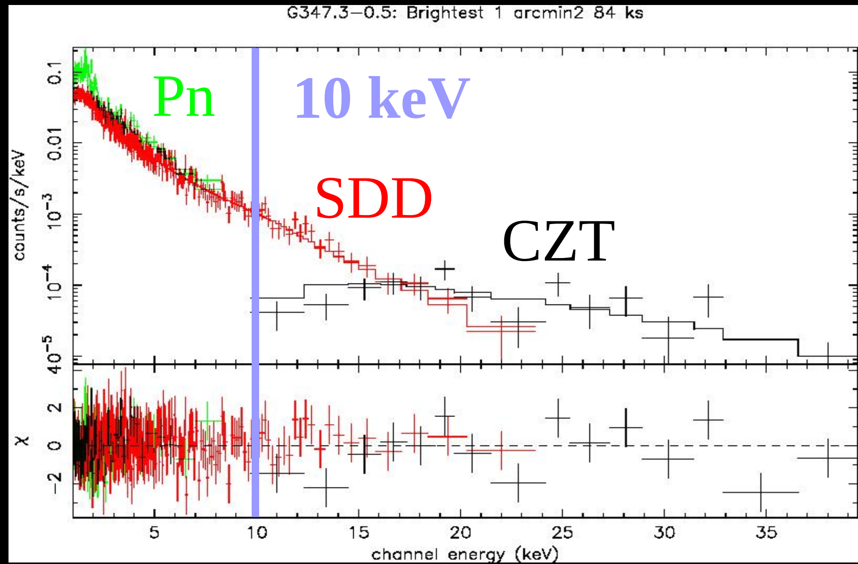
Synchrotron spectra as a function of the electron distribution function

