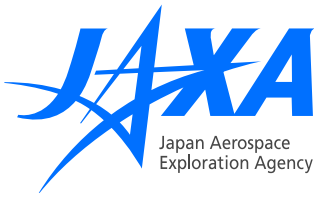


Hitomi-related Geant4 activities

Masanobu Ozaki (ISAS/JAXA) and Valentina Fioretti (INAF)

By courtesy of Masanori Ohno (Hiroshima-U), Hirokazu Odaka (RIKEN) and Shin Watanabe (ISAS/JAXA)

Outline

Japan Aerospace Exploration Agency

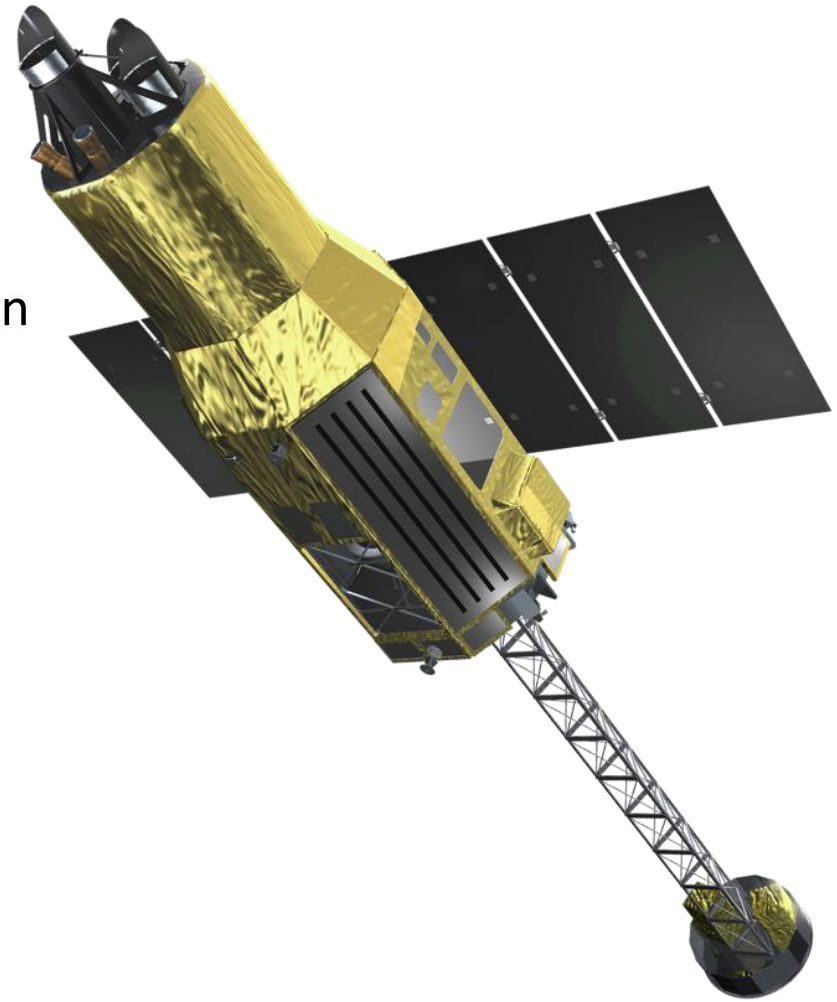
Geant4-related Hitomi scientific activities are introduced.

"Scientific"?—Detector response, background or astrophysical simulations☺

1. Hitomi introduction
2. Detector science—responses and backgrounds
   - Background simulation of **SXS**
   - **HXI** background simulation, including activation
   - GRB localization by **SGD**
   - Polarimetry performance of Si/CdTe Compton camera
   - X-ray polarization detection from Crab nebula by **SGD**
3. Astrophysical application
   - Resonance scatter in Perseus cluster core

Hitomi introduction

- 6th Japanese X-ray astronomy satellite (a.k.a., ASTRO-H)
- 1.7t mass, 14m length
- LEO of 550 km altitude, ~30 deg inclination angle
- Launched on 2016-02-17
- Lost due to attitude control accident on 2016-03-26
- All the detectors worked as expected



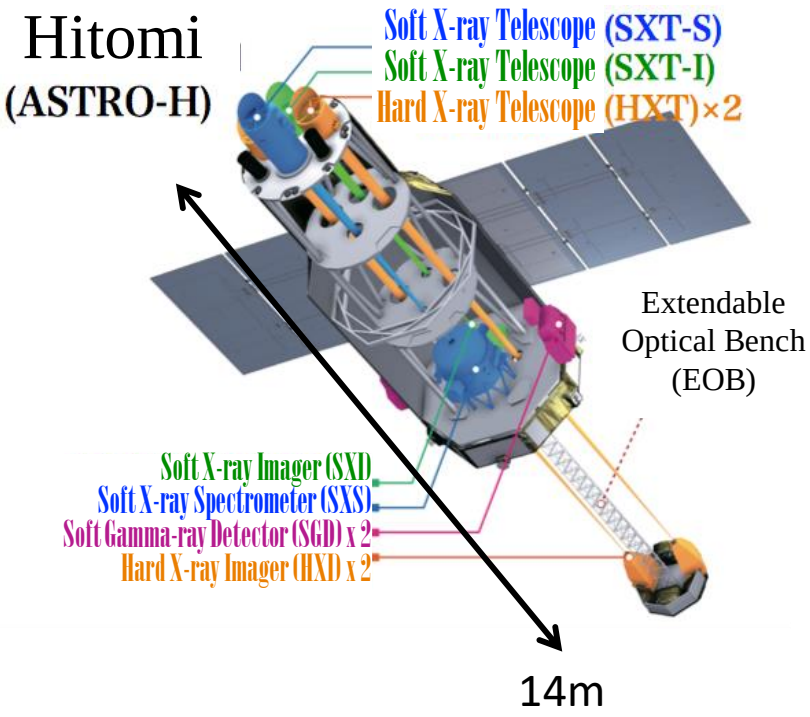
Hitomi Detectors

Four kinds of detectors:

