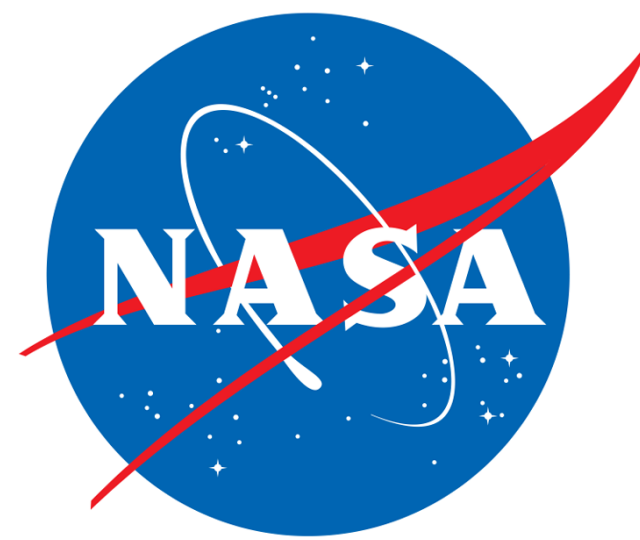# The Compton Spectrometer and Imager (COSI):
opportunities for
joint analyses with Fermi

Israel Martinez
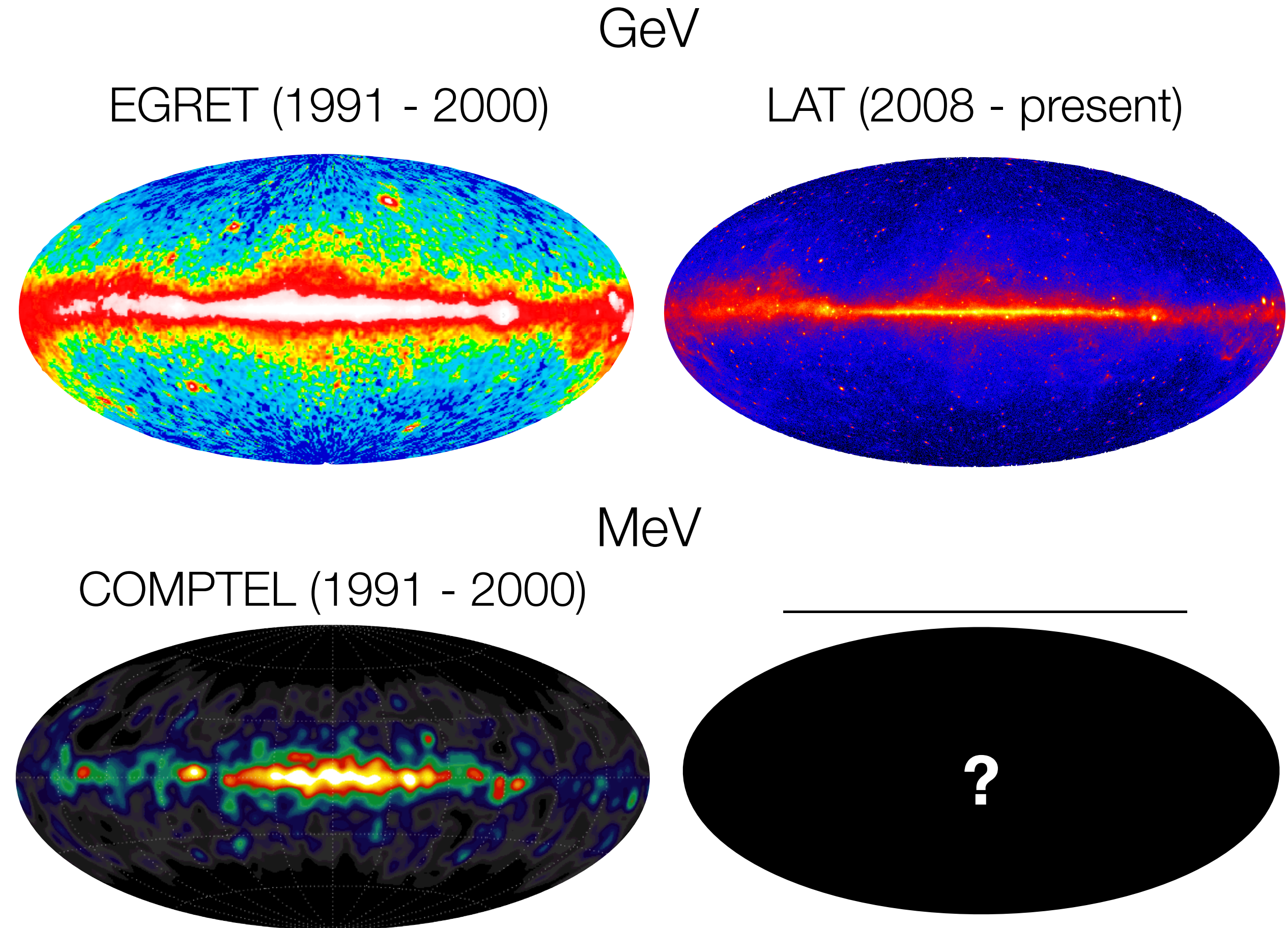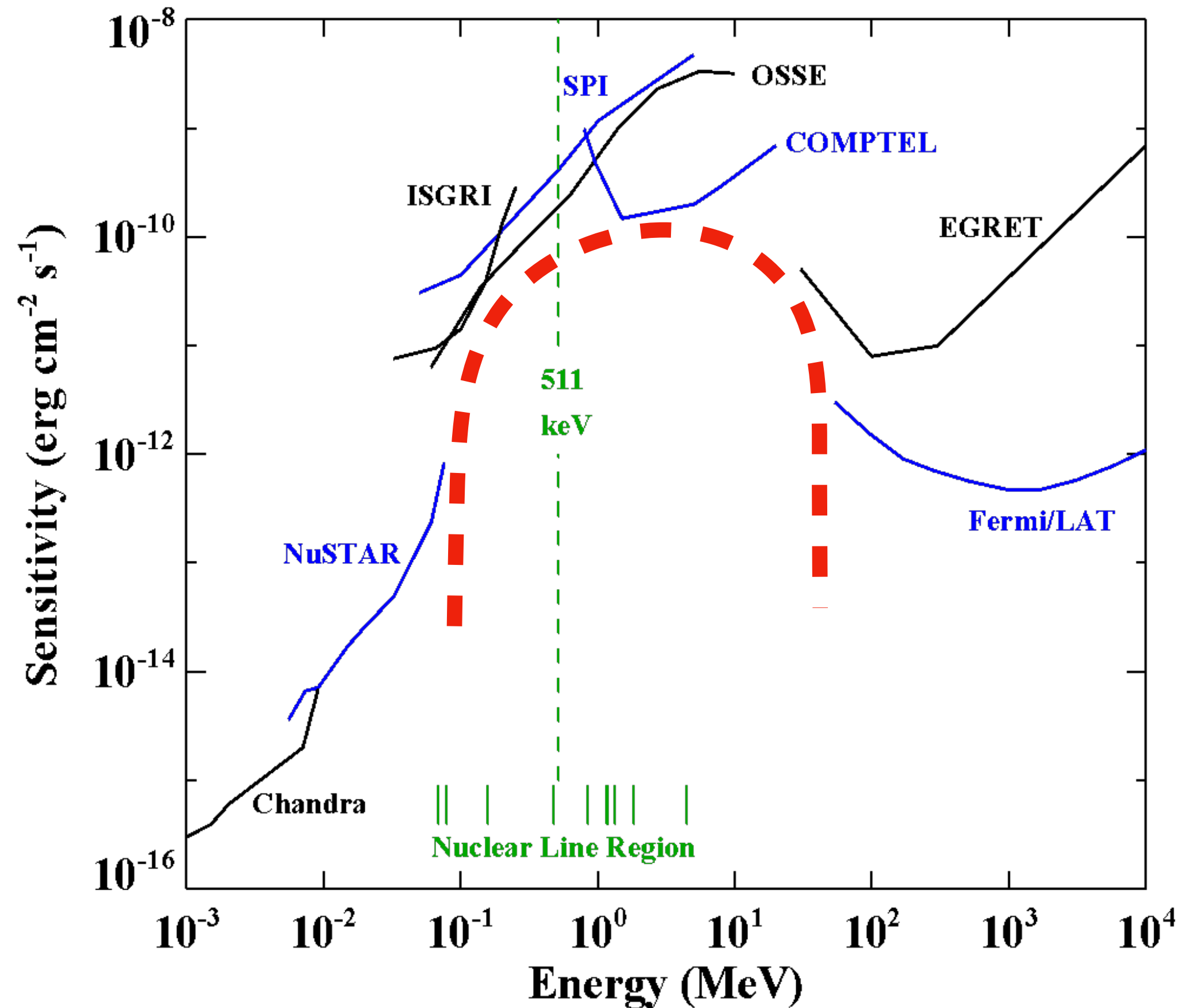University of Maryland / NASA-GSFC
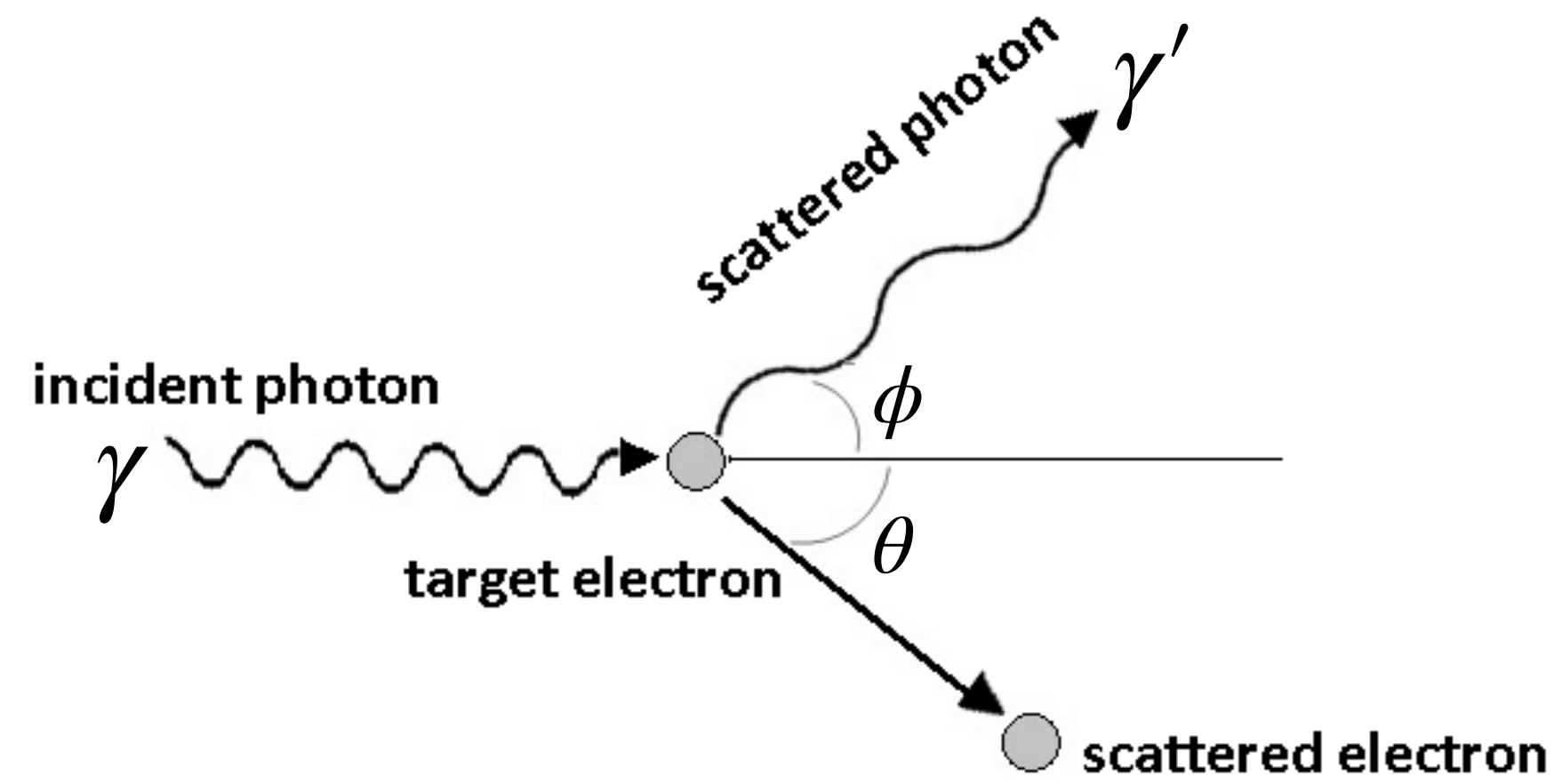September 13, 2024
11th Fermi Symposium

MeV gap

- The MeV sky is severely under explored compared to neighboring energy bands

- High discovery potential at energies slightly below Fermi-LAT's

GeV

EGRET (1991 - 2000)

LAT (2008 - present)

MeV

COMPTEL (1991 - 2000)

?

