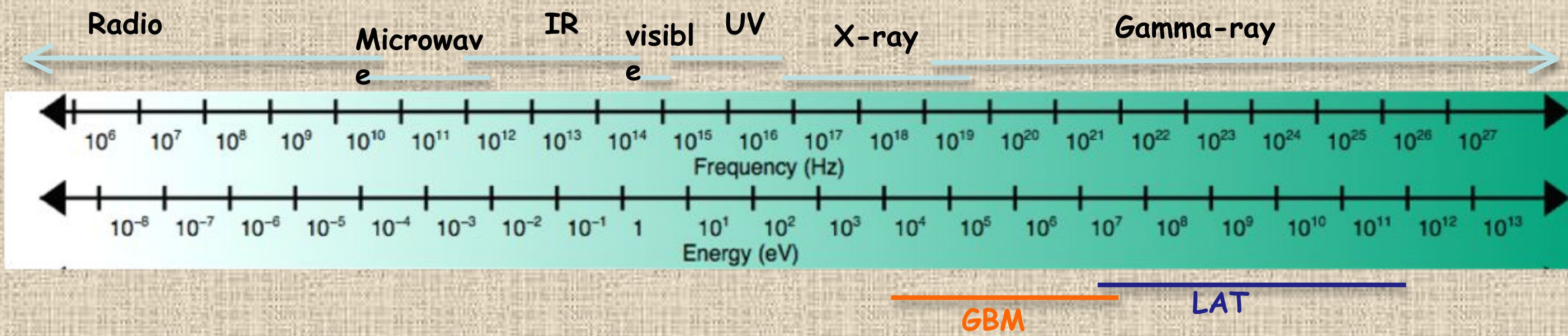
Fermi Summer School 2012

A brief retrospective

Liz on behalf of Jamie and Julie

From Julie

Gamma-ray Astrophysics

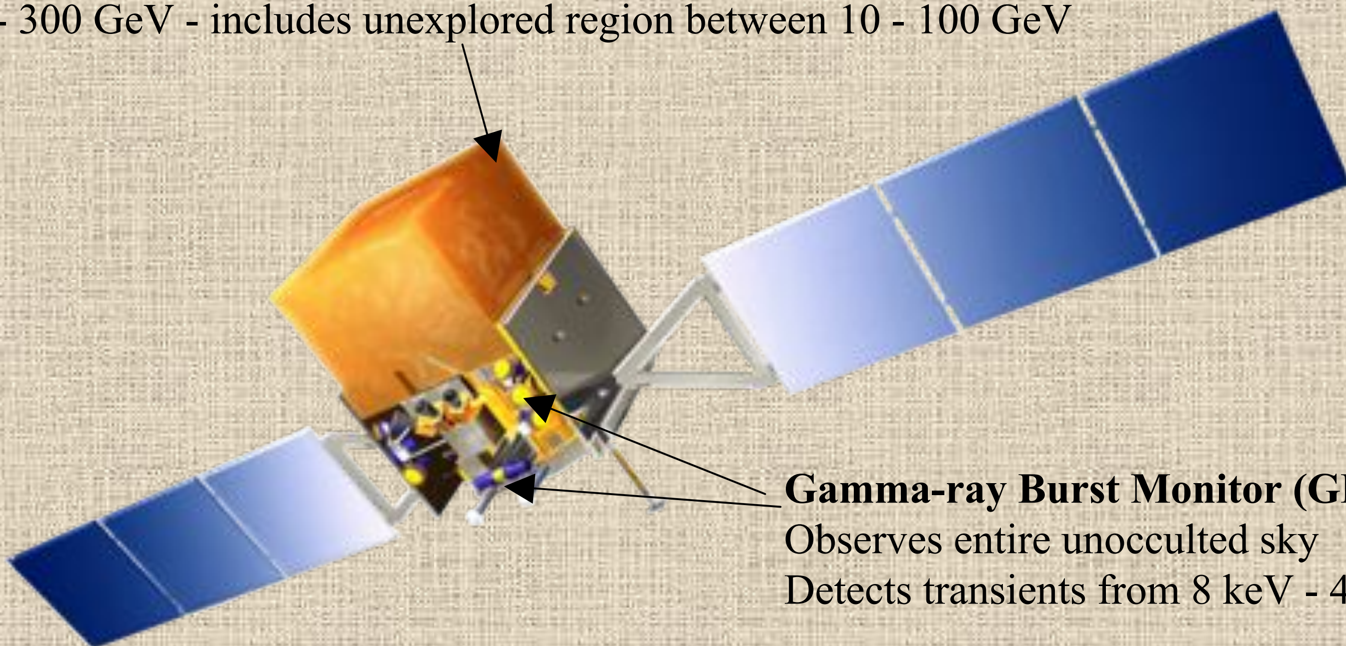


- Gamma-rays cover a huge swath of the electromagnetic spectrum
- The gamma-ray sky is still very new
- High-Energy gamma-rays probe the non-thermal universe
  - Explore extreme environments hosting powerful particle accelerators

From Julie

The Fermi Observatory

Large Area Telescope (LAT)
Observes 20% of the sky at any instant, views entire sky every 3 hrs
20 MeV - 300 GeV - includes unexplored region between 10 - 100 GeV



