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Concept study of a small Compton polarimeter to fly on a cubesat: **Compol**

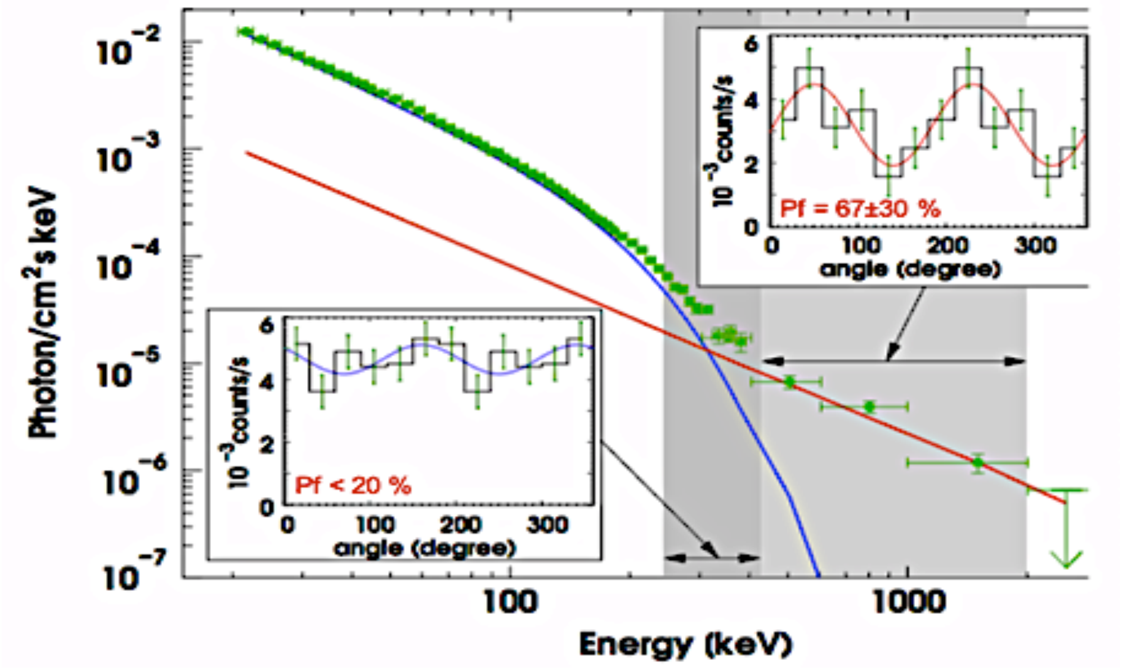
Hsiang-Kuang Chang

Institute of Astronomy, National Tsing Hua University, Taiwan

Collaborators: Philippe Laurent (CEA); Yi-Chi Chang, Che-Yen Chu, Hung-Hsiang Liang, Chien-Ying Yang (NTHU); Chih-Hsun Lin (AS); Yuan-Hann Chang (NCU); Jeng-Lun Chiu, Hsin-Chia Lin, Chen-Joe Fong (NSPO)


High-energy sources emit very few photons, and CubeSats are small ……
Looking at one special target all the time!

Polarization in soft gamma-rays from Cygnus X-1, a black-hole X-ray binary



(Laurent et al. 2011)

Earlier results from INTEGRAL:

IBIS (Laurent et al. 2011)
250-400 keV, < 20%
400-2000 keV, 67+-30%

SPI (Jourdain et al. 2012)
130-230 keV, < 20%
230-370 keV, 40+-10%
370-850 keV, > 75%

- Origin of hard X/soft gamma rays from Cyg X-1
- Physics of black-hole accretion disks and jets
- Polarization measurement provides another powerful diagnostic tool, besides spectral and timing observations.