Dominated by Compton scattering

Dominated by Compton scattering

incident photon
γ
scattered photon
γ′
target electron
ϕ
θ
scattered electron

**Imaging capable,
but it's complicated.**

(l, b)
$(l, b)'$
E_0
φ
r_1, E_1
r_2, E_2
event circle
(circle of possible source locations)

Dominated by Compton scattering

scattered photon

γ'

incident photon

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$(l, b)'$

event circle

(circle of possible
source locations)

E_0

φ

$\mathbf{r}_1, E_1$

$\mathbf{r}_2, E_2$

ϕ_i

$(l, b)'_i$

source
location

event
circle

(l, b)

Dominated by Compton scattering

γ'
scattered photon

incident photon
γ

ϕ

θ

target electron

scattered electron
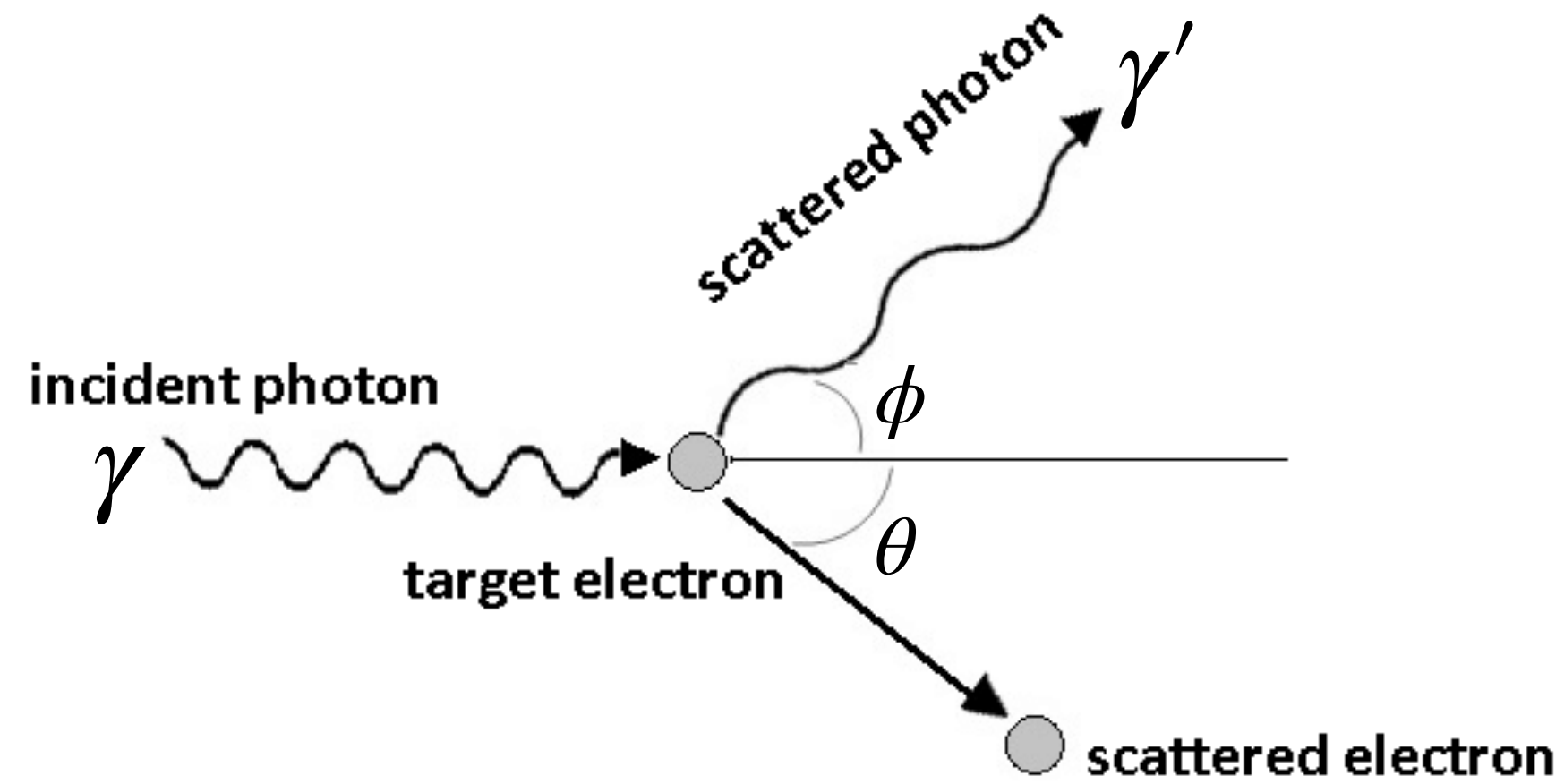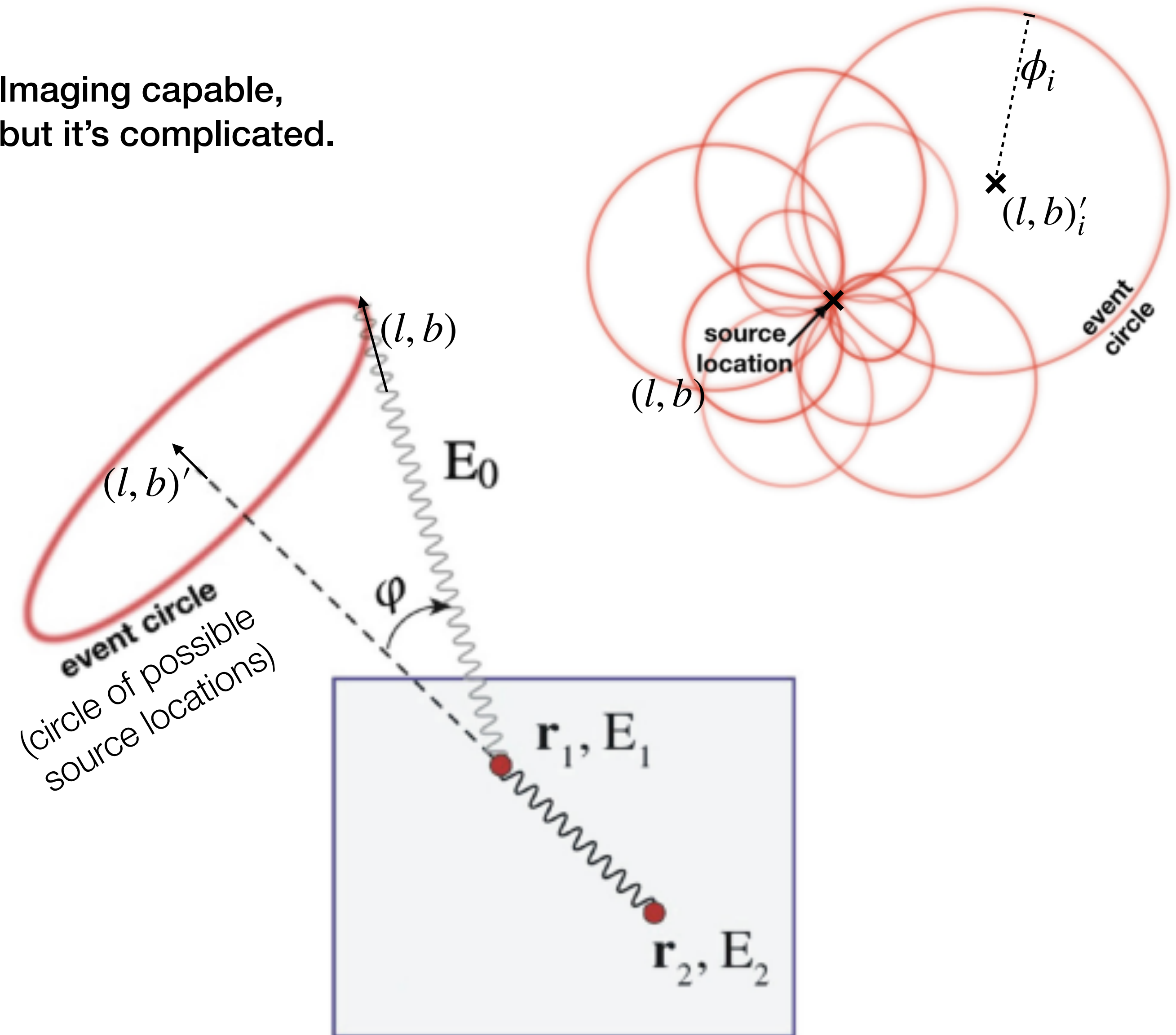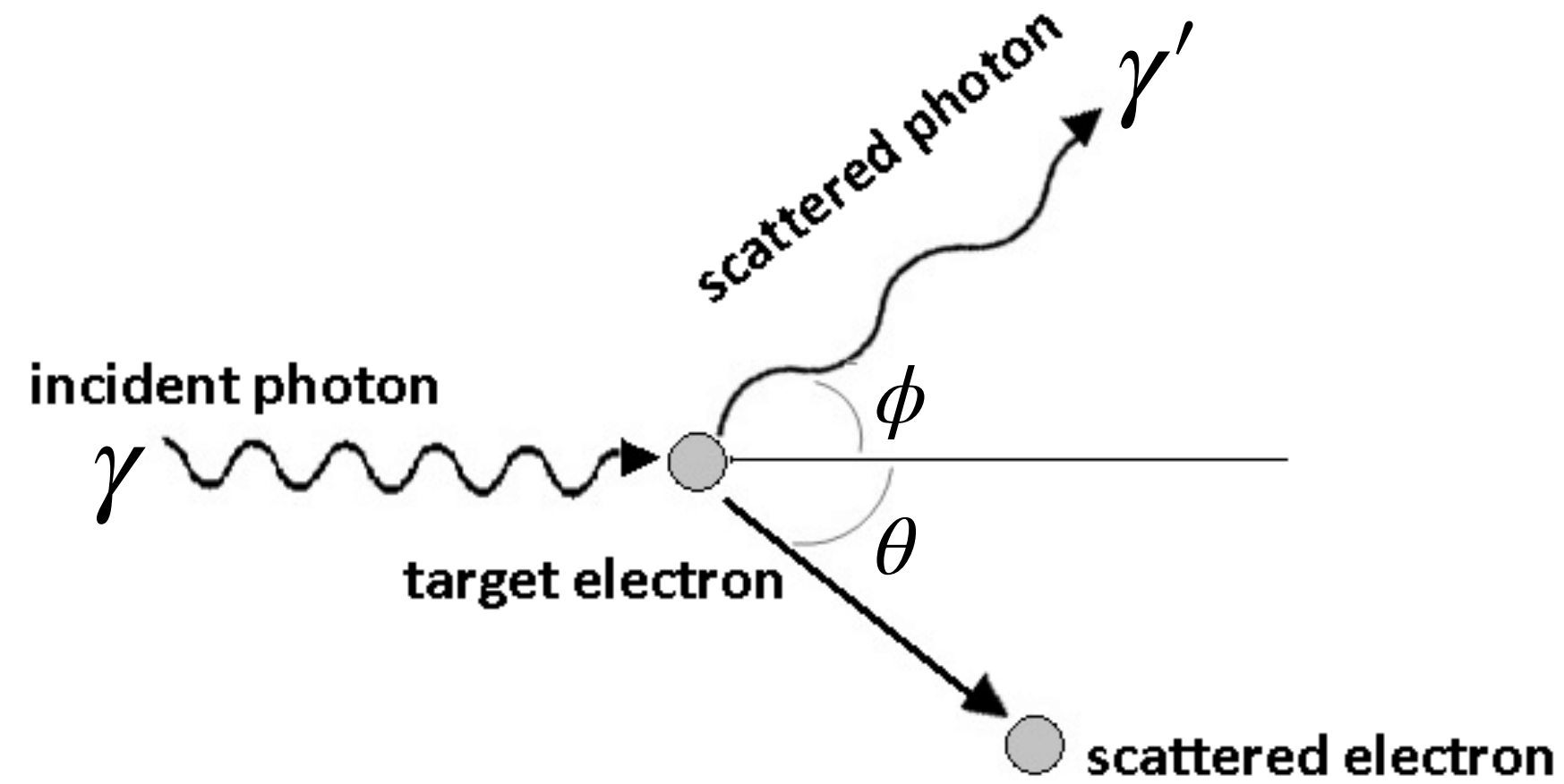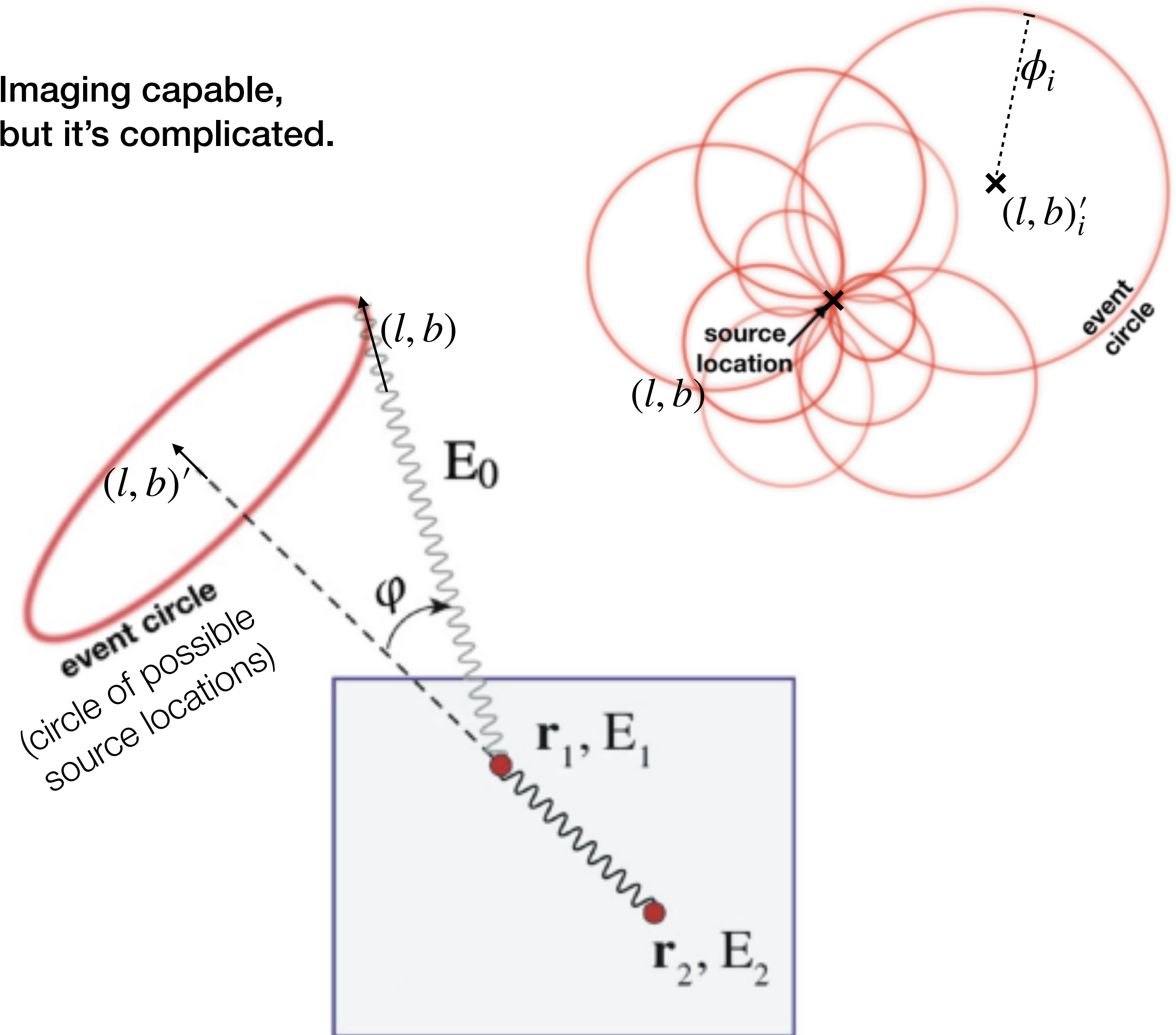
You can measure polarization

