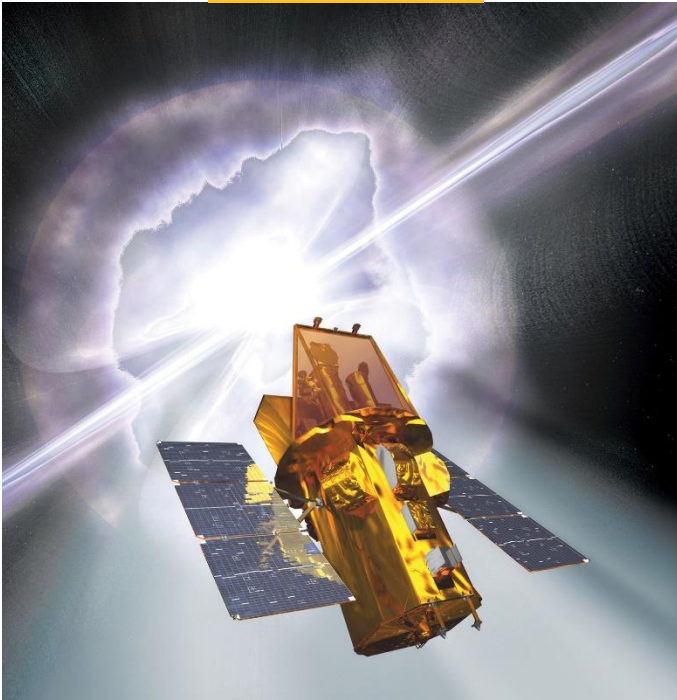


Japanese Hard X-ray activities supported by Neil

Hiromitsu Takahashi (Hiroshima University)

Satellites



Balloons



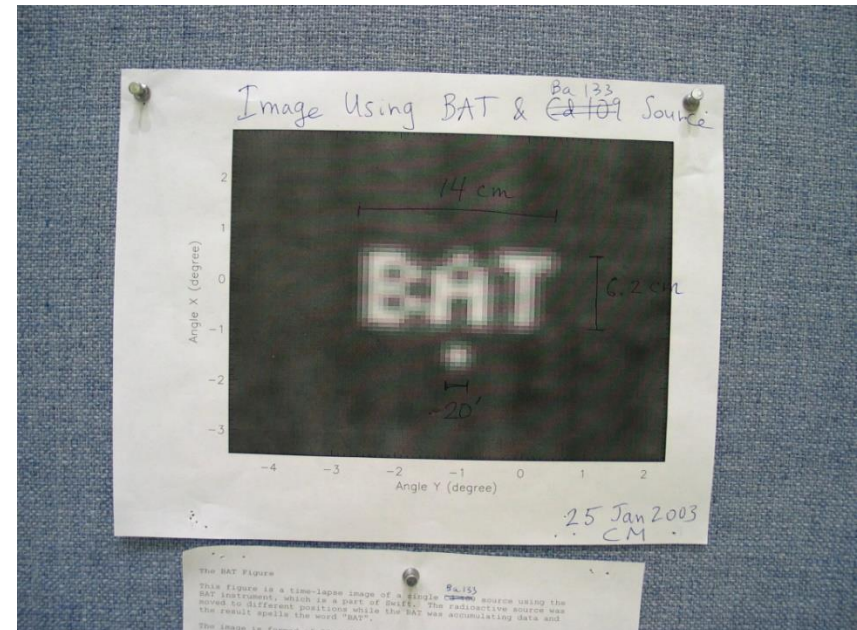
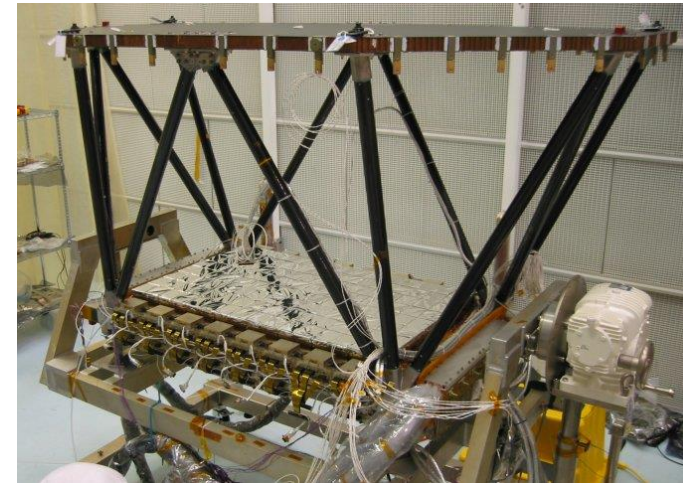
- The following presentations are from my colleagues and our supervisors. (Prof. Kawai and Dr. Sakamoto will also cover other stories.)
- We all would like to thank **Neil** for his kind supports for our activities.

