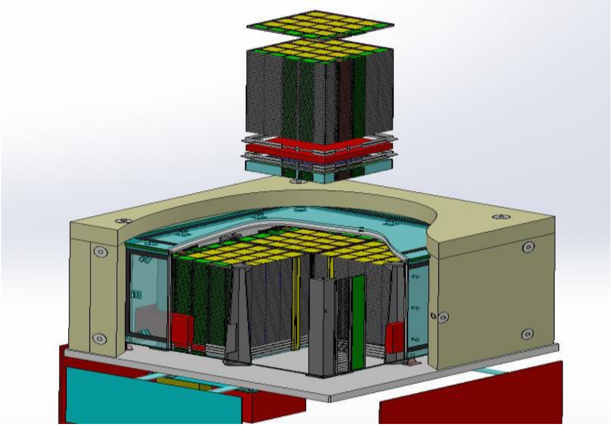
AMEGO – A Wide Field Astrophysics Discovery Mission for the MeV Band

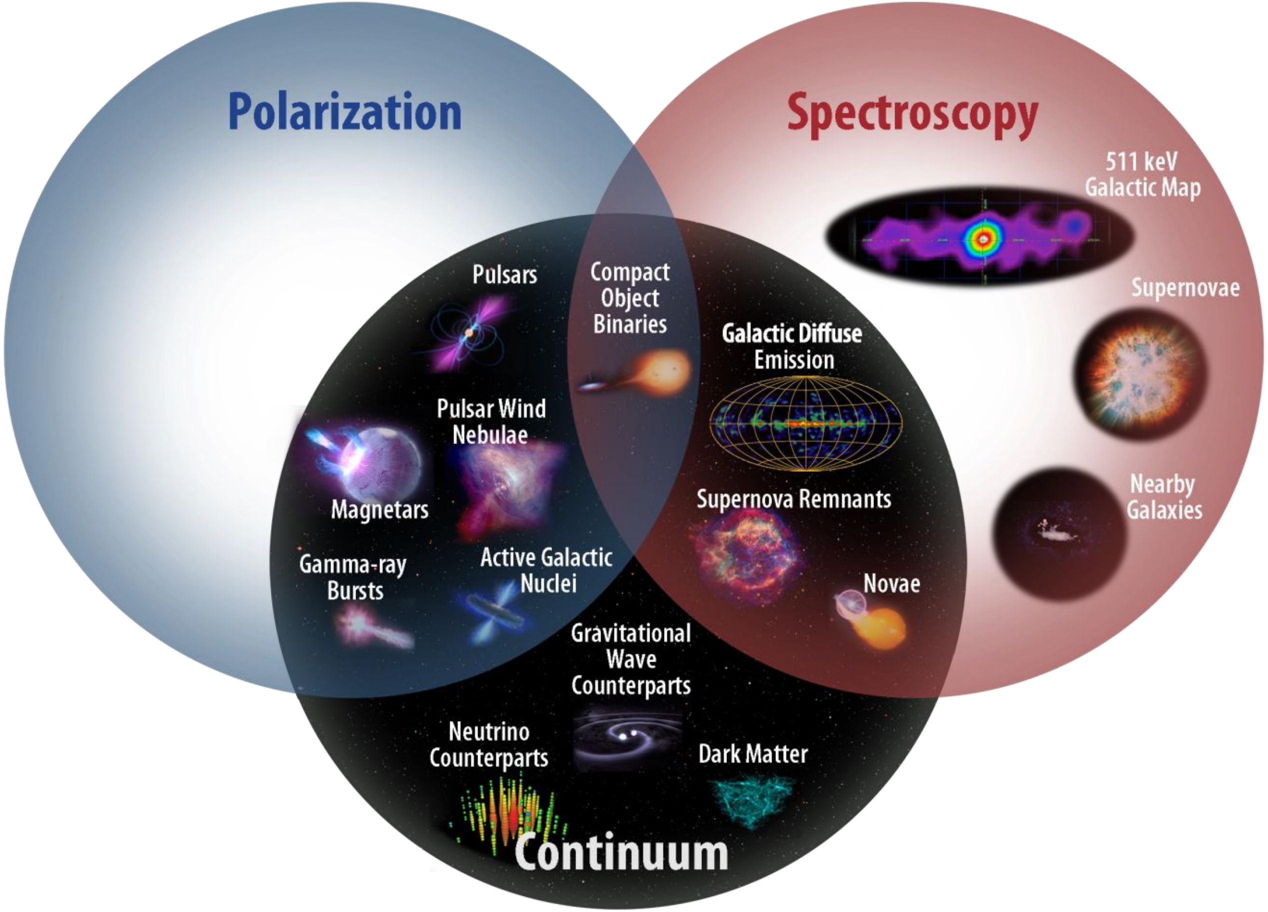
Julie McEnery (NASA/GSFC) on behalf of the AMEGO team.



