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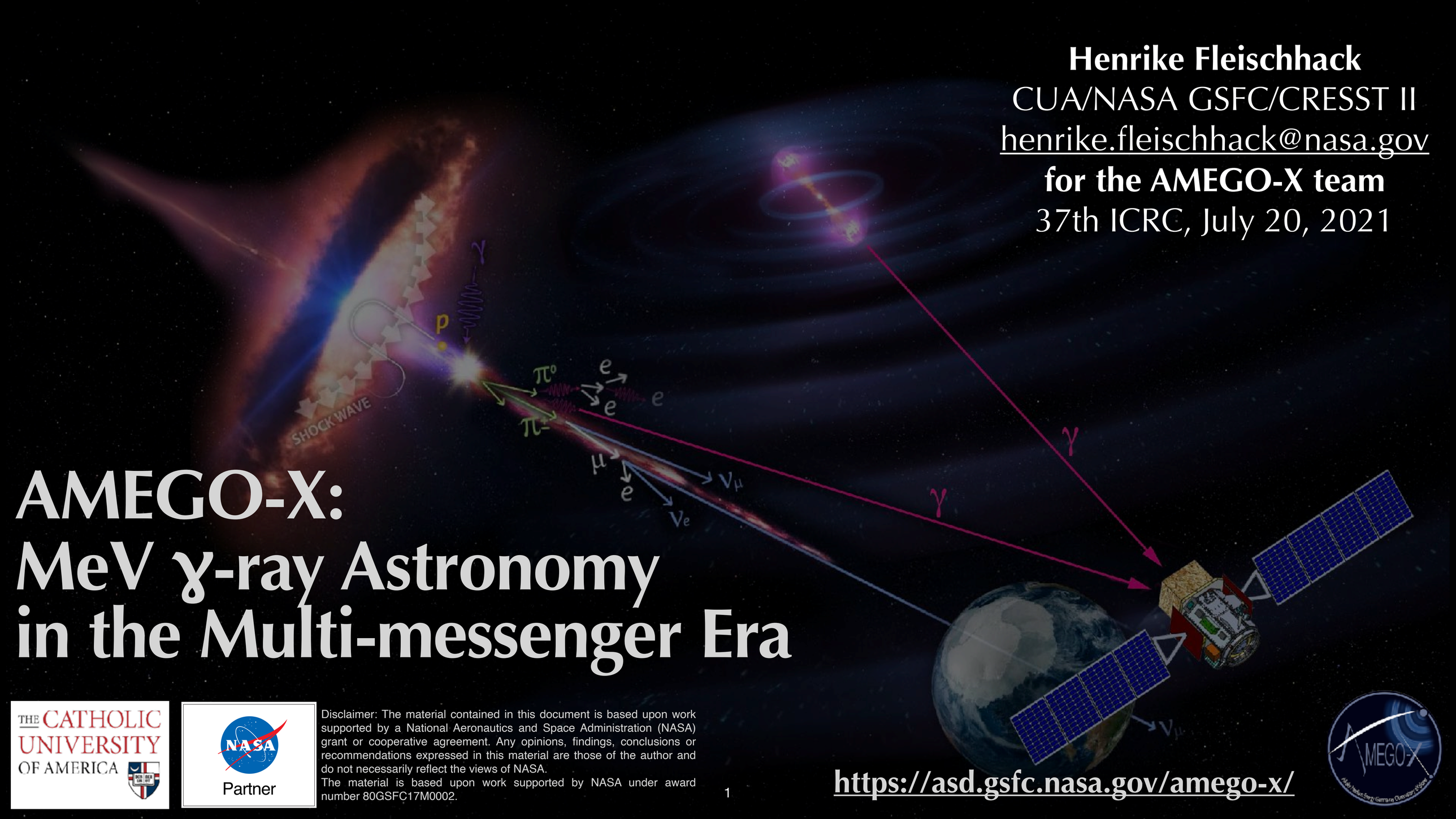
for the AMEGO-X team
37th ICRC, July 20, 2021

AMEGO-X: MeV γ-ray Astronomy in the Multi-messenger Era



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The material is based upon work supported by NASA under award number 80GSFC17M0002.

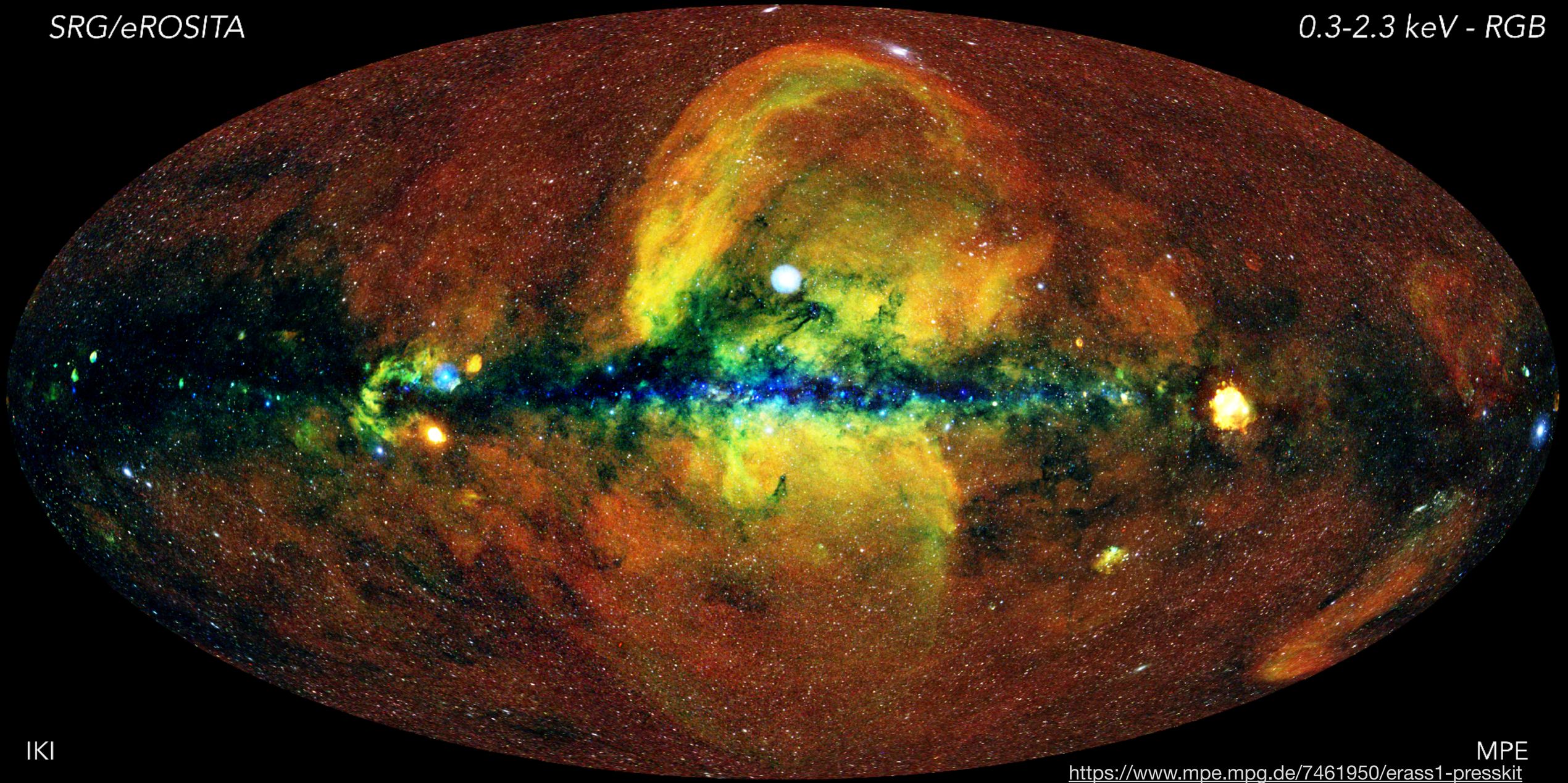
https://asd.gsfc.nasa.gov/amego-x/

AMEGO-X

eROSITA: X-ray sky (~keV)