My Introduction

Hiromitsu Takahashi (Hiroshima University)

2000: **ASTRO-E** was lost due to launch failure
(**ASCA** stopped the observation)
⇒ No existing/planned X-ray missions in Japan

2002-: **Neil** invited us (4 Japanese students) to stay
at GSFC for **Swift/BAT** ground calibration.
⇒ We could enhance our hard X-ray experiences.



What we did for **Swift/BAT** calibration in 2002-2003 at NASA/GSFC

Swift/BAT uses **CdZnTe** detector => Spectrum has **Peak + Tail** with $\mu\tau$ parameters.
We (Japanese students) studied **CdTe** detector.

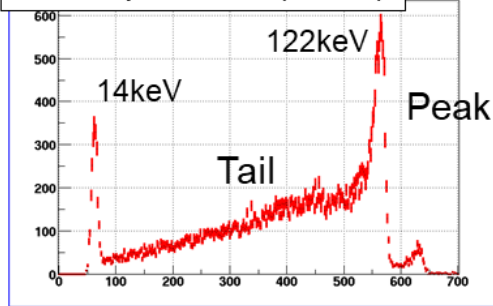
=> We develop analysis software and obtained the response for all **32,768** pixels.

My presentation at Swift team meeting in 2002

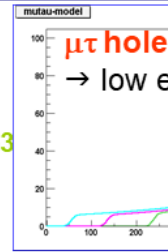
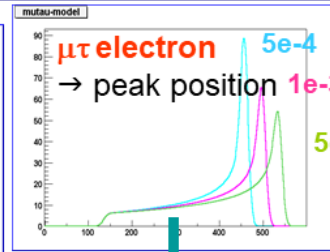


CZT Response (Poor Carrier Transport)

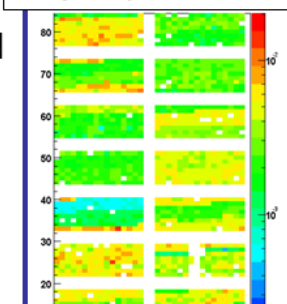
⁵⁷Co Spectrum (200V)



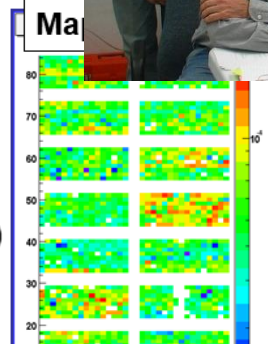
Shape of spectrum is determined by μ (Mobility) and τ (Life Time) of carriers in CZTs.



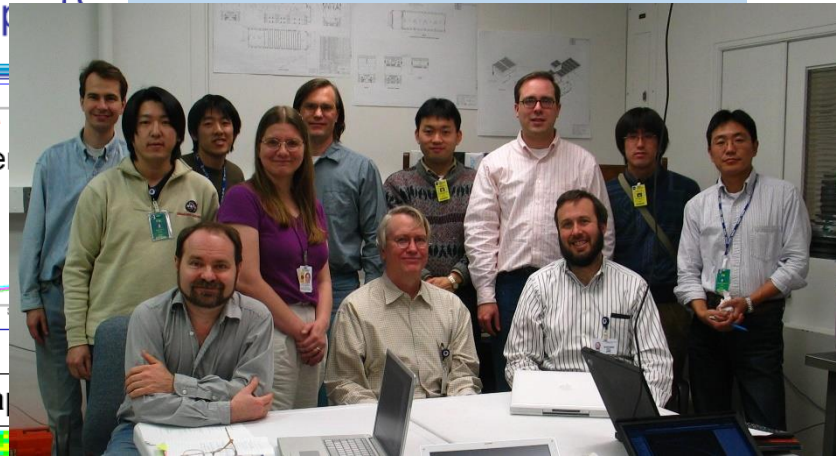
Map of $\mu\tau$ electron



1 block (2048 CZTs)



BAT team after launch (2005)



HPB-CZT: poly-crystal

To mea
is Cr

Dr. Sakamoto talks more details after 2004 (Swift launch).

