Studying the Universe with gamma-rays

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QuarkNet workshop
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Questions you may have

• What are gamma-rays?
• Why do we need a satellite to detect the ones coming from space?
• How do we detect them, and especially, measure what direction they came from
• What can we learn about the universe from them?
  • Physics of the objects that emit them
  • Connection to the processes that create cosmic rays
  • Properties of the gamma-rays themselves, given cosmological distances
Yesterday was an anniversary!

• We started collecting data on Aug 4, 2008.

• The nominal mission duration was to be 5 years!
Two views of the sky: the data
The sources
An (artistic) view of the Milky Way
What does it look like?

Public Data Release:
All $\gamma$-ray data made public within 24 hours (usually less)

Si-Strip Tracker:
convert $\gamma \to e^+e^-$
reconstruct $\gamma$ direction
EM v. hadron separation

Hodoscopic CsI Calorimeter:
measure $\gamma$ energy
image EM shower
EM v. hadron separation

Fermi LAT Collaboration:
~400 Scientific Members, NASA / DOE & International Contributions

Anti-Coincidence Detector:
Charged particle separation

Sky Survey:
With 2.5 sr Field-of-view LAT
sees whole sky every 3 hours

Trigger and Filter:
Reduce data rate from ~10kHz to 300-500 HZ
How does it work?

charged particle anticoincidence shield
pair conversion foils
particle tracking detectors
calorimeter
e^+ e^−
Some basic, but non-trivial physics concepts
Mass (m)
Energy (E)
Frequency (f or ν)

\[ E = mc^2 = hf \]

Where \( c = \) speed of light, \( h = \) Planck’s constant

Units: electron Volt, eV:
eV: chemistry (battery: 1.5 eV per electron, photons from Sun: 2.5 eV)
MeV (million): nuclear physics
GeV (billion): mass of proton
TeV (trillion): LHC energies
Light is discrete photons

• Photons have **no** mass, always travel at speed of light
• Gamma-rays are very energetic (high frequency, short wavelength) photons: Fermi works from $30 \text{ MeV}$ to $1 \text{ TeV}$
• Radio waves have very low energies.
The mystery of mass: the Standard Model and the Higgs

Why is zero mass so special?
Particles vs. waves

• Newton vs. Huygens: how to explain refraction?
• Einstein, black-body radiation, and the photoelectric effect (PM tubes!)
• Feynman’s picture
Something “special” about those muons you will be detecting

Physicists use mean life, 2.2μs, not half-life.