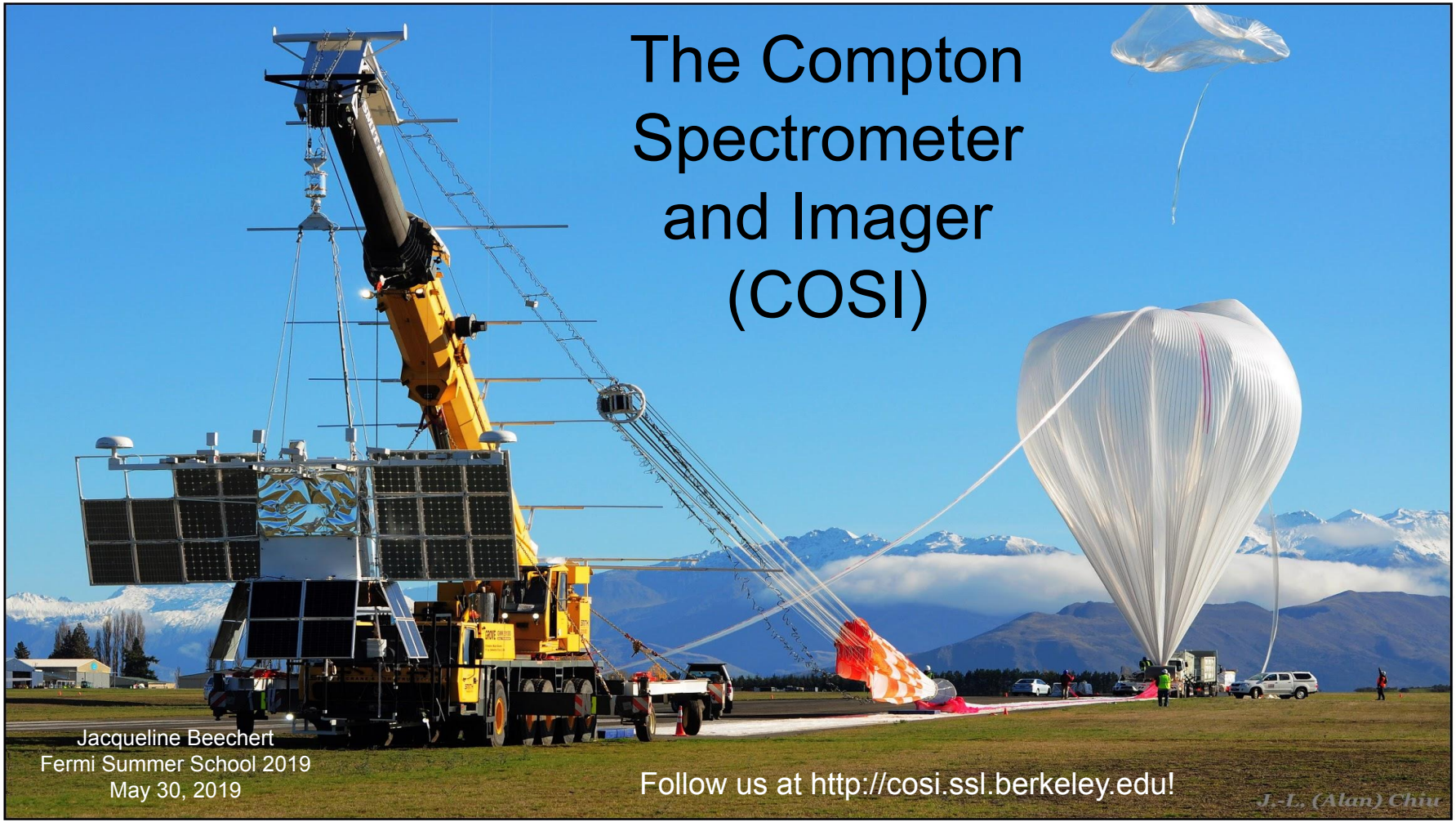
The Compton Spectrometer and Imager (COSI)