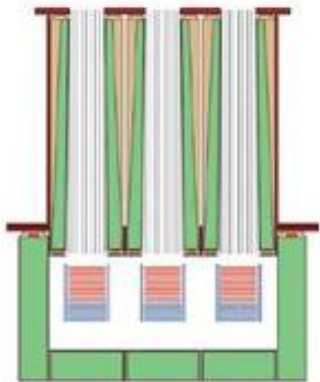
Japanese Hard X-ray Activities

2002: I met **Neil** at GSFC for the first time

2005: **Suzaku (ASTRO-EII)** was launched.
 We developed **Hard X-ray Detector (HXD)**.
 Well-type active shield to reduce background
 Large effective area with 4π FOV for GRBs

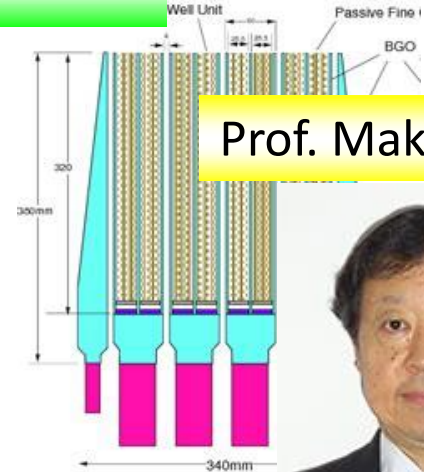
2016: **Hitomi (ASTRO-H)**
Hard X-ray Imager (HXI)
Soft Gamma-ray Detector (SGD)

Prof. Takahashi



ts (for HXI)
 (for SGD)

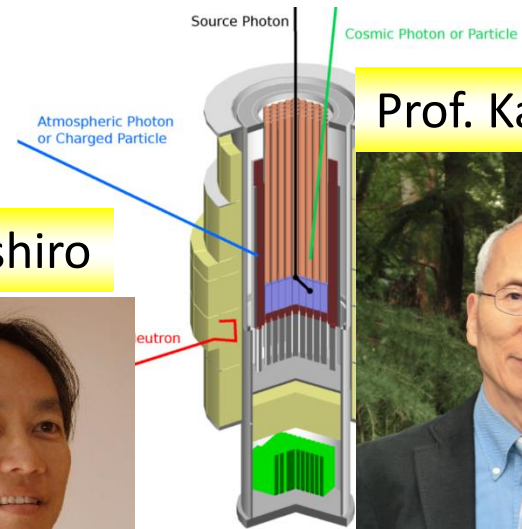
Prof. Tashiro



Prof. Makishima



PoGOLite/PoGO+
 (Hard X-ray polarimeter)



Prof. Kamae



Now: **X-ray Astronomy Recovery Mission (XARM)**
 Future: FORCE (hard X-ray astronomy)
 PhoENiX (soft gamma-ray heliophysics)

Hard X-ray activities supported by Neil

- They are our supervisors, and sent us to GSFC for **Swift/BAT** calibration when Japan did not have any X-ray satellites.
⇒ We could keep our research activities about hard X-ray astronomy.
- They all thanked **Neil** for his continuous supports for Japanese missions.
- Personally, my research was starting from **Swift/BAT**, and I really appreciate his kind supervising.

Prof. Kamae



Prof. Makishima



Prof. Takahashi



Prof. Tashiro



PoGOLite, PoGO+ balloon **Suzaku/HXD**

Hitomi

XARM

Fermi/LAT Si-strip detector from Japan

Fermi LAT collaboration meeting in 2009 (Hiroshima)

Me: one of LOC



Prof. Kawai talks another Japanese mission, MAXI (Japanese ISS mission).

Balloon activities related to Neil

Neil performed/supported many balloon missions.