SRG/eROSITA

0.3-2.3 keV - RGB

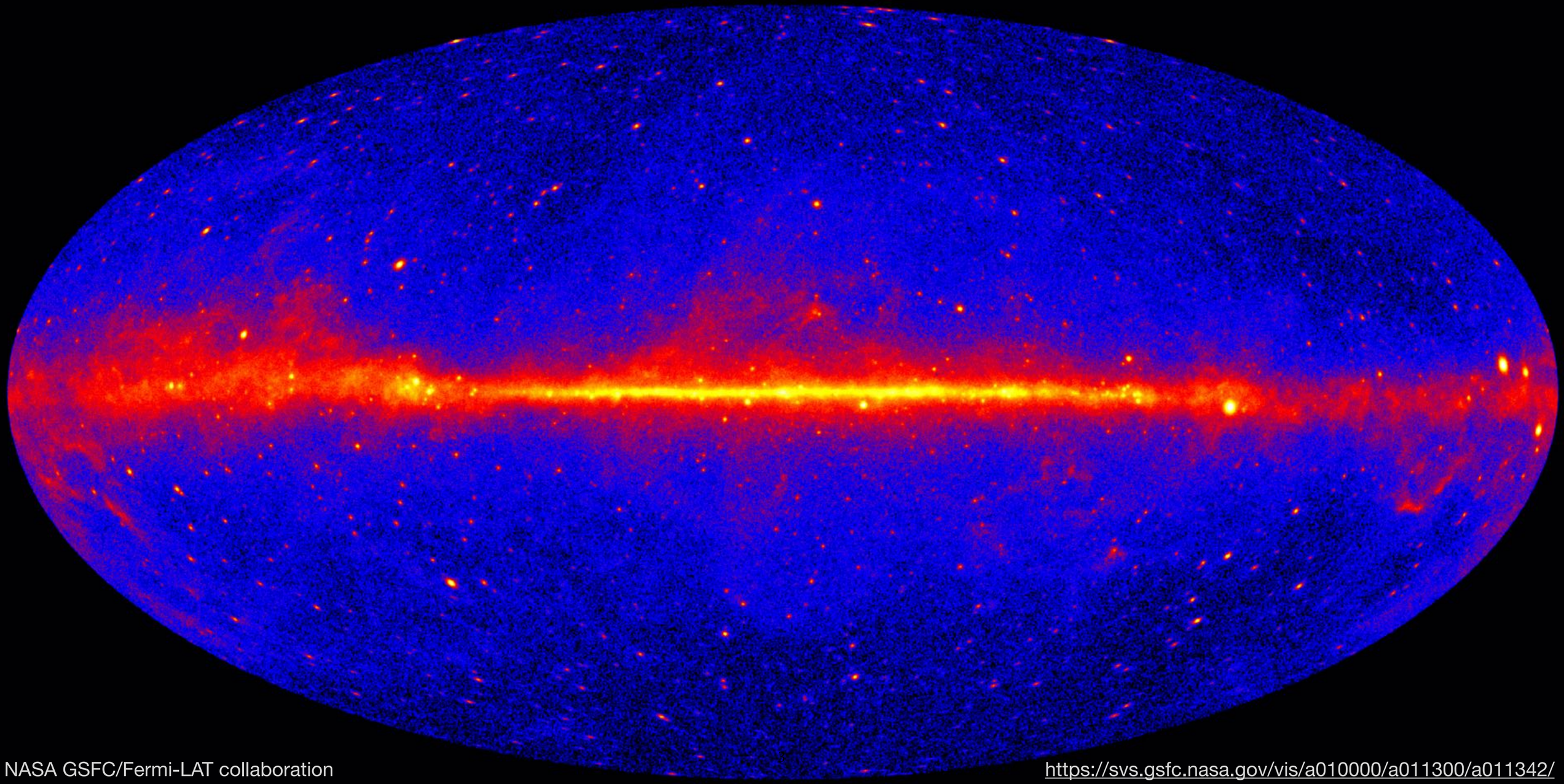


IKI

MPE

https://www.mpe.mpg.de/7461950/erass1-presskit

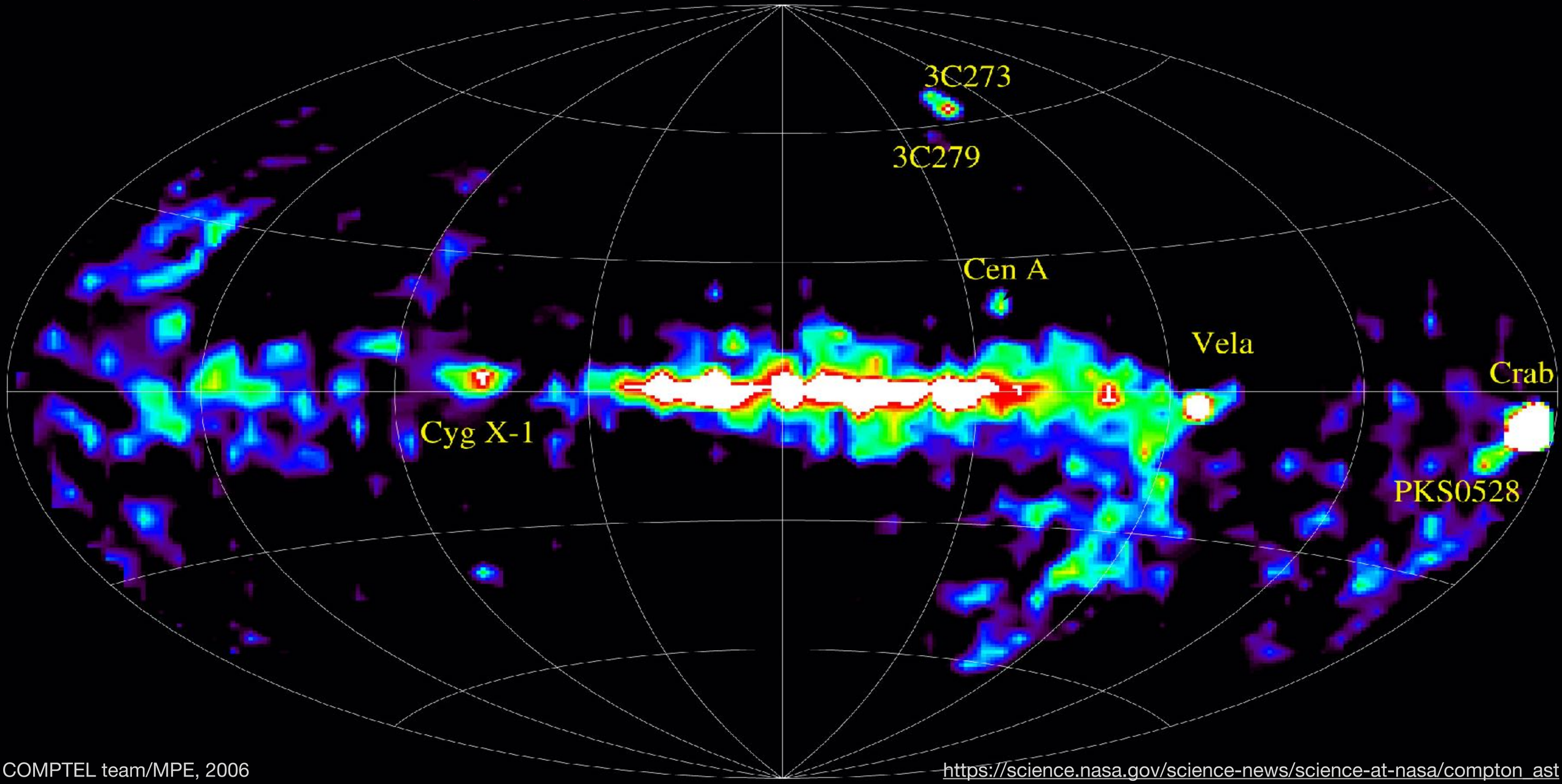
Fermi-LAT: HE γ-ray sky (>1GeV)



NASA GSFC/Fermi-LAT collaboration

https://svs.gsfc.nasa.gov/vis/a010000/a011300/a011342/

COMPTEL: γ-ray sky (1-30 MeV)