- **SXS**: X-ray micro calorimeter, with a few hundred kg aluminum alloy
- **HXI**: Si-strip and CdTe-pixel cameras for > 10 keV band, also sensitive for activation and atmospheric neutron backgrounds
- **SGD**: Compton kinematics telescopes with BGO active shields for a few hundred keV band
- **SXI**: X-ray CCD camera with thick Al shield for < 10 keV band (← not presented this time)

Different photon detection mechanism, complicated structure and sensitivity for background radiation

-> **MC simulation is essential**



Detector science—responses and backgrounds

- Background simulation of **SXS**
- **HXI** background simulation, including activation
- GRB localization by **SGD**
- X-ray polarization detection from Crab nebula by **SGD**

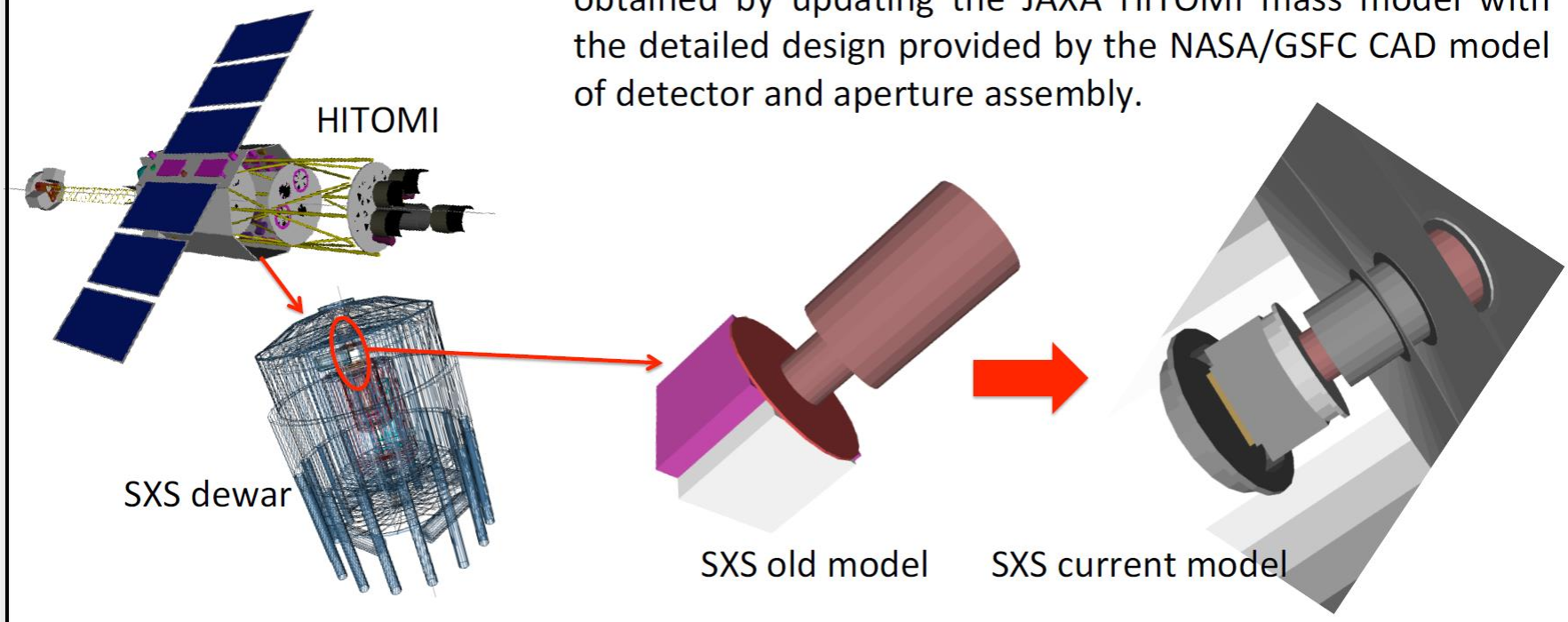
Background simulation of SXS

Fioretti+ (2018) simulated the BGDs using Geant4

(from the poster at "Exploring the Hot and Energe2c Universe: 2° ATHENA Science Conference", 24 – 27/09/2018, Palermo, Italy)

2. Geant4 Mass model

The Geant4 mass model of the SXS system has been obtained by updating the JAXA HITOMI mass model with the detailed design provided by the NASA/GSFC CAD model of detector and aperture assembly.



Background simulation of SXS (cont'd)

Japan Aerospace Exploration Agency

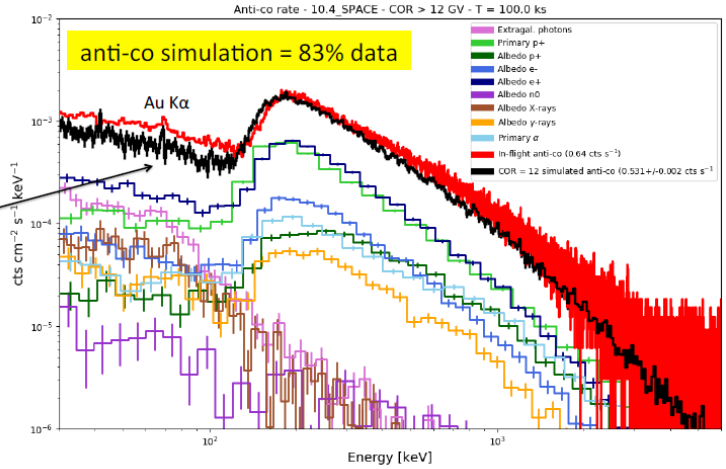
Fioretti+ (2018) simulated the BGDs using Geant4