Counts

PA

−100   0   100

Azimuthal angle [deg]

**Imaging capable,
but it's complicated.**

(l, b)

$(l, b)'$

E_0

φ

event circle
*(circle of possible
source locations)*

$\mathbf{r}_1, E_1$

$\mathbf{r}_2, E_2$

ϕ_i

$(l, b)'_i$

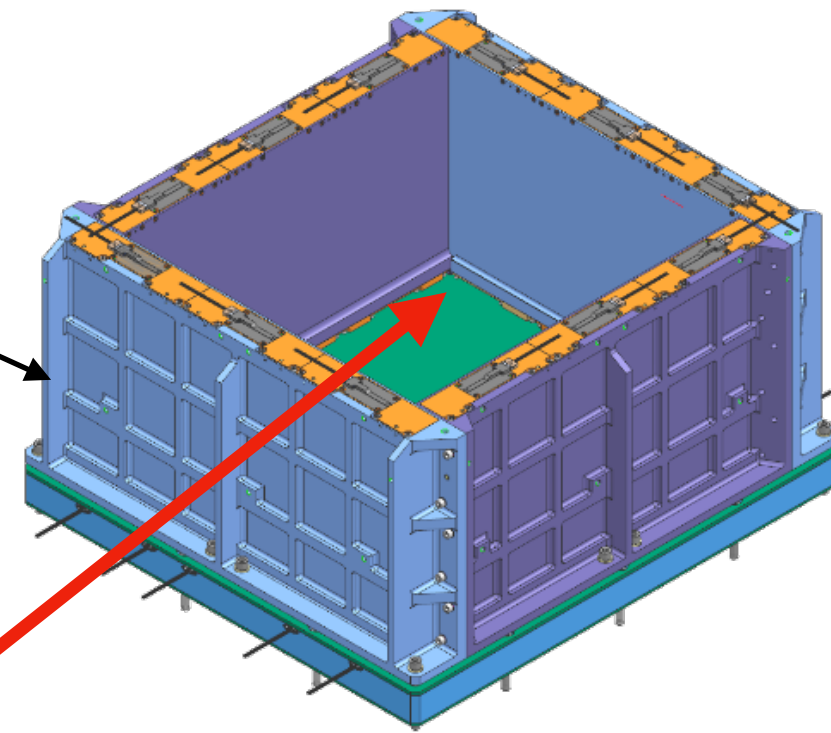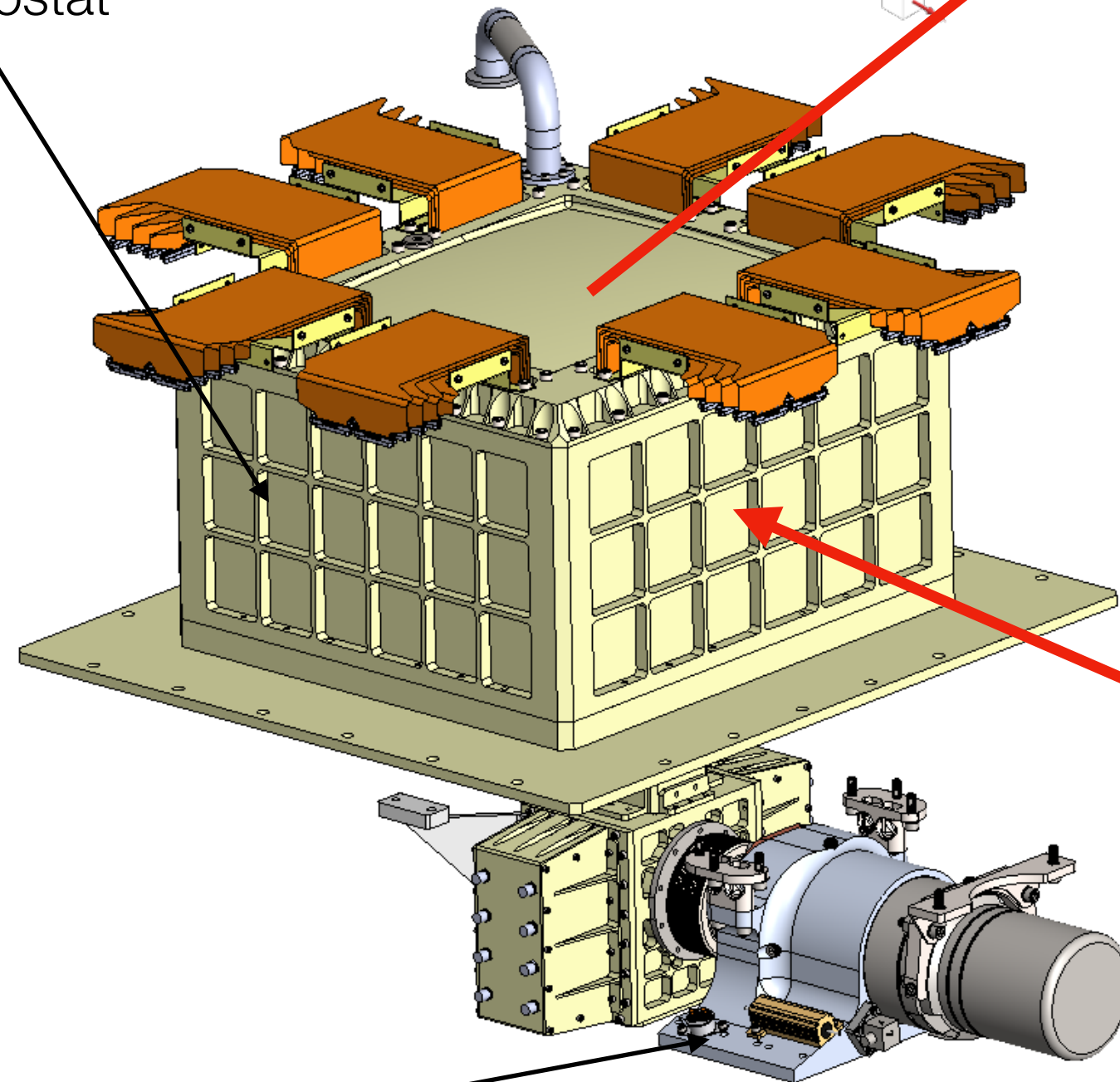(l, b)

source
location

event
circle
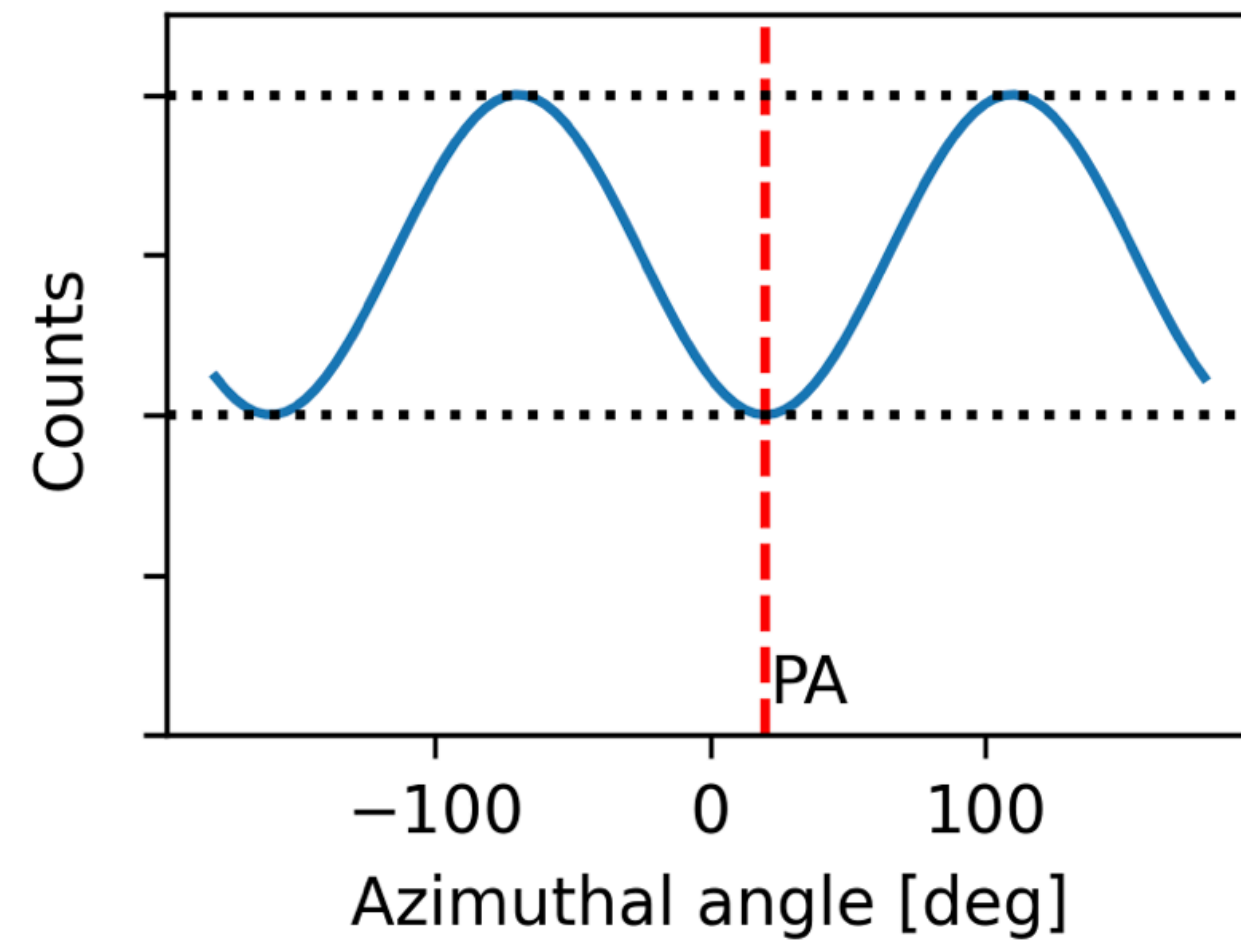
The Compton Spectrometer and Imager (COSI)