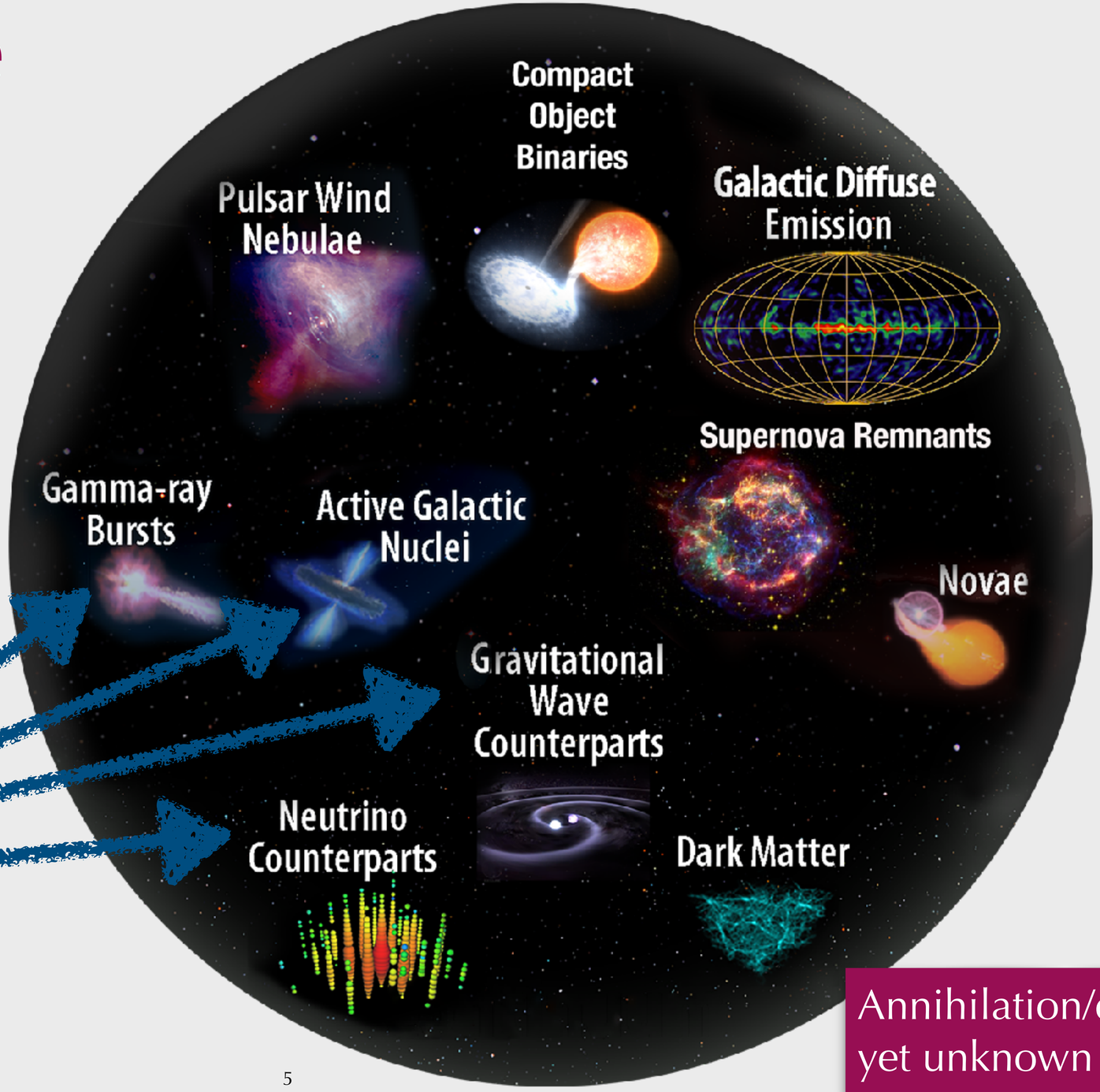


COMPTEL team/MPE, 2006

https://science.nasa.gov/science-news/science-at-nasa/compton_ast

MeV γ-ray Science

Relativistic $e^{\pm}$ and protons interacting with ambient…
- matter
- radiation fields
- magnetic fields

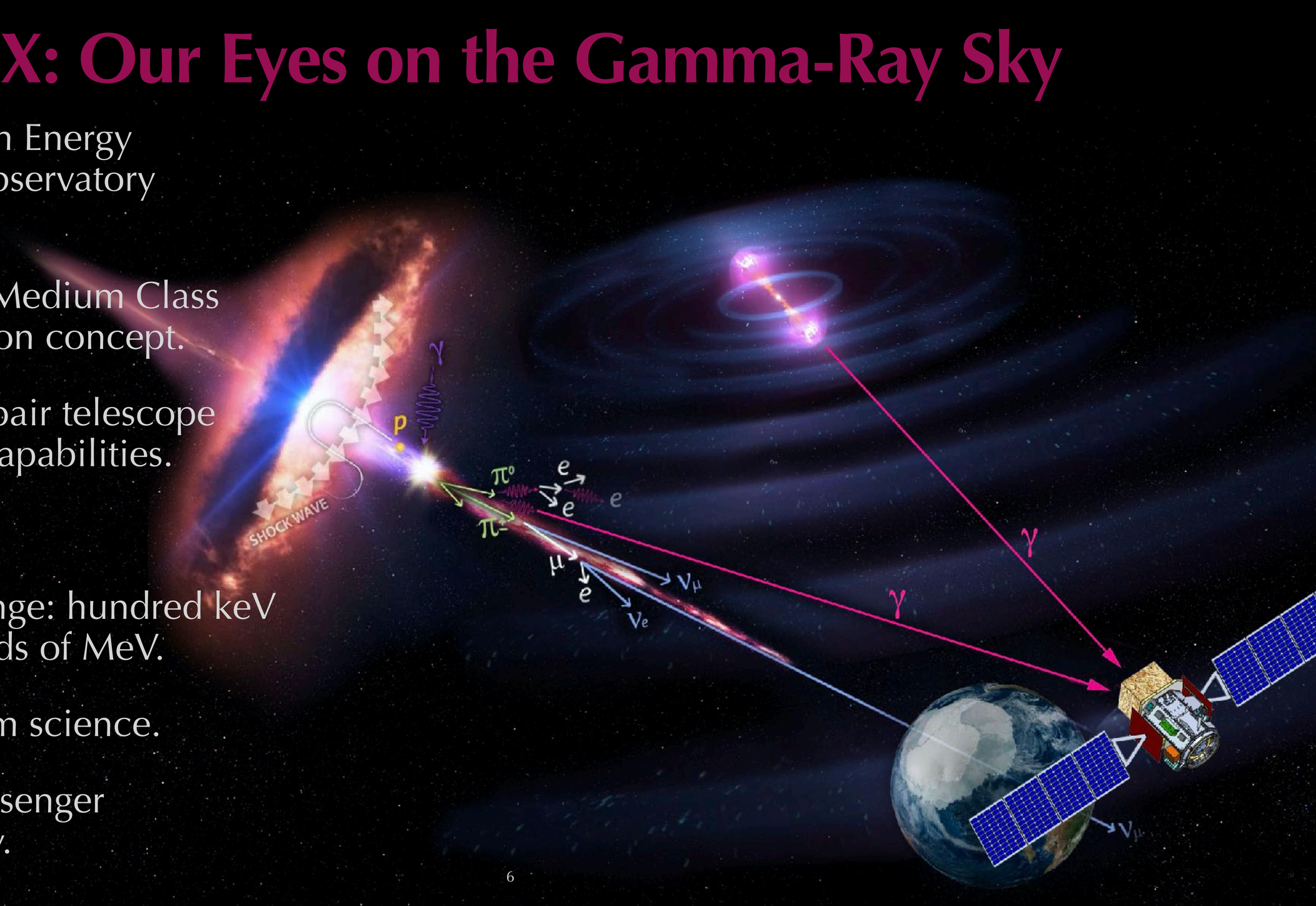


Multi-wavelength/ multi-messenger astrophysics!

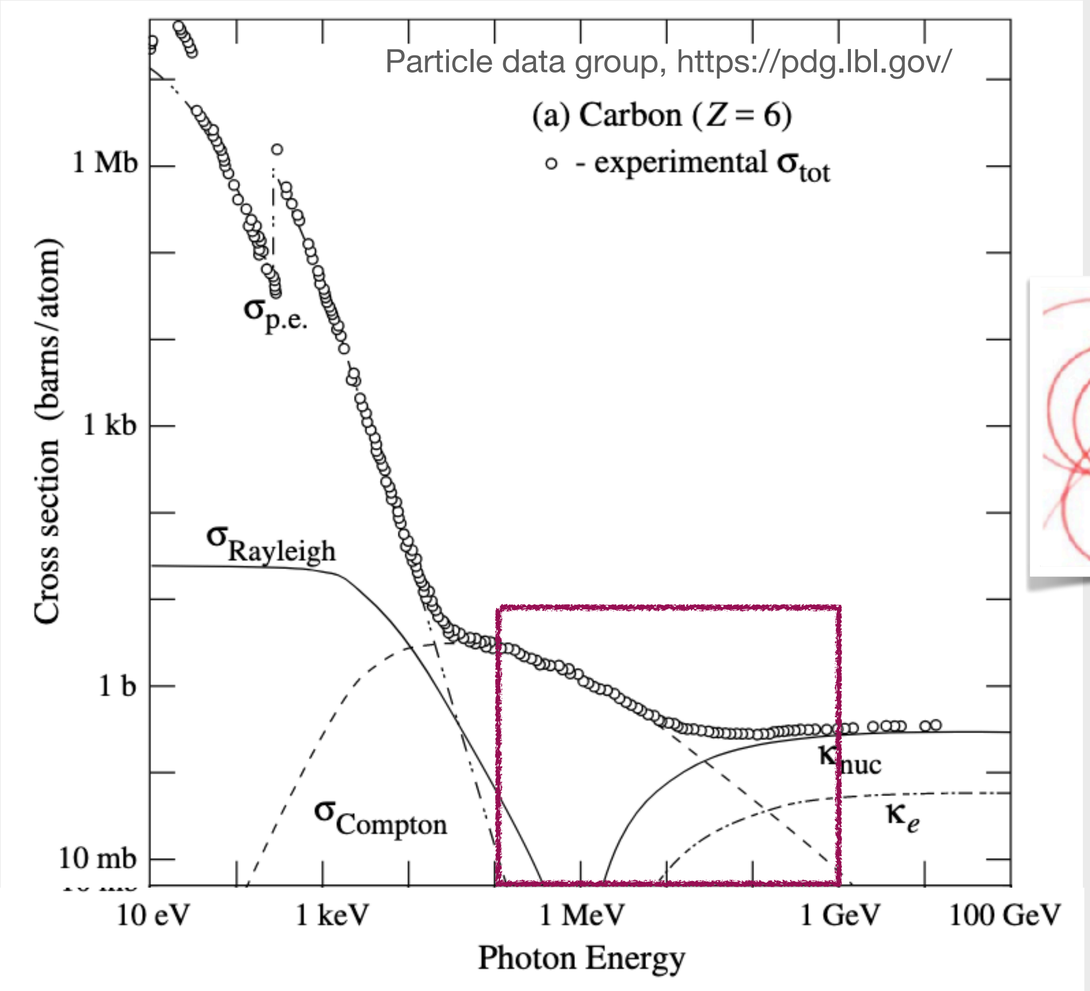
Annihilation/decays of yet unknown particles

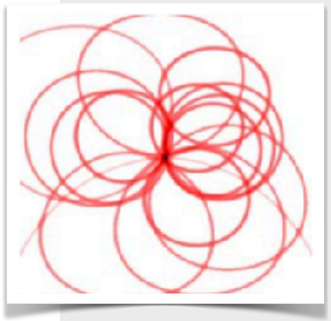
AMEGO-X: Our Eyes on the Gamma-Ray Sky

- All-sky Medium Energy Gamma-ray Observatory eXplorer
- MIDEX-sized (Medium Class Explorer) mission concept.
- Compton and pair telescope with imaging capabilities.
- Optimized for:
  - Energy range: hundred keV to hundreds of MeV.
  - Continuum science.
  - Multi-messenger astronomy.

