Building ASCI* based on the COSI' mission performance

*All-Sky Compton Imager
'COMpton Spectrometer and Imager

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**COSI: Flight 2016.**

**Balloon + gondola**

**Start:**
New Zealand
16th May 2016.

**End:**
South America
2. July 2016

**Flight time (data):**
46+ days!

**Support data:**
Geolocation:
altitude, longitude, latitude

ACS count rates:
total, lifetimes, timestamps

![Map showing the flight path from New Zealand to South America with markers for launch and land.](image)
**COSI: Instrument**

- Balloon-borne telescope: 0.2 - 10. MeV
- Double-sided strip Ge detectors (GeDs)
- 12 GeD: ~ 8x8 cm² x 1.5 cm w/
  
  37 x 2 mm strips / 0.25 mm gaps
- Controlled cryostat
- ACS: CsI panels
- Electronics + balloon gondola

- Energy res: 1.5-3.0 keV FWHM
- Angular res: up to ~4° FWHM
- Field-of-view: almost 1/4 of sky
- X/Y res: 2. mm or less
- Depth-of-int: ~0.2 mm RMS
COSI: 511 keV as bkg. indicator

Lifetime > 95%

Data extraction and pre-analysis - Berkley: events + ACS + flight data

Energy spectra for 1 day of flight

511 keV

Peak selection

10
20
30

keV
**COSI: 511 keV rates**

511 keV rates:
- Avg. per 10 min of flight time
- Statistical error ~ 3-4%
- Excluded events:
  - instrumental malfunctions
  - small anomalies

**Compton evts**
- Photoel. evts
- ACS shield x 5e-3

**Instrumental**
- 30th of May - 10h of data

**Altitude**

**DREPs**

**Graphs:**
- Average rate values per 10 mins [cts/s] vs. Time [x10 mins]
**COSI: 511keV rates**

**Linear fit:** \( R_{511} = 0.11 + 1.46 \times 10^{-4} \times R_{ACS} \)

**Quadratic fit:** \( R_{511} = -0.77 + 2.39 \times 10^{-4} \times R_{ACS} - 2.36 \times 10^{-9} \times R_{ACS}^2 \)

**Linear' fit:** \( R_{511} = -0.19 + 1.49 \times 10^{-4} \times R_{ACS} \)

**Quadratic' fit:** \( R_{511} = -0.29 + 1.65 \times 10^{-4} \times R_{ACS} - 0.47 \times 10^{-9} \times R_{ACS}^2 \)

**Compton vs photoelectric**

**Compton vs ACS rate**

Stronger rejection

**Quadratic fit**

\( R_{511}^{CO} = 6.863 \times 10^{-3} + 3.191 \times R_{511}^{PE} + 0.102 \times (R_{511}^{PE})^2 \)
- "Confirm" geometry
- 3 layers of 2x2 GeDs
- GeD ~ 8 x 8 x 1.5 cm³
- 37 strips per GeD
- Search for malfunctioning GeDs
**COSI: GeDs ON / OFF**

- 12 GeDs: 0 - 11
- Loss of detectors: 2, 3, 8
- Loss of 2 bottom rows of GeDs
- Small problems
- 4 “configurations”

**PASSIVE ACTIVE MATERIAL RATIO**

**Compton evts**
**Photoel. evts**
**ACS shield x 5e-3**
Shifted dipole approximation

Geoloc. (lat, lon, alt) → Geomagnetic coords.

Background modeling: Altitude

Background: Ability to extrapolate outside the atmosphere!

1. Altitude [km]
2. Cut-off rigidity [GeV]

\[ R_{511}(t) = \{ f[R_{\text{cut-off}}(t)] \times g[\text{Altitude}(t)] \} \]

exponential / polynomial fit:

\[ R_{511} = f_1 \times e^{f_2 \times \text{Altitude}} \]

\[ R_{511} = p_0 + p_1 \times \text{Altitude} + p_2 \times \text{Altitude}^2 \]
Background modeling: Rigidity

X: Rigidity (GeV)  
Y: Compton 511 (cts/s)

However:
problem - unknown:
1. polynomial x exp.  
2. polynomial

\[ R_{511} = (5.77 + 0.45 \times \text{Rig} - 6.6 \times 10^{-6} \times \text{Rig}^2) \times e^{-0.22\times \text{Rig}} \]

\[ R_{511} = (5.88 - 0.70 \times \text{Rig} + 0.03 \times \text{Rig}^2) \]
Background modeling: "Model 0"

\[ R_{511} = \left( (29.58 + 4.47 \times \text{Rig} + 0.18 \times \text{Rig}^2) \times e^{0.06 \times \text{Rig}} \right) \times e^{-0.05 \times \text{Alt}} \]

\[ R_{511} = 5.80 - 2.26 \times 10^{-2} \times (\text{Rig} \times \text{Alt}) + 2.57 \times 10^{-5} \times (\text{Rig} \times \text{Alt})^2 \]
Take into account different “configurations”: ALL / -1 / -2 / -3 GeDs