- COSI is launching in 2027 after a series of ballon flights
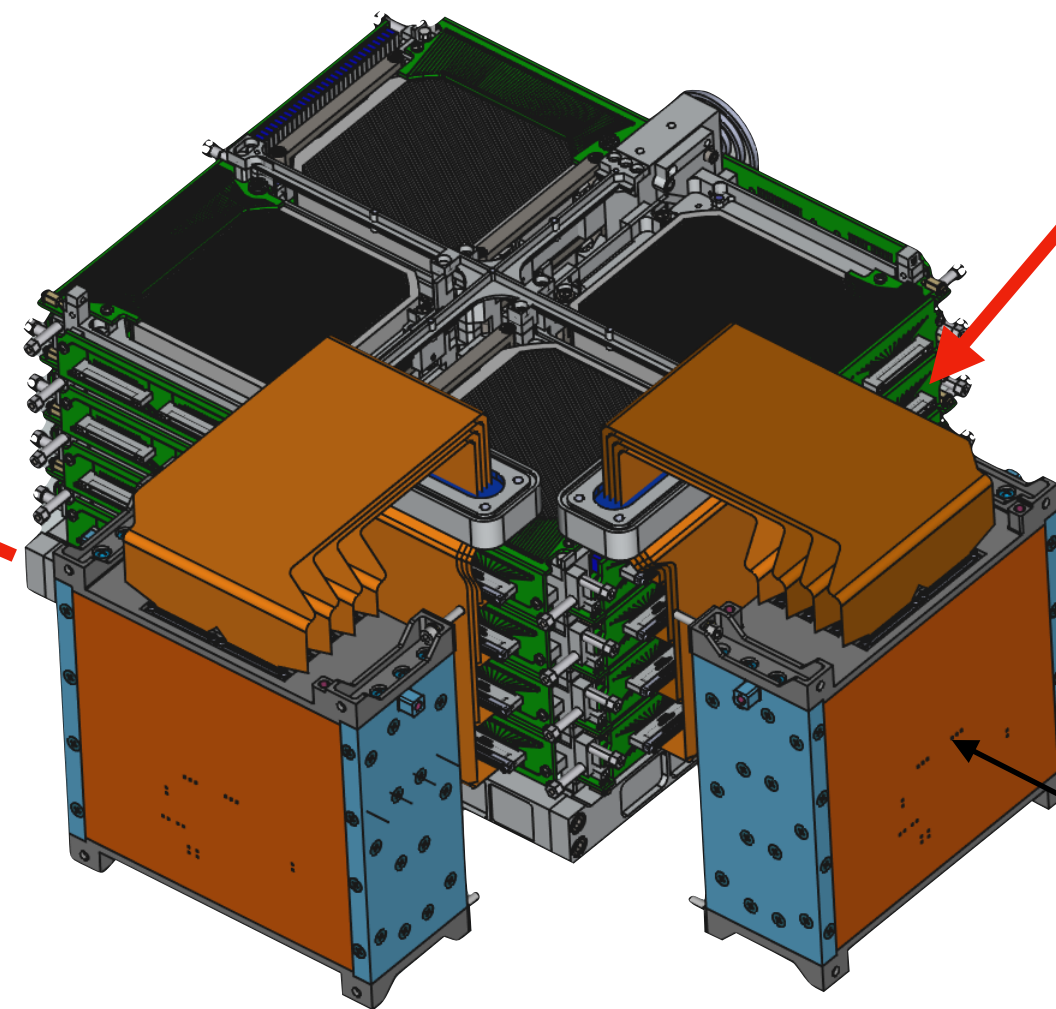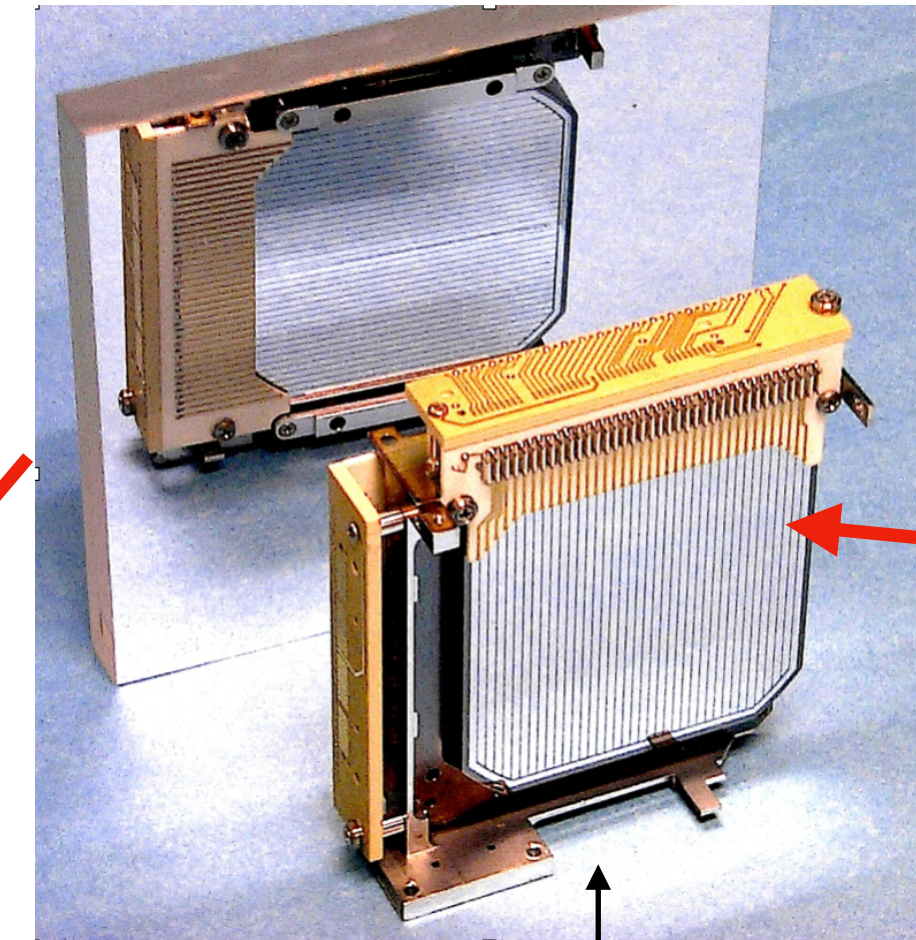- COSI makes use of germanium double sided strip detectors

2014   2016   2020   2027

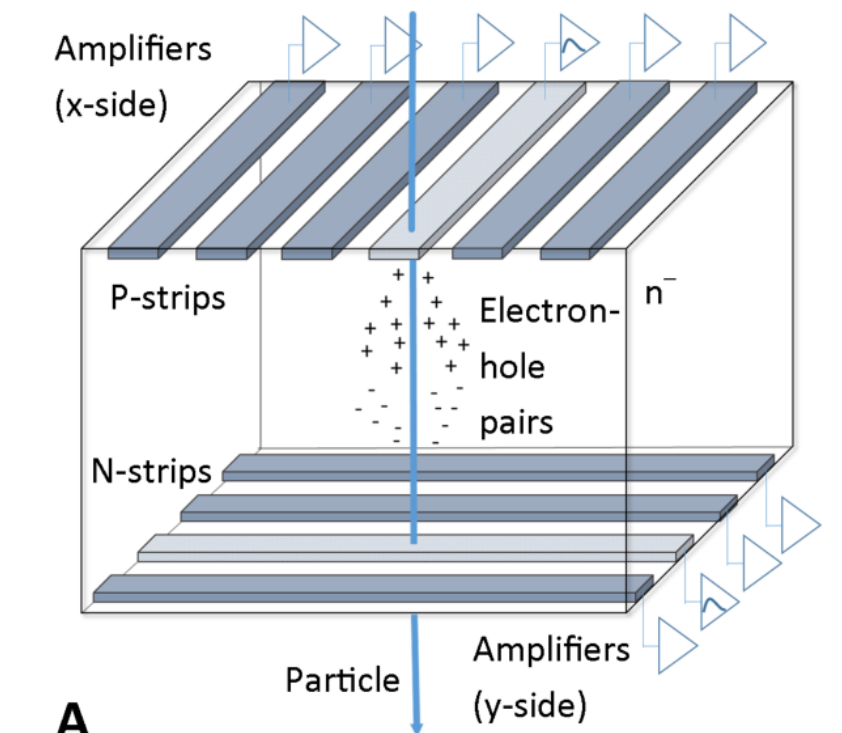Anti-coincidence shields

Cryostat

Cryocooler

Germanium detectors (16x)

Readout electronics

Amplifiers (x-side)

P-strips

N-strips

Electron-hole pairs

n^-

Particle

Amplifiers (y-side)

A

Double sided strips (3D hit positions)

Decent continuum sensitivity, carving into the MeV gap
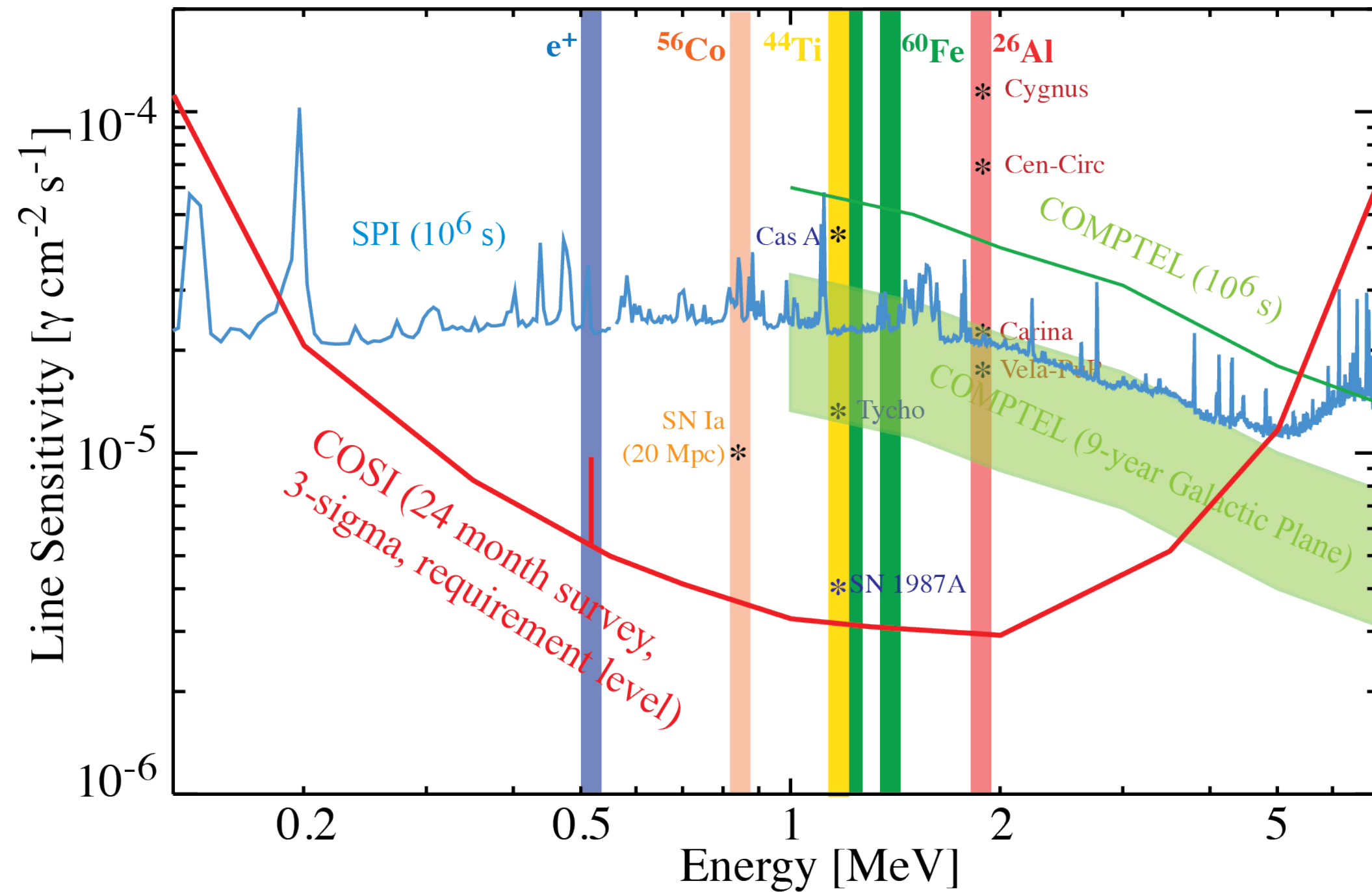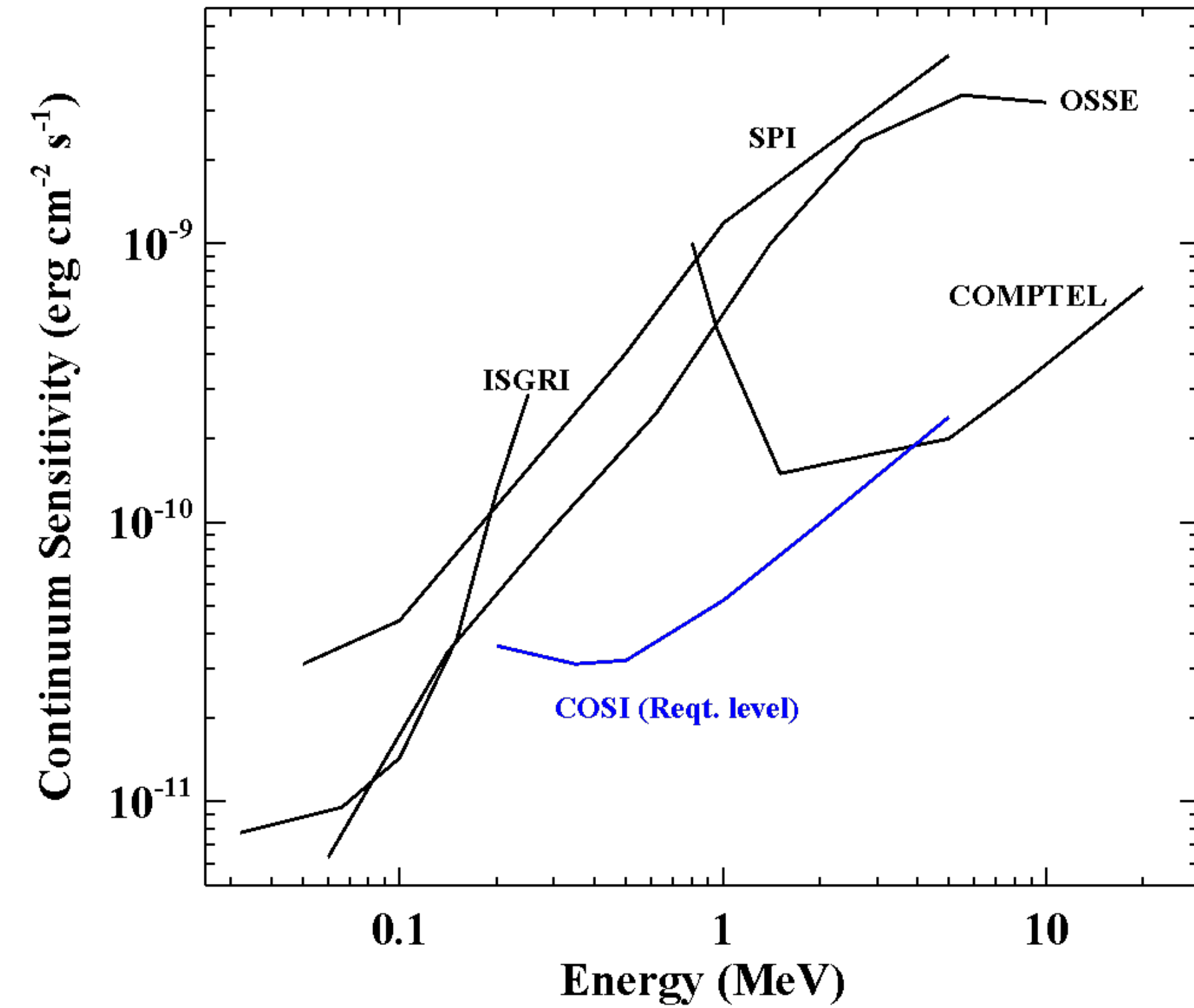