Hard X-ray Polarimeter PoGOLite/PoGO+



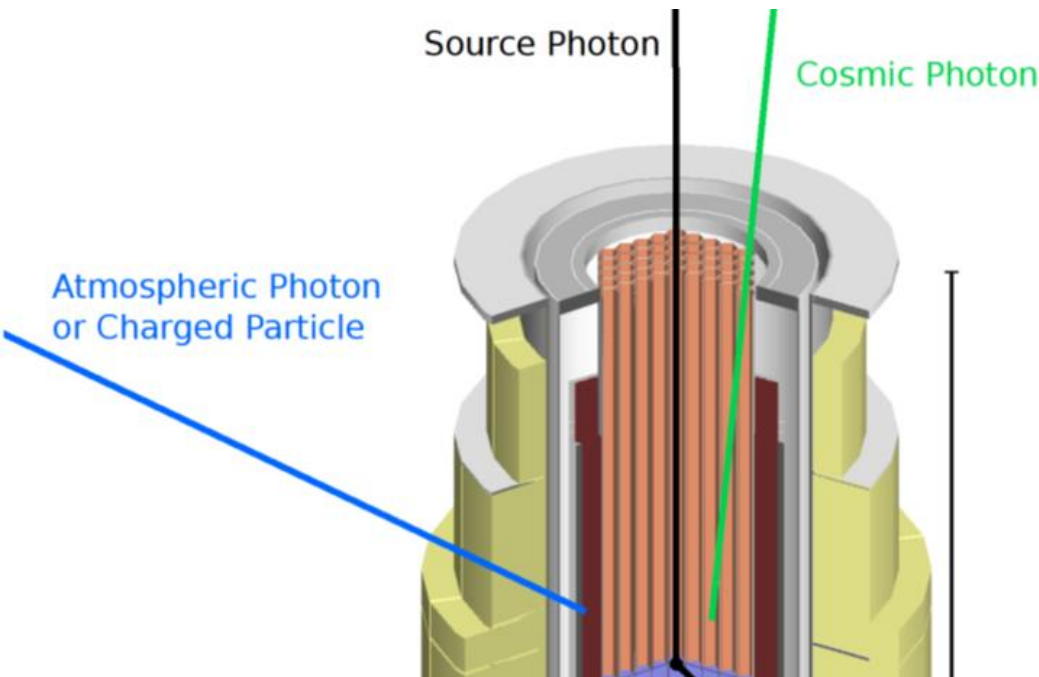
PI: Mark Pearce (Royal Institute of Technology in Sweden)
Japanese lead: Hiromitsu Takahashi (Hiroshima University)

Prof. Kamae



$\Phi 100\text{m}$ balloon@40km

Hard X-ray Polarimeter (PoGO+)



High background due to low geomagnetic cut-off at high arctic latitudes $\sim 71^\circ$

Active shield: particle & γ -ray
Passive shield: neutron
(it did not exist in initial design, and added later.)