AMEGO Collaboration

- NASA/GSFC, George Wash. Univ., Clemson Univ., Naval Research Lab, UC Berkeley, Wash. Univ., University of New Hampshire, NASA/MSFC, University of Alabama, Huntsville, USRA, the Ohio State University, UIUC, UNLV, LANL, University of Delaware, UC Santa Cruz, SLAC, Argonne, Stanford University, University of North Florida, Yale University, Rice University, INFN, Pisa University, Padova University, INAF, Udine University, Rome University, Yale University, University of Maryland

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


Polarization
Spectroscopy
511 keV Galactic Map
Supernovae
Nearby Galaxies
Pulsars
Compact Object Binaries
Galactic Diffuse Emission
Pulsar Wind Nebulae
Magnetars
Supernova Remnants
Gamma-ray Bursts
Active Galactic Nuclei
Novae
Gravitational Wave Counterparts
Neutrino Counterparts
Dark Matter
Continuum

AMEGO Science

Understanding Extreme Environments

Astrophysical Jets

Understand the formation, evolution, and acceleration mechanisms in astrophysical jets

Compact Objects

Identify the physical processes in the extreme conditions around compact objects

Dark Matter

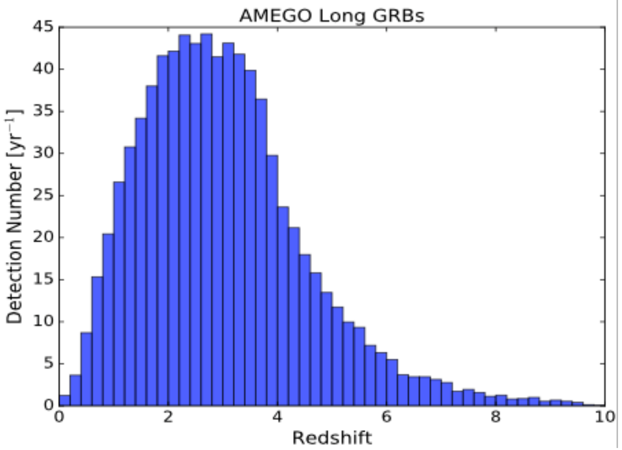
Test models that predict dark matter signals in the MeV band

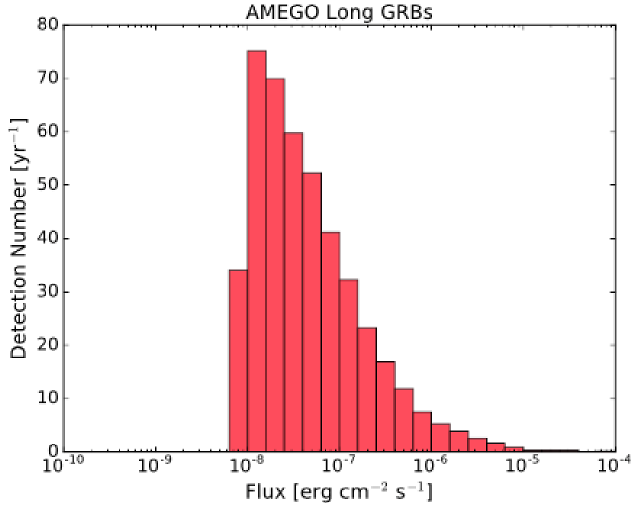
MeV Spectroscopy

Measure the properties of element formation in dynamic systems

AMEGO and GRB

- 440 long GRB/year (determined using method of Lien et al 2014)
  - 19.2/year with z>6
  - All with localization
- Polarization! - 20% MDP for brightest 1% of AMEGO GRB
  - AMEGO observations will probe the GRB emission mechanism and jet composition
- ~80 short GRB/year (by scaling short/long ratio from GBM)
  - Important implications for gravitational wave counterpart searches