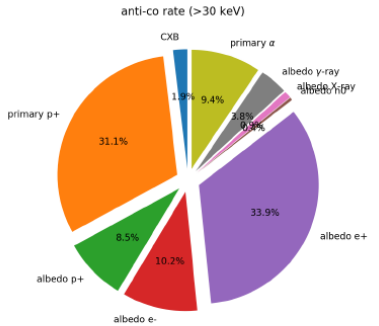
5. Non X-ray Background: Simulation vs in-flight data

Anti-co:

- real rate = 0.64 cts s^{-1}
- simulated rate = 0.531 ± 0.002 cts s^{-1}

- the MIP peak at ≈200 keV is reproduced with high accuracy;
- missing low energy (<100 keV) events:
  - we found no influence of SAA low energy electrons - not simulated - on the real NXB
  - GCR protons and albedo positrons contribute to 65% of the anti-con rate



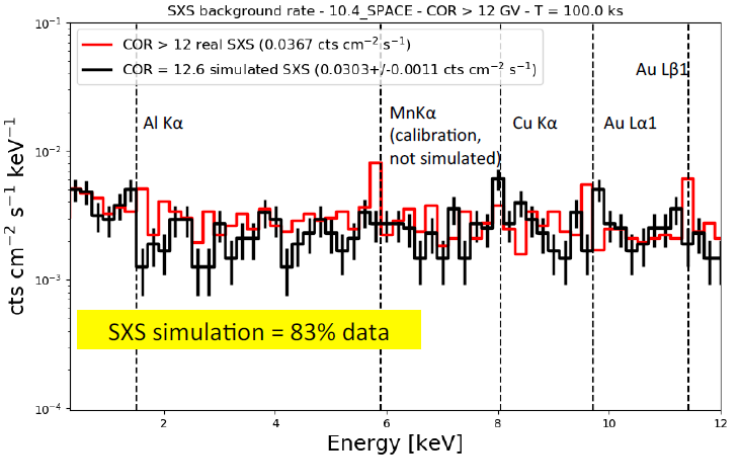


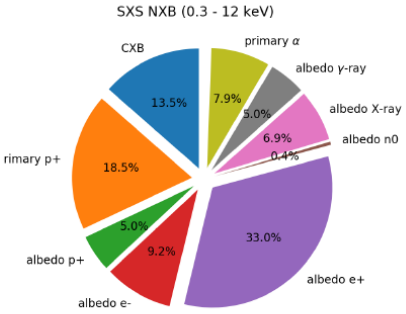
Primary background source contribution to the total anti-co rate.

SXS [0.3 – 12 keV]:

- real NXB = 0.037 cts cm^{-2} s^{-1}
- simulated NXB = 0.030 ± 0.001 cts cm^{-2} s^{-1}

- X-ray fluorescence lines are reproduced by the Geant4 simulation (not including the MnKα calibration source)
- the errors on the real NXB spectrum are of the order of the simulated ones
- albedo particles and photons contribute to 60% of the residual NXB



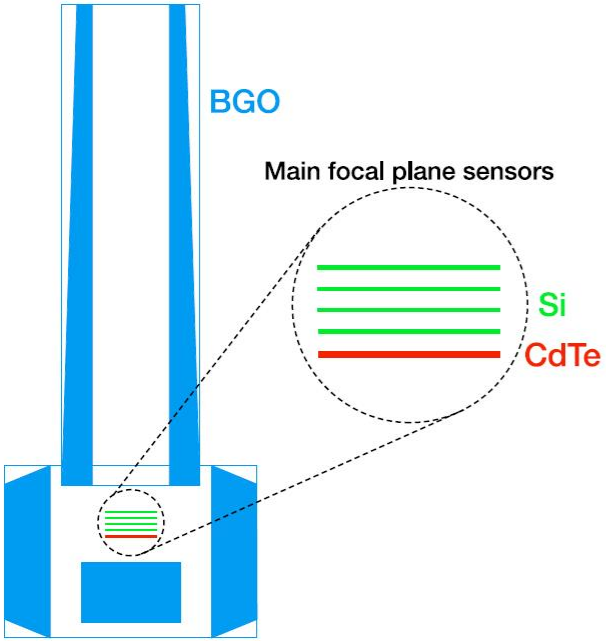


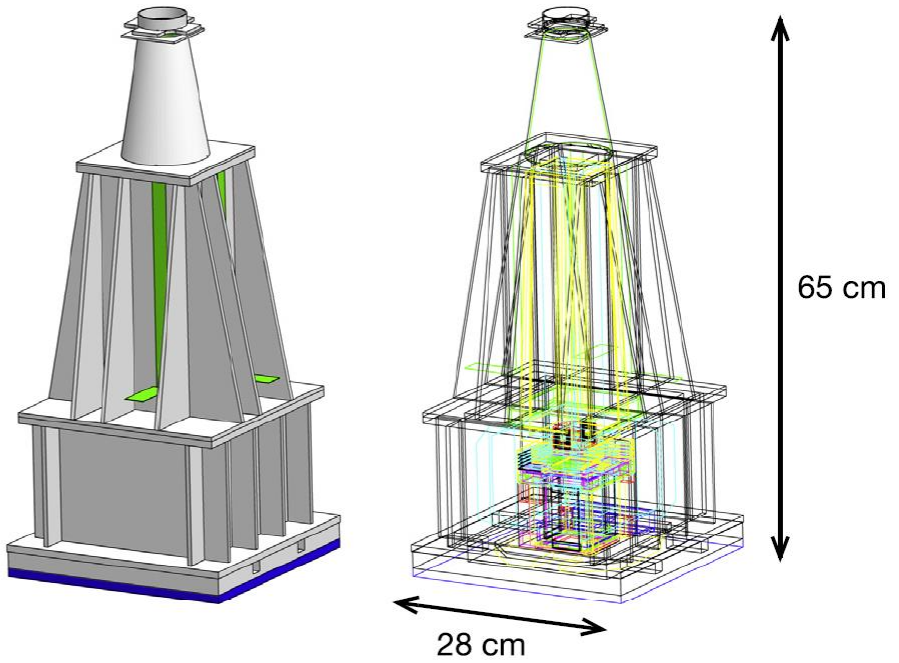
Primary background sources contribution to the total NXB.