INSTRUMENTAL BACKGROUND IN BALLOON-BORNE GAMMA-RAY SPECTROMETERS AND TECHNIQUES FOR ITS REDUCTION

N. GEHRELS

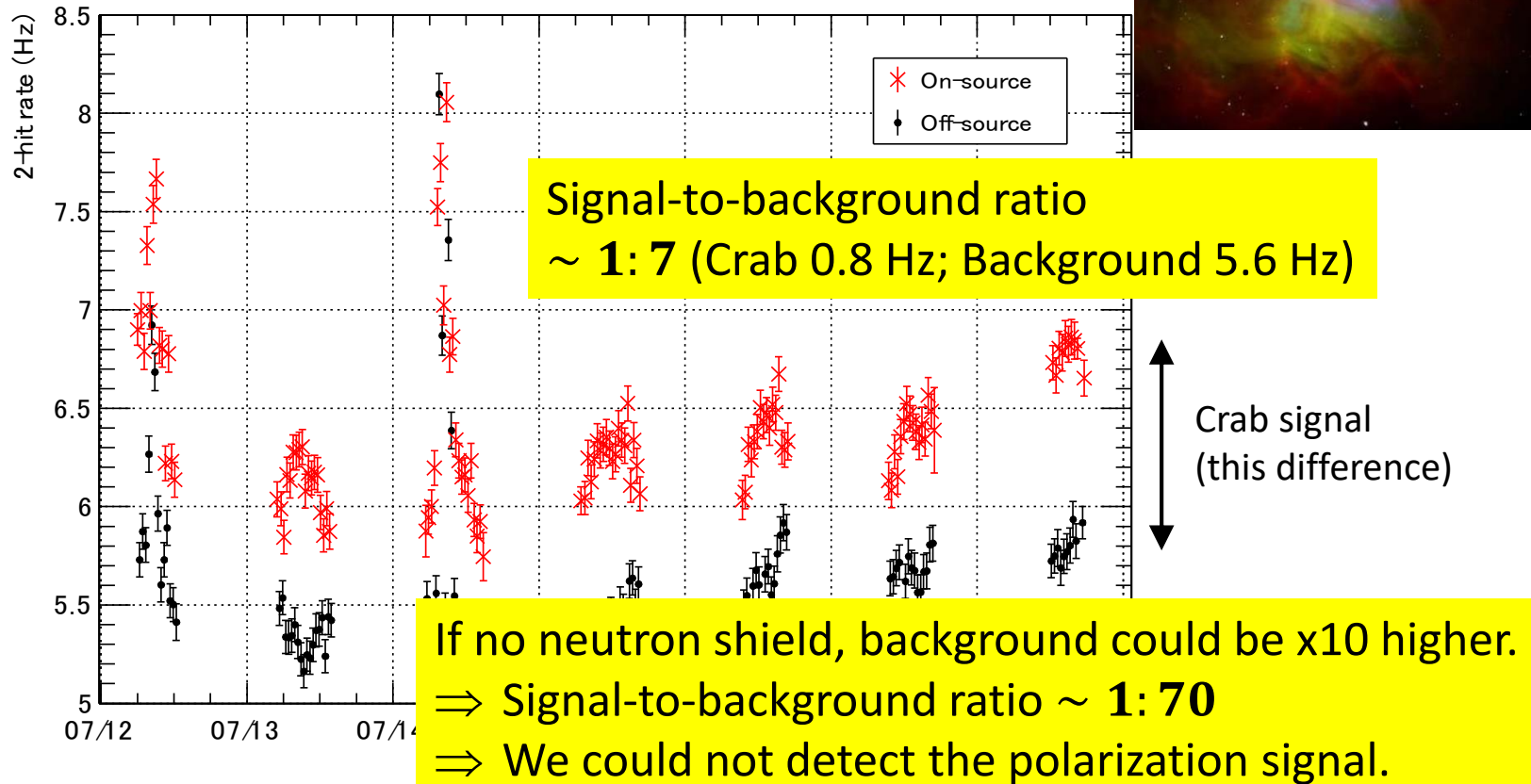
Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA

Received 8 October 1984 and in revised form 21 February 1985

A study of the instrumental background in balloon-borne gamma-ray spectrometers is presented. The calculations are based on newly available interaction cross sections and new analytic techniques, and are the most detailed and accurate published to date. Results compare well with measurements made in the 20 keV to 10 MeV energy range by the Goddard Low Energy Gamma-ray Spectrometer (LEGS). The principal components of the continuum background in spectrometers with Ge detectors and thick active shields are (1) elastic neutron scattering of atmospheric neutrons on the Ge nuclei, (2) aperture flux of atmospheric and cosmic gamma

Crab observation (light curve)

Chauvin, et al., 2017, Sci. Rep., 7, 7816.