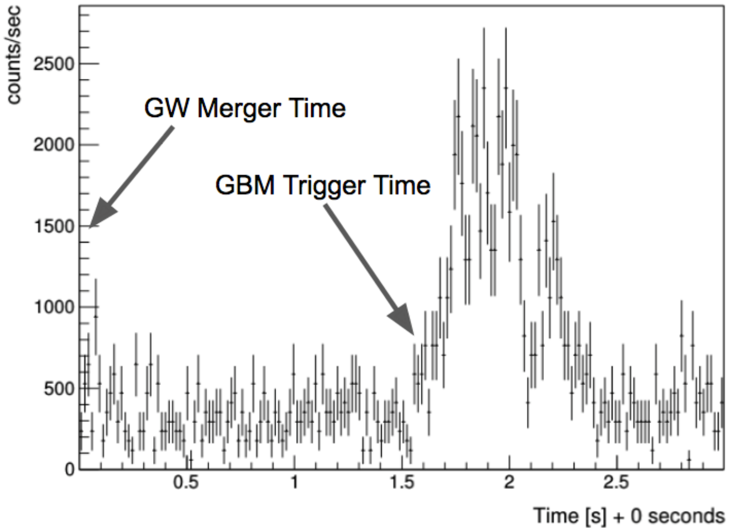


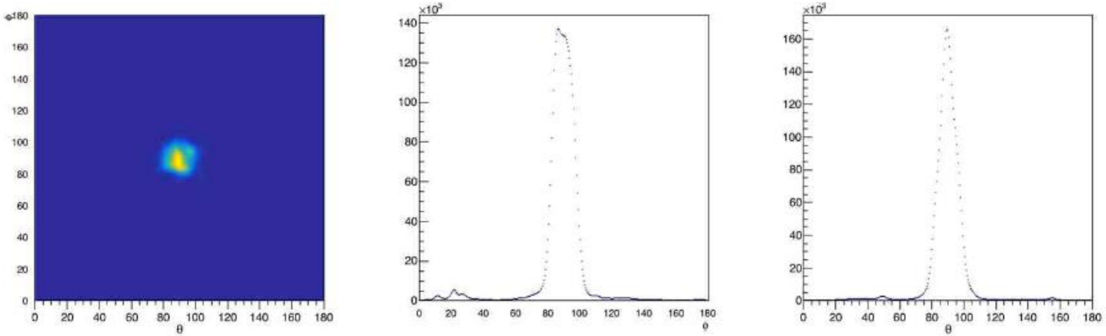
GRB 170817A

GRB 170817 is the EM counterpart to GW 170817 at 43 Mpc

With AMEGO:

- Detectable out to 130 Mpc
- <6 deg localization (with very preliminary analysis
- ~20% probability being within the FoV

