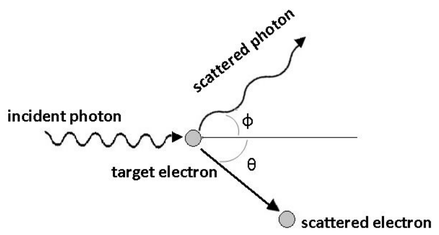
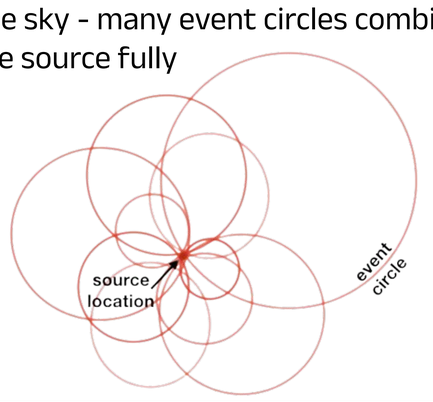
# Compton Imaging with Daksha

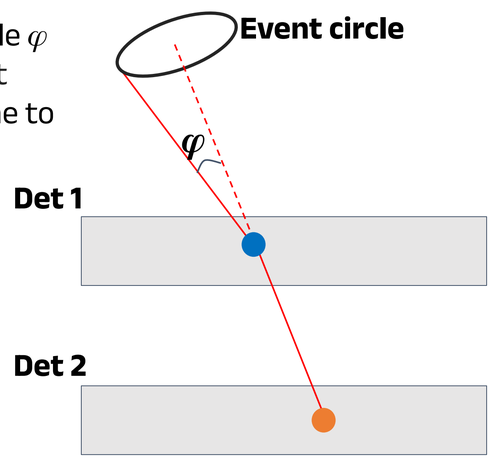
Advait Mehla (IIT Bombay), Gulab Dewangan (IUCAA Pune), Varun Bhalerao (IIT Bombay)

## Compton Imaging

- Imaging of sources in the 100 keV - 10 MeV band is challenging with conventional methods - Compton scattering is the dominant interaction process
- Need to accurately measure the energy deposits and positions from both interactions to find source information
- Observing a single Compton pair gives the scattered photon vector and scattering angle $\varphi$
- This lets us constrain the source to an event circle in the sky - many event circles combine to localize the source fully




## Opportunity with Daksha

- Potential for all-sky Compton imaging of sources in the sub-MeV band, thanks to its unique dome-shaped arrangement of Medium Energy (ME) detectors
- Current focus on events where an ME detector acts as the scatterer, High Energy (HE) detector as the absorber
- Energy ranges are 20-200 keV for ME, 200 keV-1 MeV for HE, leading to its combined sub-MeV sensitivity for Compton imaging

## Other Notable missions

- All sky maps in the X-ray have been attempted by several missions previously, such as Swift-BAT in the 14-195 keV range, COMPTEL in the 1-30 MeV range
- The upcoming COSI mission (2027 launch) aims to do this over 0.2-5 MeV
- There is thus still a gap in information about sources in the sub 1 MeV band, known as the MeV gap
- Daksha can attempt to fill this with integrations over ~1 Ms timescales to find new sources and improve spectra of existing ones

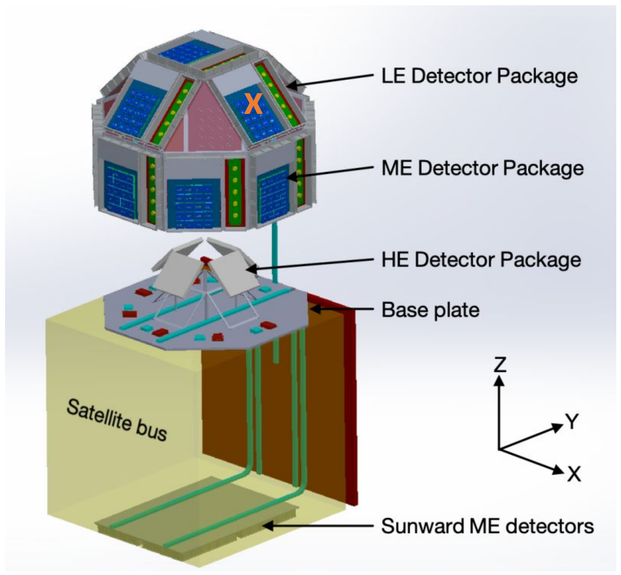
## Satellite layout and Detectors

### ME Packages (13 dome-mounted)

| | |
|---|---|
| Energy range | 20-200 keV |
| Energy resolution | 10% |
| Timing resolution | 1 us |
| Position resolution | 3.4 mm |

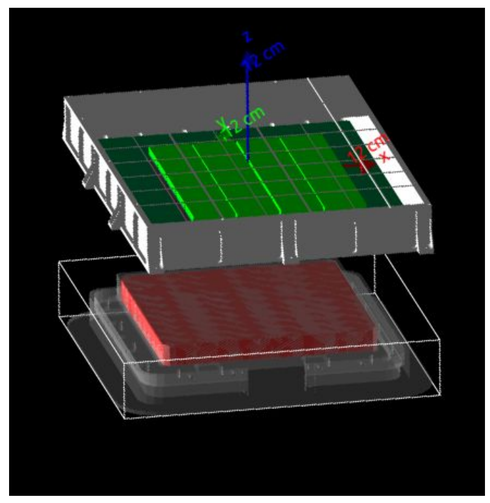
### HE Packages (4 inside dome)

| | |
|---|---|
| Energy range | 200 keV-1 MeV |
| Energy resolution | 7% |
| Timing resolution | 10 us |
| Position resolution | 1 cm |