Jacqueline Beechert
Fermi Summer School 2019
May 30, 2019

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J.-L. (Alan) Chiu

COSI in a Nutshell

Balloon-borne compact Compton telescope

> Energy range: 0.2 - 5 MeV

> Spectral resolution: ~2.9 keV from HPGe crystals (~0.4% at 662 keV)

> Angular resolution: <= 4° at 662 keV

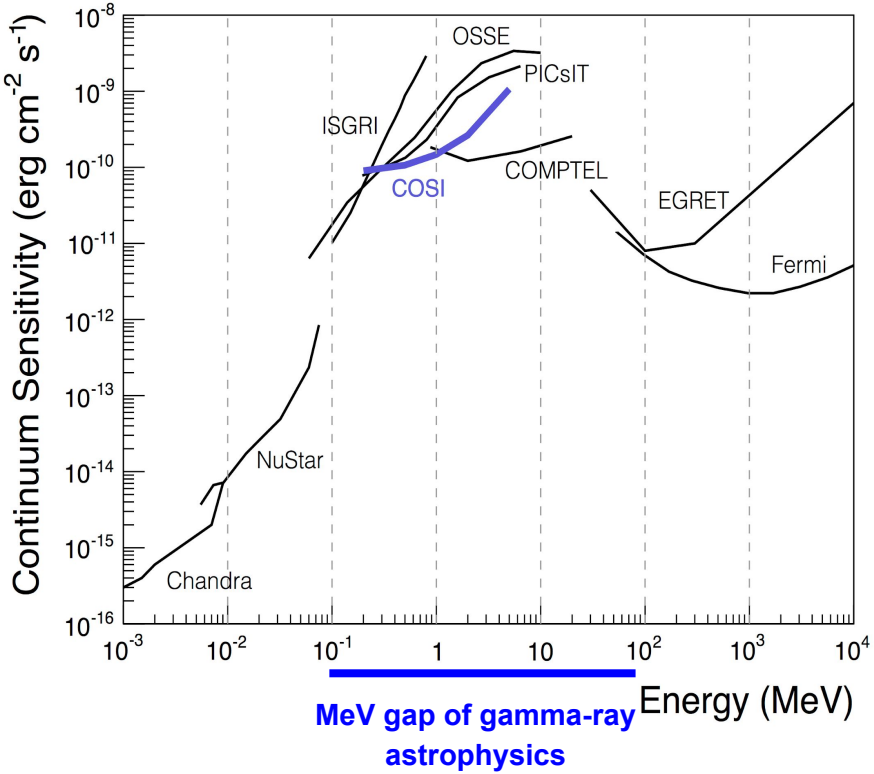
> FOV: 25% of the sky

Science goals

> Map the 511-keV electron-positron annihilation line

> Image emission of nuclear lines (^{26}Al, ^{60}Fe, etc.)

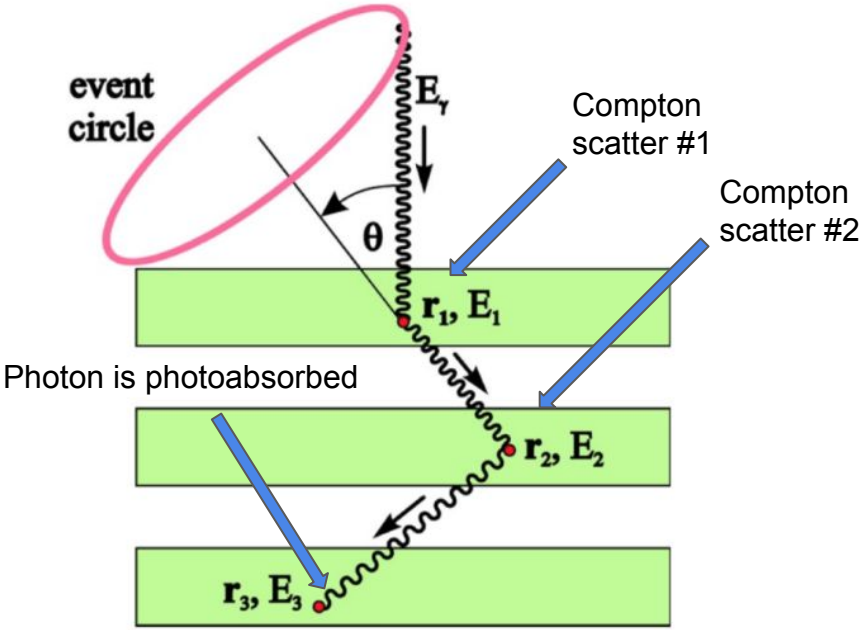
> γ-ray polarization of compact objects and GRBs



http://cosi.ssl.berkeley.edu/instrument/science/

What is a compact Compton telescope?