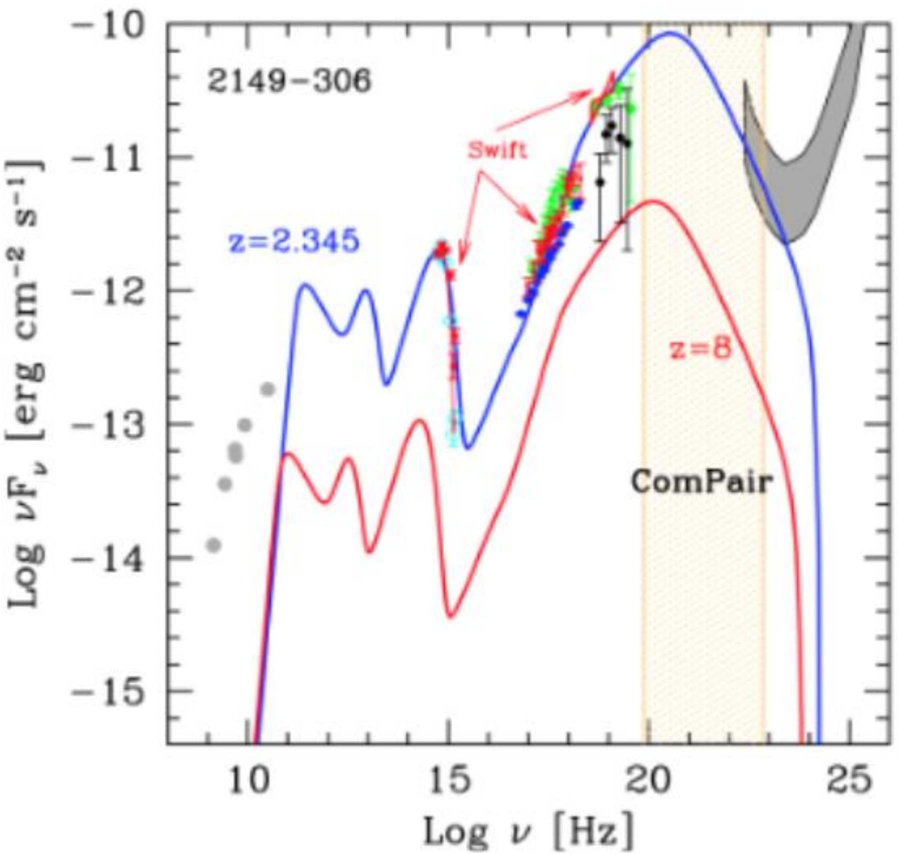




See talk by J. Racusin, Wed 1:30-4:30 splinter session

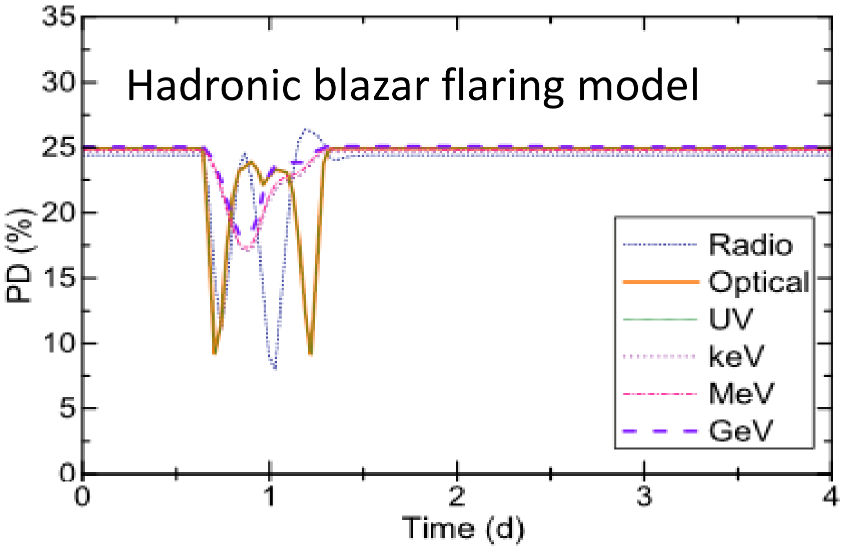
MeV Blazars

- Among the most powerful persistent sources in the Universe
- Large jet power, easily larger than accretion luminosity
- Host massive black holes, near 10^9 solar masses or more
- Detected up to high redshift
- Evolution of MeV blazars is stronger than any other source class – i.e. maximum density might be very early on
  - AMEGO will detect >500 MeV blazars
  - ~100 at z>3

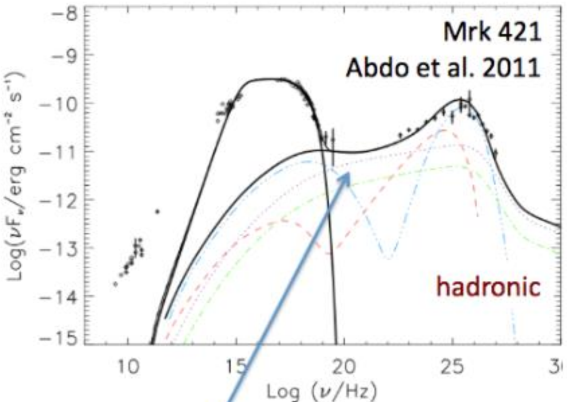


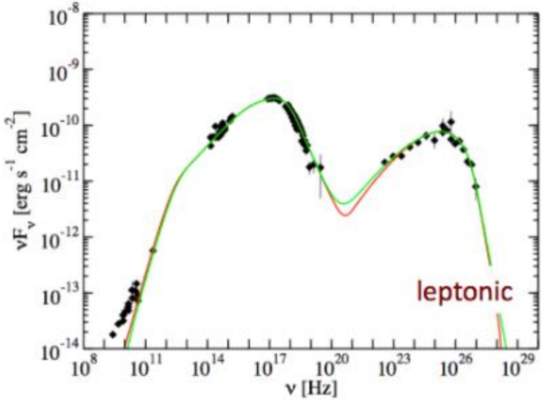
Relativistic Jets in AGN

- Do AGN jets accelerate protons to extremely high energies?
  - Producing PeV neutrinos, UHECR and high energy gamma-rays
  - Simultaneous observations of optical and MeV flux and polarization during blazar flares can test hadronic acceleration models