Gamma-ray Burst Monitor (GBM)
Observes entire unocculted sky
Detects transients from 8 keV - 40 MeV

- **Unique capabilities for GeV astrophysics**
  - **Largeeffective area**
  - **Good angular resolution**
  - **Huge energy range**
  - **Wide field of view**

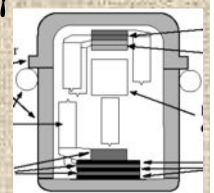
From Seth

Brief History of Detectors* for GeV Gamma-ray Astronomy

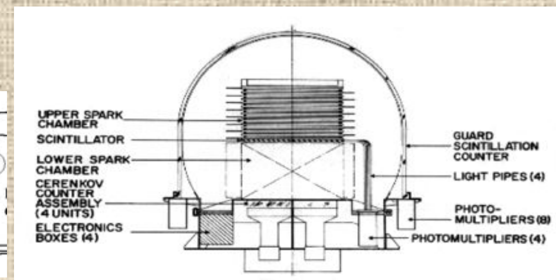
* in space

- 1967-1968, OSO-3 detected Milky Way as an extended γ-ray source, 621 γ-rays
- 1972-1973, SAS-2, ~8,000 celestial γ-rays
- 1975-1982, COS-B, orbit resulted in a large and variable background of charged particles, ~200,00 γ-rays
- 1991-2000, EGRET, large effective area, good PSF, long mission life, excellent background rejection, and >1.4 × 10^6 γ-rays
- 2007-, AGILE, like 1/16-th LAT, with small calorimeter, sensitivity ~EGRET