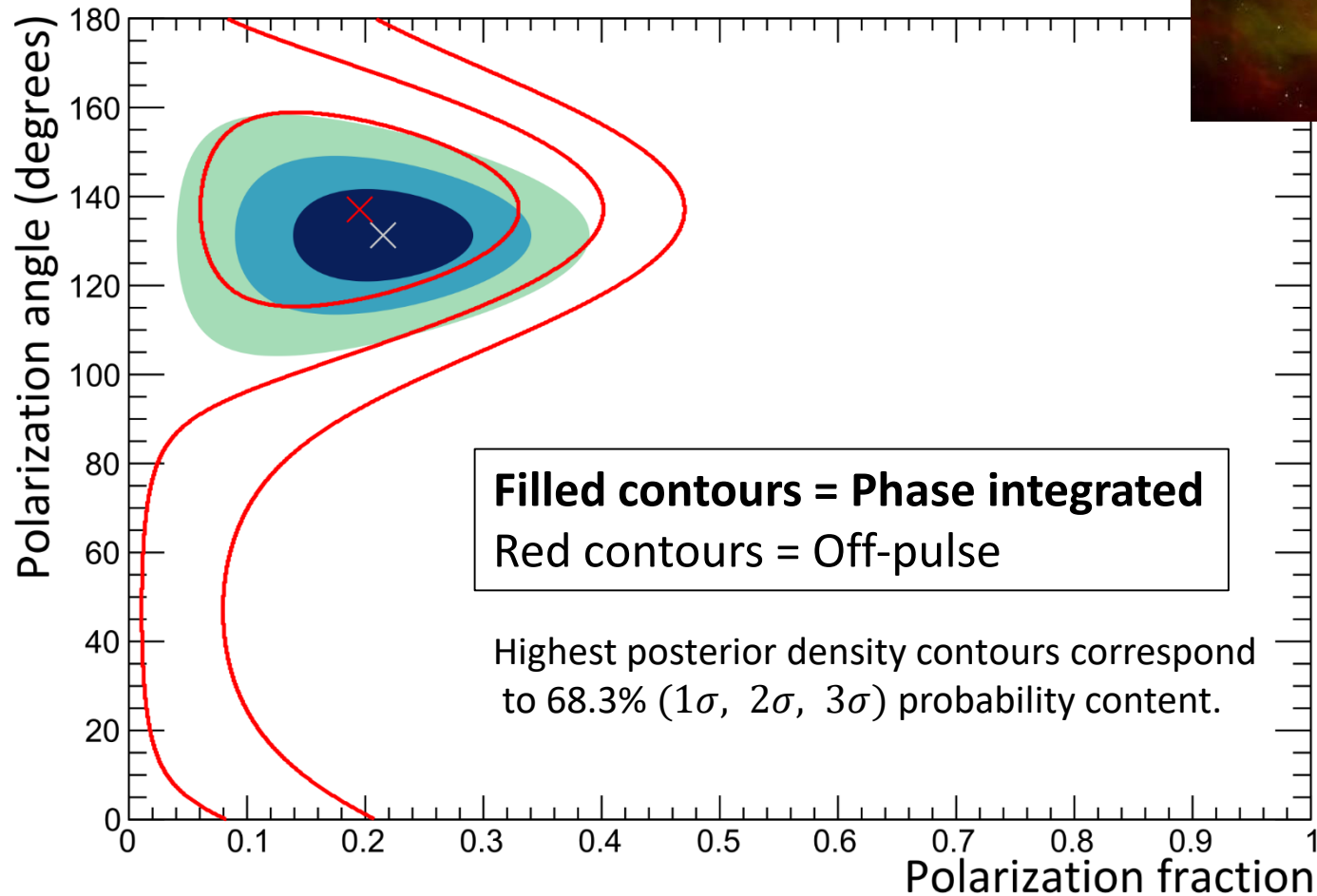
2-hit events (used for polarization analysis) @20-160 keV

- Red : On-source
- Black : Off-source

(every 15 mins, 5 degree right/left to Crab were observed)

Crab observation (polarization)

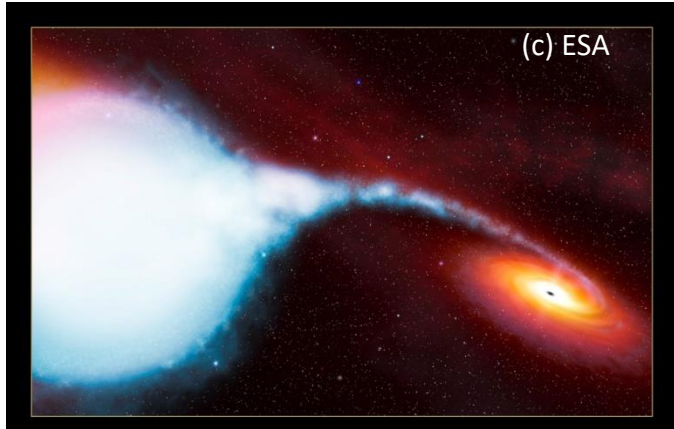
Chauvin, et al., 2017, Sci. Rep., 7, 7816.



Polarization fraction $\sim 20\%$ \Rightarrow Magnetic field is randomized (not 100% toroidal).
Polarization angle: aligned to pulsar rotation axis