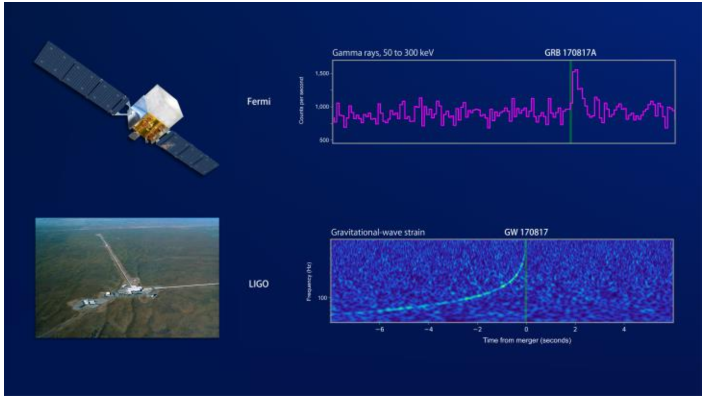
Quiescent: Hard X-rays/soft gammas: secondaries from pion production and proton synchrotron

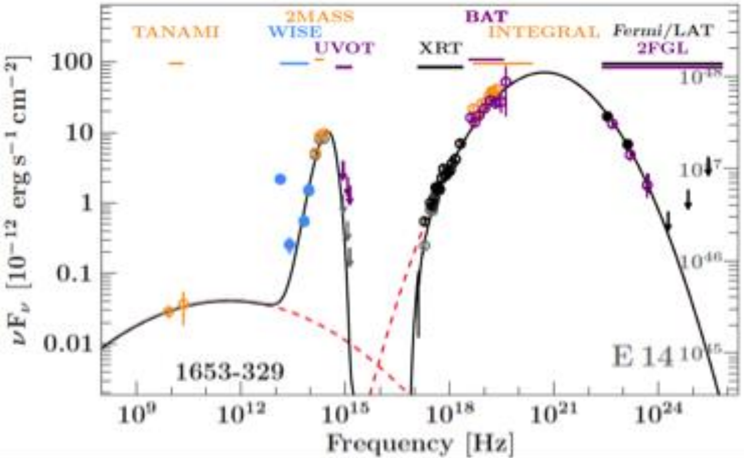




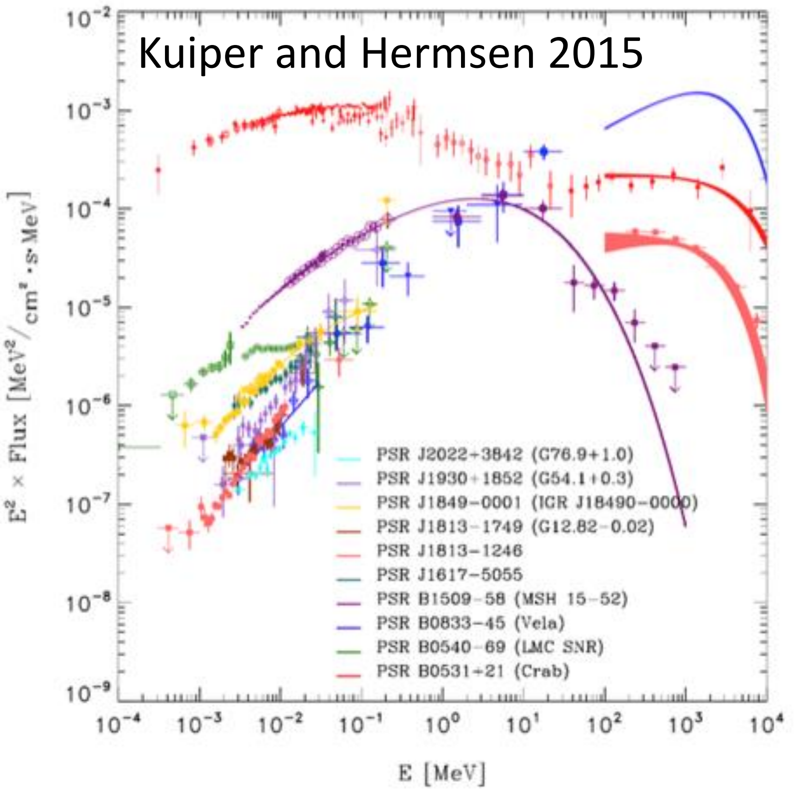
Multimessenger Astrophysics

- GRB and GW sources: AMEGO will detect ~80 sGRB/year with ~degree localization - significantly more than any currently operating GRB detector
- Do AGN jets accelerate protons to extremely high energies?
  - Producing PeV neutrinos, UHECR and high energy gamma-rays
  - MeV range is crucial