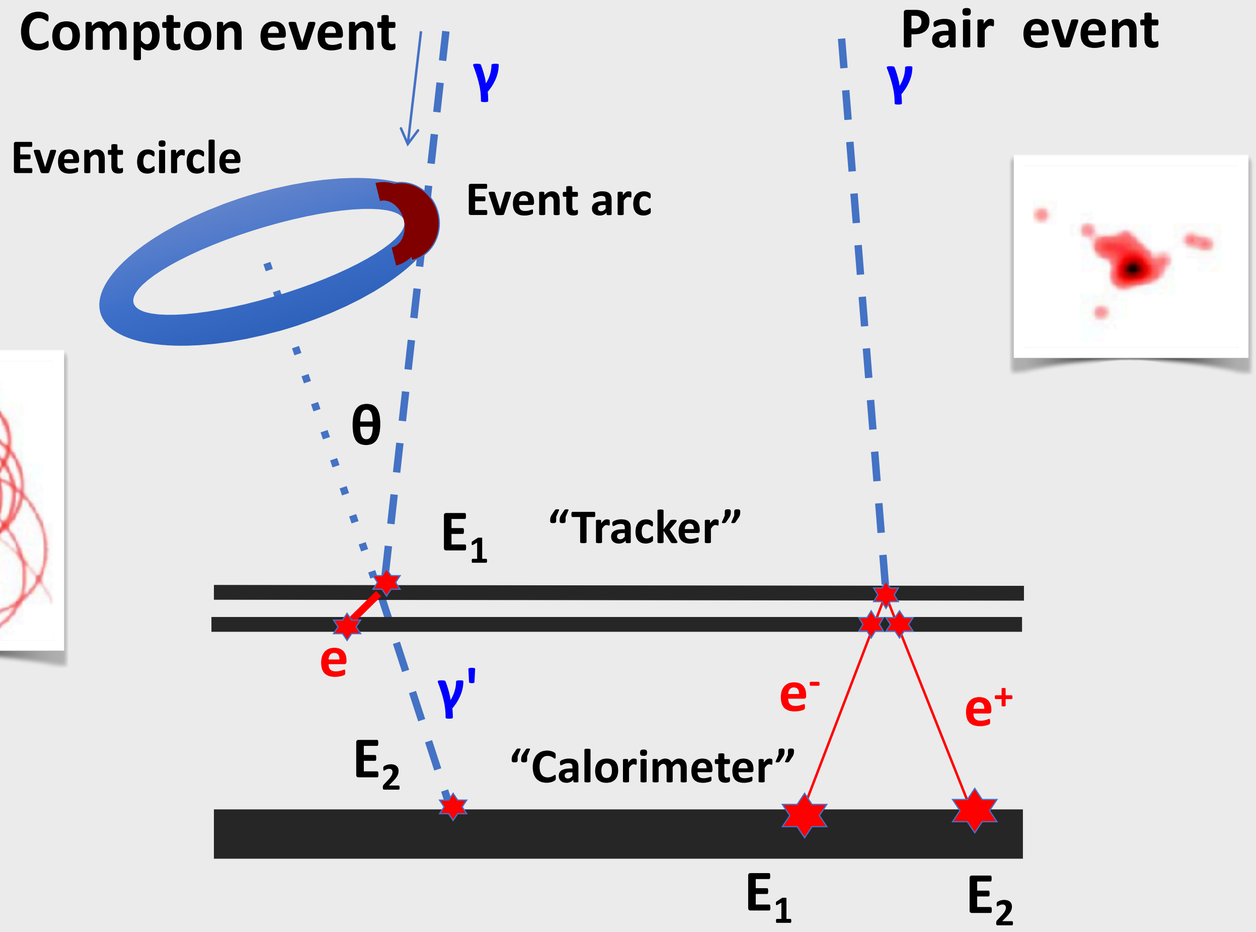


MeV γ-ray Detection





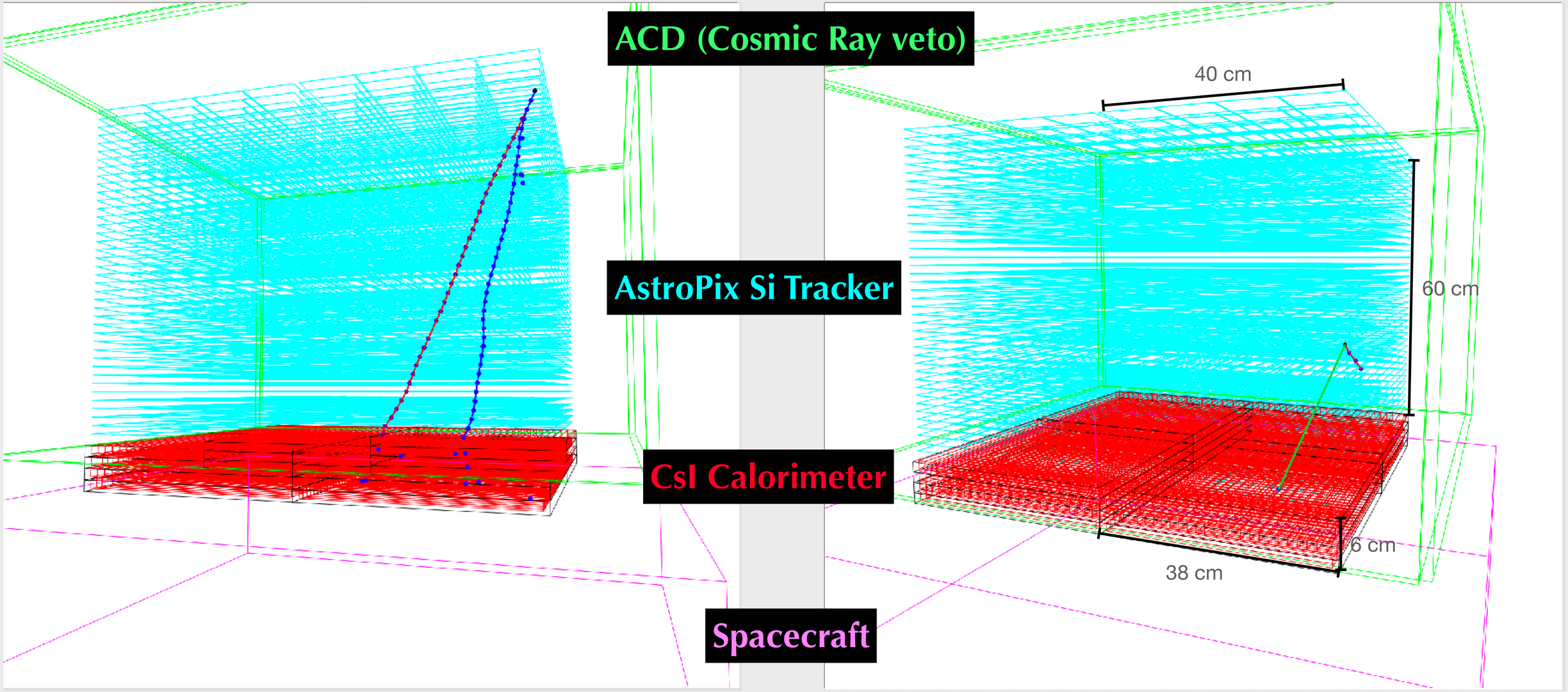
$\sigma_{p.e.}$ = Atomic photoelectric effect (electron ejection, photon absorption)
$\sigma_{Rayleigh}$ = Rayleigh (coherent) scattering–atom neither ionized nor excited
$\sigma_{Compton}$ = Incoherent scattering (Compton scattering off an electron)
κ_{nuc} = Pair production, nuclear field
κ_e = Pair production, electron field



