# Study of Al-26 in the COSI 2016 Superpressure Balloon Flight

Jacqueline Beechert[a] for the COSI collaboration (a: UC Berkeley, Email: jbeechert@berkeley.edu)

**The Compton Spectrometer and Imager (COSI)** is a balloon-borne gamma-ray telescope (0.2-5 MeV) which utilizes Compton scattering in its detector volume to reconstruct incident photons. Its scientific capabilities span detecting and measuring GRB polarization, mapping the 511 keV emission, and **studying Galactic nucleosynthesis, particularly Al-26 at 1809 keV.**

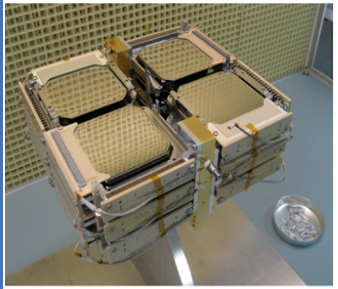


Fig. 1: COSI's detector volume comprised of 12 high-purity germanium semiconductor detectors (8 x 8 x 1.5 cm$^3$, 2-mm strip pitch, energy resolution of 0.24% at 1.84 MeV)

Fig. 2: COSI before the 2016 launch from Wanaka, NZ

## Search for Al-26: COSI 2016 Balloon Flight Data (46 days: May 17-July 2, 2016)

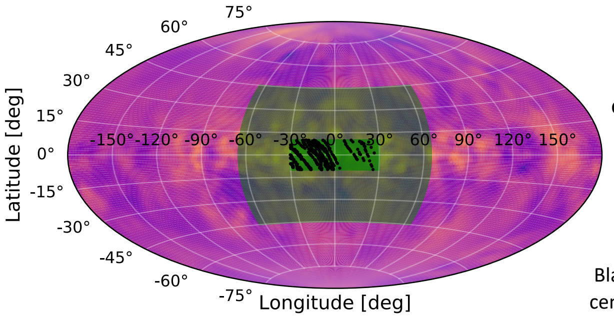



Fig. 3: SPI Al-26 image[1] shows emission concentrated in the Inner Galaxy (I.G.) → choose the I.G. as the signal region (green) and the rest of the sky as the background region.

Black points: COSI exposures within the I.G. central green region: ($|\ell| \leq 30°, |b| \leq 10°$) Extended green region: extension out to maximum Compton scatter angle of 35°

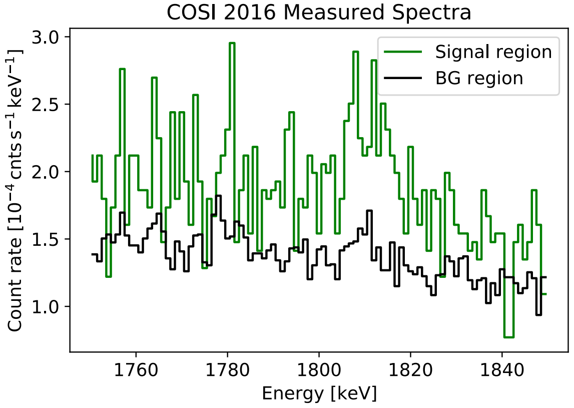



Fig. 4: COSI 2016 measured spectra in the signal region (Fig. 3) and the BG region (everywhere else)

## Maximum-Likelihood Approach:

Find sky amplitude $\alpha$ and BG amplitude $\beta$ which best describe the flight data in the signal region, $N^i_{signal}$.

$$N^i_{signal} = \alpha N^i_S + \beta N^i_B$$

Sky model (Al-26) BG model

1-keV energy bins $i$ in 1750-1850 keV

Fig. 5: Sky model: COSI's normalized response to Al-26 over 50 simulated 2016 flights

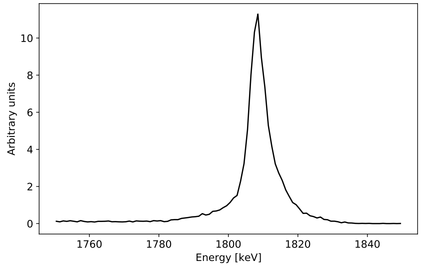
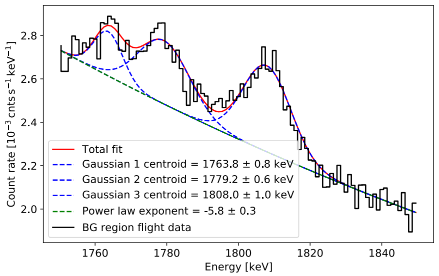



Fig. 6: BG model shape parameters: Power law + 3 Gaussians fit to all data in the background region




Gaussian shape parameters (Fig. 6) are included in a fit of the BG model, defined as the BG flight spectrum (Fig. 4) normalized to its mean.

