The X-ray simulators for Suzaku/NeXT

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5th Geant4 Space Users' Workshop 2008
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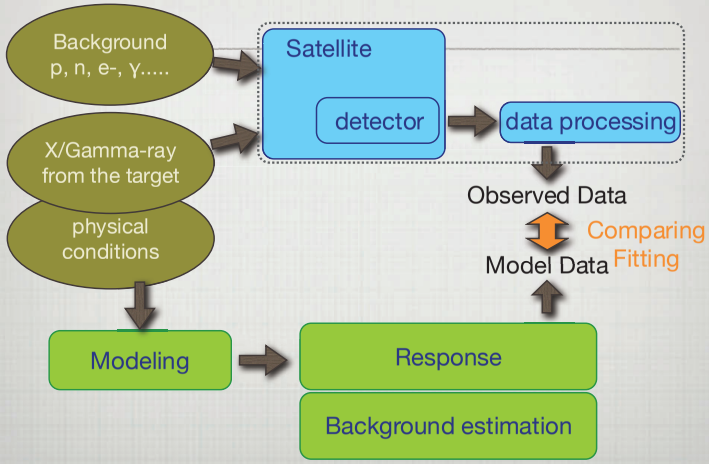
Data Analysis of X-ray Observation



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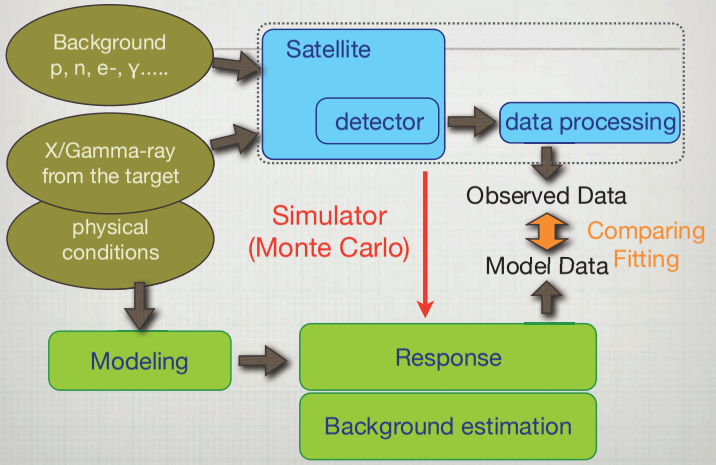
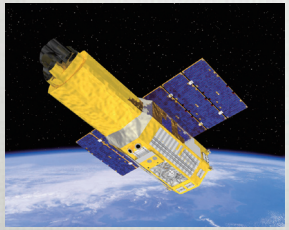


Suzaku(Astro-E2)

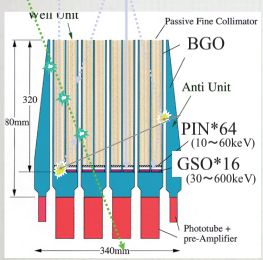


Suzaku: the 5th Japanese X-ray astronomy satellite

Launched on July 10, 2005

- XIS(X-ray CCD)
- HXD(hard X-ray detector)

Suzaku/HXD



HXD:
Si-PIN [2mm thick](10—70 keV)
GSO [5mm thick](40—600keV)

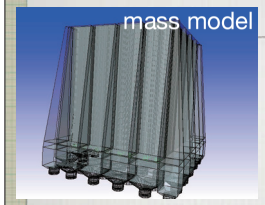
Shield BGO well + Fine Collimator
-> narrow FOV
-> Low Background
-> High Sensitivity

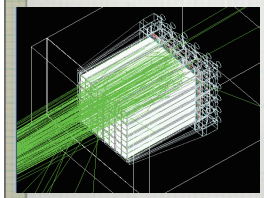
Complex Response

Anti Coincidence, GSO-BGO phoswitch

simHXD

simHXD-> Full Simulator of HXD





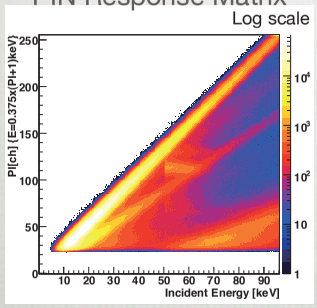
γ, energy, direction
↓
Mass Model → MC simulation based on Geant4
↓
energy deposit-> signal
↓
Make Event Packet On board event selection → simAE
↓
On board event selection → simDE
↓
On ground event selection (same code as pipeline) → HXDgrade → simulation data

our original framework (Ozaki et al. IEEE TNS 2006)