MeV Pulsars



- Pulsars seen in hard X-ray but not by Fermi-LAT, peak lies in MeV band
- 11 MeV pulsars known
  - Extremely energetic Edot > 10^{36} erg
- Possible "hidden" population of energetic soft gamma emitting pulsars
- Emission might probe different part of the magnetosphere than GeV

MeV Pulsar Puzzles: Who do most have single peaked lightcurves?
Why most are radio quiet? where do their SEDs peak and why ?

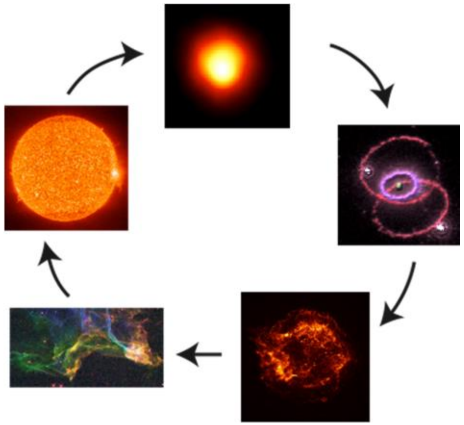
Dark matter Searches

- Unique sensitivity to the 511-keV line
  - Sensitivity to many classical positron sources: can constrain the contribution from nearby pulsars
- The MeV region is where the bulk of photons from WIMPs below 100 GeV is expected
- Axions, ALPs:
  - Sensitivity to photons emitted by SNe (Meyer et al. 2016)
  - Sensitivity to photon/ALP oscillations (Roncadelli et al. 2011; Hooper et al. 2009

Gamma-ray Spectroscopy

Nuclear lines explore Galactic chemical evolution and sites of explosive element synthesis (SNe)

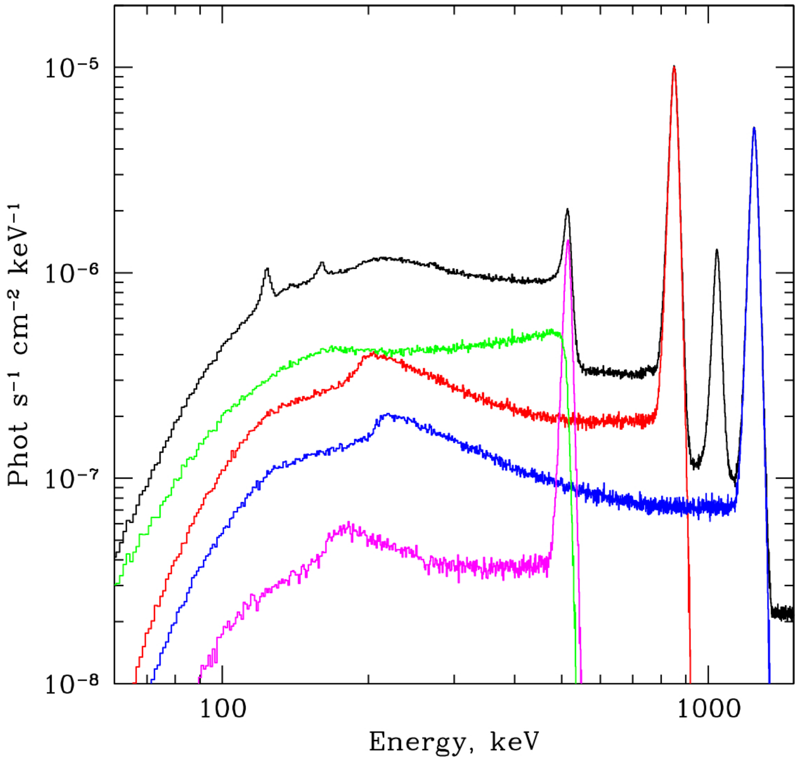
- Electron-positron annihilation radiation
  - $e^+ + e^- \rightarrow 2\gamma$ (0.511 MeV)
- Nucleosynthesis
  - Giants, CCSNe (^{26}Al)
  - Supernovae (^{56}Ni, ^{57}Ni, ^{44}Ti)
  - ISM (^{26}Al, ^{60}Fe)
- Cosmic-ray induced lines
  - Sun
  - ISM