Optimized to study MeV emission lines

Energy range: 0.2-5 MeV
Energy resolution: < 1.2% at 511 keV

Wide-field-of-view imaging-capable instrument

Field of view: > 25% of the sky
Angular resolution: < 4.1° at 511 keV
                        < 2.1° at 1.809 MeV

COSI Science Goals

Uncovering the Origin of Galactic Positrons
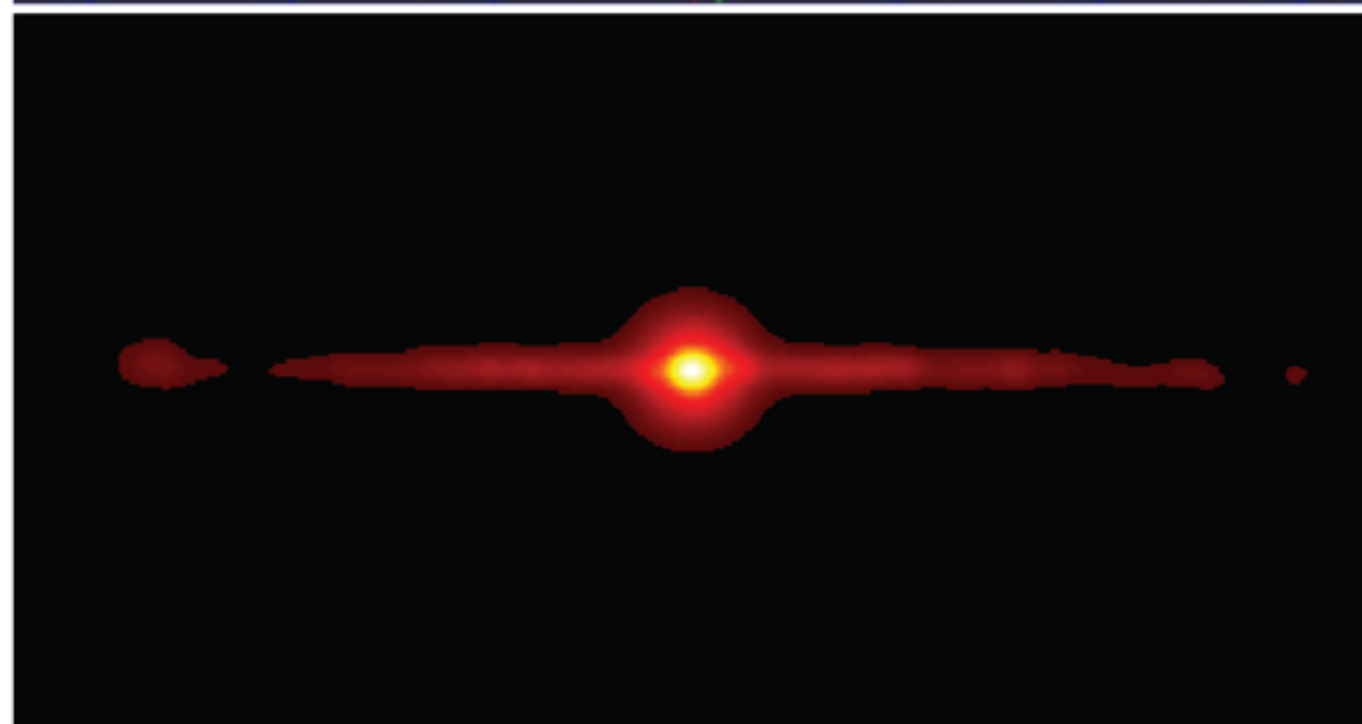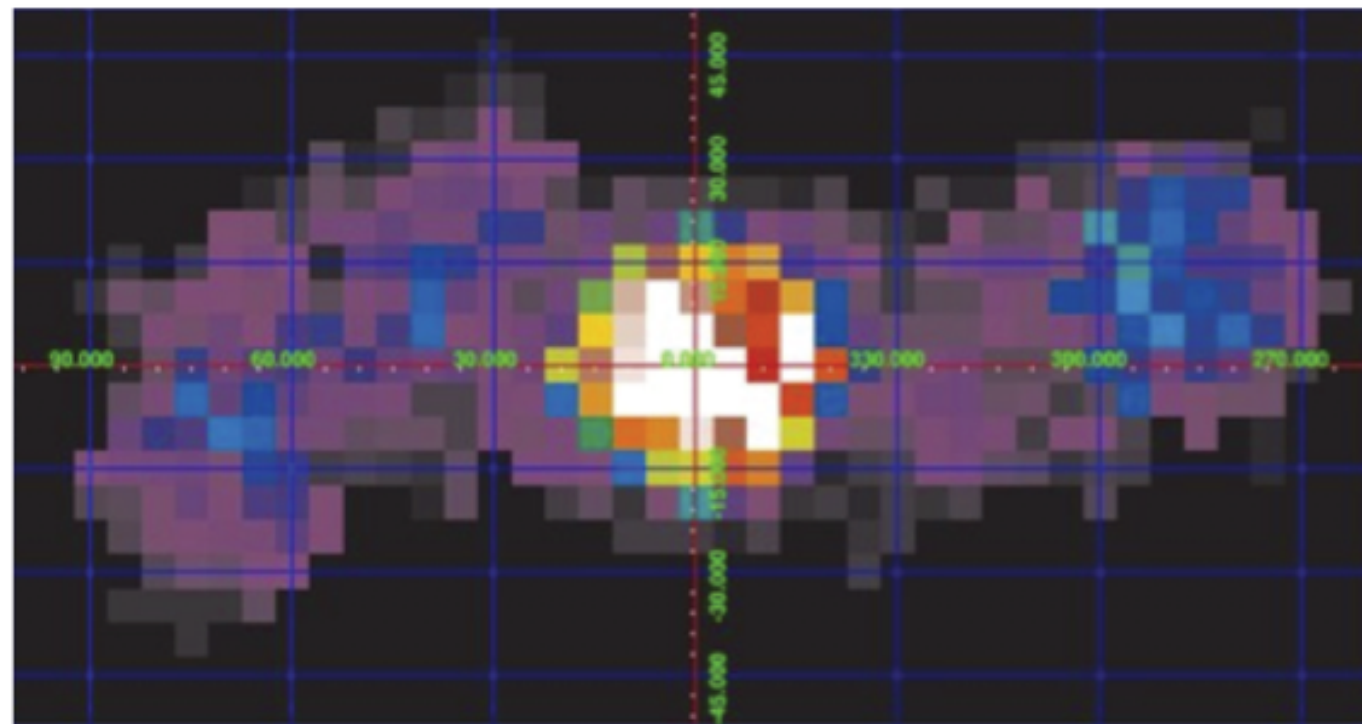
Reveal the Dynamics of Element Formation

Gain Insight into Extreme Environments with Polarization

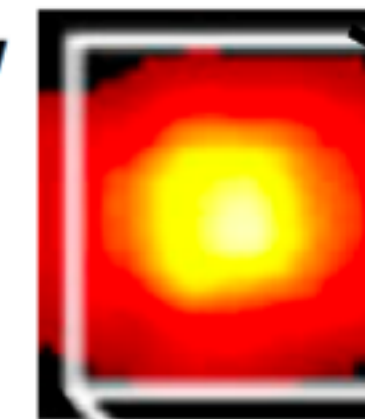Probe the Physics of Multi-Messenger Events

e+e- annihilation
511 keV

INTEGRAL/SPI (Bouchet+10)

^{26}Al decay
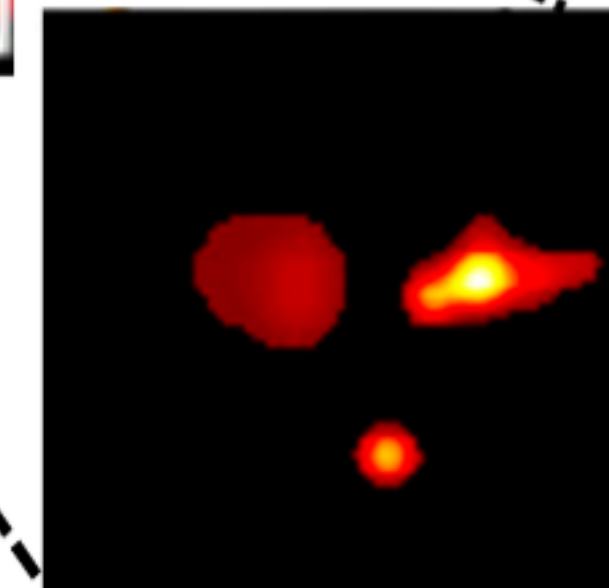1.809 MeV

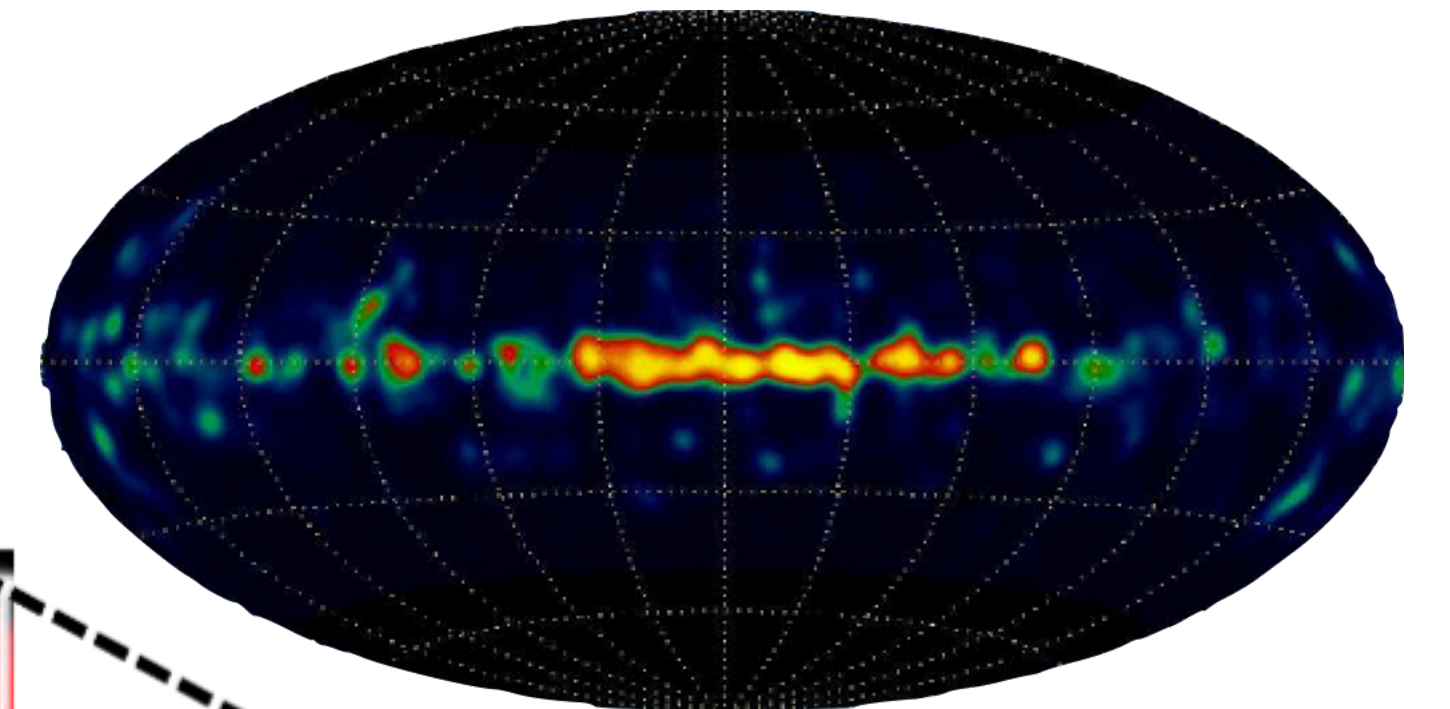COMPTEL (Oberlack+97, Pluschke+01)