HXI background simulation

By courtesy of H.Odaka (RIKEN)

- Focusing imager of hard X-rays covering 5–80 keV
- The focal plane detector consisted of stacked double-sided strip detectors of Si and CdTe.
- High sensitivity thanks to thorough background rejection design using anti-coincidence and focusing with the Hard X-ray optics.

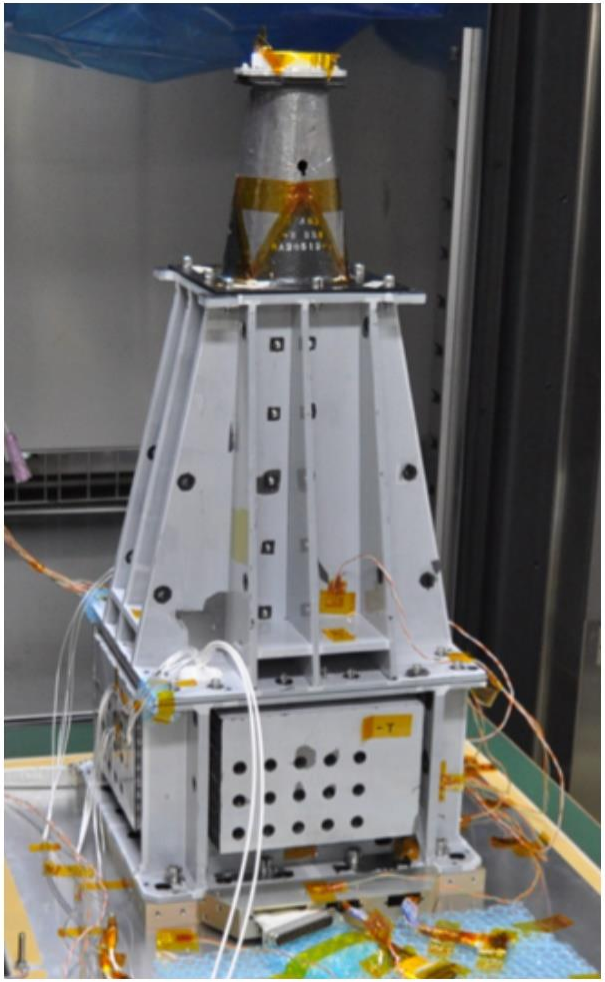




HXI background simulation (cont'd)

Japan Aerospace Exploration Agency

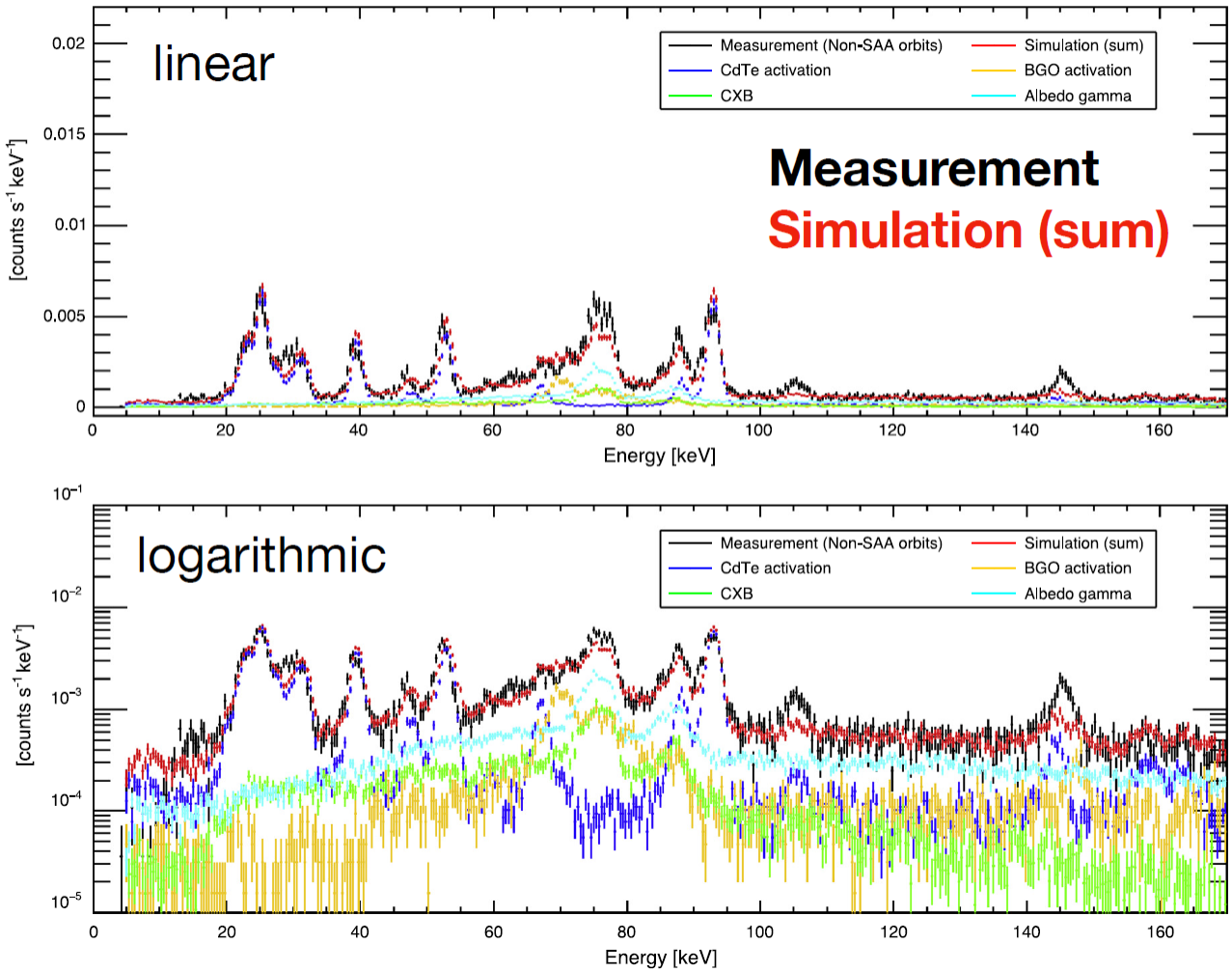
By courtesy of H.Odaka (RIKEN)