56Ni: 158 keV 812 keV (6 d)
56Co: 847 keV, 1238 keV (77 d)
57Co: 122 keV (270 d)
44Ti: 1.157 MeV (78 yr)
26Al: 1.809 MeV (0.7 Myr)
60Fe: 1.173, 1.332 MeV (2.6 Myr)

Thermonuclear Supernovae (SNIa)

- 77% of energy escapes in gamma-rays, observed for SN2014J
- Modeling gamma-ray emission (decay + Compton + absorption) much simpler than in optical band
- No obscuration – AMEGO can find SNIA in dusty starburst galaxies
- AMEGO will precisely measure 56Ni mass for nearby SNIA – critical to determine optical lightcurve
- AMEGO will detect 2 SNIA/year out to a distance of 30 MPc

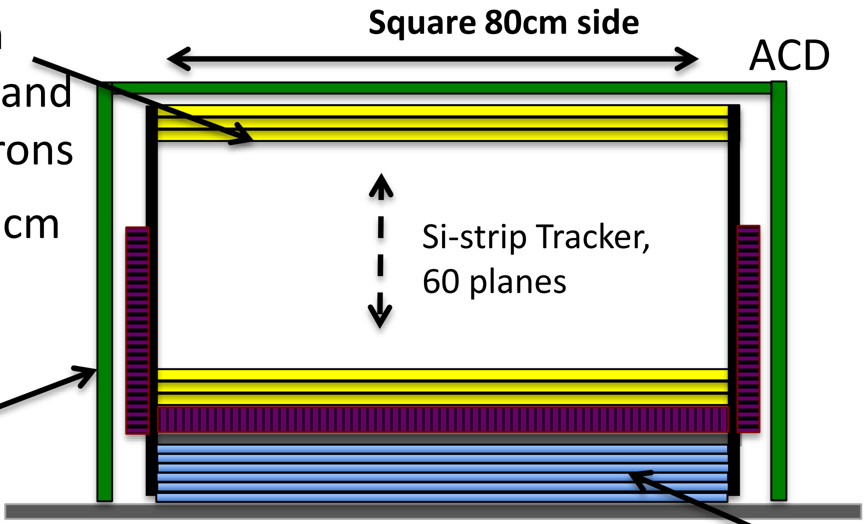


All-sky Medium Energy Gamma-ray Observatory (AMEGO)

Tracker

Incoming photon undergoes pair production or Compton scattering. Measure energy and track of electrons and positrons