Now

COSI

Now

COSI

COSI Science Goals
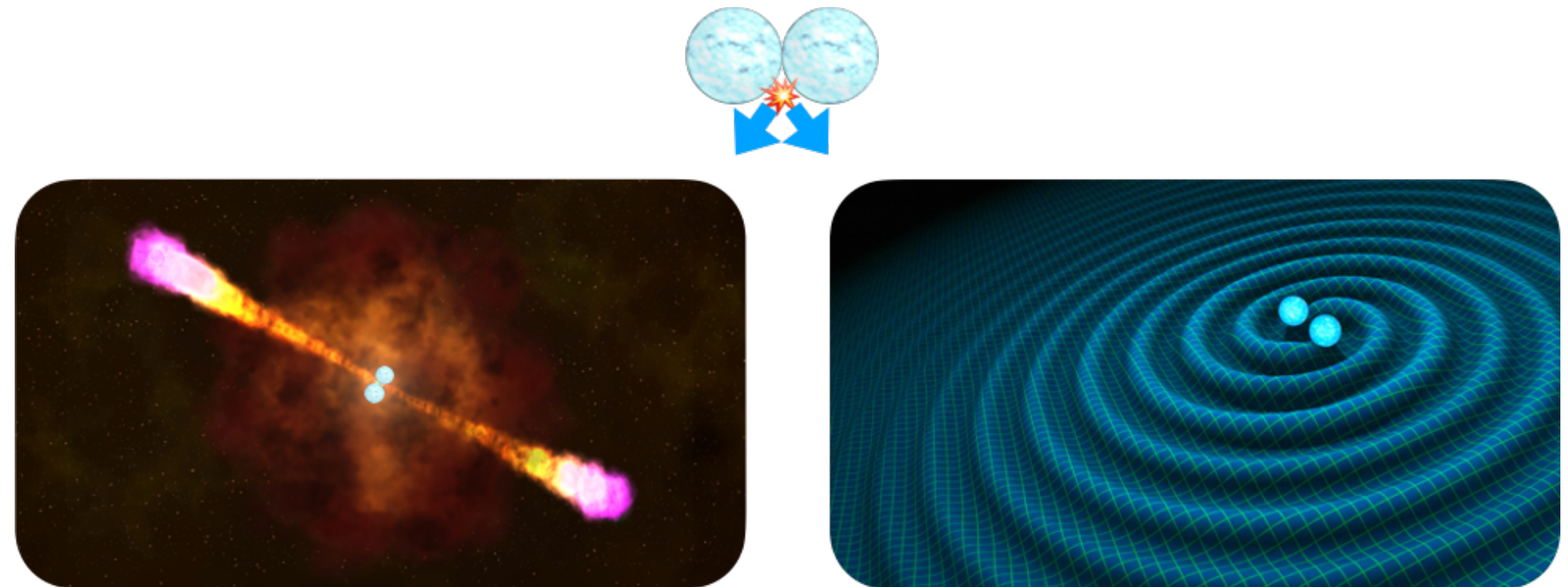
Uncovering the Origin of Galactic Positrons

Reveal the Dynamics of Element Formation

Gain Insight into Extreme Environments with Polarization

Probe the Physics of Multi-Messenger Events

AGN and GRB polarization

Gravitational wave and neutrino counterparts

The cosipy library 🚧

- Bringing modern analysis tools to MeV astronomy!

Open-source Python library

```
import cosipy
```

Poisson likelihood-based forward folding analysis

$$\mathscr{L}(s_j \,|\, n_i) = \prod_i P\left(n_i \,|\, \lambda_i(s_j)\right)$$

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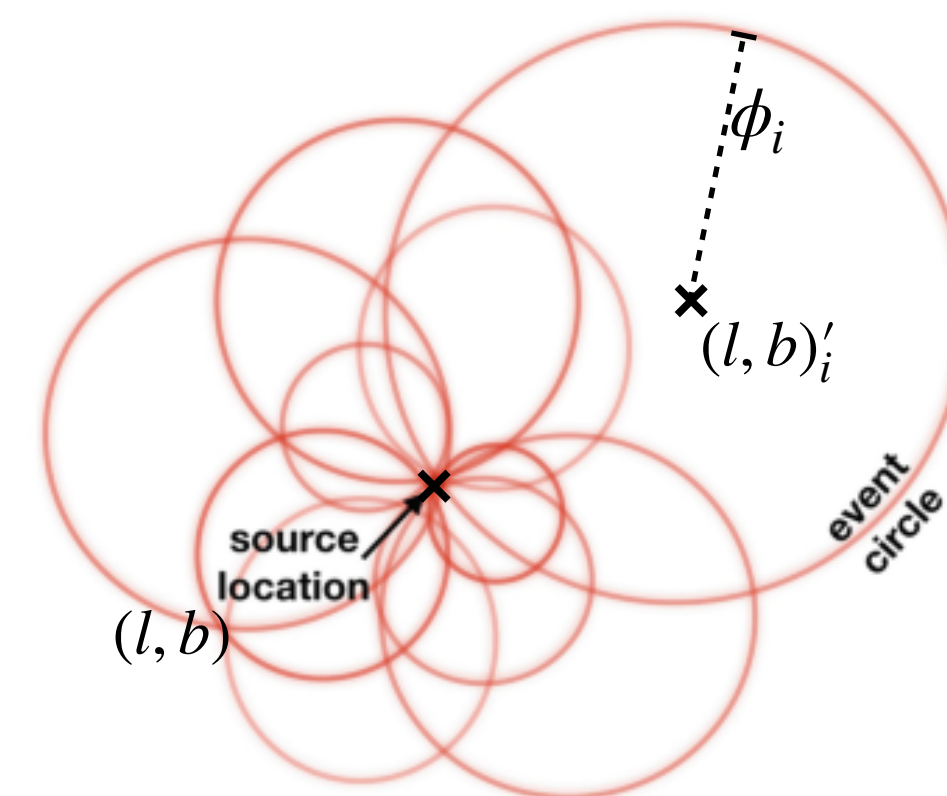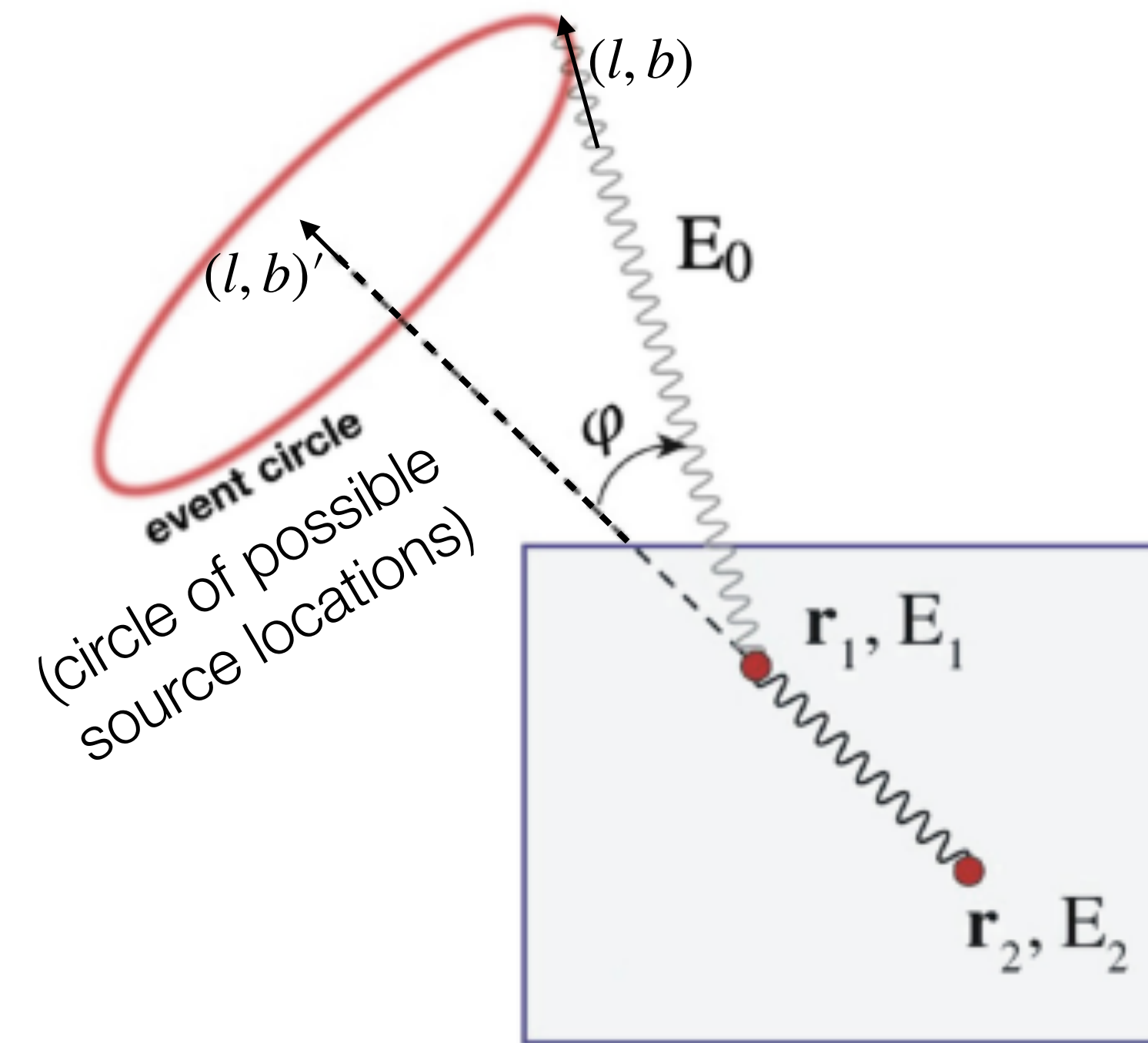
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Poisson likelihood-based forward folding analysis

$$\mathscr{L}(s_j \mid n_i) = \prod_i P\left(n_i \mid \lambda_i(s_j) \right)$$

3D Compton Point Spread Function

$(l, b)'$ space $\varphi = 0°$
$(l, b)'$ space $\varphi = 3'$
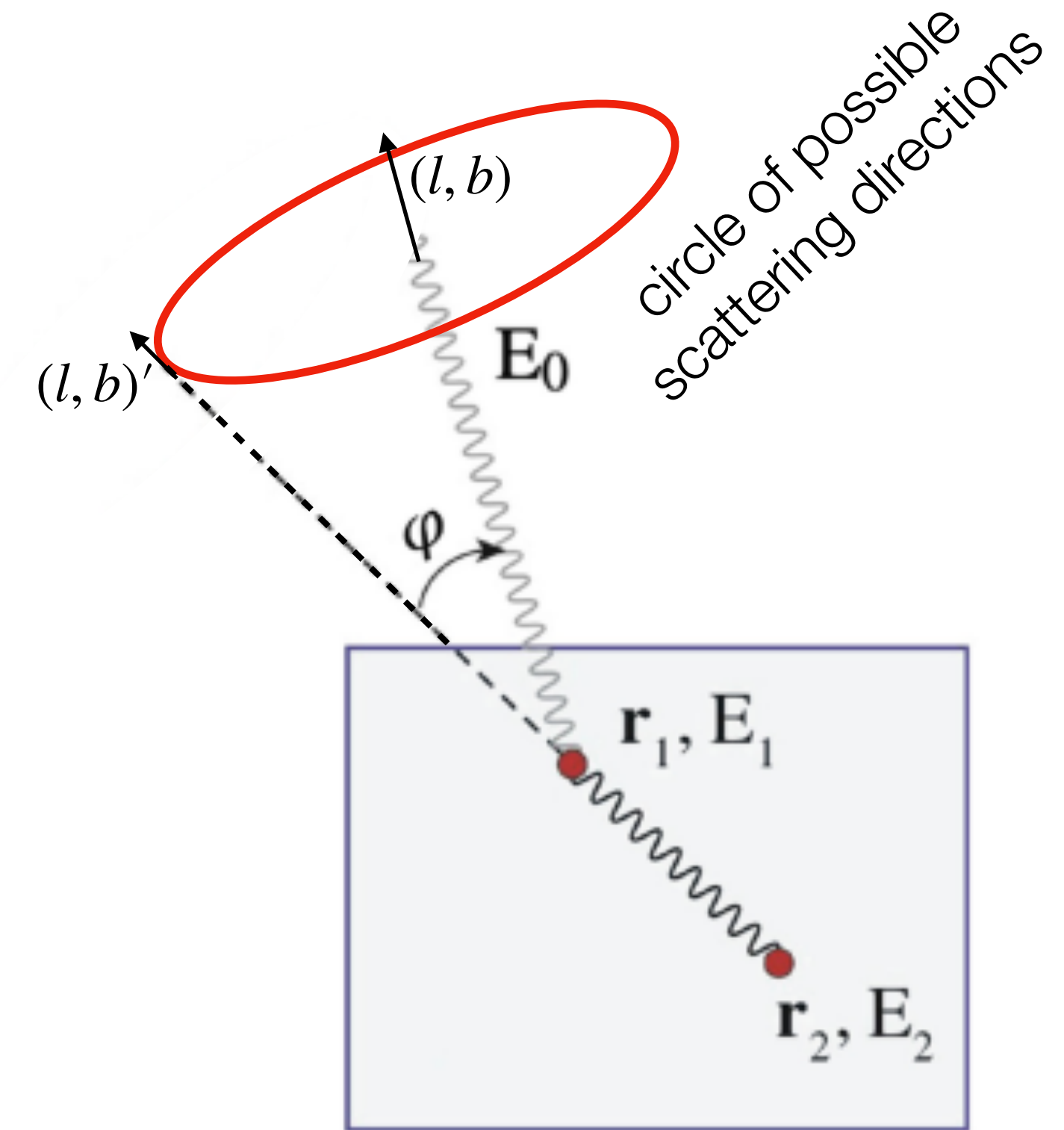$(l, b)'$ space $\varphi = 10°$
$(l, b)'$ space $\varphi = 30°$