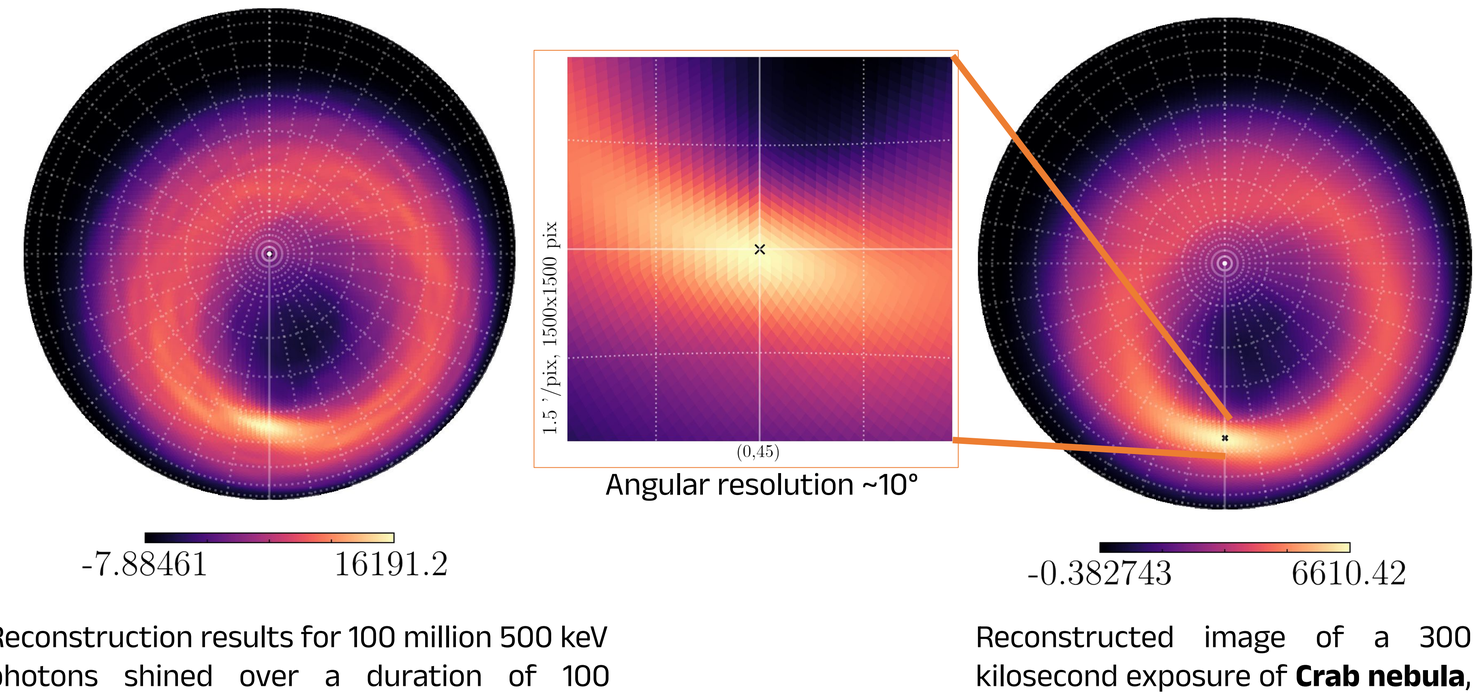

## Simulations and Analysis

- Simulations are done using Geant4, a Monte Carlo toolkit for particle-matter interactions
- The simulation output contains energy deposits and positions of interactions in all ME/HE detectors
- Sources are shined on-axis over the MEP marked by **X**
- The HEP directly underneath is parallel to this detector
- Only events from these two are used




- Events are assigned randomly sampled timestamps by assuming Poissonian arrival times
- ME and HE events that occur within the same 10 us window are assumed to be caused by a scattered and absorbed photon respectively
- Event circles are projected using the energy and position information using HealPy

## Results




Angular resolution ~10°

Reconstruction results for 100 million 500 keV photons shined over a duration of 100 seconds, yielding 6300 Compton pairs

Reconstructed image of a 300 kilosecond exposure of **Crab nebula**, modelled as a power-law spectrum

## Future Work

- Incorporate effects of the X-ray background into the reconstructions and use background rejection methods like the COMPTEL Data Space
- Use maximum-likelihood methods for deconvolving the backprojected image with the instrument response
- Combine information from multiple detector pairs to reconstruct the same source

## References

1. Bhalerao, V., Vadawale, S., Tendulkar, S., et al. 2022, Daksha: On Alert for High Energy Transients.
2. Agostinelli, S., Allison, J., Amako, K., et al. 2003, Geant4—a simulation toolkit.
3. Knodlseder, J., Dixon, D., Bennett, K., et al. 1999, Image Reconstruction of COMPTEL 1.8 MeV 26Al Line Data
4. Kierans, C., Takahashi, T., & Kanbach, G. 2022, Compton Telescopes for Gamma-Ray Astrophysics

dakshasat.in