HXI background simulation (cont'd)

Japan Aerospace Exploration Agency

CdTe activation + BGO activation + CXB + albedo gamma rays



Non-SAA orbits

reproduced important lines

agreed well with the data including the continuum

By courtesy of H.Odaka (RIKEN)
doi: 10.1016/j.nima.2018.02.071

HXI background simulation (cont'd)

Japan Aerospace Exploration Agency

H.Odaka+ (2018)
doi: 10.1016/j.nima.2018.02.071

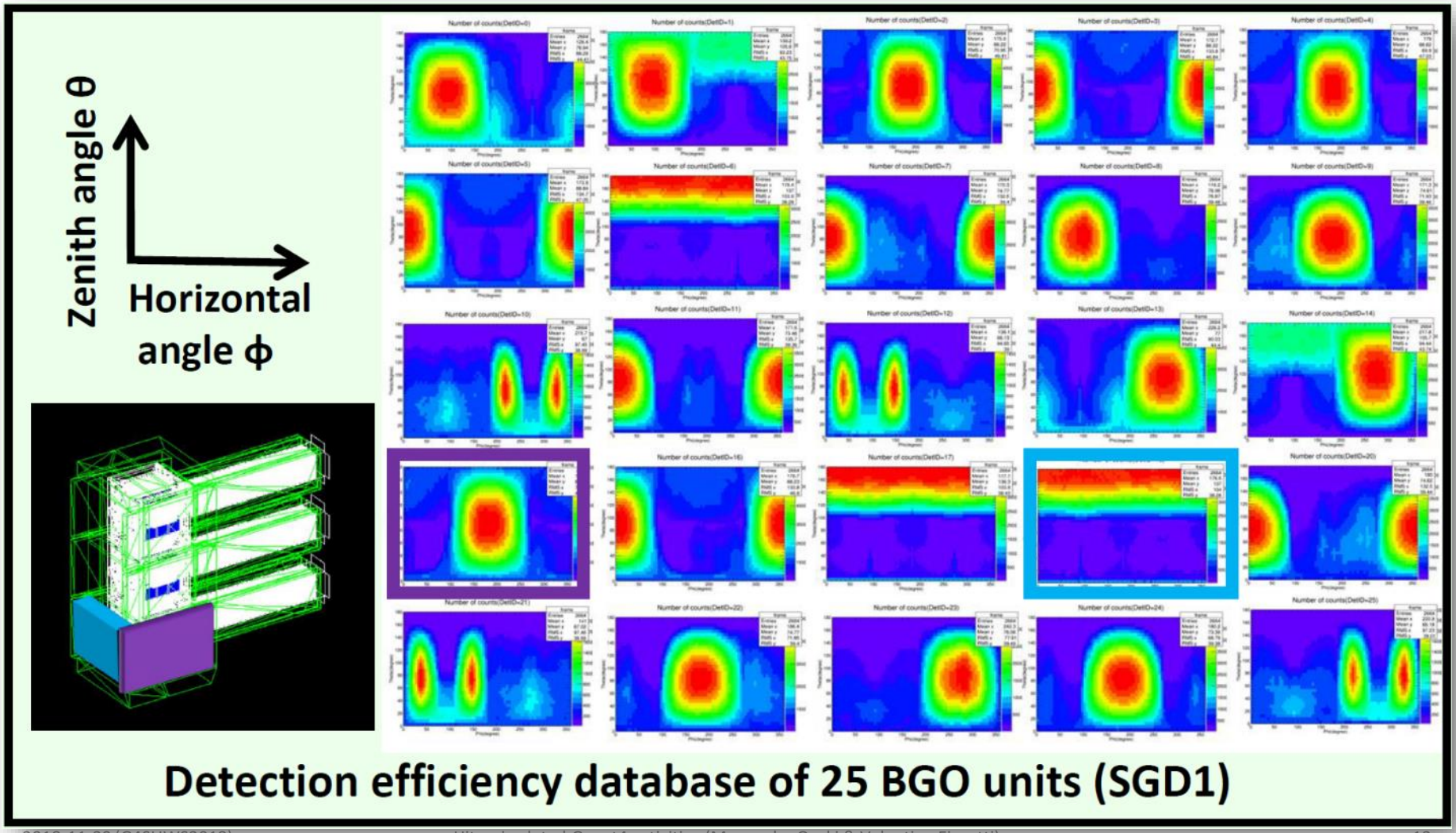
The Geant4 BGD simulation results:

- CdTe sensor:
  - radioactivation of the CdTe itself and the surrounding BGO active shields
  - leakage of photons (CXB and Earth's albedo gamma rays) through openings of the detector shields
- Si sensors:
  - insignificantly suffer from the activation
  - significant impacts from atmospheric neutrons

GRB localization by SGD

G4-based efficiency database of active shields:

By courtesy of M.Ohno (Hiroshima-U)

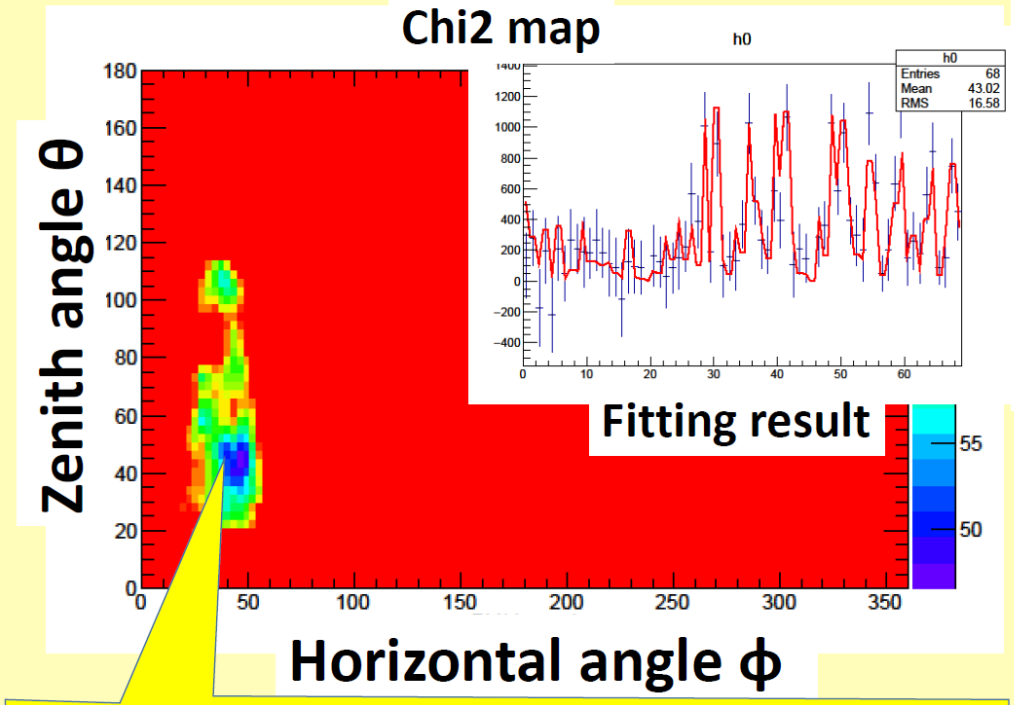


GRB localization by SGD (cont'd)

Succeeded in position localization, by Hitomi alone.

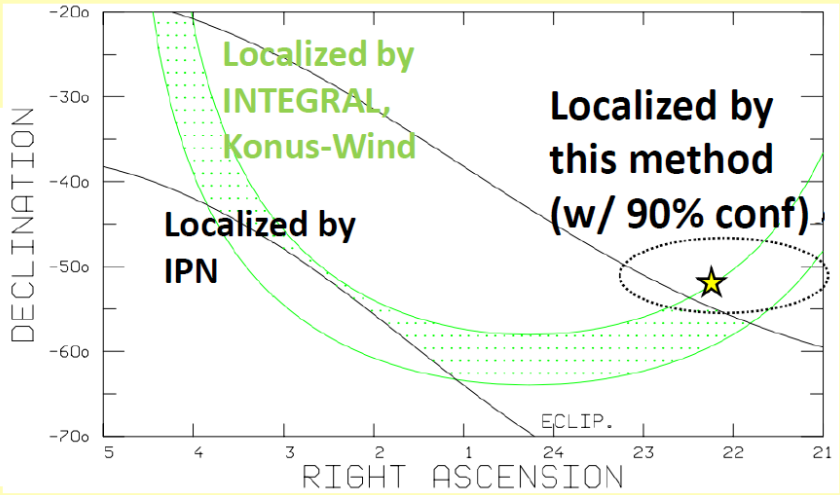
By courtesy of M.Ohno (Hiroshima-U)
Proceedings available.

③B: fitting method result



result (68% confidence level error) :
(Φ, θ)=(46.9°(+2.7,-2.0), 42.5°(+5.9,-2.6))