Compton scattering angle:

$$\cos(\theta) = 1 - \frac{m_e c^2}{E_2} - \frac{m_e c^2}{E_1 + E_2}$$

The AMEGO-X Instrument

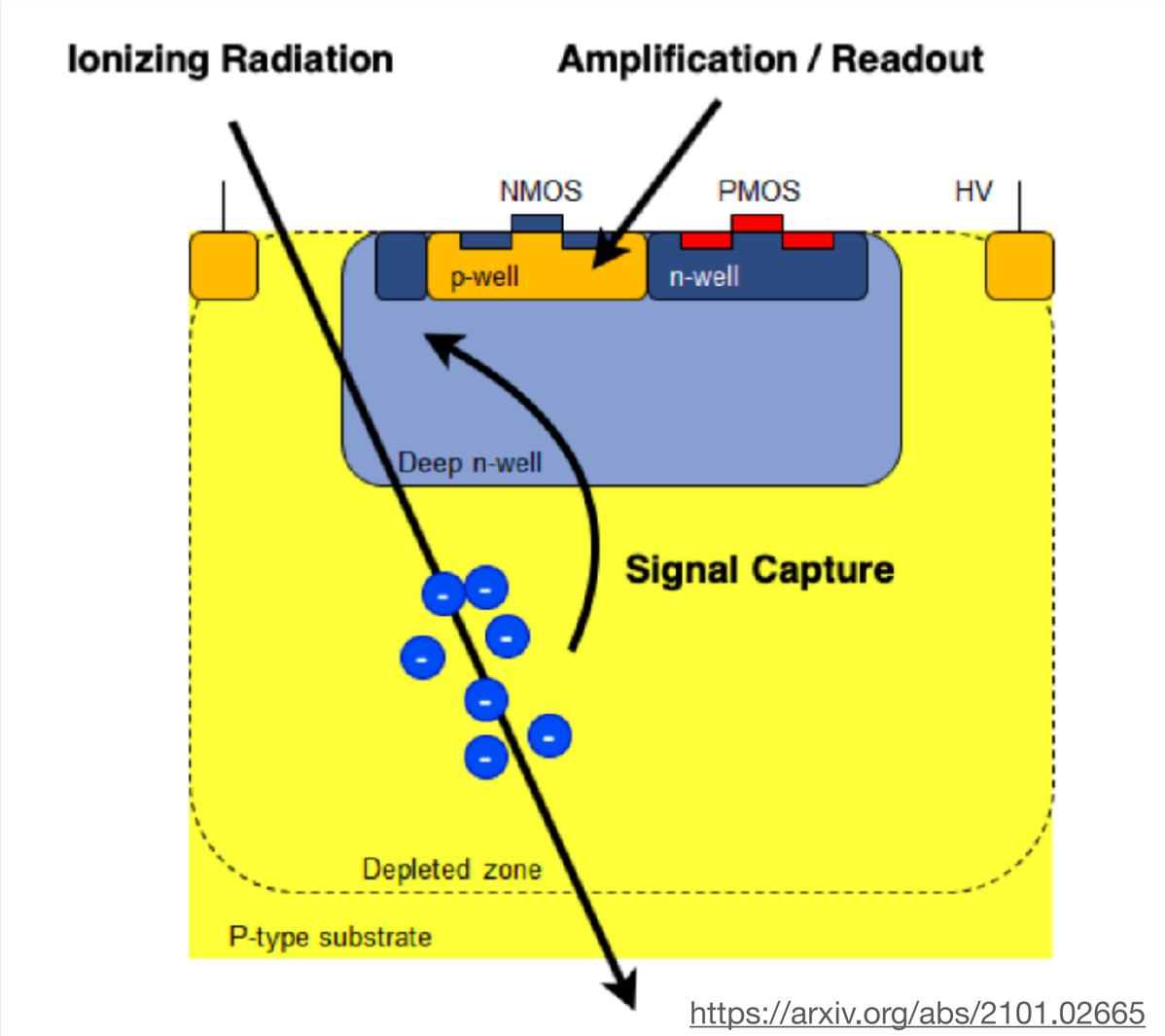


Pair interaction

Compton interaction

The AstroPix Pixel Tracker

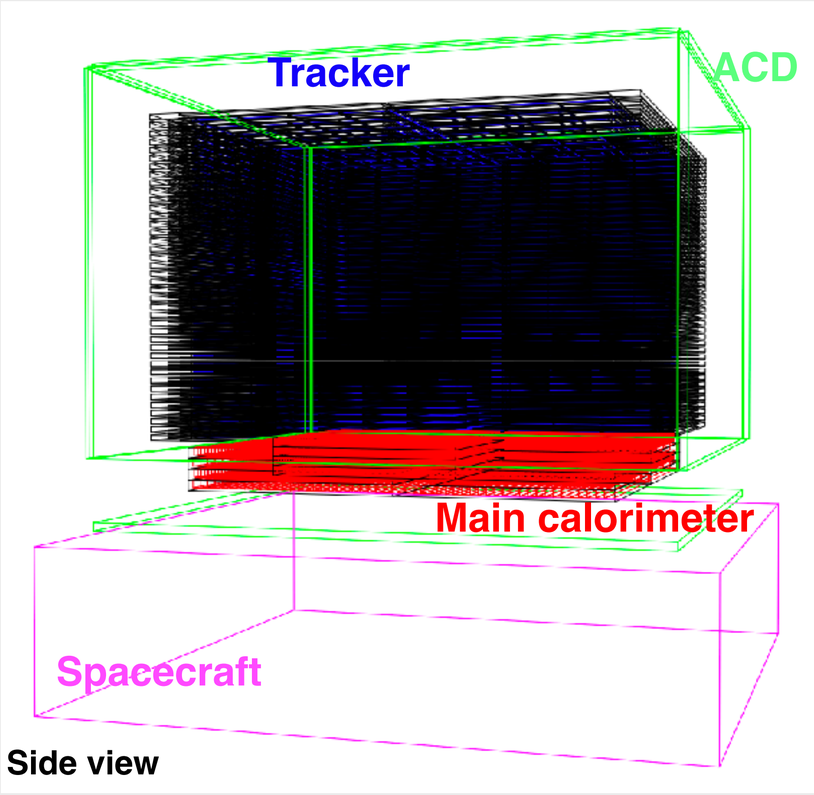
- AstroPix: silicon CMOS pixel with integrated amplification and readout.
- Based on ATLASPix technology developed for particle physics detector.
- Pixel geometry has been optimized for MeV gamma-ray detection.
- Lower noise level compared to commonly used silicon strip detectors.
- Lower trigger threshold helps allows us to detect gamma rays down to 100 keV.