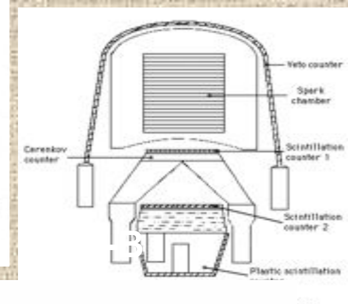
OSO-3



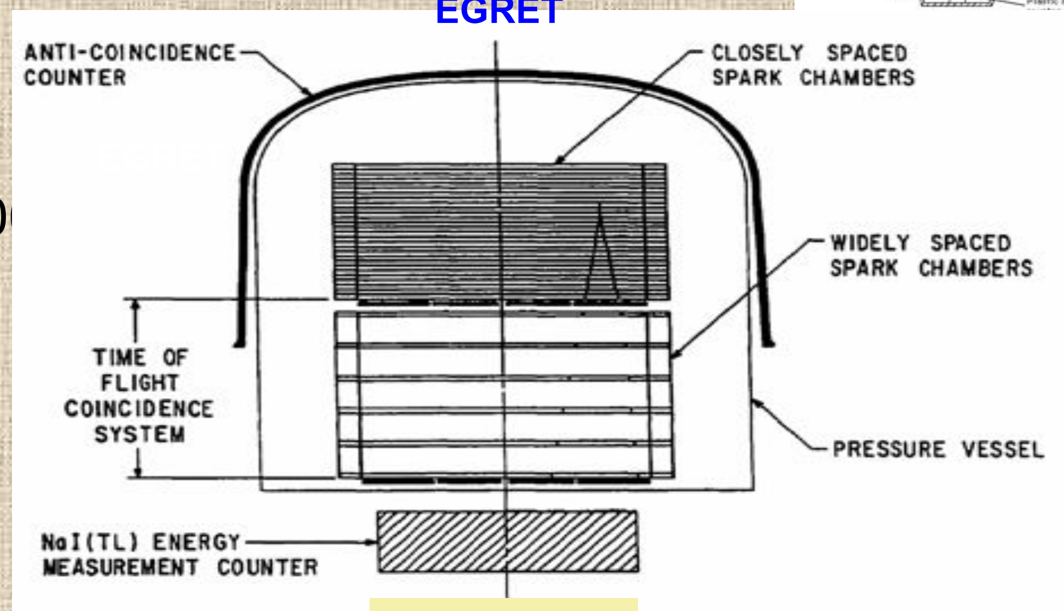
SAS-2



COS-B



EGRET

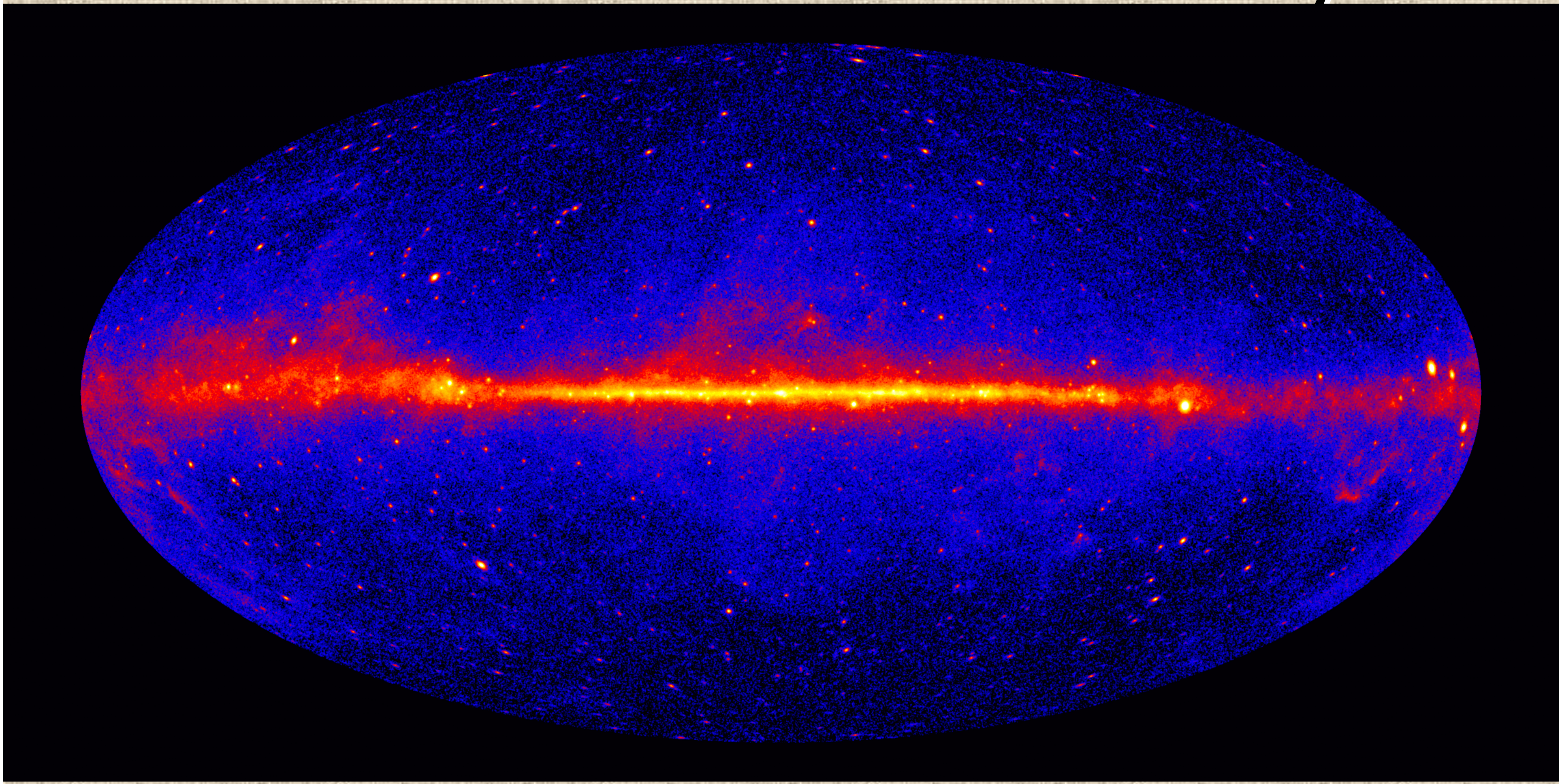


AGILE

From Seth

The GeV sky is Steady…