Original Compol concept

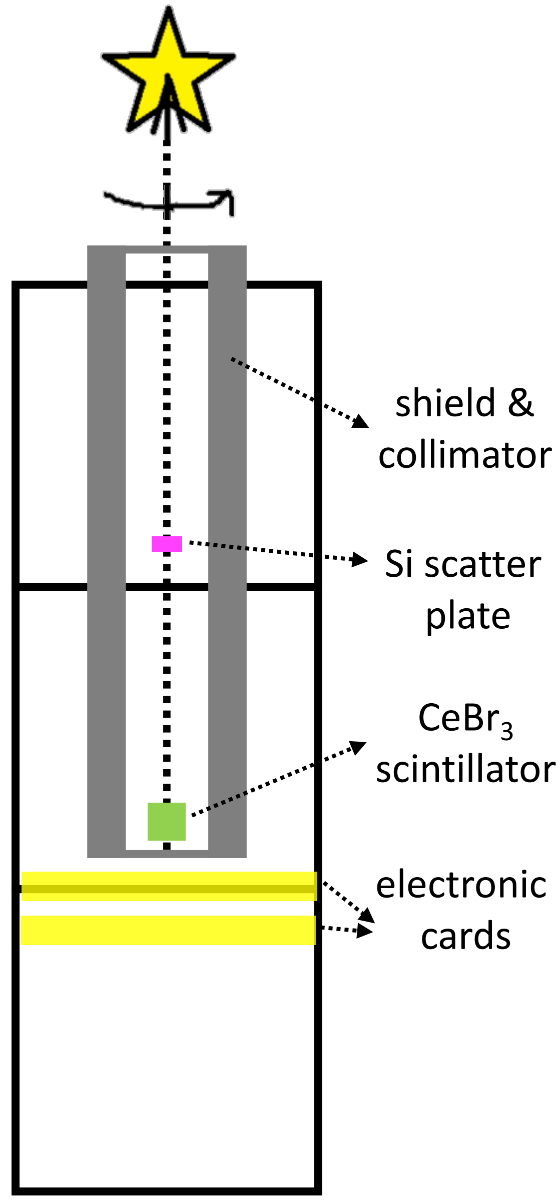
- A Compton polarimeter with two planes: a scatter and a calorimeter, onboard a 3U cubesat.
- One-source dedicated mission: always pointing to the same source.

→ Small effective area but long observation time

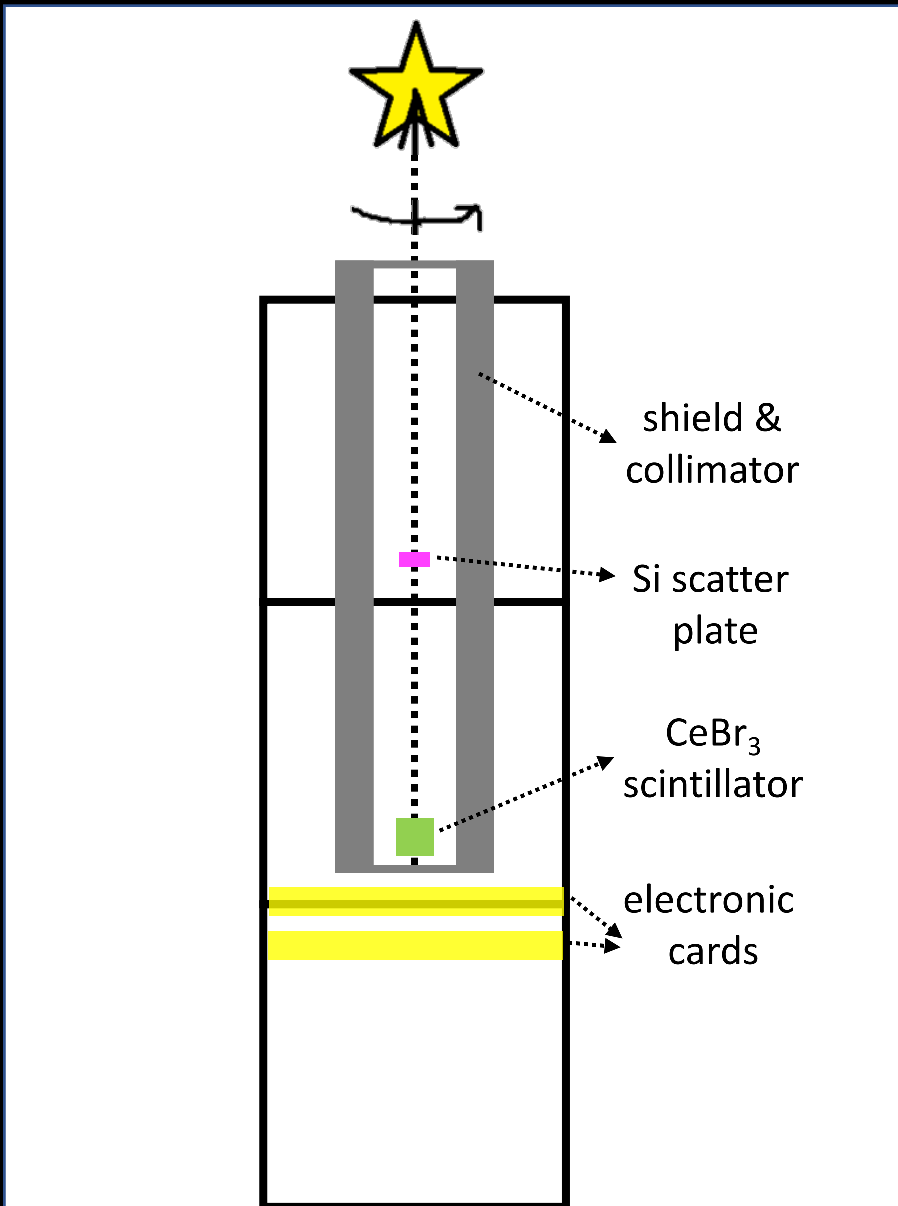
- Target: Polarization of Cygnus X-1 (a black hole X-ray binary system).