Cygnus X-1 observation in low state

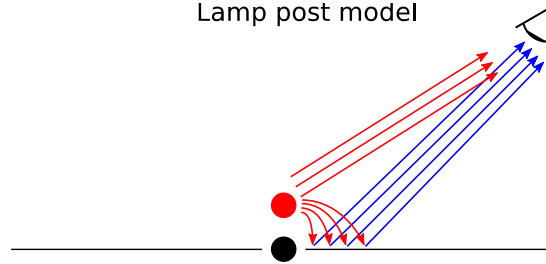
Chauvin, et al., submitted



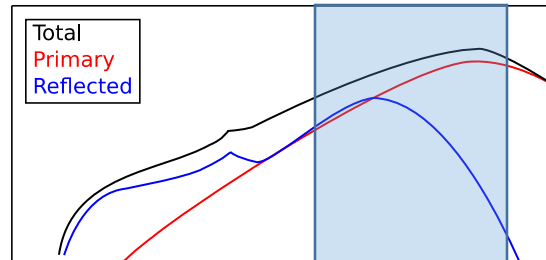
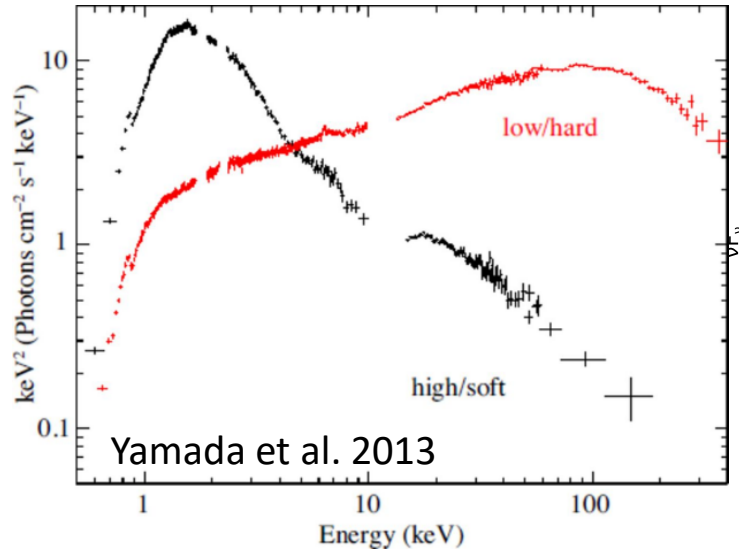
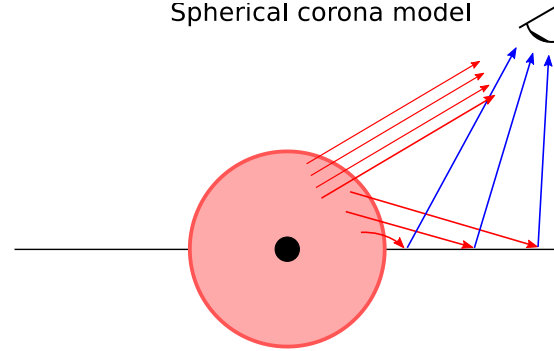
Point-like corona
close to BH
(Fabian et al. 2012)

Extended corona
(Makishima, HT et al. 2008)

Lamp post model

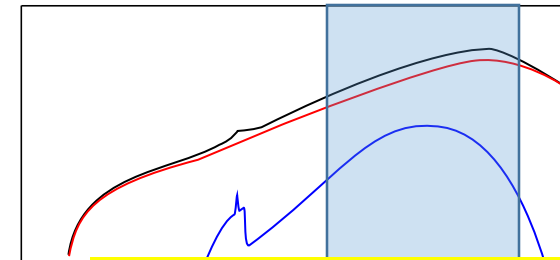


Spherical corona model



**Large reflection:
15% (max) polarization**

Dovciak et al. 2013



**Small reflection:
a few% polarization**

Schnittman et al. 2010

Next hard X-ray balloon mission: X-Calibur

PI: Henric Krawczynski (Washington University in St. Louis)

Japanese lead: Hiromitsu Takahashi (Hiroshima University)

- **PoGOLite/PoGO+** sensitivities are limited by background.
 - ⇒ Mirror is need to focus photons and reduce detector volume.
 - Hard X-ray polarization of Crab and Cygnus X-1 (brightest sources in northern hemisphere) was observed by **PoGOLite/PoGO+**.
- ⇒ **X-Calibur** uses **InFOCuS** hard X-ray mirror (also supported by **Neil**) and will be launched at Antarctica this year.

X-Calibur: hard X-ray polarimeter (in 2018, 2021, ...)



Hard X-ray activities supported by Neil

- **Neil** provided us opportunities of **Swift/BAT** calibration at NASA/GSFC to keep hard X-ray activities in Japan, when Japan did not have any X-ray satellites.
- My colleagues and our professors all would like to thank **Neil** for his kind/continuous supports for Japanese missions.

Four Japanese (May/7/2018)



Prof. Kamae



Prof. Makishima



Prof. Takahashi



Prof. Tashiro



PoGOLite, PoGO+ balloon **Suzaku/HXD**
Fermi/LAT Si-strip detector from Japan

Hitomi

XARM