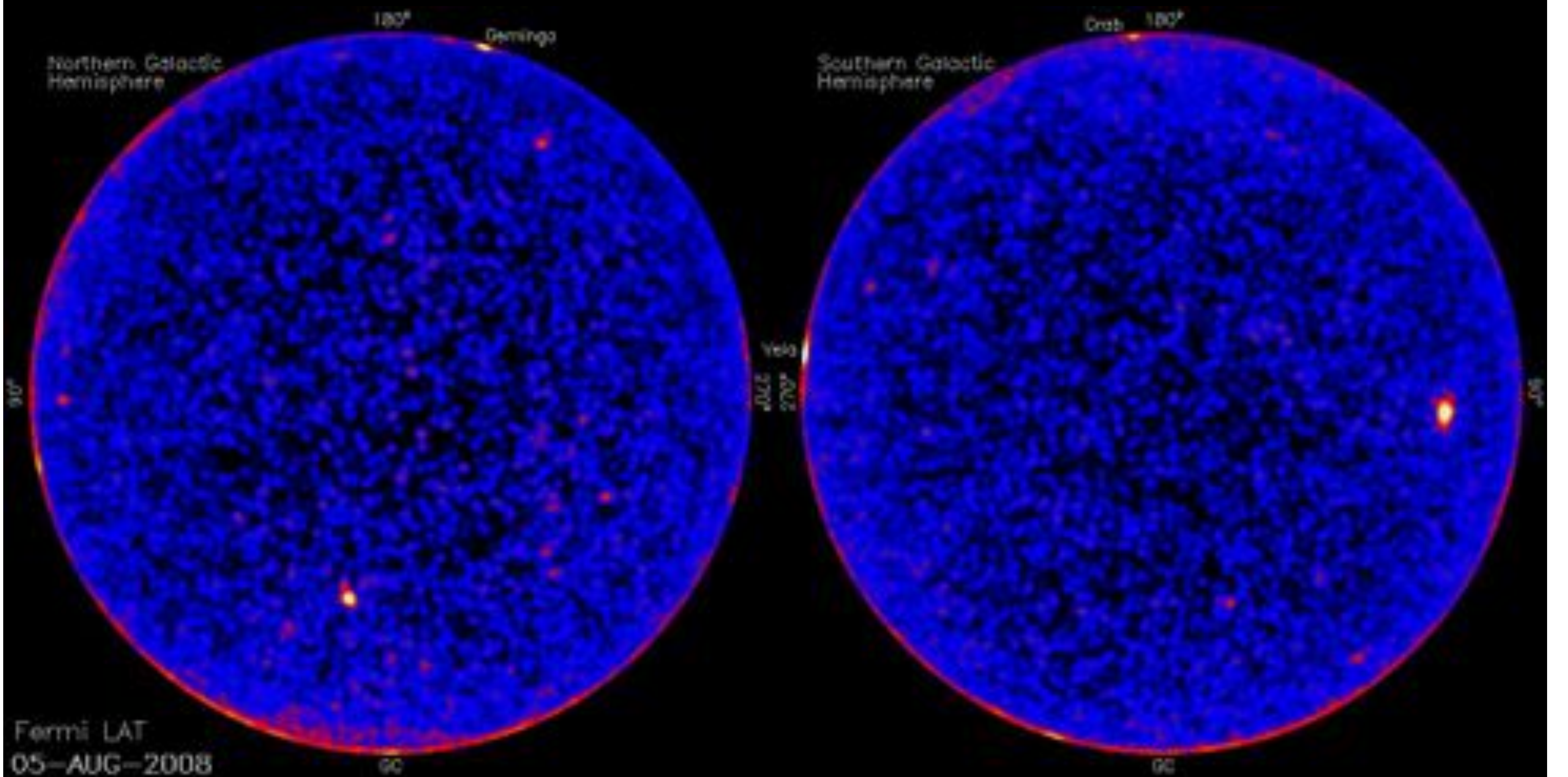
Reminder: The LAT Sky

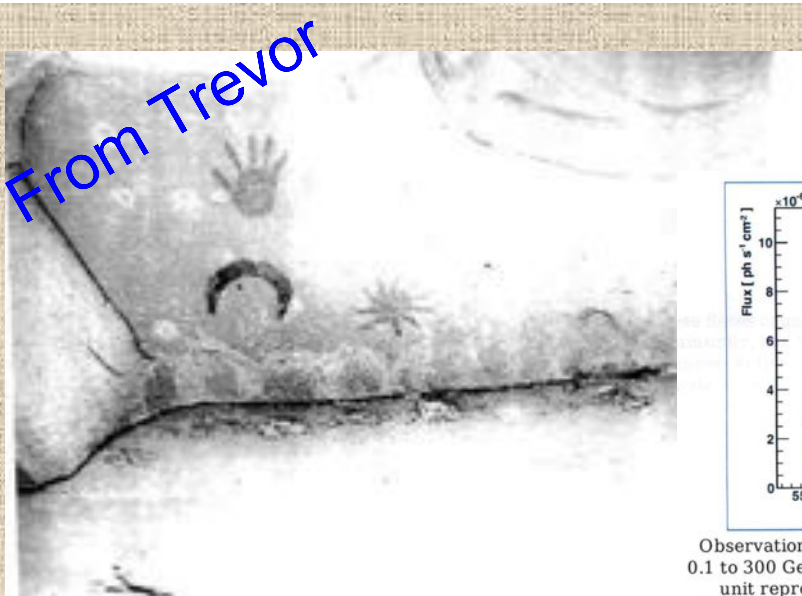


>1 GeV for three years

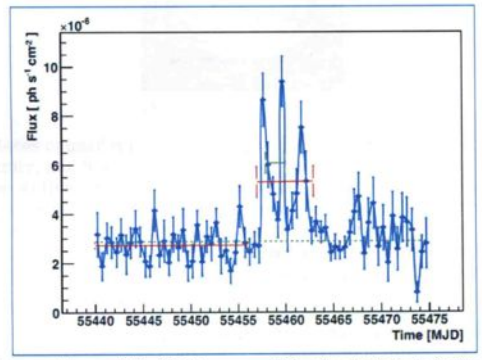
From Julie

and Variable!