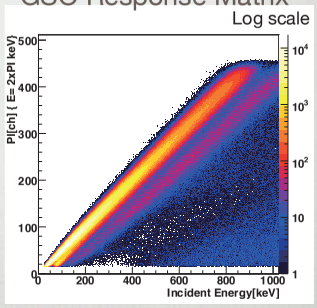
HXD Response

HXD(PIN & GSO) responses constructed with simHXD
distributed to world wide Suzaku users
physical process: G4LowEnergyEM

PIN Response Matrix



GSO Response Matrix



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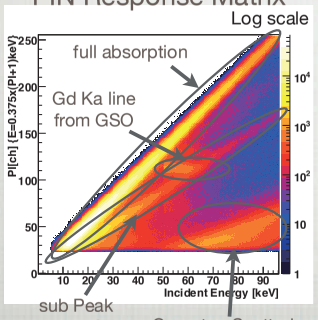

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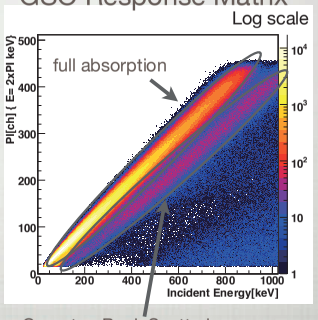
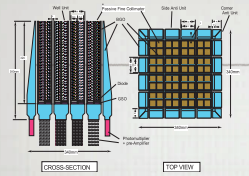


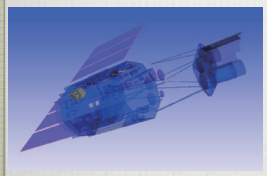
simHXD WAM



WAM: Wide All-sky Monitor
20 Large Volume BGO

Shield
GRB Detection & Spectroscopy
Bright Source Monitor

50 keV —5 MeV



Absorption and scattering of
solid Ne dewar, panels, solar array
panel, ...

Response <- Constructed GRB by GRB

~70 GRBs have been analyzed with the simulator.

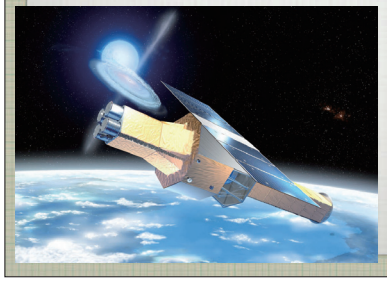
NeXT

New exploration X-ray Telescope [NeXT] (2013)

At Present, Pre-Project phase

We have constructed some prototype MC simulators.

Using prototype responses -> Science Topic
Detector Design



In Suzaku case,
after FM design almost finished,
Geant4 use started.

We plan to use Geant4
simulations for FM design
of all science instruments

NeXT/SGD

SGD: Soft Gamma-ray Detector [50(10)–600 keV]
advance the concept of HXD (Low background)

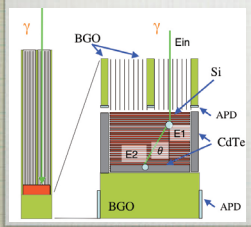
Compton camera inside a well-type shield

using Compton reconstruction-> Background reduction

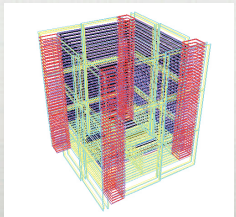
Compton camera -> Si-Pad and CdTe-Pad

for Gamma-ray response: G4LowEnergyEM+G4LECS(Kippen's talk)

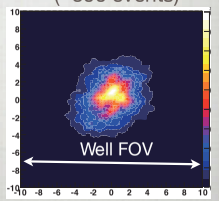
Concept of SGD



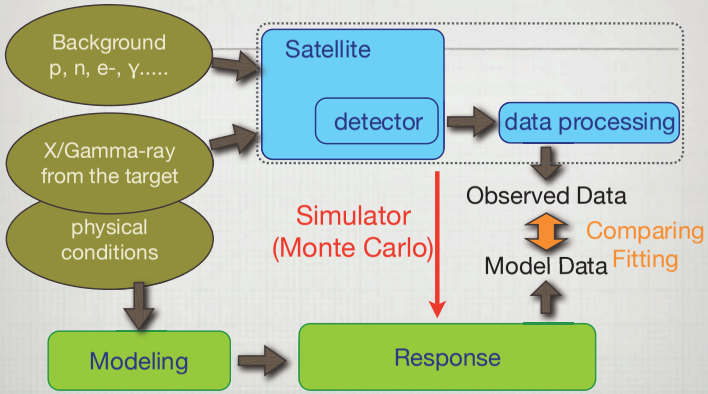
Mass Model of
a Compton Camera part



511 keV image
(~500 events)