SIMBOL−X simulated spectra

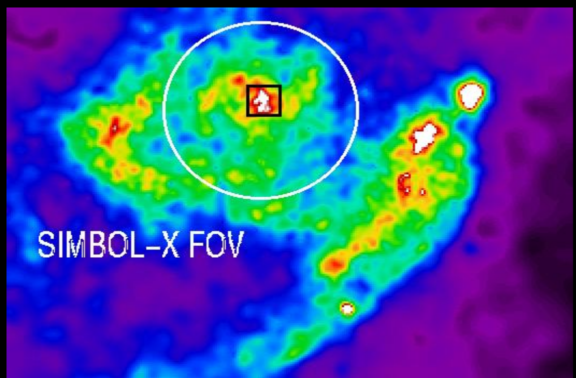
84 ks



Power−law



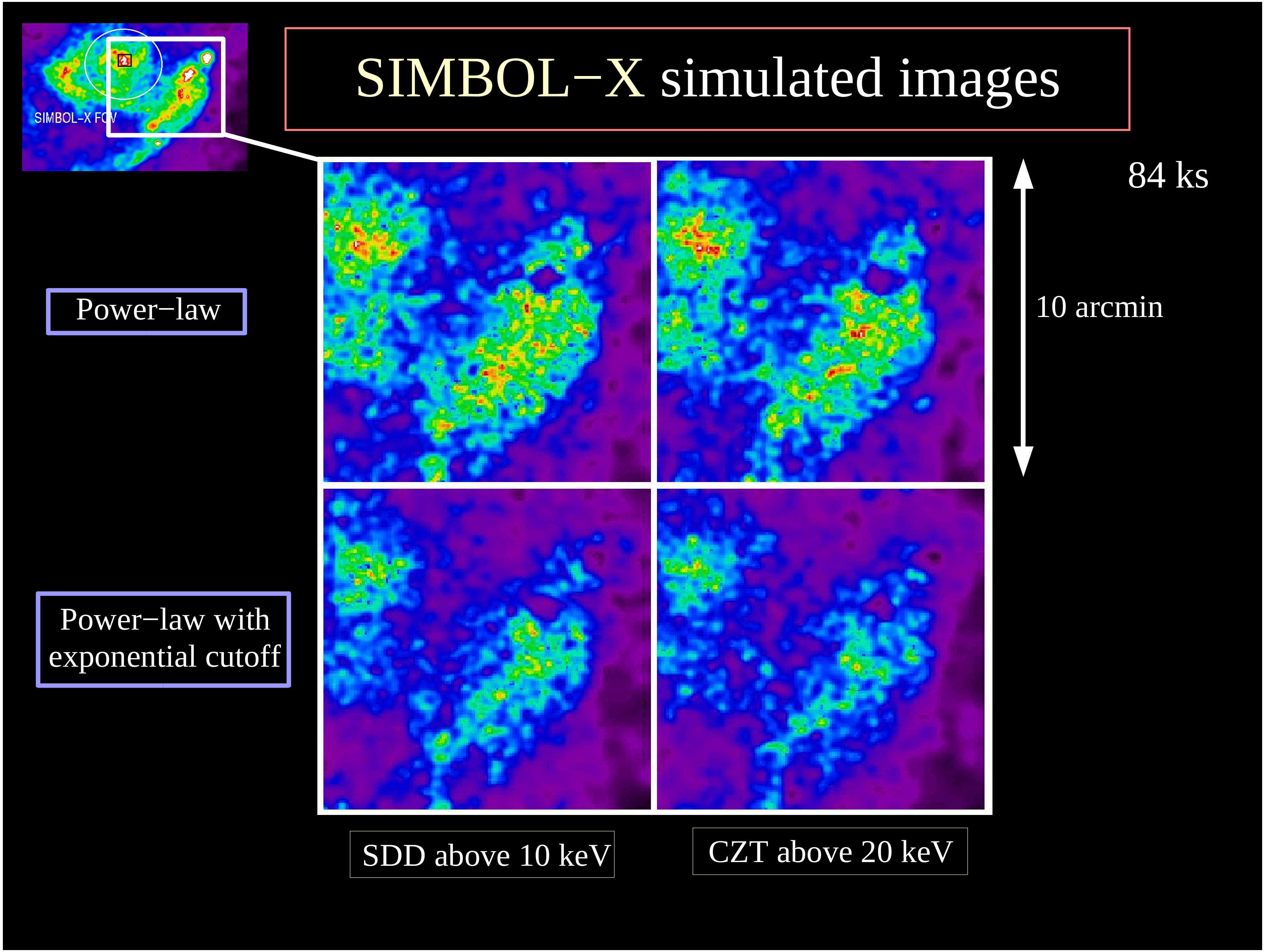
Power−law with exponential cutoff



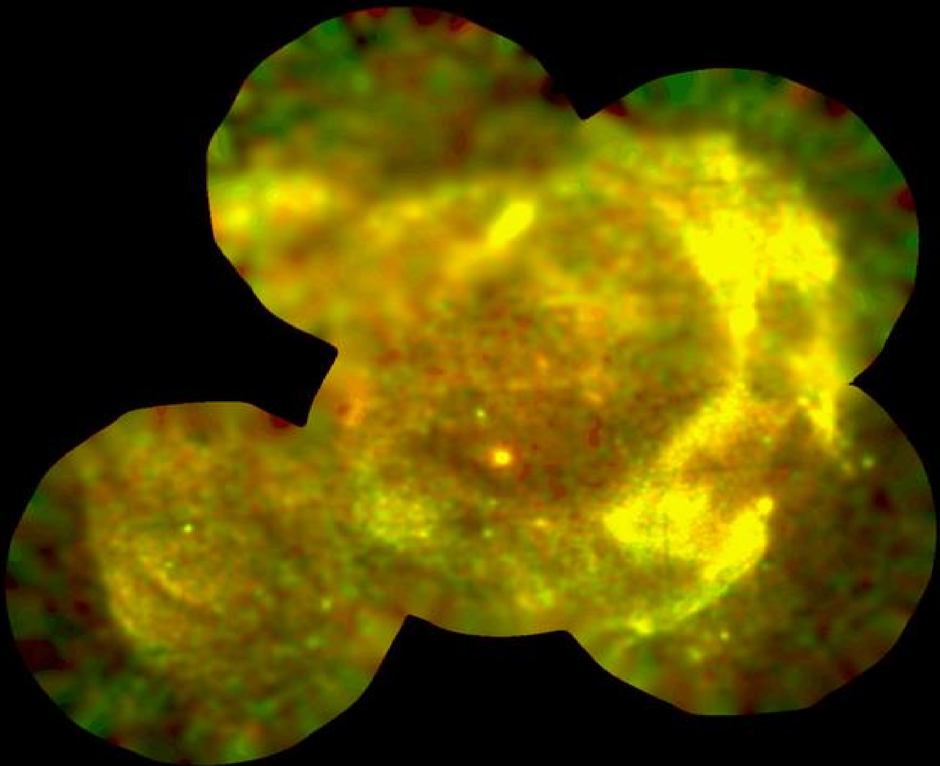
Cutoff frequency

- XMM−Newton: 3.1×10^{17} Hz (2.0 − 4.1)
- SIMBOL−X: 2.9×10^{17} Hz (2.4 −2.9)

(1 keV = 2.4×10^{17} Hz)


SIMBOL−X simulated images
SIMBOL−X FOV
Power−law
Power−law with exponential cutoff
84 ks
10 arcmin
SDD above 10 keV
CZT above 20 keV

CONCLUSION



SIMBOL−X will allow us to:

- Constrain the rolloff frequency which is related to the maximum energy to which electrons are accelerated
- Constrain the decrease of the synchrotron spectrum which is important to constrain the shape of the electron spectrum
- Study the spatial variations of the rolloff frequency and then the geometry of the particle acceleration process
- To have a good knowledge of the synchrotron spectrum which is crucial with regards to the GeV and TeV γ−ray emissions

Cosmic−ray acceleration in SNRs

- SNRs are considered as primary source of Galactic cosmic−rays with energies up to the knee of the CR energy spectrum (around 10^{15} eV)

- Diffusive shock acceleration, in which particles gain energy from scaterring back and forth across the shock, has been suggested as the most probable acceleration mechanism in SNR shocks

- Observational evidence for the production of high energy particle in SNRs came mainly from the fact that SNRs emit synchrotron radiation in the radio band

- The major observational break−through came only recently with the detection of nonthermal X−ray emission from the shell−type SNR SN 1006

  Koyama et al. 1995, Nature, 378, 255

- Two more remnants with dominant nonthermal X−ray spectra have been identified: Vela Junior and G347.3−0.5

  Slane et al. 2001, ApJ, 548, 814

Interaction with molecular clouds

Results:

- XMM−Newton has revealed an unexpected strong absorption in the SW with regard to the morphology of the CO distribution at 6 kpc
- This is confirmed by the good correlation between the absorbing column density derived from the X−rays and the optical brightness
- The CO and HI observations show tha the infered cumulative absorbing column densities are in excellent agreement with the X−ray findings in different places of the remnant provided that the SNR lies at a distance of 1 kpc
- There are a few clues indicating that the shock front is impacting molecular clouds among wich is the positive correlation between the X−ray absorption and and the X−ray brightness

Cassam−Chenaï et al. 2004, A&A, on the stove