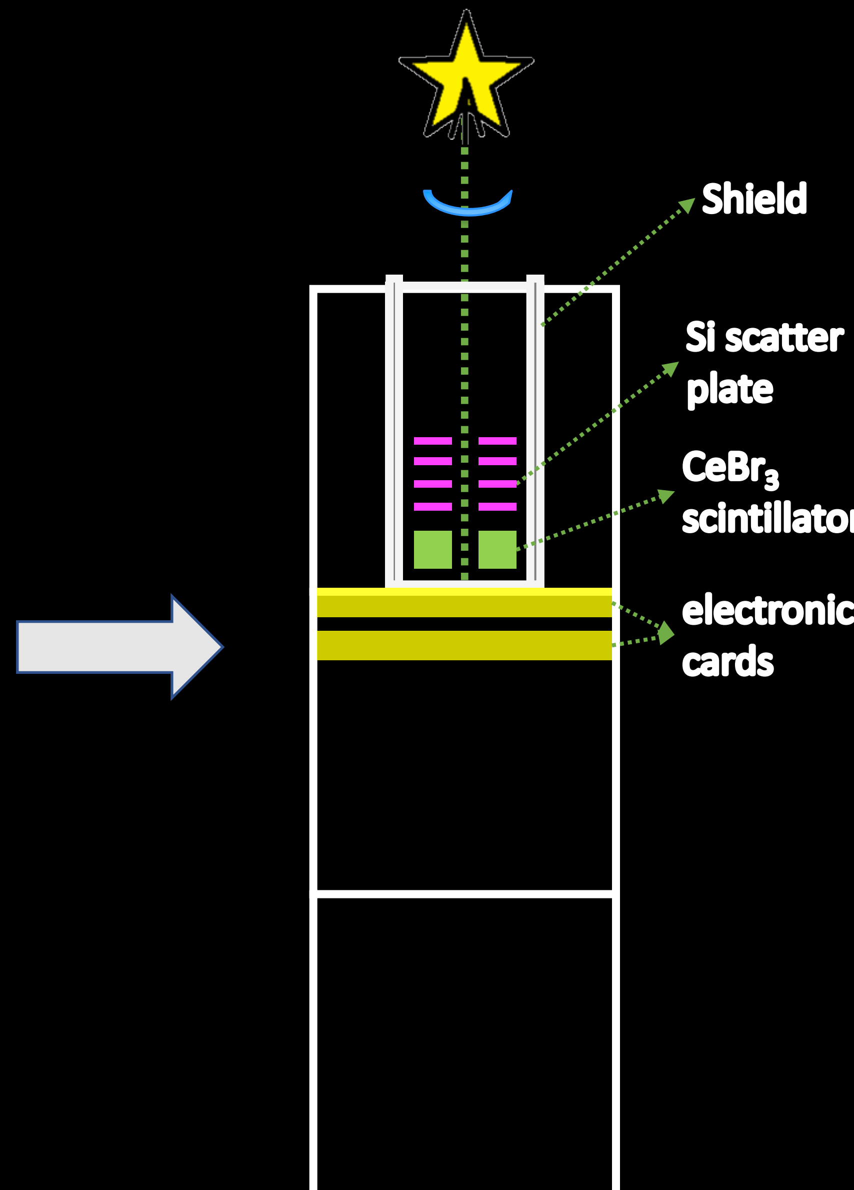
Compton scattering is polarization dependent:

$$\frac{d\sigma}{d\Omega} = \frac{r_0^2}{2}\left(\frac{E'}{E}\right)^2\left(\frac{E}{E'} + \frac{E'}{E} - 2\sin^2\theta\cos^2\eta\right)$$