https://arxiv.org/abs/2101.02665

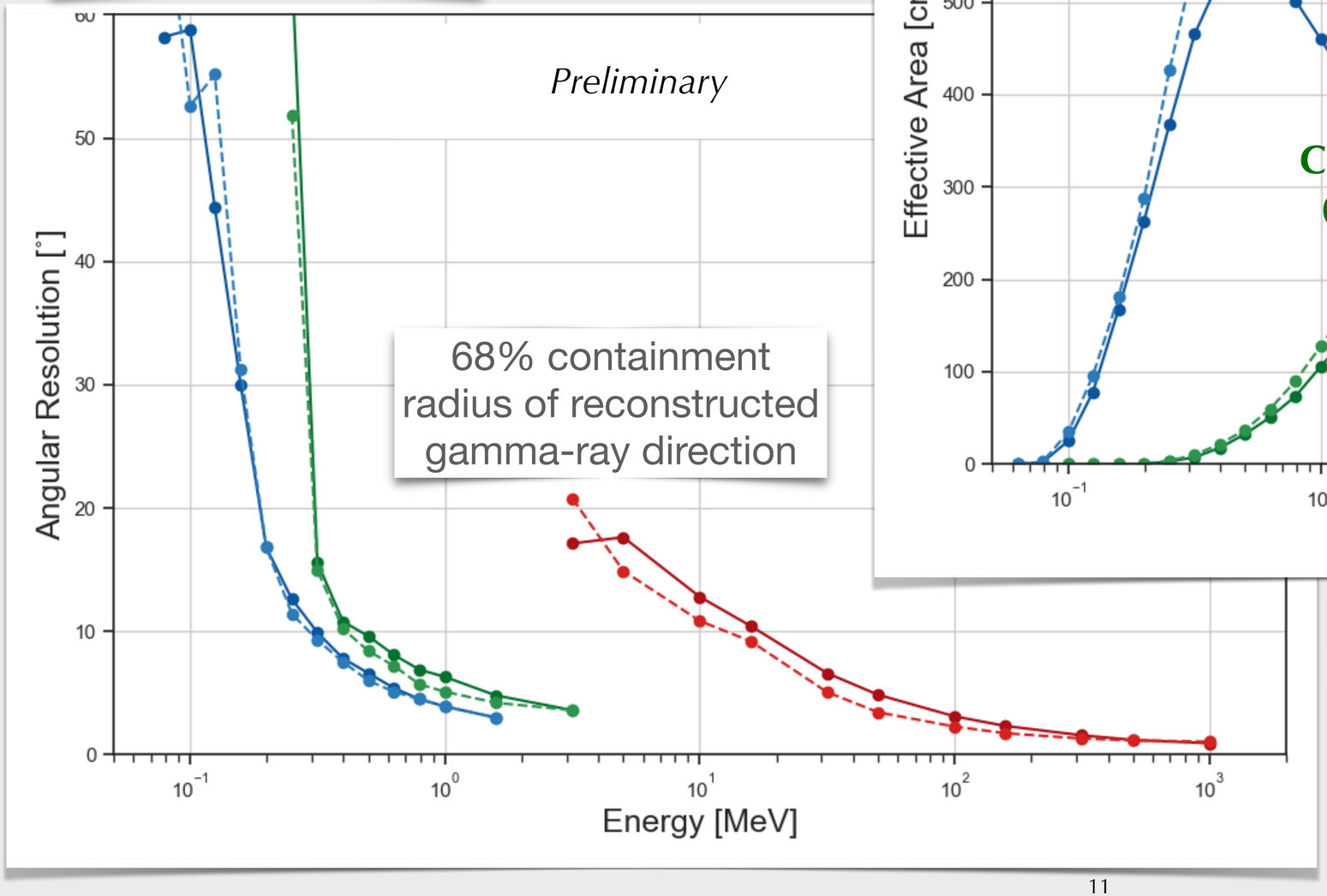
Simulating AMEGO-X

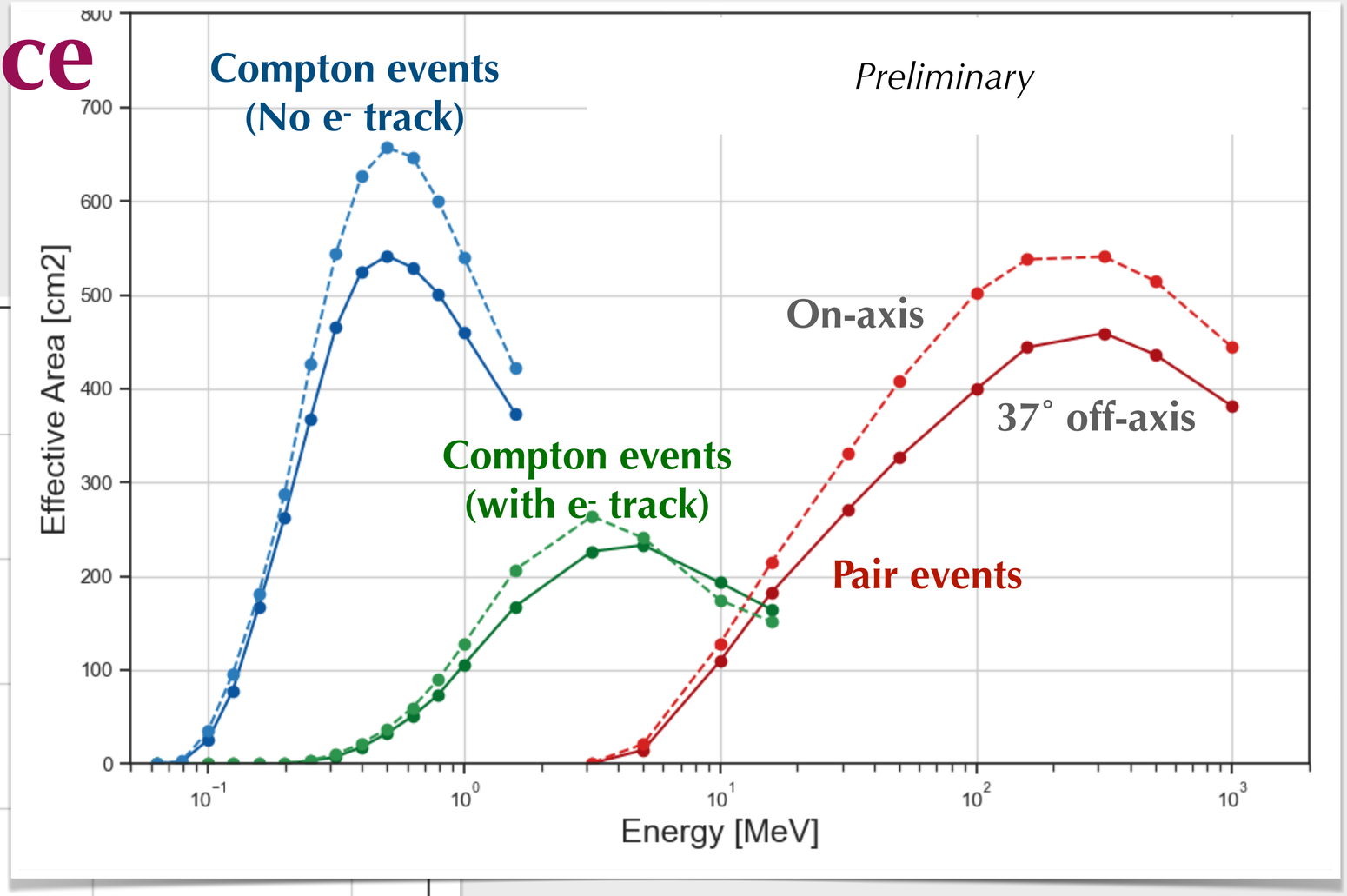
- MEGAlib framework (http://megalibtoolkit.com) and GEANT4
- Simulation steps:
  - γ-ray photon and particle interactions in the detector.
  - Production of secondary particles (e.g. e^+e^- cascades).
  - Energy deposition in active material.
  - Detector effects: noise, energy smearing etc.
  - Reconstruction of primary photon direction from simulated detector hits.
  - Backgrounds: Earth limb, cosmic rays, activation.
- All results shown are preliminary, awaiting final detector design.



Predicted Performance

Uncertainty (FWHM) in the radius of the Compton "cone"

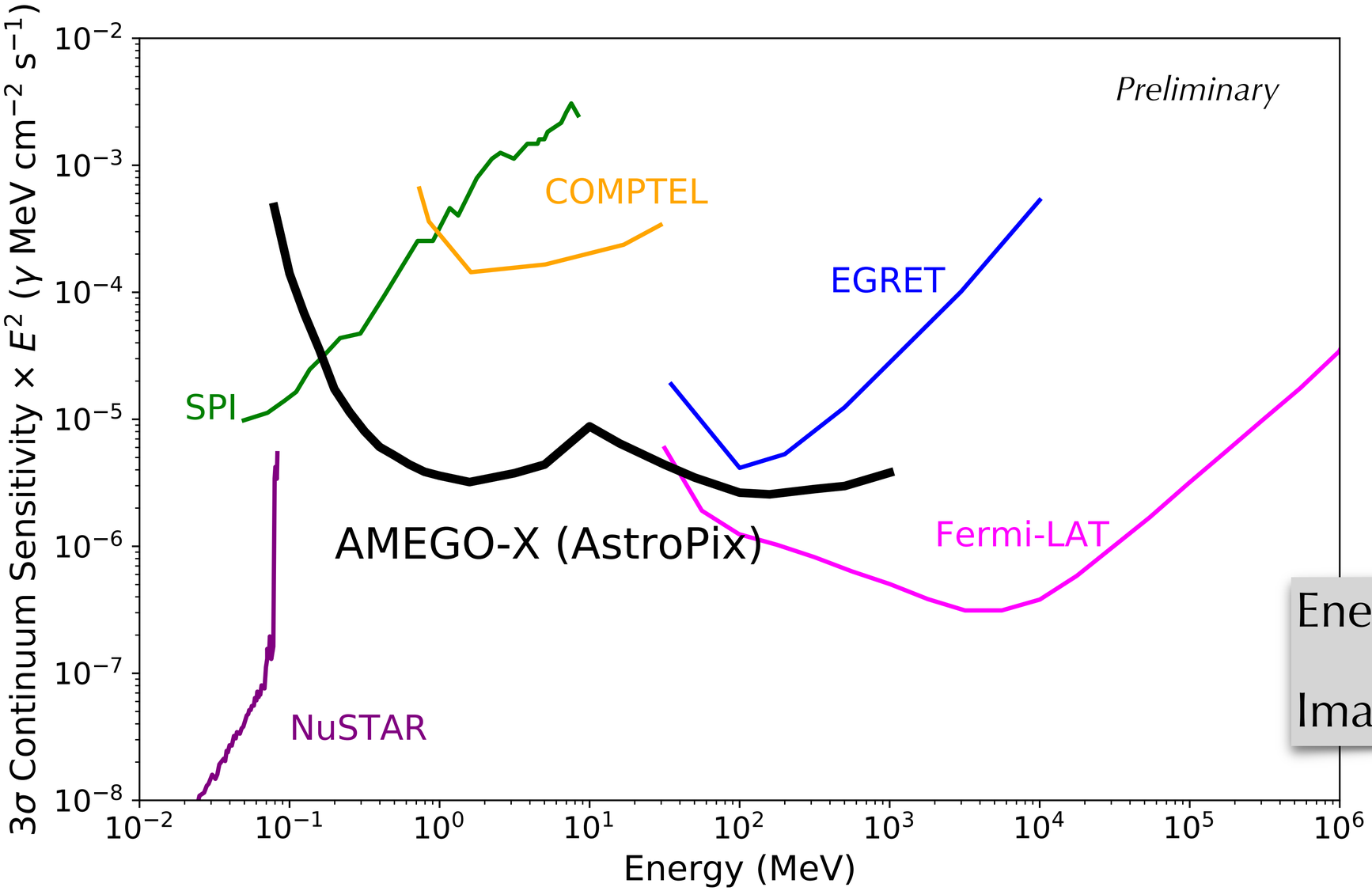




Energy threshold: **100 keV**

Imaging: above **300 keV**

Survey Sensitivity (3 years)