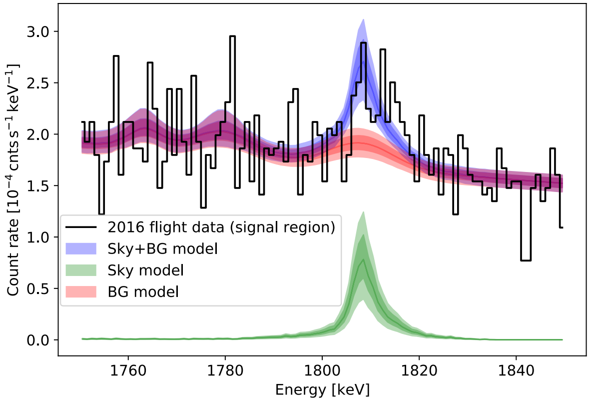
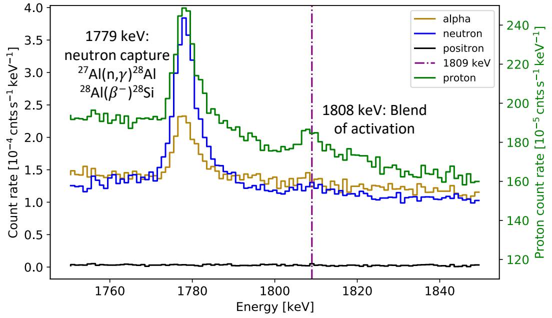



Fig. 7: Sky model (Al-26) contribution to the flight data in the signal region, with fitted sky amplitude $\alpha = 1.1 \pm 0.3$ and approximately 100 sky counts, yields **3.7$\sigma$ significance**

| | Significance | Centroid [keV] | Flux [$10^{-4}$ ph cm$^{-2}$ s$^{-1}$] |
|---|---|---|---|
| COSI | 3.7 | 1811.3 ± 1.9 | 17.0 ± 4.9 |
| SPI[3] | 53.6 | 1809.83 ± 0.04 | 7.3 |
| COMPTEL[4] | >20 | ---- | 8.2 |

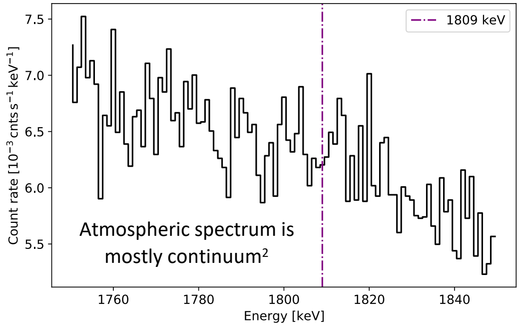
## Background simulations: 46-day instrumental activation + 1 day atmospheric

Fig. 8: Instrumental BG origin by particle, in decreasing order of prominence: proton, neutron, alpha, positron




Instrumental shape differs from real data (Fig. 6), which exhibits a peak near 1764 keV.

Fig. 9: Atmospheric background




## Take home messages

- **COSI finds an excess at 1.8 MeV consistent at the 2$\sigma$ level with expectations from Al-26**
- Instrumental and atmospheric background simulations are being used to validate the results
- Investigations ongoing: using different template maps (COMPTEL, SPI), image reconstruction, model fitting

References:
1 L. Bouchet, E. Jourdain and J.-P. Roques, *The galactic 26Al emission map as revealed by INTEGRAL SPI, The Astrophysical Journal* 801 (2015) 142.
2 J.C. Ling, *A semiempirical model for atmospheric $\gamma$ rays from 0.3 to 10 MeV at $\lambda$= 40°*, Journal of Geophysical Research 80 (1975) 3241.
3 M.M.M. Pleintinger, *Star groups and their nucleosynthesis*, Ph.D. thesis, Technische Universität München, 2020.
4 J. Knödlseder et al. *Modelling the 1.8 MeV sky: tests for spiral structure. Astronomy and Astrophysics Supplement Series*, vol. 120, pp. 335-338 (1996).

Acknowledgements: COSI is supported through NASA APRA Grant 80NSSC19K1389.