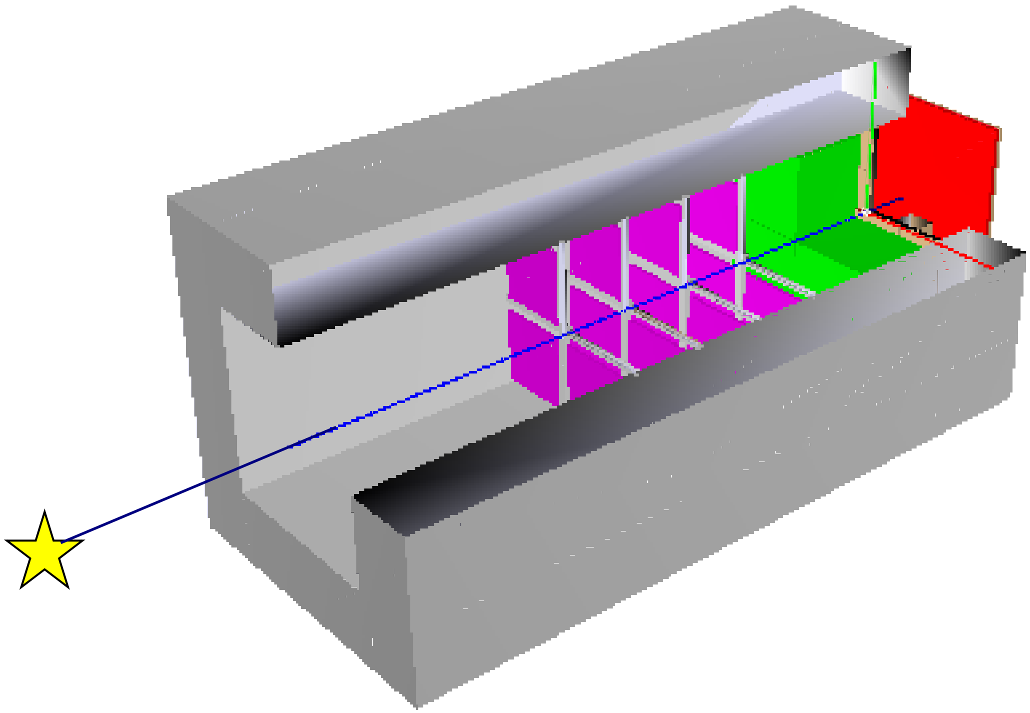


Revised Compol Concept



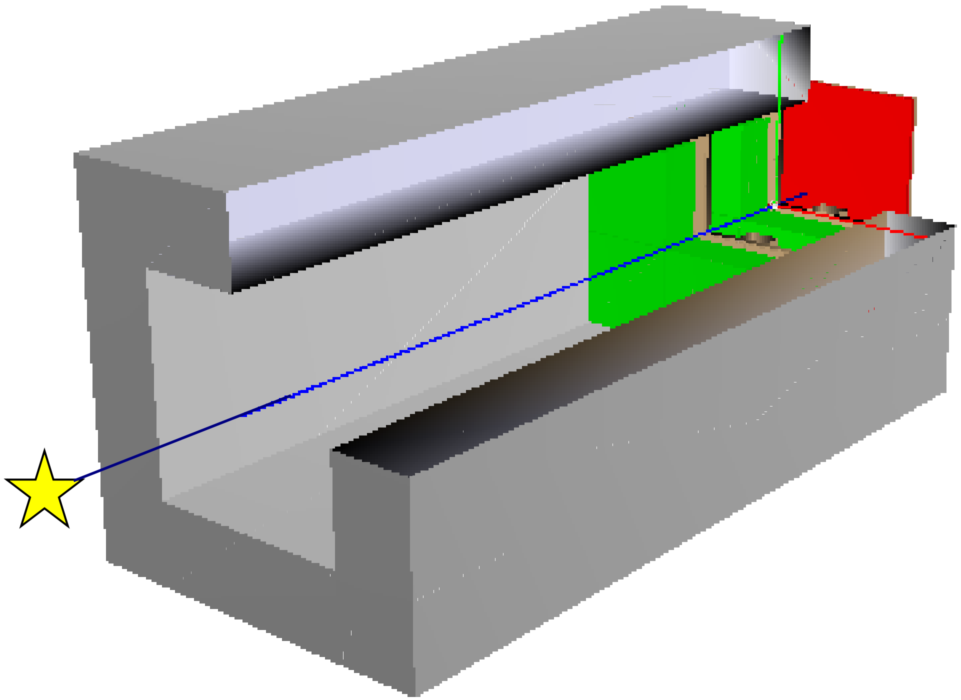


Detector Design - Model 1



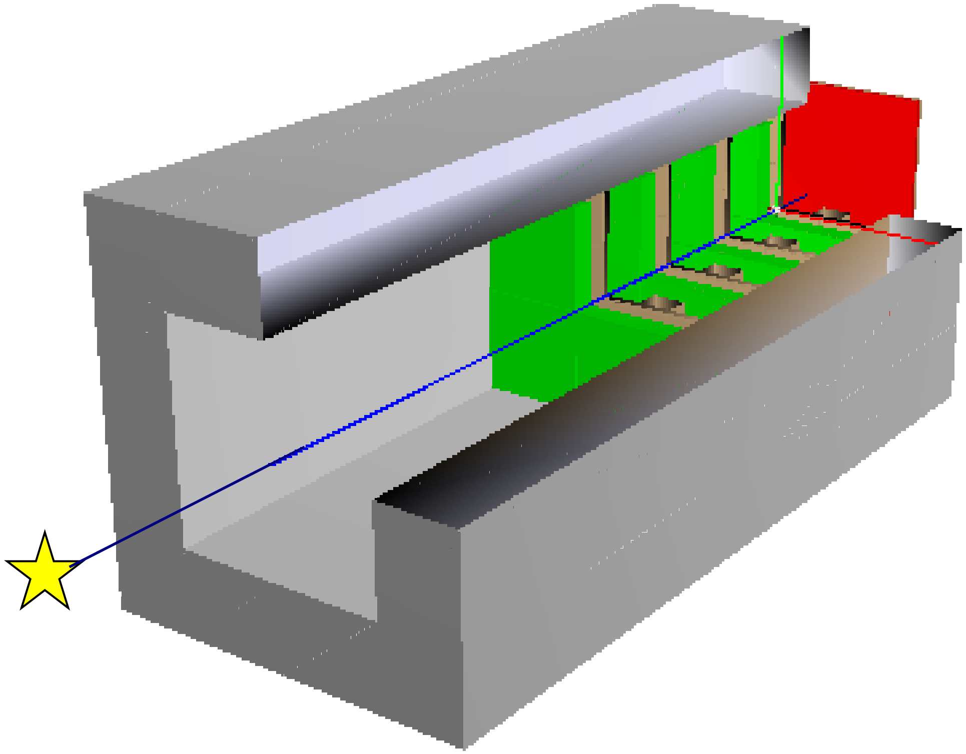
Model 1
Silicon scatter plate 2x2x4 (each 10x10x0.5 mm^3)
CeBr3 Scintillator 2x2 (each 12x12x12 mm^3)
SiPM (MPPC) array (4x4 in 12x12 mm^2)
Al shield (10mm thickness)
Ta + Al shield (0.6mm+0.6mm)