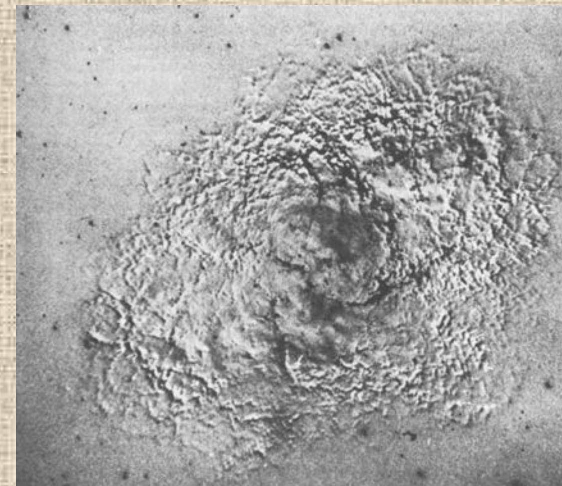




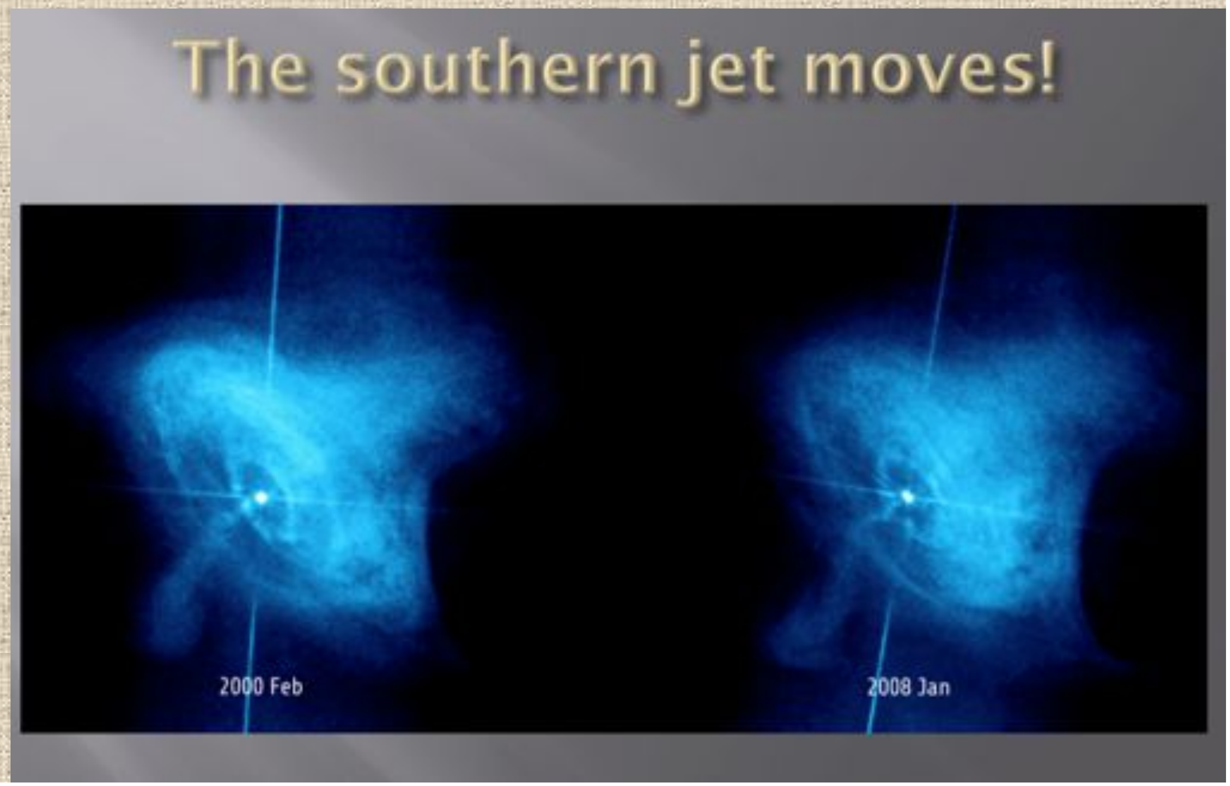
The Crab is variable



Observations of the light curve of the Crab Nebula in the range 0.1 to 300 GeV showing the three observed flares. Each horizontal unit represents a 12h time bin. The red lines represent the average flux before and during the flares (image: Balbo et al. 2011).