Principle: Compton scattering dominates the 0.2-10 MeV energy range



> Find most likely order of interactions → most probable γ path

> Constrain γ to event circle defined by θ:

$$E' = \frac{E_0}{1 + \frac{E_0}{m_e c^2}(1 - cos\theta)}$$

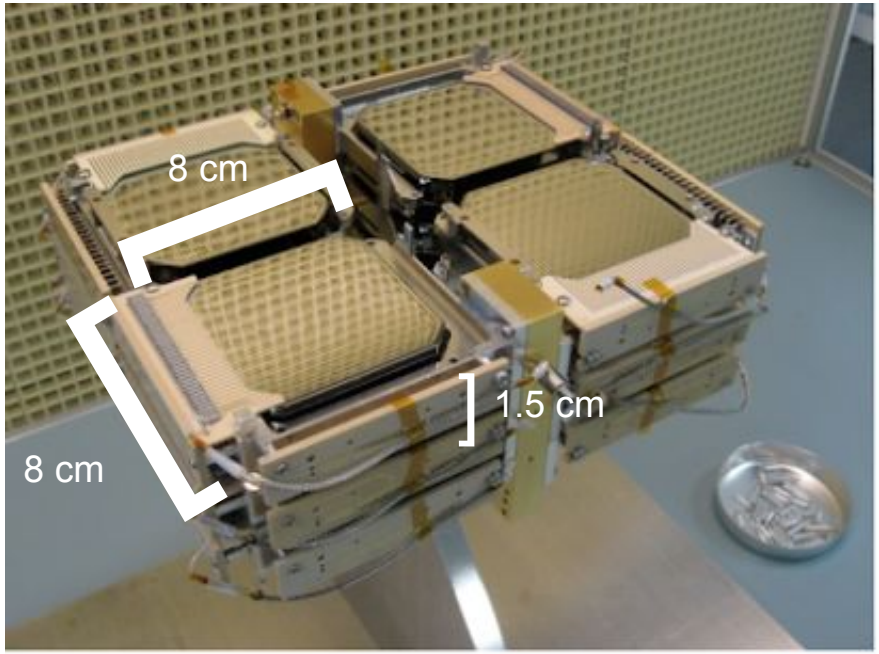
> Klein-Nishina differential cross section:

$$\frac{d\sigma}{d\Omega} = \frac{r_e^2}{2}\left(\frac{E'}{E_0}\right)^2\left(\frac{E'}{E_0} + \frac{E_0}{E'} - 2sin^2\theta cos^2\eta\right)$$

Azimuthal scatter angle between photon's E-field and scatter direction → sensitive to polarization!