Detector Design – Model 2



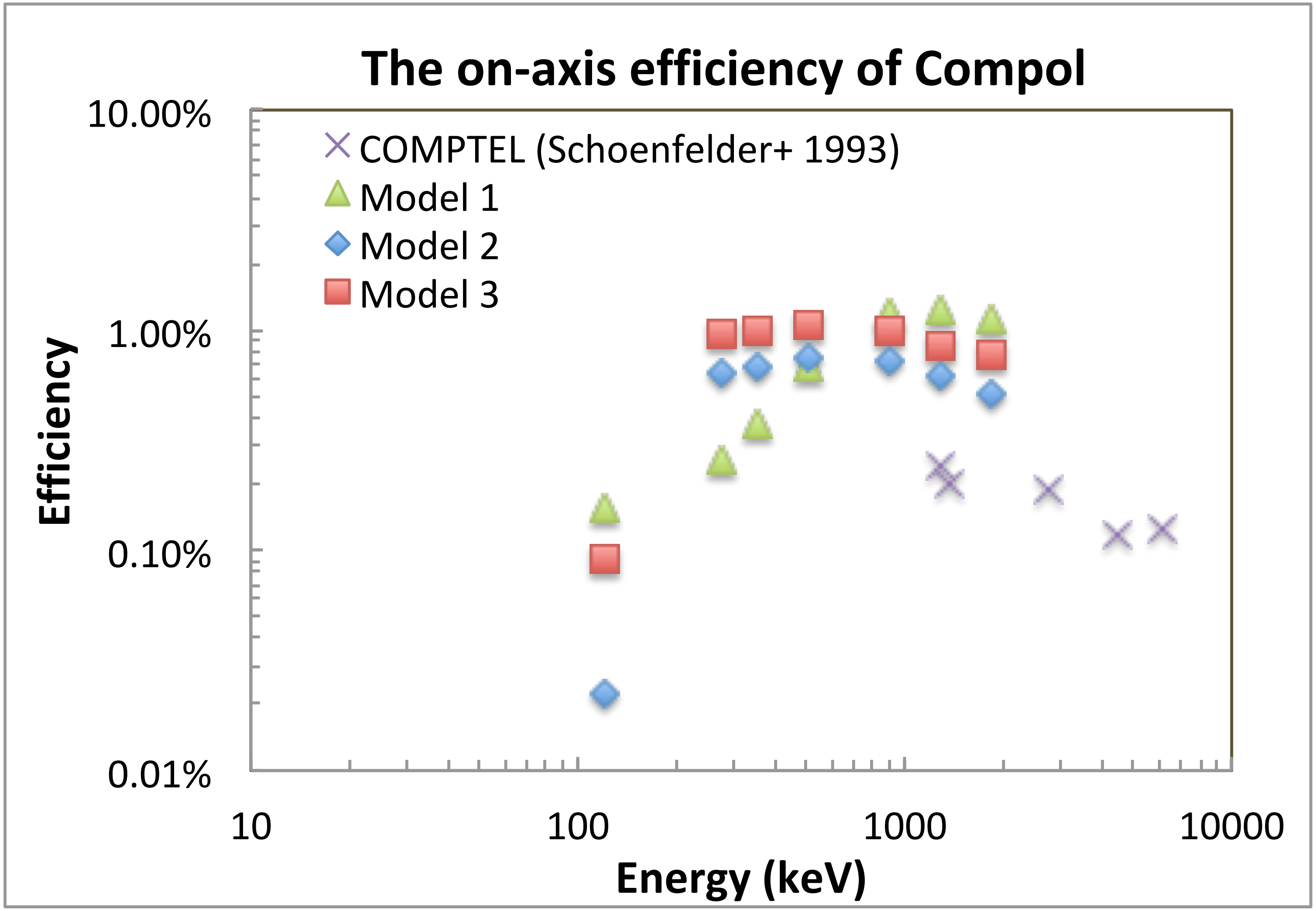
Model 2 Siliicon removed
CeBr3 Scintillator 2x2x2 (each 12x12x6 mm^3)
SiPM (MPPC) array (4x4 in 12x12 mm^2)
Al shield (10mm thickness)
Ta + Al shield (0.6mm+0.6mm)

Detector Design – Model 3



Model 3 Silicon removed
CeBr3 Scintillator 2x2x4 (each 12x12x3 mm^3)
SiPM (MPPC) array (4x4 in 12x12 mm^2)
Al shield (10mm thickness)
Ta + Al shield (0.6mm+0.6mm)