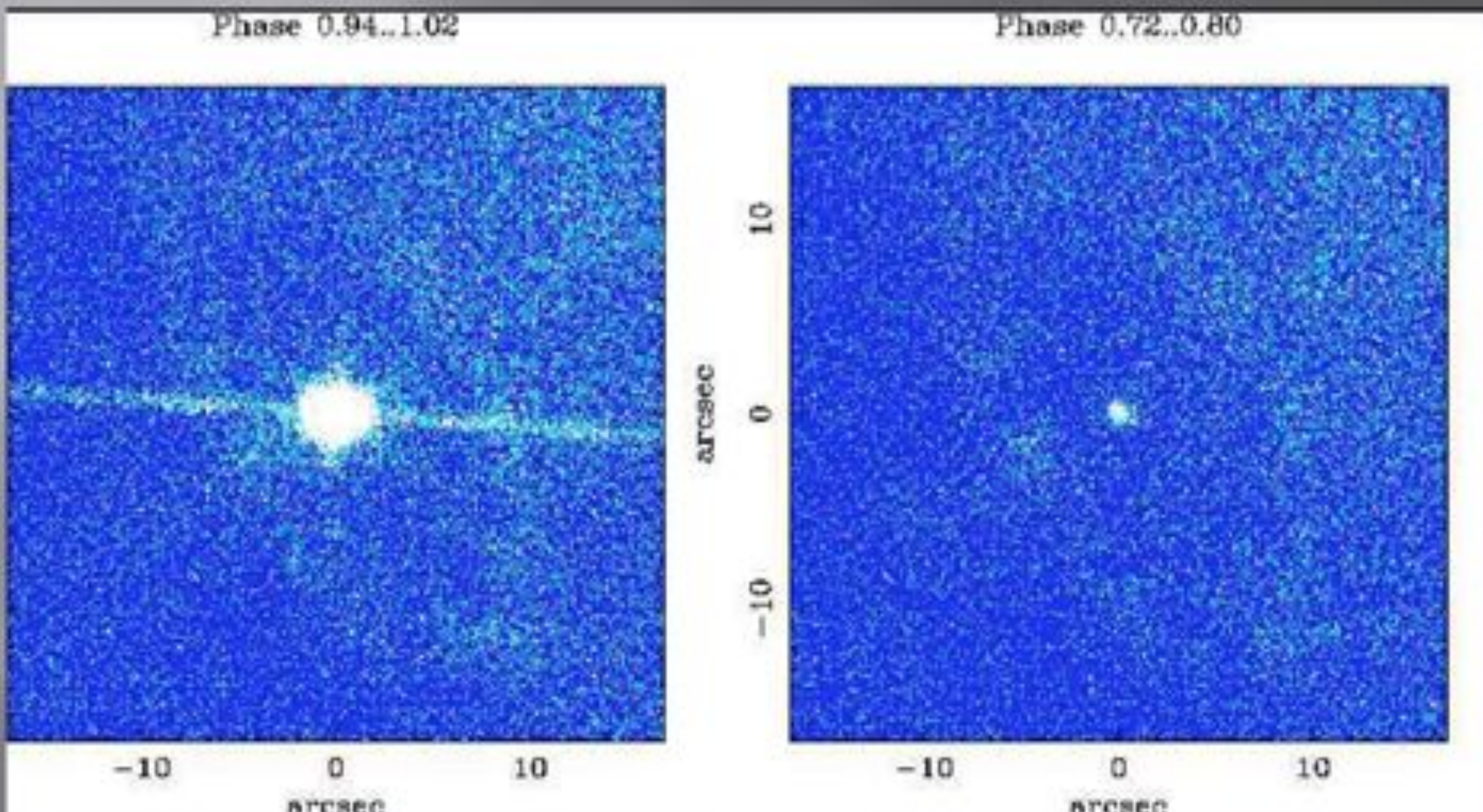


"You can divide astronomy into two parts: the of Crab Nebula and the astronomy of everything else"
Burbidge



From Martin

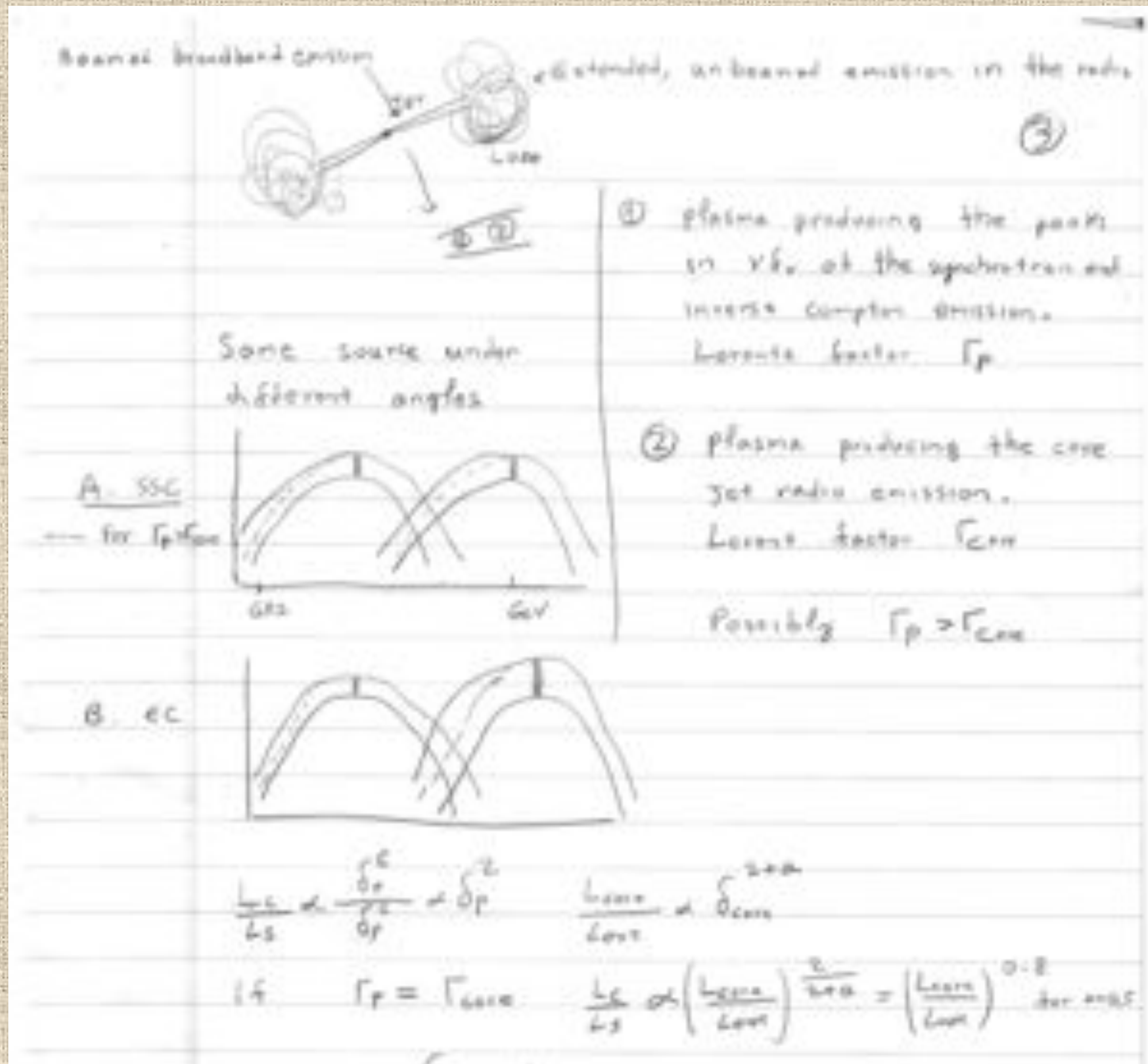
The pulsar is always on



Crab is also yummy and fun!