Another Use



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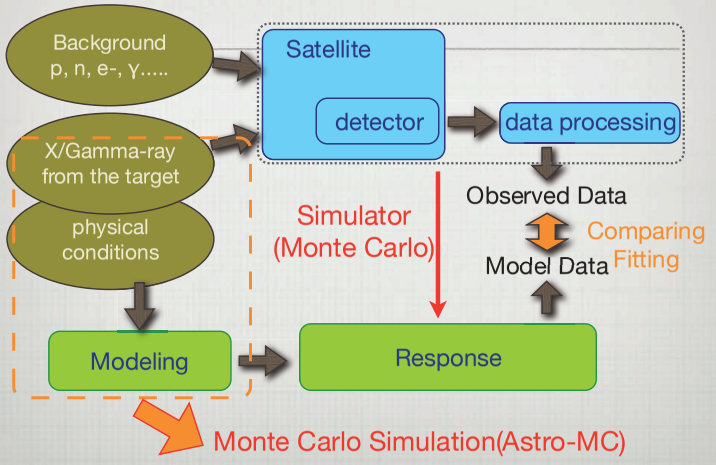
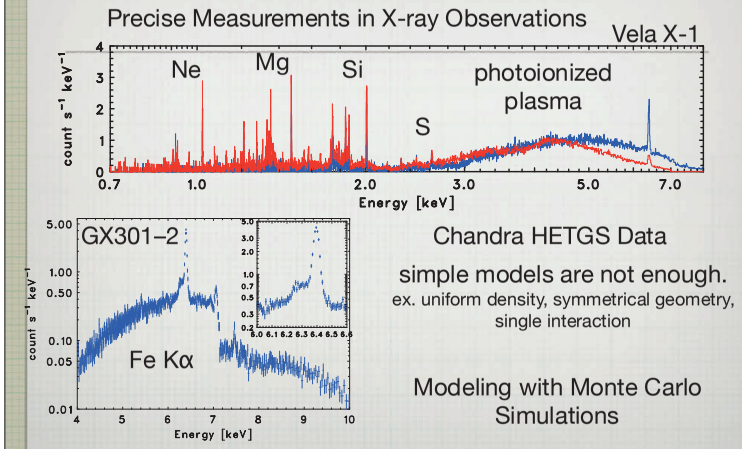


Precise Observations

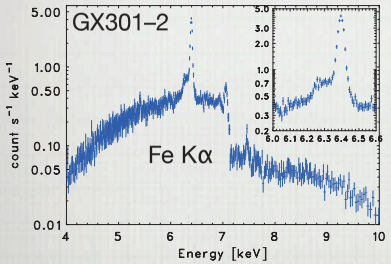


Geant4 and Astro-MC

Issues

- ☐ Large Scale (10^{10}cm -- >10^{20}cm)
  - ☐ no need to take care
  - ☐ scalable (geometry, physical process)
- ☐ Physical Process
  - ☐ In some cases, need new physical processes (G4 physical processes ≠ physical condition in space)
  - ☐ flexible

Ex.1: Direct Evidence of Compton Scattering



Compton Shoulder

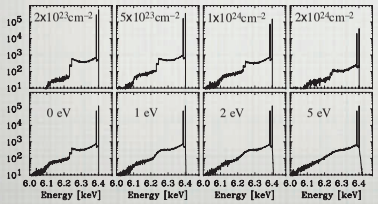
Fe Kα X-ray photons are Compton-scattered.

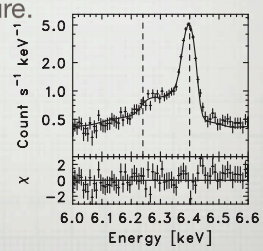
MC for a Dense Cloud

S. Watanabe et al. 2003 ApJL 597 pp. L37-L40

An X-ray source (neutron star) surrounded by a cloud
Compton Scattering process
H atoms are fully ionized and electrons have a temperature.