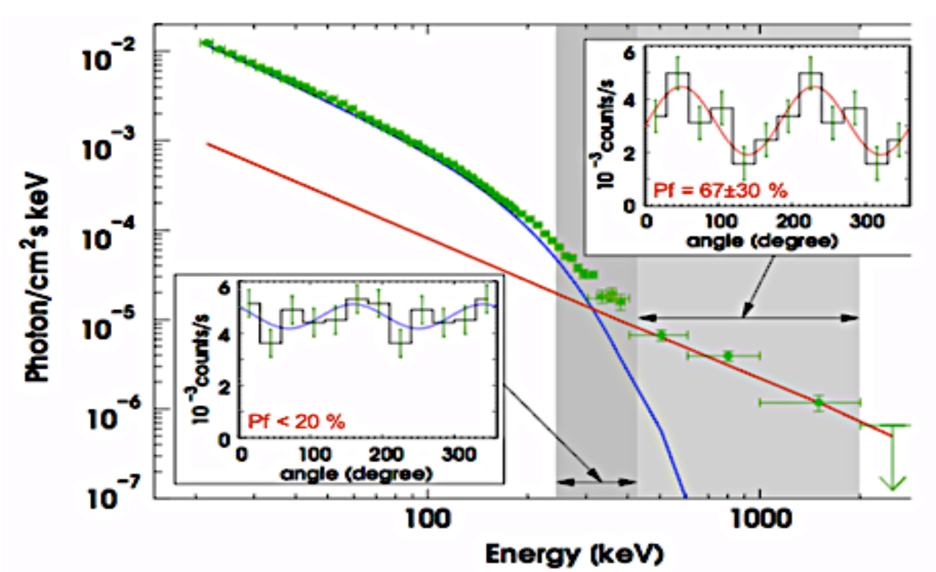
Detector Efficiency



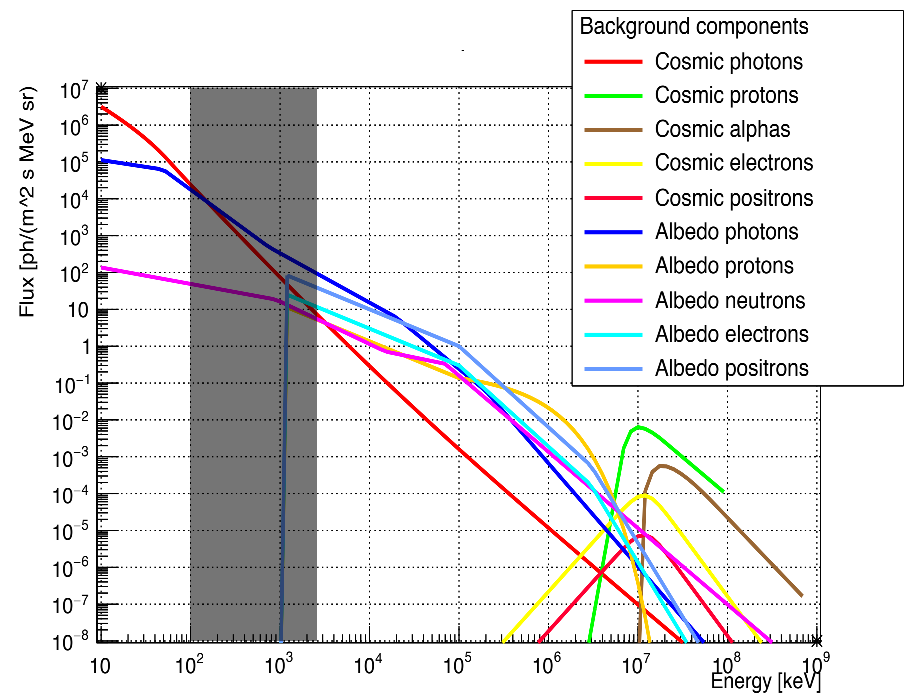
Data rate estimate in low-inclination LEO