http://cosi.ssl.berkeley.edu/instrument/design/

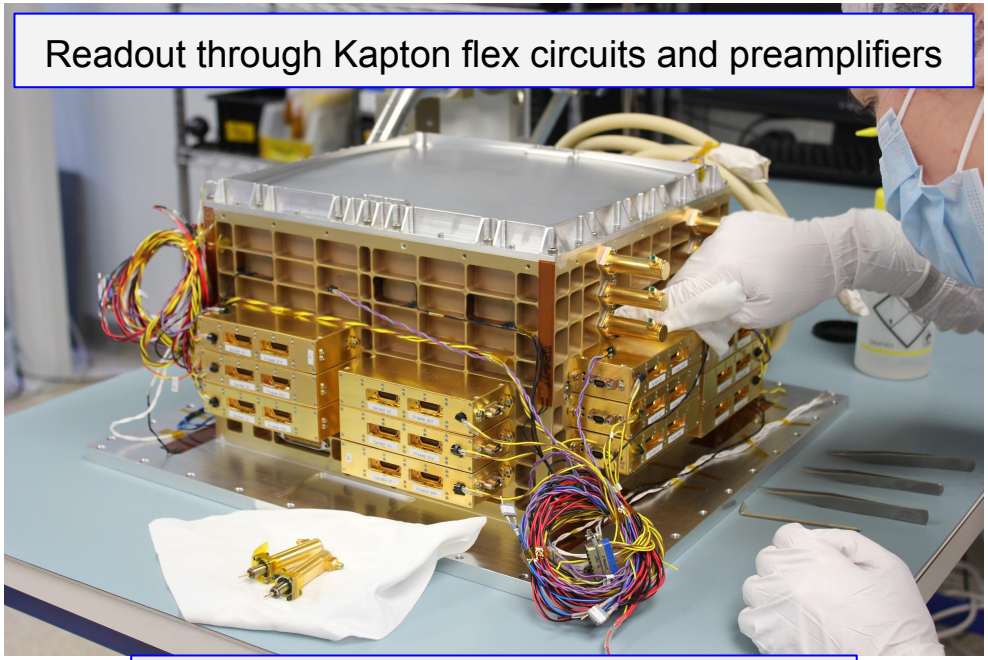
COSI's GeD Array



12 HPGe cross-strip detectors

12 x 37 strips x 2 sides = 888 strips of pitch of 2 mm → 3D positioning with 2 mm^3 resolution

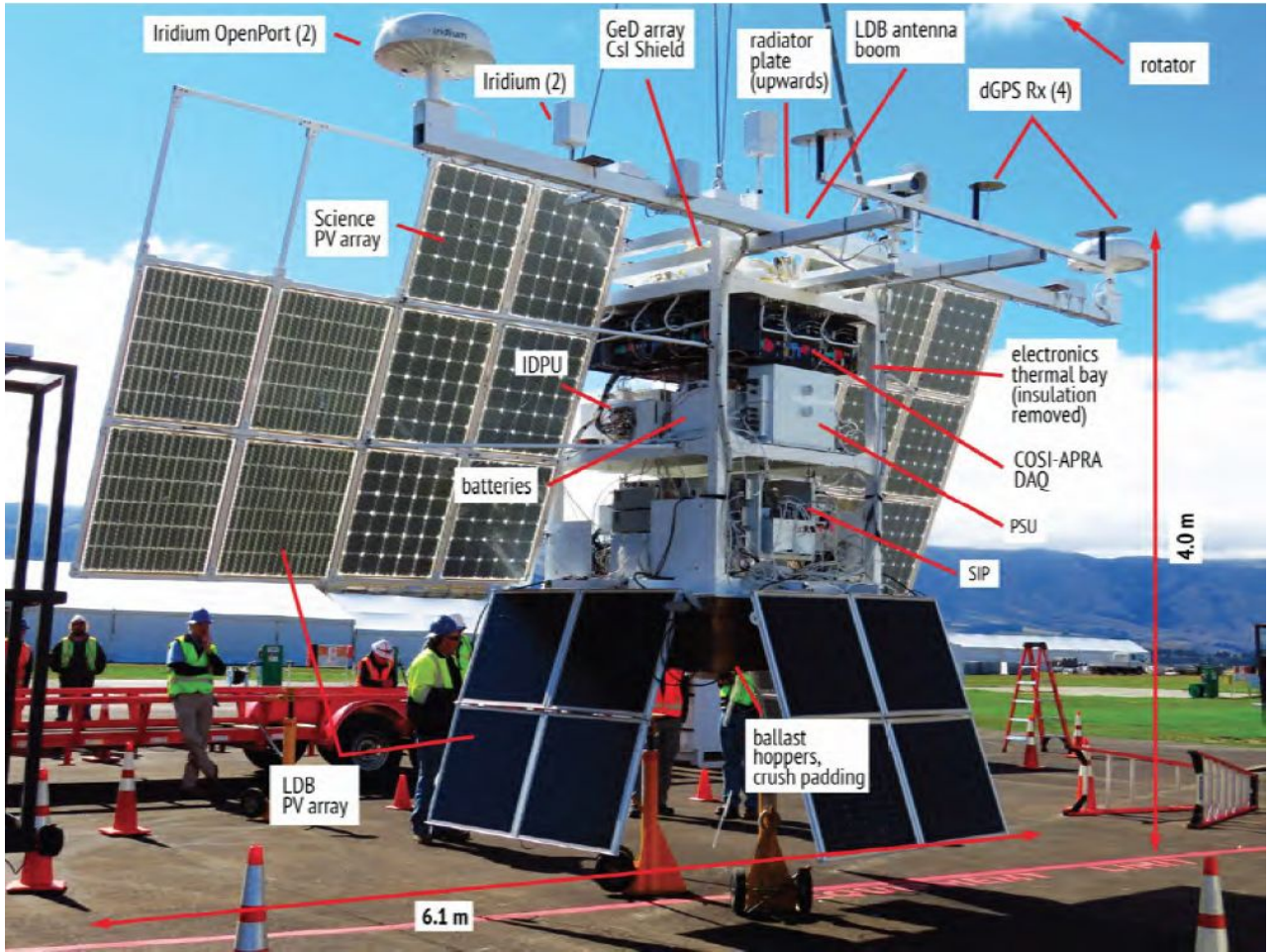
Readout through Kapton flex circuits and preamplifiers