Apply one of the above models, e.g. 2nd order polynomial:
\[ R_{511}(t) = p_1 + p_2 \cdot x(t) + p_3 \cdot x(t)^2 \quad ; \quad x(t) = [\text{Altitude}(t) \cdot \text{Rigidity}(t)] \]

Parametrize the same function for each period

\[ \text{Fit. Res.} \approx 9\% \]
Background estimation: ACS rate

\[ R_{511} = -0.63 + 2.16 \times 10^{-4} \times R_{AC} - 1.56 \times 10^{-9} \times R_{AC}^2 \]

Quadratic fit:
\(<\text{Fit. Res.0}> \approx 6.9\% \)
\(<\text{Fit. Res.1}> \approx 5.9\% \)
1. **Delayed component:** $F(t) = Atmo.(t) + prompt(t) + delayed(t)$

Compton events $\rightarrow \theta_{\text{Compton}} \leq 30^\circ$ + downward evts. (no backscatter) + FOV (CsI shields) selection

2. **Galactic Center**

   Instrument orientation
   Effect evts. rate?
Expressing altitude as atmospheric pressure

\[ T[K] = -131.21 + 0.00299 \cdot \text{Alt}[\text{km}] \cdot 1000. \]

\[ p[\text{kPa}] = 2.488 \cdot \left[ \frac{(T+273.1)}{216.6} \right]^{-11.388} \]

\[ R_{511}(t) = 0.73 \cdot e^{(0.3 \cdot p)} \]

\[ R_{511}(t) = 0.53 + 0.52 \cdot p - 0.04 \cdot p^2 \]

\[ R_{511}(t) = (6.72 - 0.84 \cdot \text{Rig} + 0.03 \cdot \text{Rig}^2) \times (0.68 + 0.11 \cdot p + 0.06 \cdot p^2) \]

\(<\text{Fit.Res.}>\approx 9-10\%\]
ASCI: COSI as a building block

- 37 Ge strips (GeD/Wafer)
- Ge Wafer /w PC boards
- 4 x 3 stacks /w cold fingers
- Cryostat + PreAmps + cryocooler
- 6* CsI ACS: 4 side + 2 bot in Al housing /w PMTs
ASCI: Detector geometry idea

- **45 GeD:** 5 rows of 9 GeD
- **GeD:** 100 x 100 x 15 mm\(^3\)
  - ~100 strips: 2 mm pitch, 0.25 mm gaps
- **Guard ring and thermal isolation**
- **Cryostat:** at 85 K with IR isolation
- **Performance (~COSI):**
  - Position: <2. mm in X-Y ; 0.2 mm D.O.I
  - Energy: 1. - 3. keV FWHM
**ASCI: In space**

- **Compact “360°” GeD head**
- **4π FOV + low background**
- **Deployable mast**
- **Far from Earth: L2 orbit**

**Energy range**
- 0.1 – 10 MeV

**Spectral resolution (10 MeV - 0.1 MeV)**
- 0.2 – 1 % FWHM

**Field of view**
- $4\pi$ at all times

**Angular resolution**
- 511 keV: 2.7° (4.5° at sensitivity limit)
- 847 keV: 2.1° (3.5° at sensitivity limit)
- 1809 keV: 1.6° (2.7° at sensitivity limit)

**Narrow line sensitivity**
- Any DC source after $T_{\text{obs}} = 3$ year:
  - 511 keV: $2.6 \times 10^6$ ph cm$^{-2}$ s$^{-1}$
  - 847 keV: $1.1 \times 10^6$ ph cm$^{-2}$ s$^{-1}$
  - 1809 keV: $7.2 \times 10^5$ ph cm$^{-2}$ s$^{-1}$

**Continuum sensitivity**
- Any DC source, $T_{\text{obs}} = 3$ year:
  - 500 keV: $4.2 \times 10^5$ ph cm$^{-2}$ s$^{-1}$ MeV$^{-1}$
  - 5 MeV: $1.5 \times 10^6$ ph cm$^{-2}$ s$^{-1}$ MeV$^{-1}$

**Polarization sensitivity (MDP)**
- 1 Crab: 0.2% (statistical limit only)
- 3σ, any DC source, 200-500 keV
  - $T_{\text{obs}} = 3$ year: 2.4%
  - 0.1 Crab: 23.6%

**GRB sensitivity (5σ)**
- $\sim 10^6$ erg/cm$^2$

**Timing**
- 1 μsec relative, 1 ms absolute
Ongoing and future work

Complete the work regarding background
- Finish secondary contributions
- Finish publication

Connection between COSI and ASCI?
- Is the background model applicable?
  number of detectors, passive material, balloon vs satellite… ?
- Can the main geometry be improved?
  detector head / mast design / materials …

ASCI final performance
- Find the performance estimate with the best possible background estimation
Thank you