Source and Background Model

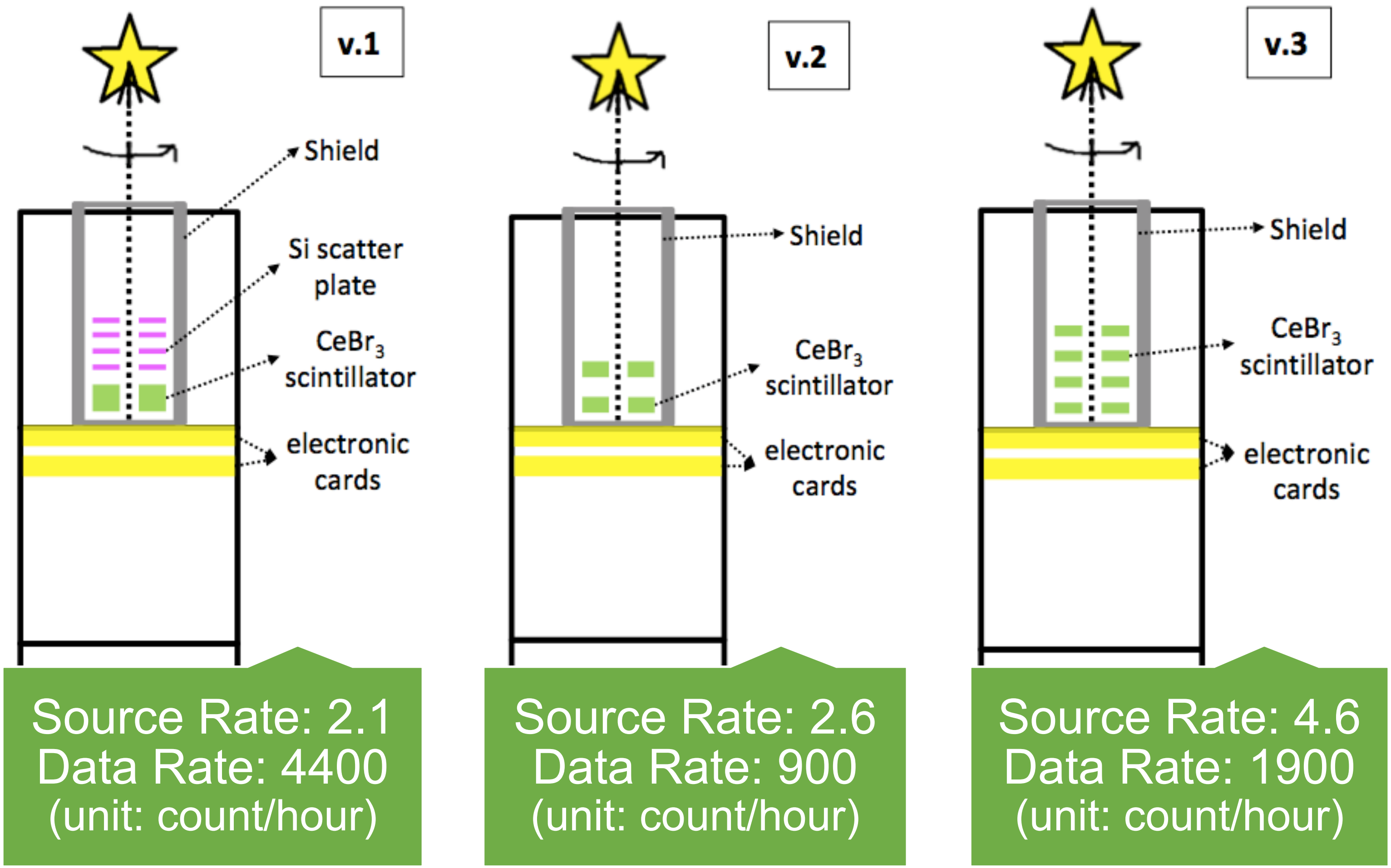
Source Cyg X-1:
A black-hole X-ray binary, the energy spectrum as measured by INTEGRAL/IBIS, shown below (Laurent+ 2011)



Background:
Based on Beppo-SAX & AGILE missions, in a low-inclination (~ 4°), low-altitude (500 - 600 km) Earth orbit



Data rate estimate in low-inclination LEO



Source Rate: the detection rate of usable photons from Cyg X-1.

Date Rate: Mainly from background, selected and transferred to the ground.

Assuming 30 bytes for each count, Model 3 leads to about 1.5 MB per day.

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Summary

1. Among the investigated models, Model 3 is the best.
2. We will also study the performance of a model with plastic scintillators on the top, to replace one or two layers of $CeBr_3$.
3. We will further check the optimal thickness of the aluminum shielding and also try thicker silicon sensors.
4. We will then conduct science feasibility study to estimate how much observing time is needed for a meaningful polarization measurement.
5. There are opportunities of cubesat missions offered by NSPO in Taiwan.