Localized detection of other detectors

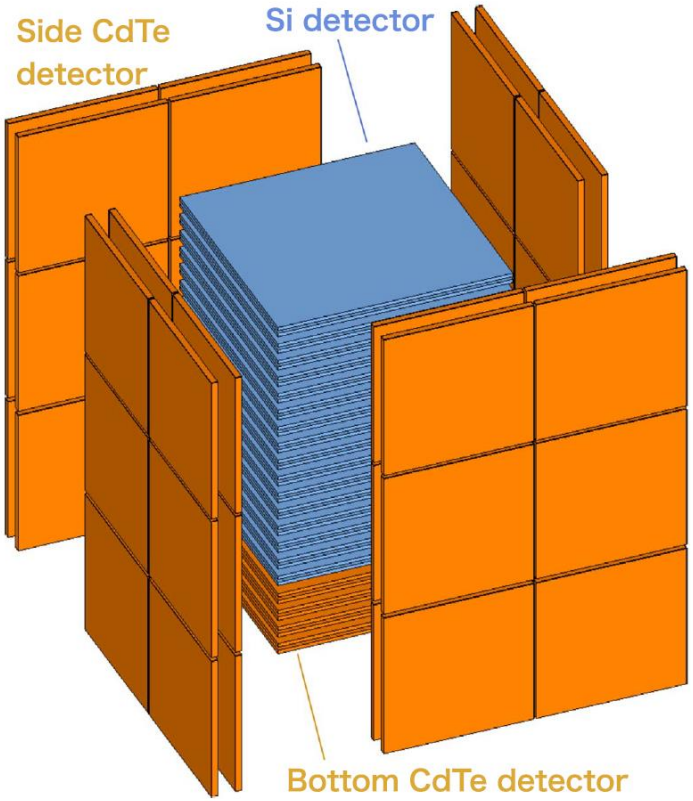


The result is roughly consistent with the detection localized by IPN
We estimated systematic error of this method by repeating simulation 100 times. As a result, it was about 10 degrees.

Polarimetry performance of Si/CdTe Compton camera

SGD can detect the gamma-ray polarization:

- Detection efficiency was modeled by Geant4 simulation.
- G4 model was tuned by beam-line calibration.
- Details are found in Katsuta+ 2016 (doi: 10.1016/j.nima.2016.09.057).



X-ray polarization detection from Crab nebula by SGD

Using the polarization response, [Watanabe+ 2018 (doi: 10.1093/pasj/psy118)] succeeded in detecting the X-ray polarization from Crab nebula.

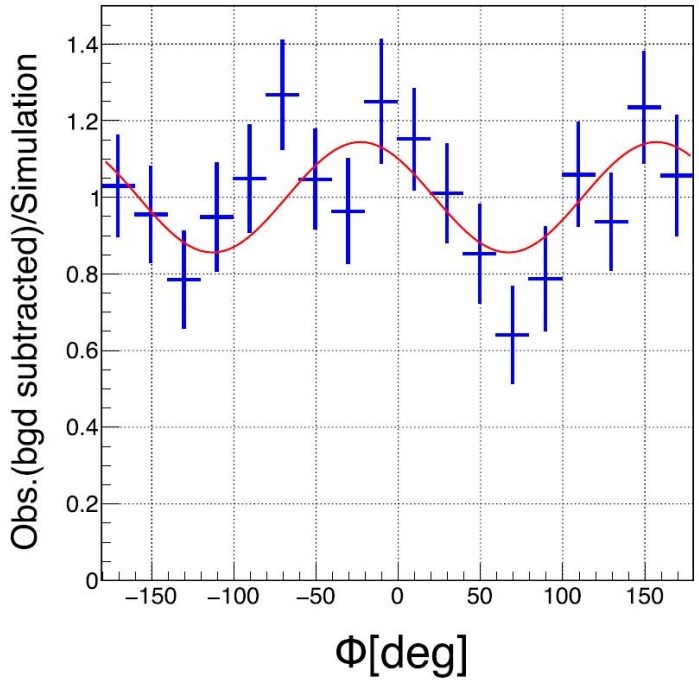


Fig. 17. Modulation curve of the Crab nebula observed with SGD. The data points show the ratio of the background-subtracted observation data to the unpolarized simulation data. The error bar size indicates their statistical errors. The red curve shows the sine curve function substituting the estimated parameters by the log-likelihood fitting.