- 60 layer DSSD, spaced 1 cm
- Strip pitch 0.5mm



CZT Calorimeter

Measure location and energy of Compton scattered photons

- Layer of 0.6x0.6 x 2cm bar CZT

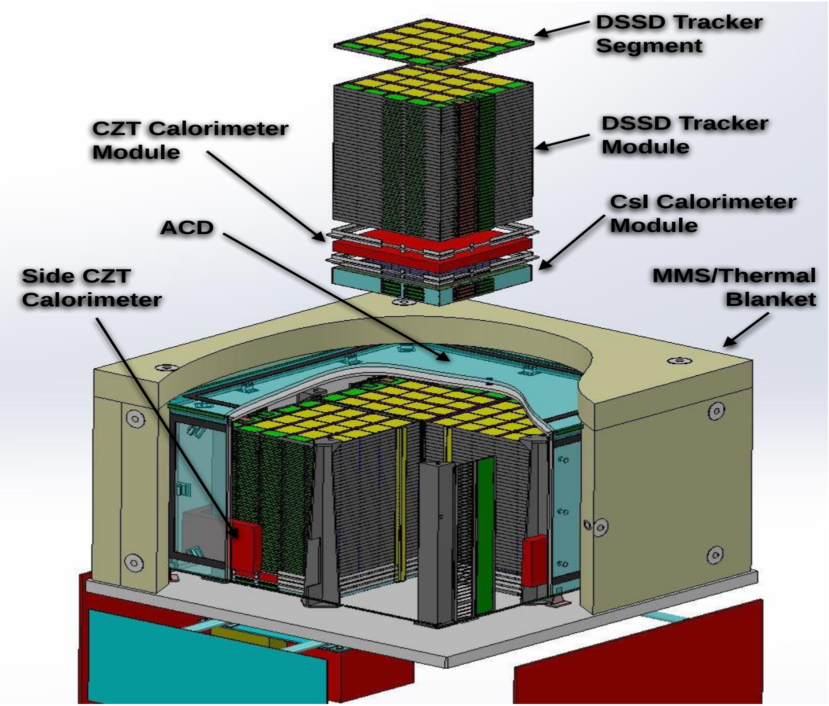
CsI Calorimeter

Extend upper energy range

- 6 planes of 1.5cm x 1.5 cm bars

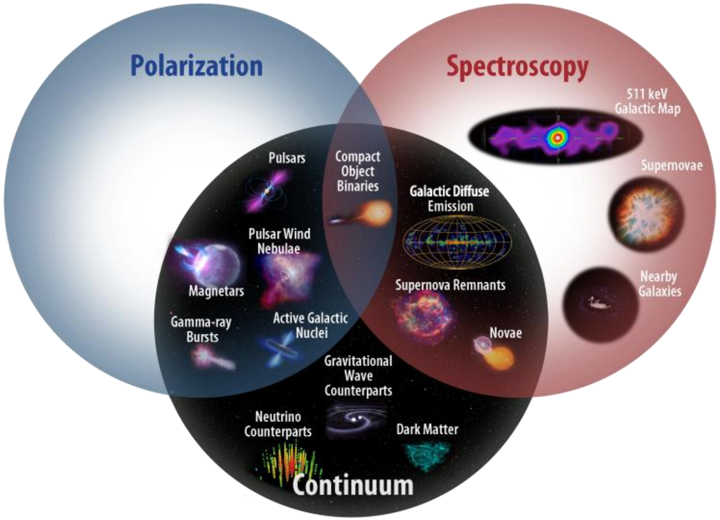
AMEGO

- Optimized for continuum sensitivity in 1 MeV – 100 MeV range with 0.2 MeV – 10 GeV full range
- Uses well understood, space qualified technology
- Minimize passive material
- Fine segmentation of all detector elements for particle tracking and identification



Plans and activities

- Prototyping/testing readout for CZT and daisy chained double-sided Si strip detectors
- Developing prototype instrument for beam tests and balloon flight in 2018/2019
- Engineering study of full instrument/mission concept (IDL/MDL)
  - Robust resources and cost estimate
- Developing and communicating AMEGO science case
- Plan to submit white papers to the upcoming decadal survey



AMEGO will provide three new gamma-ray science capabilities in the MeV band

- AMEGO, optimized for high flux sensitivity, broad energy range and a wide field of view will focus on astrophysical extremes
  - Astrophysical jets and multimessenger astrophysics
  - Compact objects (neutron stars and black holes)
  - Element formation in dynamic environments
  - Dark matter and new physics

AMEGO at the 231st AAS

http://asd.gsfc.nasa.gov/amego

Monday

Gamma-SIG at 11:00 am (MD Ballroom 3)

Tuesday

Poster Session at 5:30 pm

MeV Emission from Local Seyfert Active Galaxies (E. Mullin)

Wednesday

Talk at 10:00 am (Maryland B)

Polarization Observations of Fermi Blazars (B. Rani)

Wednesday

***Astrophysical Extremes and Life Cycles of the Elements* at 1:00 - 4:30 pm (National Harbor 8)**
https://asd.gsfc.nasa.gov/conferences/aas2018/

(A. Harding, D. Hartmann, J. Racusin, A. Fabian, R. Woolf, & T. Linden)

Poster Session at 5:30 pm

Fermi-LAT VIP AGN (D. Thompson)

GRBs and GW Counterparts with AMEGO (J. Racusin)

Neutrino Astrophysics in the MeV Band (R. Ojha)

Thursday

iPoster Session at 9:00 am

Development and Testing of the Tracker (S. Griffin)

Poster Session at 5:30 pm

Exploring Dark Matter (R. Caputo)

CsI Calorimeter Development for AMEGO (J. E. Grove)

Friday

Talk at 2:10 pm (Potomac C)

Advancing the MeV Frontier with AMEGO (D. Hartmann)