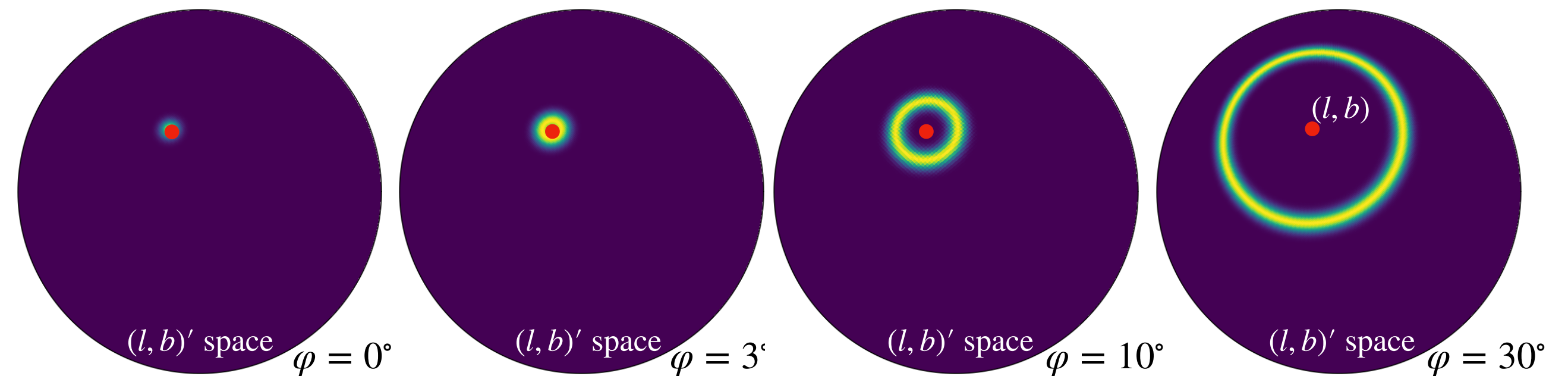- Bringing modern analysis tools to MeV astronomy!

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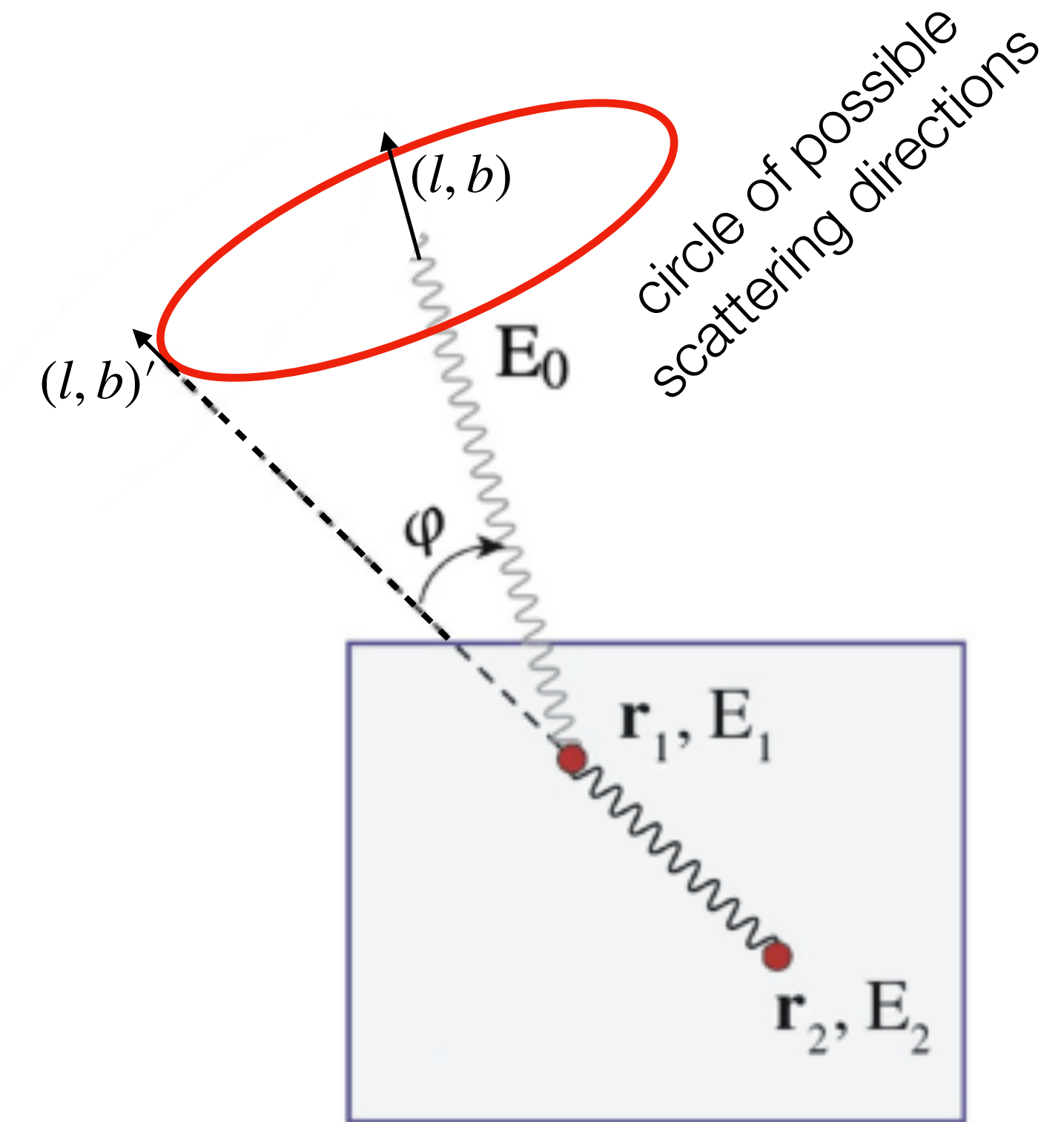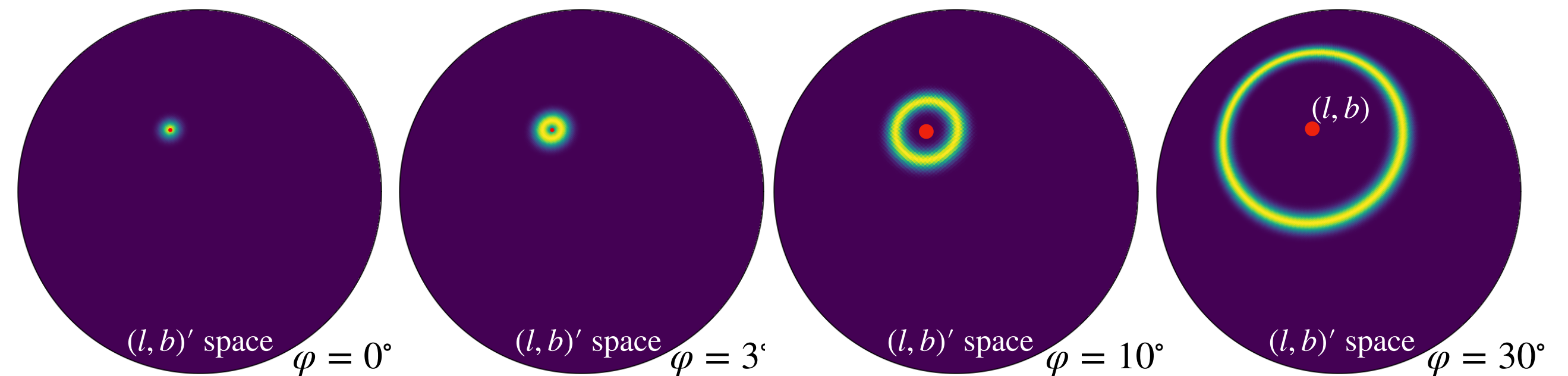
Compatibility with 3ML for multi-wavelength studies

3ML Multi-Mission Maximum Likelihood Framework

$$\mathscr{L} = \mathscr{L}_{\text{Fermi}} \mathscr{L}_{\text{COSI}}$$

3D Compton Point Spread Function

$(l, b)'$ space $\quad \varphi = 0°$ $(l, b)'$ space $\quad \varphi = 3°$ $(l, b)'$ space $\quad \varphi = 10°$ $(l, b)'$ space $\quad \varphi = 30°$
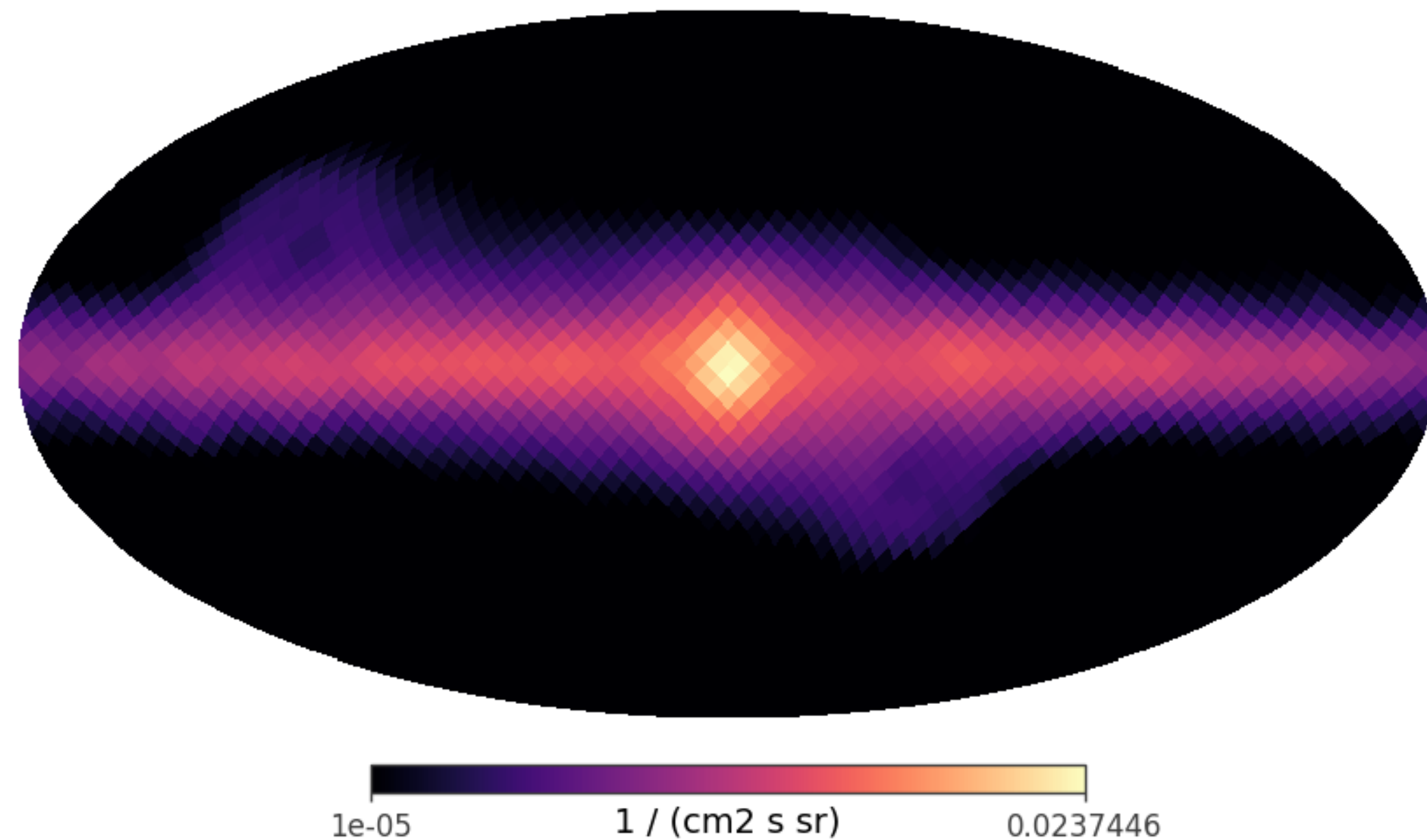
Data challenges