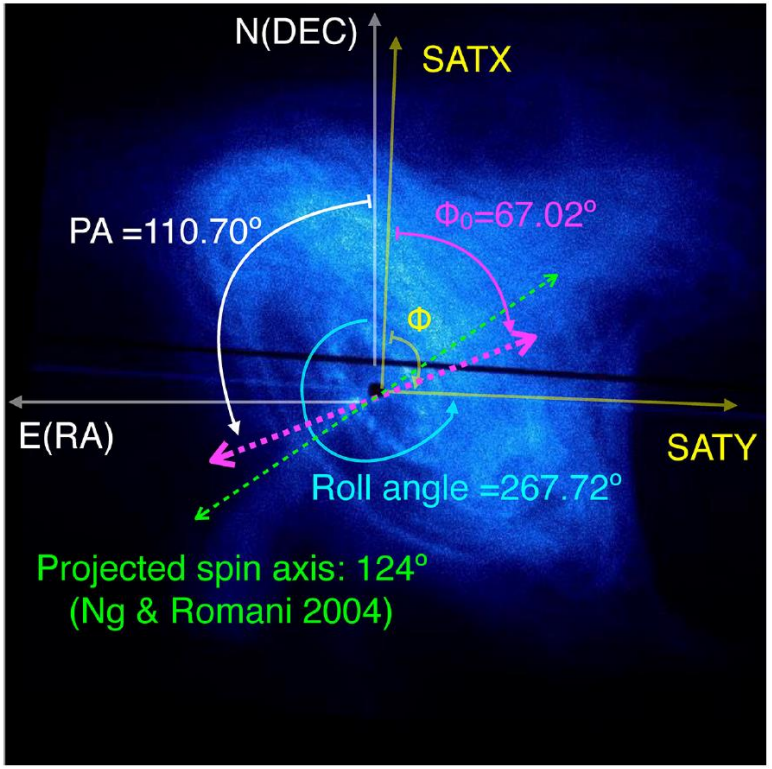


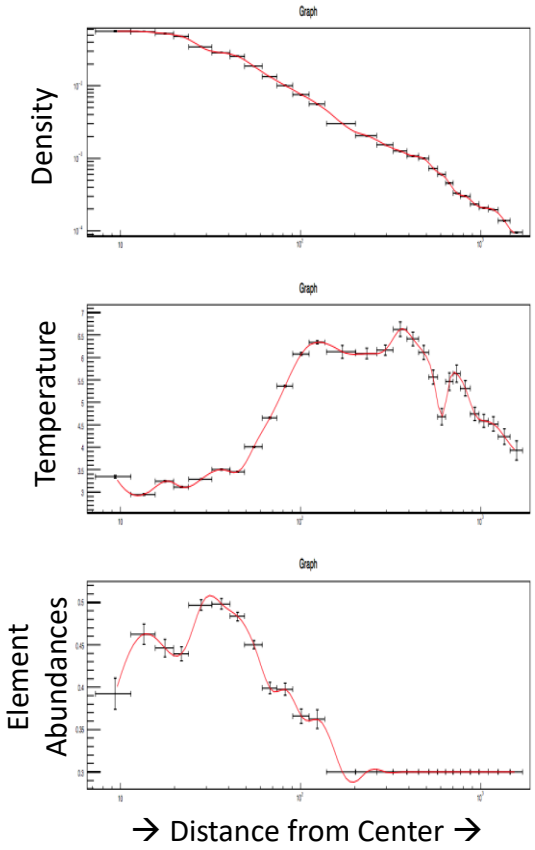
Fig. 18. Polarization angle of the gamma-rays from the Crab nebula determined by SGD. The direction of the polarization angle is drawn on the X-ray image of Crab with Chandra.

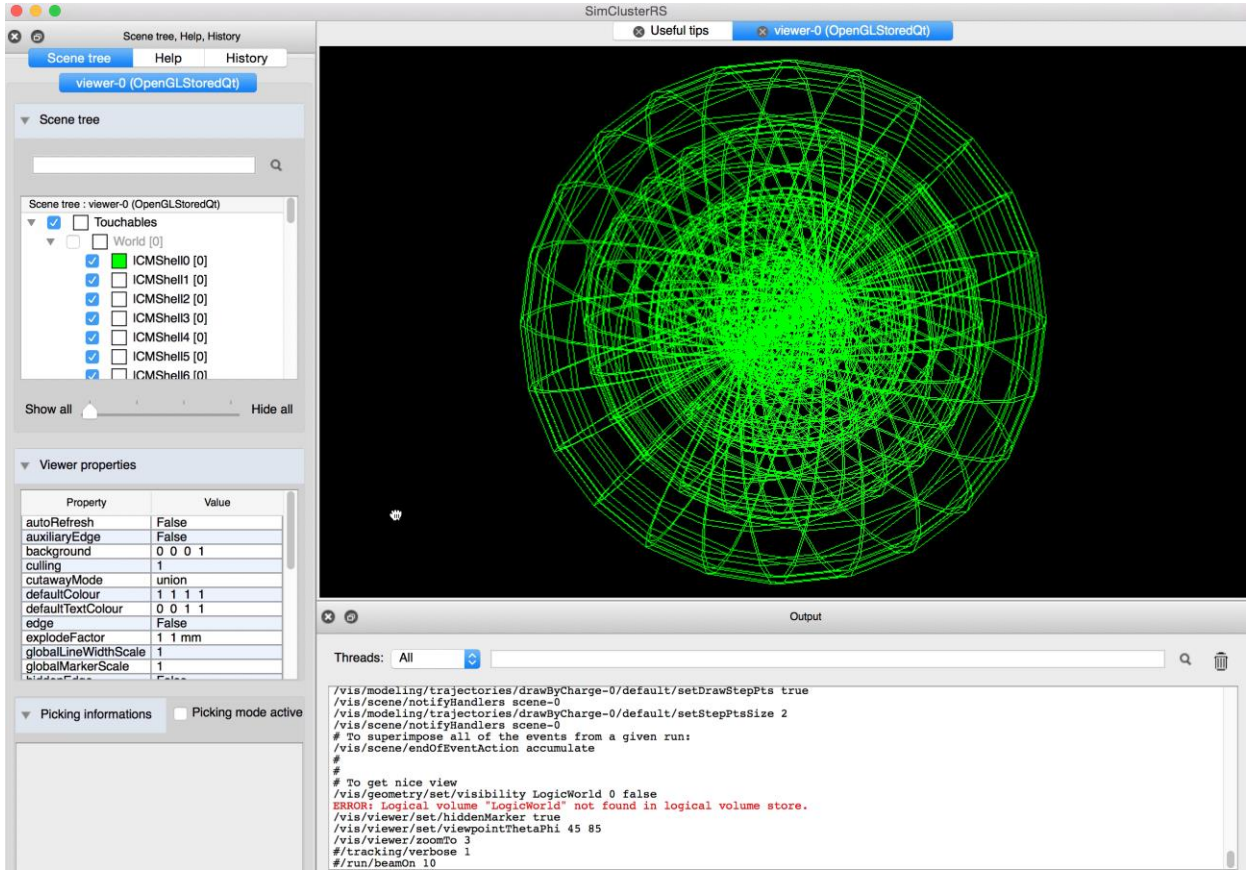
Astrophysical Simulation

Japan Aerospace Exploration Agency

- X-ray spectrum from Perseus cluster was computed based on Geant4 simulation and used for Hitomi data analysis (Hitomi collaboration 2018, doi: 10.1093/pasj/psx127).

By courtesy of M.Ohno (Hiroshima-U)





Conclusion

Hitomi worked only one month, but the team is still generating outputs, with helps by Geant4.

Thank you very much for listening!