Simulation Results of Fe $K\alpha_1$, $K\alpha_2$

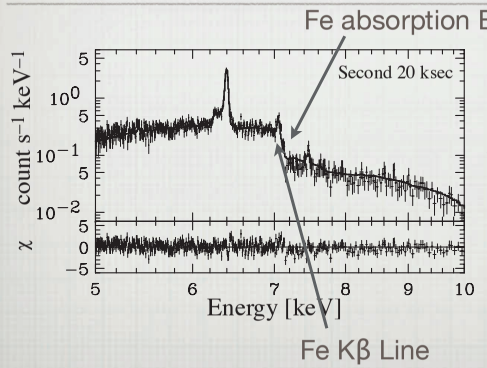




NH = (1.20+0.35–0.13)×$10^{24}$$cm^{-2}$
kTe < 3.4 eV

Whole spectrum

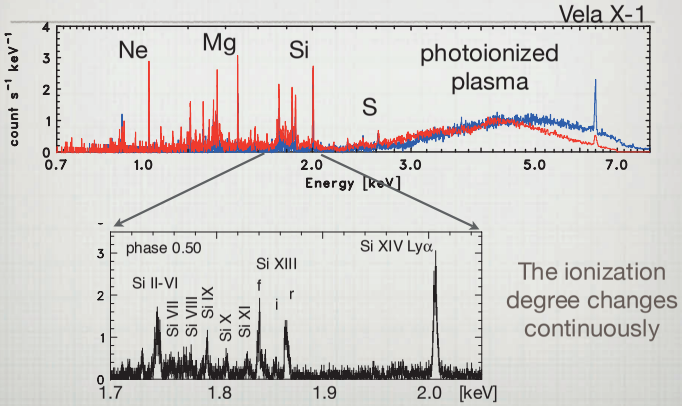
MC Model and Observed Data



An X-ray source surrounded by a cloud

reproduce the whole observed spectrum

Ex.2: Many Emission Lines from Plasma



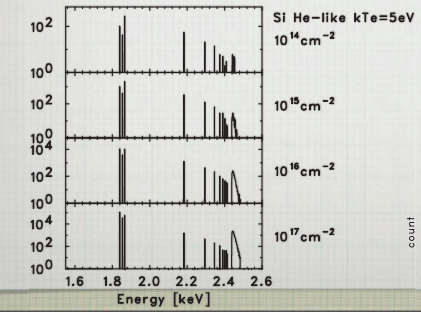
The ionization degree changes continuously

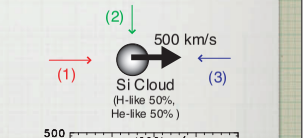
Physical Process Code for X-rays in Photoionized Plasma

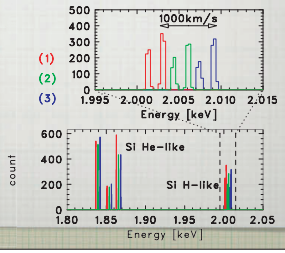
New Physical Processes

S. Watanabe et al. 2006 ApJ 651 pp.421-437

Photoionized Materials(C,N,O,Ne,Mg,Si,S,Ar,Ca,Fe)
H-like, He-like-> Photoionization(Recombination), Photoexcitation(Cascade)
Li-like to neutral-> Photoabsorption (crosssection and edge energy depend on the ionization stages.)
Compton Scattering
Doppler shift (Stellar Wind [100-1000 km/s])

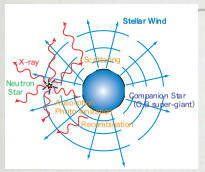






X-ray simulation in Photoionized Plasma

S. Watanabe et al. 2006 ApJ 651 pp.421-437



apply to Vela X-1 (neutron star high mass X-ray binary)

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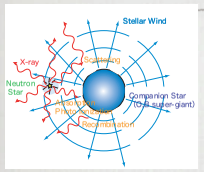

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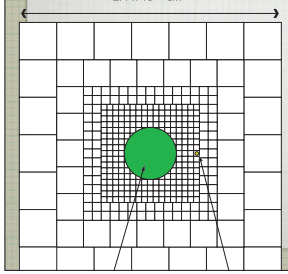

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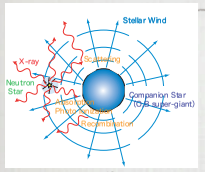

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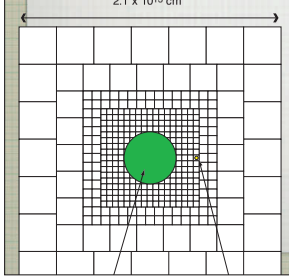
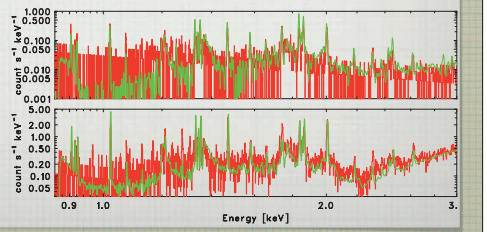


Observed Data, MC Data



Summary

- ☐ Geant4 use for Suzaku (HXD Response, HXD Background, HXD-WAM)
- ☐ Geant4 use for NeXT and plan
  - ☐ Soft Gamma-ray Detector case
- ☐ Astro-MC and examples of application (HMXB X-ray spectroscopy)