Energy threshold: **100 keV**

Imaging: above **300 keV**

Science Example: Short GRBs

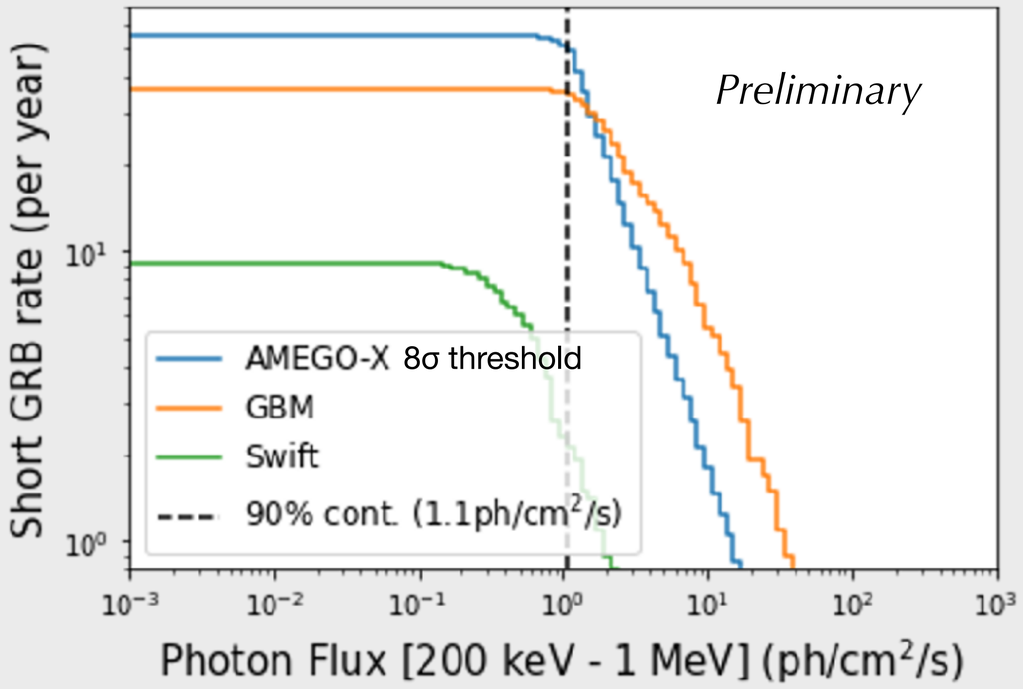
Burst sensitivity (1s): better than 1.5 ph/cm²/s between 120 keV and 1 MeV.

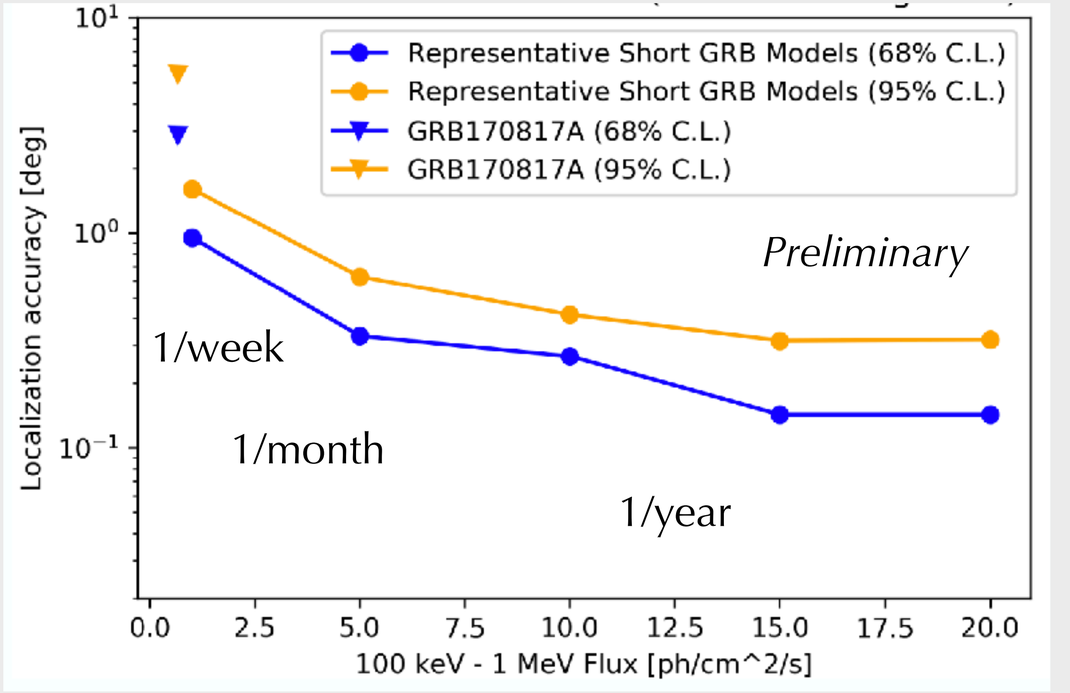
AMEGO-X is expected to detect:

- Hundreds of short GRBs per year (≥5σ)
- At least 40-60 short gamma-ray bursts (GRBs) per year with high significance (≥ 8σ), resolved spectra, and excellent localization (≤ 1˚ at 68% CL).
- Almost certainly more counterparts of BNS mergers.

Real-time alerts to be distributed to community within ≤ 30 s for most bursts.

Special trigger mode could enable readout of single-site events (photoelectric effect), reducing energy threshold to tens of keV and increase GRB detection rate to thousands per year.



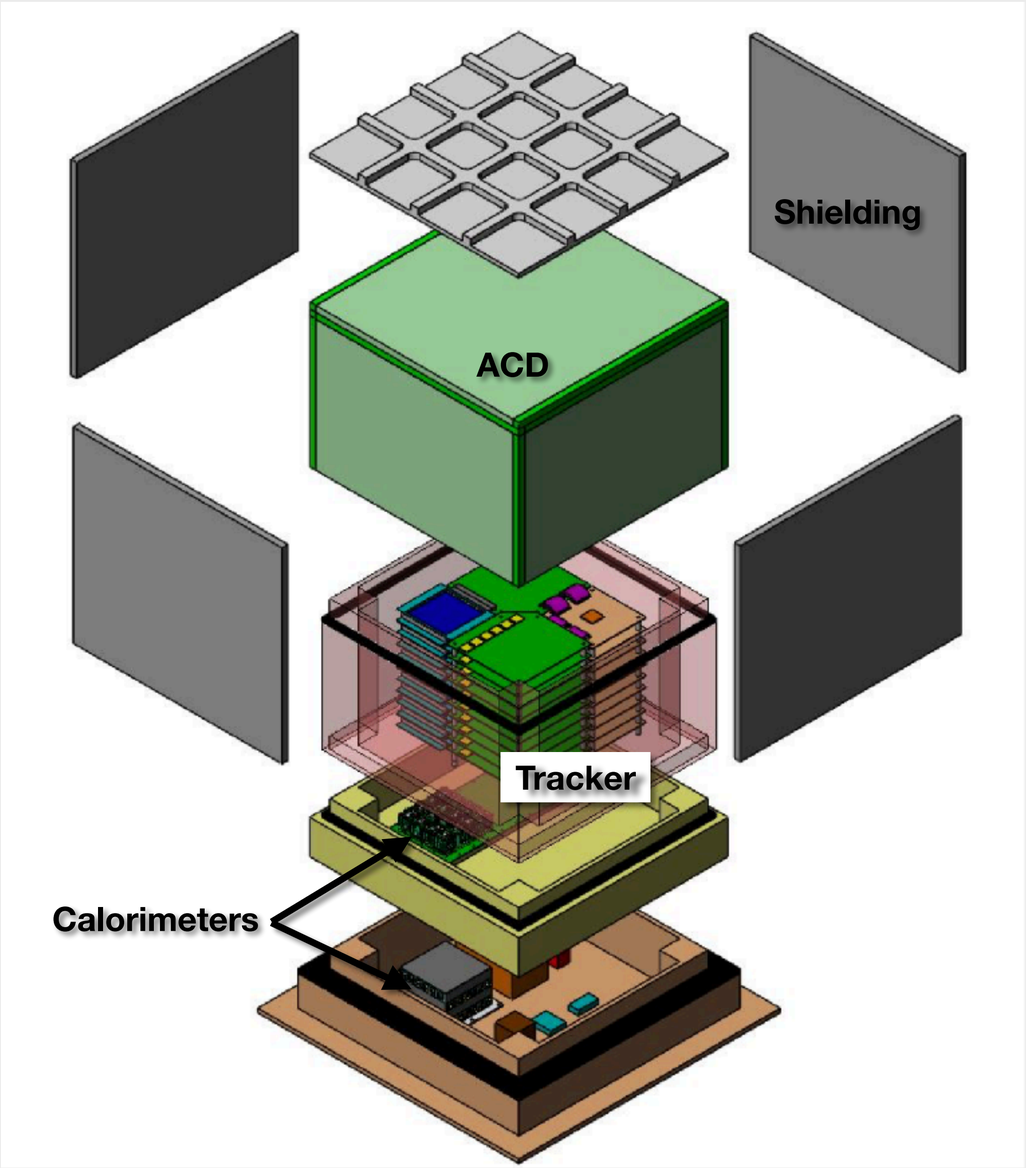


Status and Plans

An all-sky MeV gamma-ray instrument like AMEGO-X would close the “MeV gap” and complement existing MW/MM astronomy efforts.