- We'll have yearly (beta) public cosipy releases

  - First released this past March, 2024

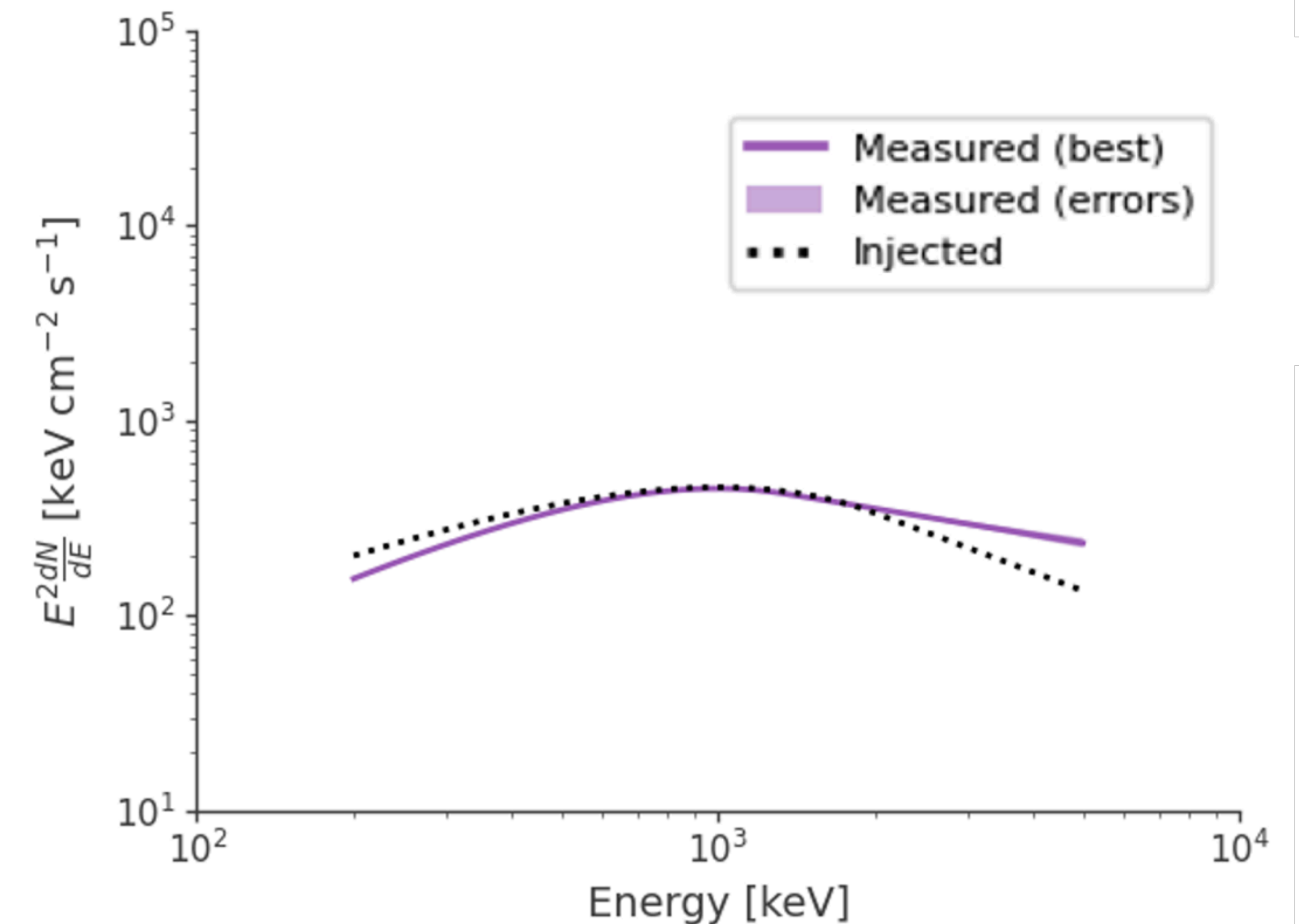- Each release is accompanied by a set of realistic simulated data
  and "challenges"

github.com/cositools/cosi-data-challenge-2
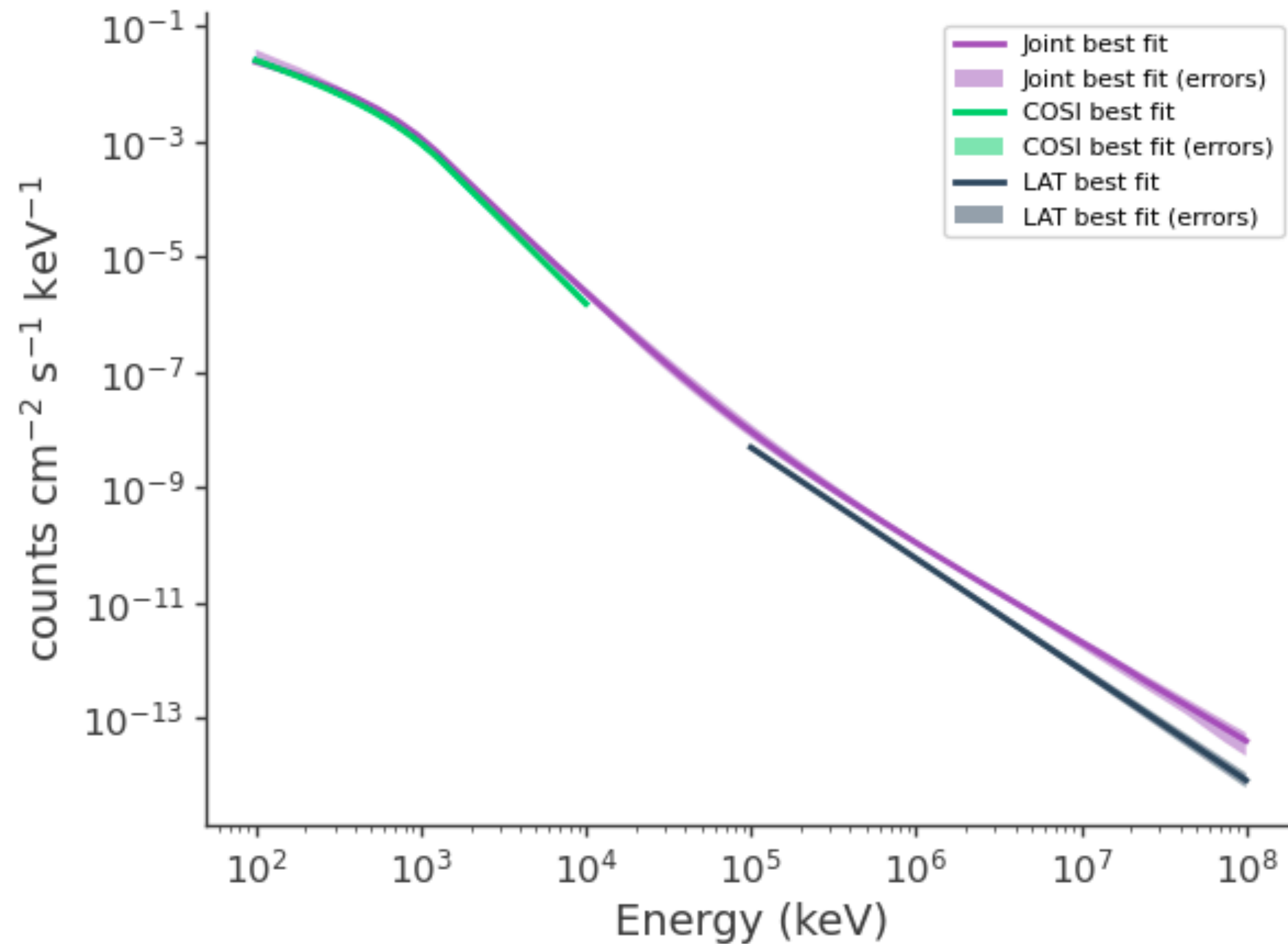
Image deconvolution:

511 keV image at 30th iteration

Spectral and spatial model fitting:

Eliza Neights
GW PhD student

- Very first attempt: fitting the spectrum of GRB 130427A

    - Real LAT data

    - Simulated COSI data

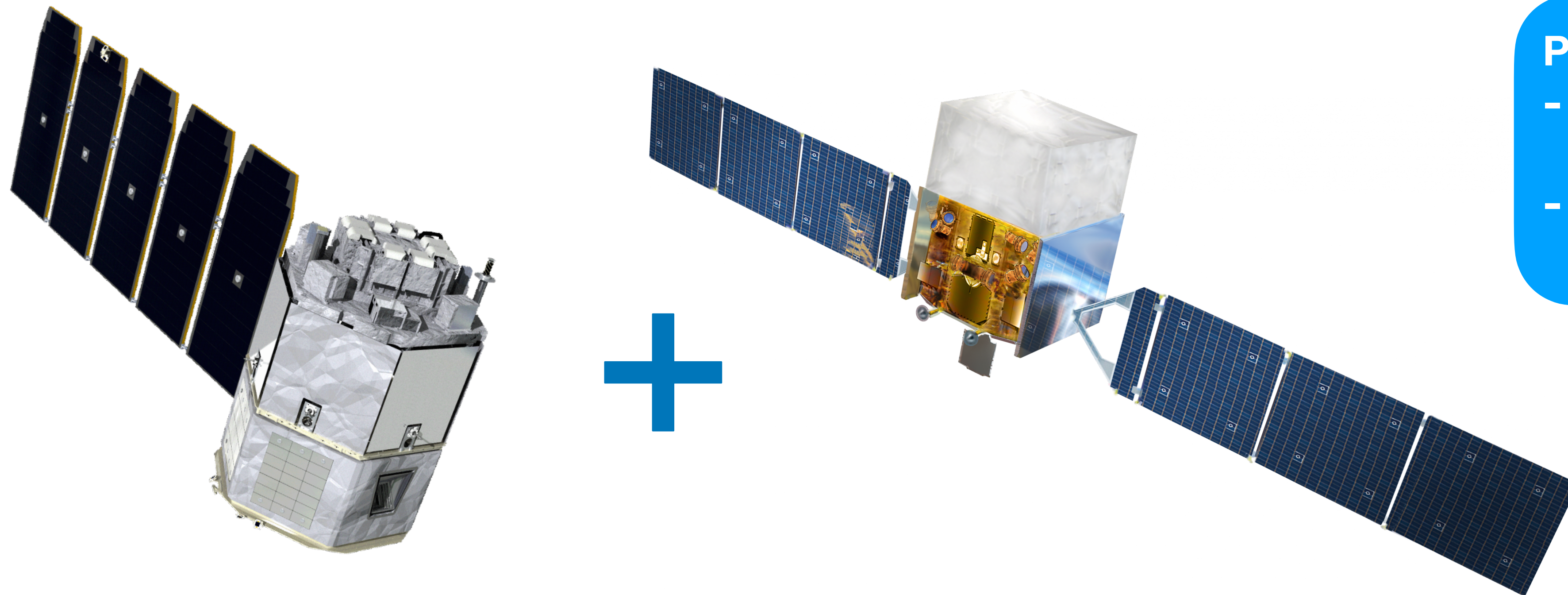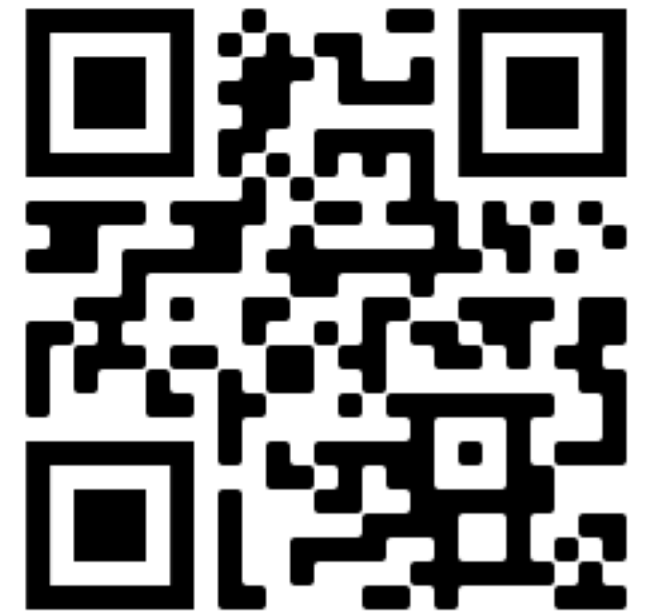- The machinery is working, but it still needs to be tuned

3ML **Multi-Mission Maximum Likelihood Framework**

Conclusions

- COSI is launching in 2027

  - Sensitive between 0.2-5 MeV

  - It can resolve emission lines

  - Wide-field-of-view imager

- The cosipy library and 3ML will allow to perform joint analyses with Fermi-GBM and Fermi-LAT

cosi.ssl.berkeley.edu

Posters:
- **Savitri Gallego:**
  - #26: Background sims
- **Robin Anthony-Petersen:**
  - #27: Event reconstruction