Detectors housed in aluminum cryostat

Operating conditions: ~84 K, 10^{-6} Torr (~0.7 eV bandgap)

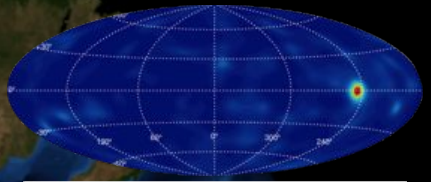
Also, a few other components...

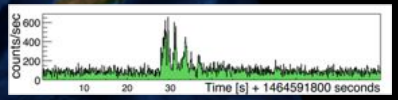


Kierans, C. A. 2018, PhD thesis, University of California, Berkeley

COSI 2016 Wanaka Flight

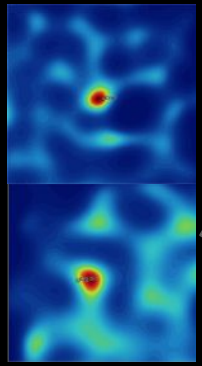
46 days later, COSI lands in Peru, completing the longest mid-latitude flight for a large balloon

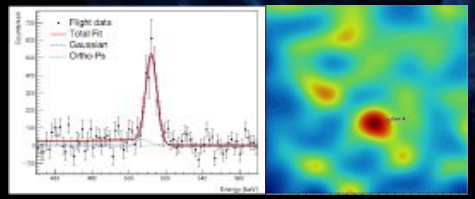




May 30, 2016: First balloon to circulate a real-time GRB detection with Gamma-ray Coordination Network (GCN): **GRB 160530A**

COSI detects the Crab nebula (top) and Cyg X-1 (bottom)





COSI detects 511-keV e^+-e^- annihilation (left) and Centaurus A (right)

May 17, 2016: COSI launch is the first mid-latitude science flight with NASA's Super Pressure Balloon (SPB) technology

Kierans, C. A. 2018, PhD thesis, University of California, Berkeley

Slide adapted from Alex Lowell.

COSI-2 2020 Wanaka Flight

Hardware repairs: Fixed 3 detectors that failed during 2016, replaced 2 faulty HV filters, repair card cage analog readout boards, etc.

Perform energy, polarization, depth, and crosstalk calibrations with improved structures.

Looking forward to a longer flight, more data, and advanced analysis incorporating new machine learning techniques.

Stay tuned!

2016 integrated gondola

My work

- Energy, depth, and crosstalk calibration
- Cold leak testing of the cryostat
- Testing of detectors post-repair
- Simulations of charge transport through semiconductor detectors
- Probing next-generation ASIC readout for future satellite missions
- General preparations for COSI-2 and data analysis