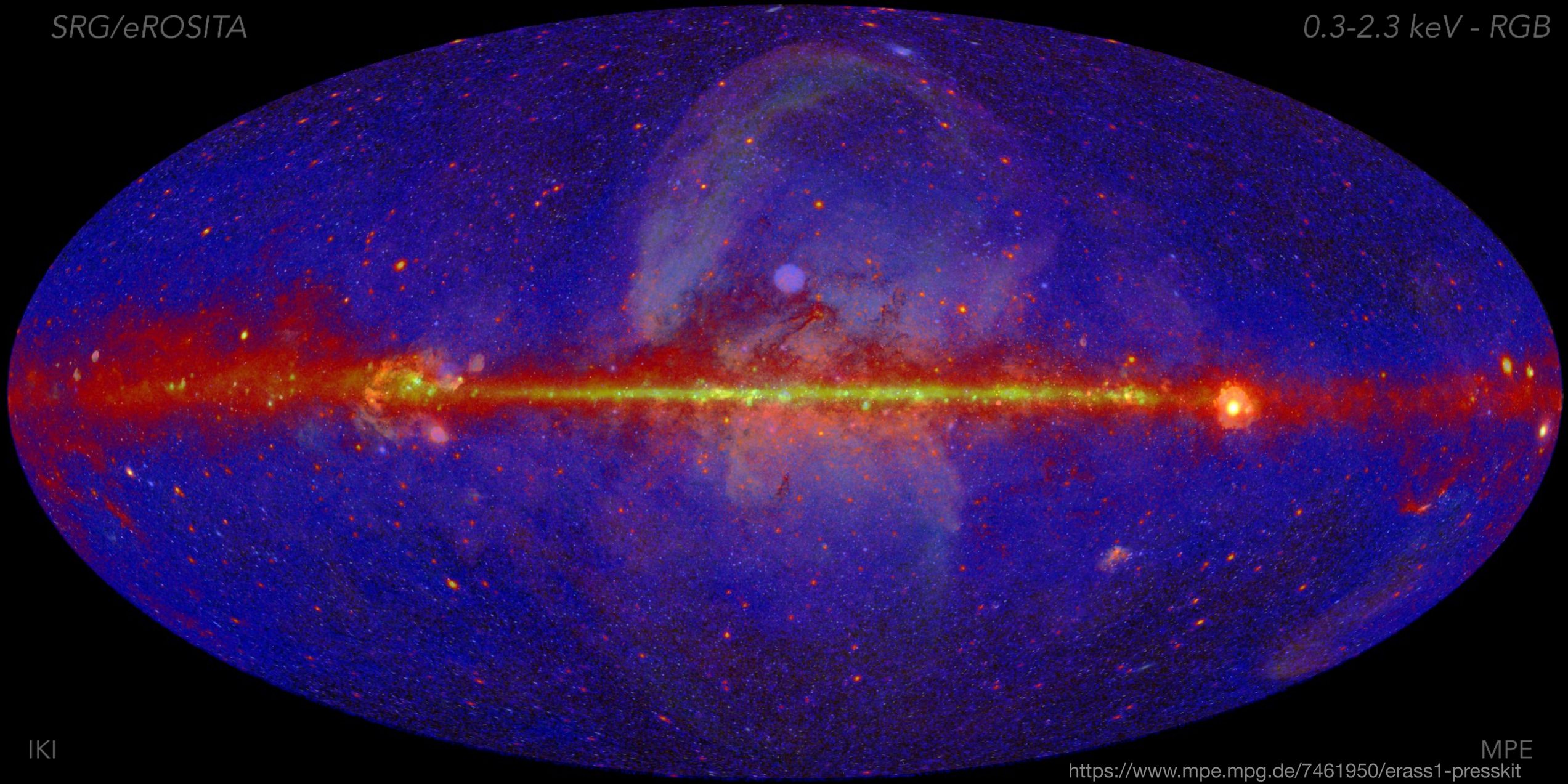
Three “incarnations”:

- **MIDEX-class AMEGO-X concept: Will submit proposal to 2021 Astrophysics MIDEX Announcement of Opportunity.**
- Probe-class AMEGO concept: Waiting for results of decadal survey.
- ComPair: Smaller prototype detector for beam tests and eventually balloon flight (2021-2023).



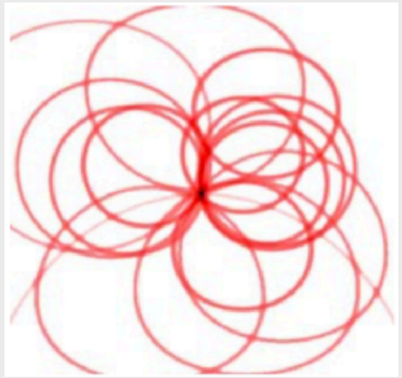
BACKUP

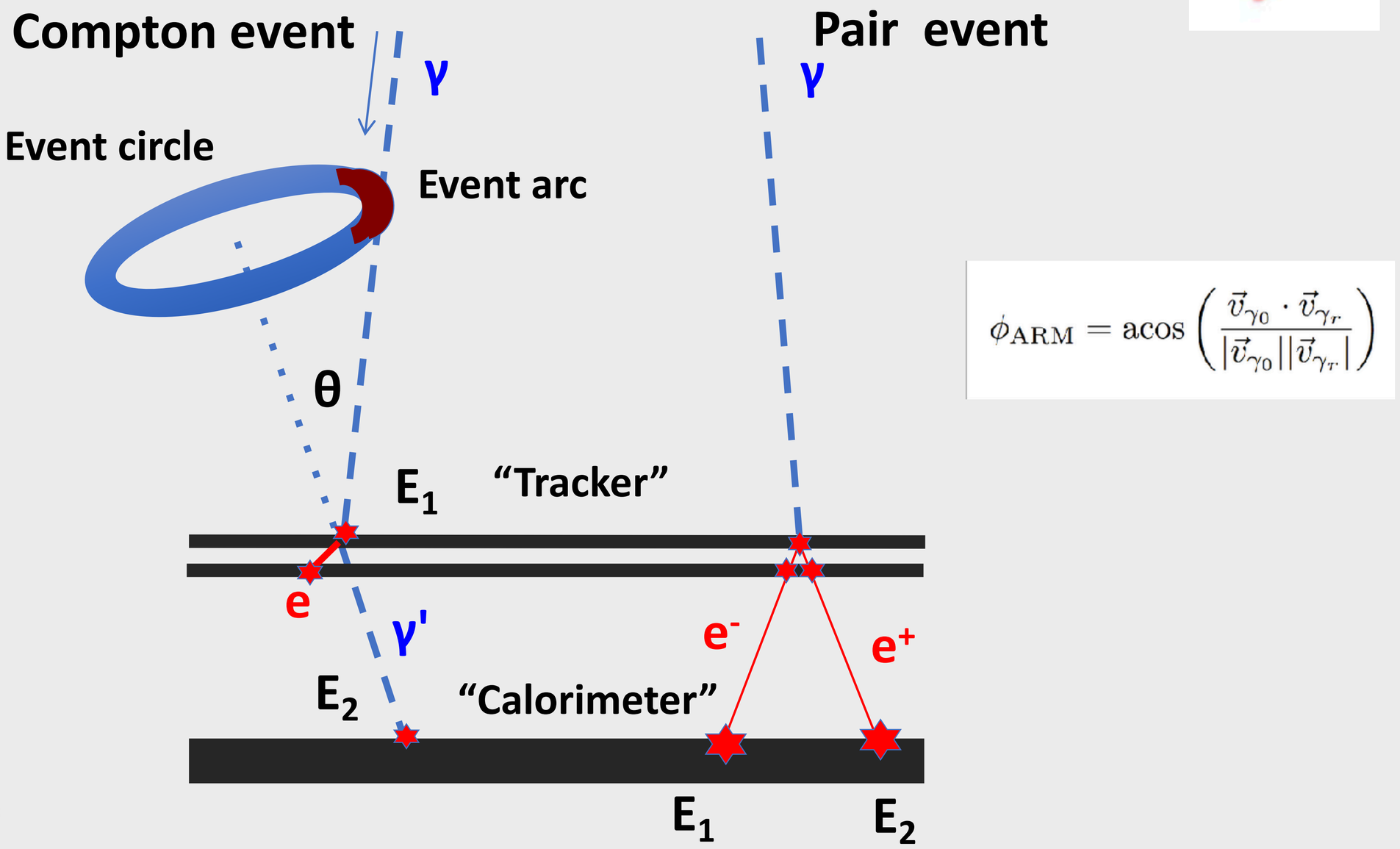
The X-ray to GeV γ-ray sky



https://www.mpe.mpg.de/7461950/erass1-presskit

A word on angular resolution





Compton scattering angle:

$$\cos\left(\theta_m\right) = 1 - \frac{m_e c^2}{E_2} - \frac{m_e c^2}{E_1 + E_2}$$

$$\phi_{\mathrm{ARM}} = \theta_m - \theta_c$$

Uncertainty in the radius of the Compton "cone"

$$\phi_{\mathrm{ARM}} = \mathrm{acos}\left(\frac{\vec{v}_{\gamma_0} \cdot \vec{v}_{\gamma_r}}{|\vec{v}_{\gamma_0}||\vec{v}_{\gamma_r}|}\right)$$