Blazars beaming from the blackboard

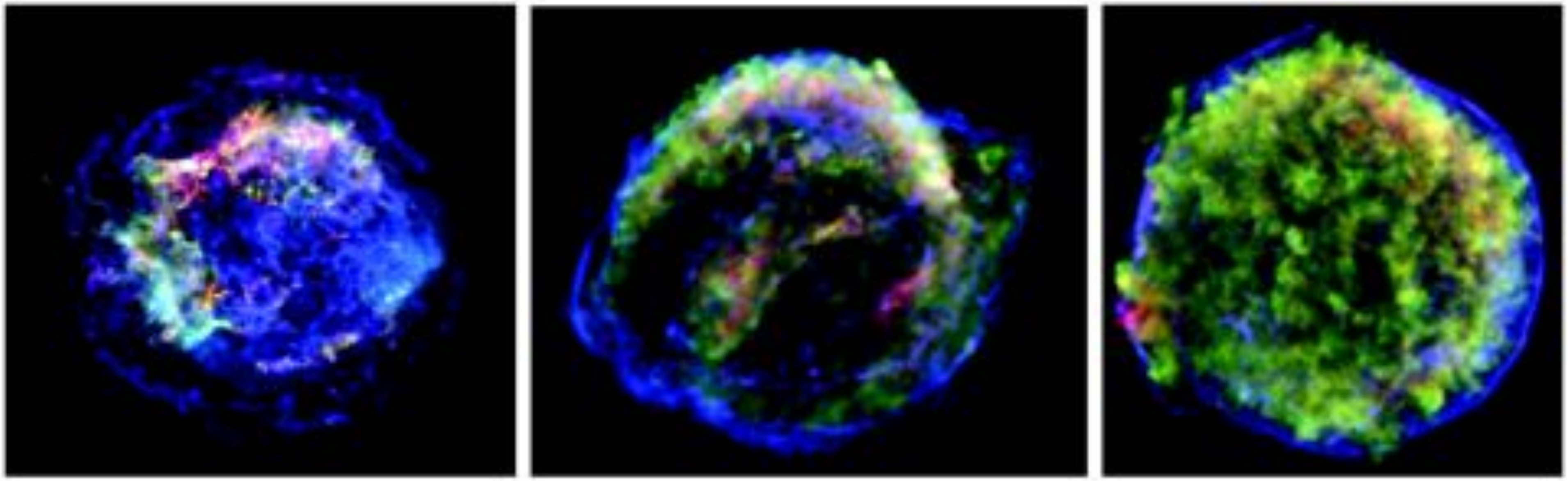
From Markos



From Pasquale

Accleration comes from something moving

SUPERNOVA BLAST WAVE



FREE EXPANSION VELOCITY: $V_s = \sqrt{\frac{2E_{ej}}{M_{ej}}} = 10^9\ E_{51}^{1/2}\ M_{ej,\Theta}^{-1/2}$ cm/s

THE EXPANSION SPEED DROPS DOWN DURING THE SEDOV-TAYLOR PHASE, BUT THE MACH NUMBER IS ~100

A STRONG SHOCK WAVE DEVELOPS

From Pasquale

Diffusion is easy!

NOW WE RECALL THE TRANSPORT EQUATION IN CONSERVATIVE FORM:

$$\frac{\partial f_0}{\partial t} = -\frac{\partial J}{\partial z}$$

AND PUTTING THINGS TOGETHER:

$$\frac{\partial f_0}{\partial t} = -\frac{\partial}{\partial z}\left[-\kappa_t \frac{\partial J}{\partial z} - \kappa_z \frac{\partial f_0}{\partial z}\right]$$

BUT IT IS EASY TO SHOW THAT THE FIRST TERM MUST BE NEGLIGIBLE:

$$J = \frac{v}{2}\int_{-1}^{1} d\mu \mu f_0(1+\delta\mu) = \frac{1}{3} v\delta f_0 \ll v f_0 \qquad \delta \ll 1$$

IT FOLLOWS THAT THE ISOTROPIC PART OF THE DISTRIBUTION FUNCTION MUST SATISFY THE DIFFUSION EQUATION:

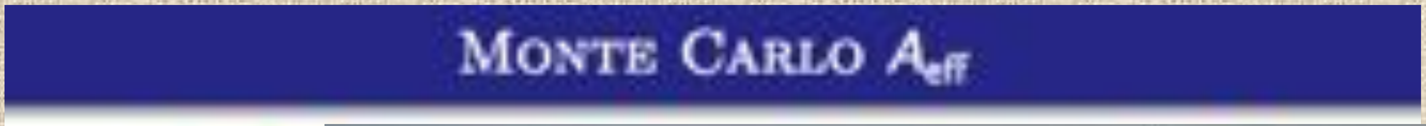
$$\frac{\partial f_0}{\partial t} = \frac{\partial}{\partial z}\left[\kappa_z \frac{\partial f_0}{\partial z}\right]$$

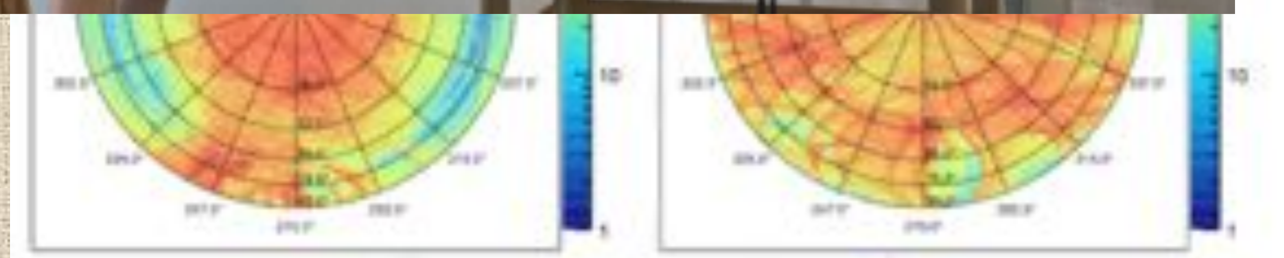
DIFFUSION EQUATION

$$\kappa_z = \frac{v^2}{8}\int_{-1}^{1} d\mu \frac{(1-\mu^2)^2}{D_{\mu\mu}} = \frac{1}{3} v\lambda_{\parallel}$$

SPATIAL DIFFUSION COEFFICIENT

From Luca





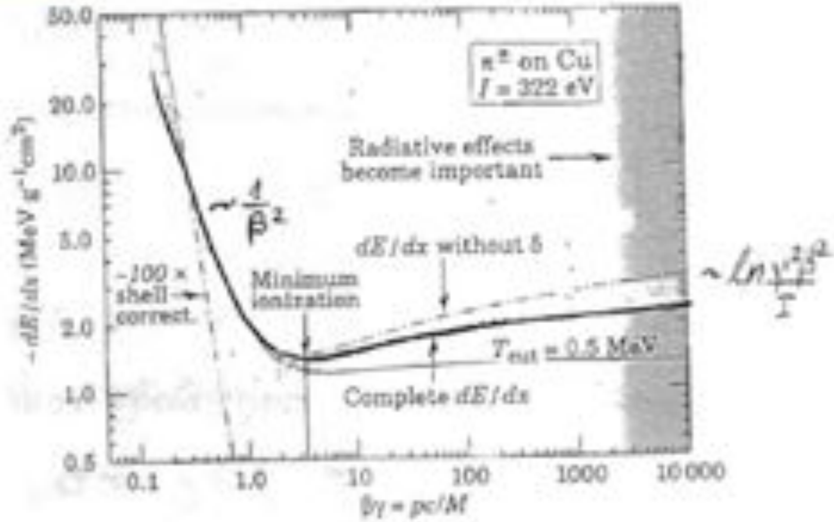
The LAT performs well

Thanks, Luca!

Energy Loss of heavy ($M \gg m_e$) charged Particles in Matter

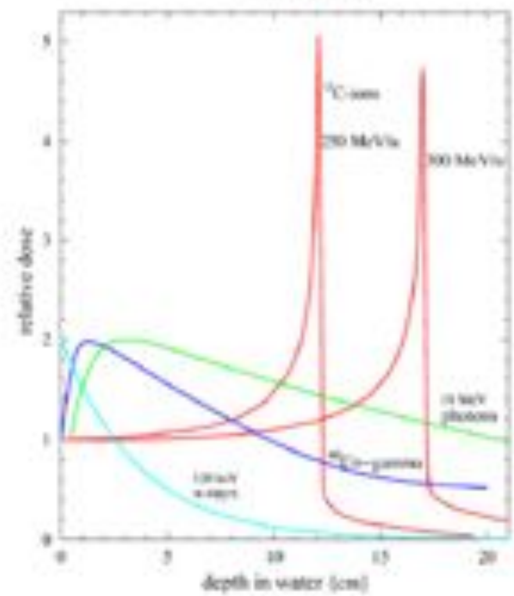
From Nepomuk

- Energy loss described by Bethe-Bloch formula
- Ionisation through inelastic scattering & atomic excitation
- Global minimum in dE/dX @ **βγ~3.5** -> Minimum Ionizing Particle (MIP)
- dE/dx at minimum ~ **2 MeV cm² / g** (multiply with density and thickness of material to get total energy loss)
- dE/dx ~ **Z** with Z=atomic number of absorber
- dE/dx ~**z²** with z=charge of incident particle
- Hadronic interactions come in addition (needed for shower development)



What would you chose?

High density and **high Z?**
or
Low density and **low Z?**



From Michael

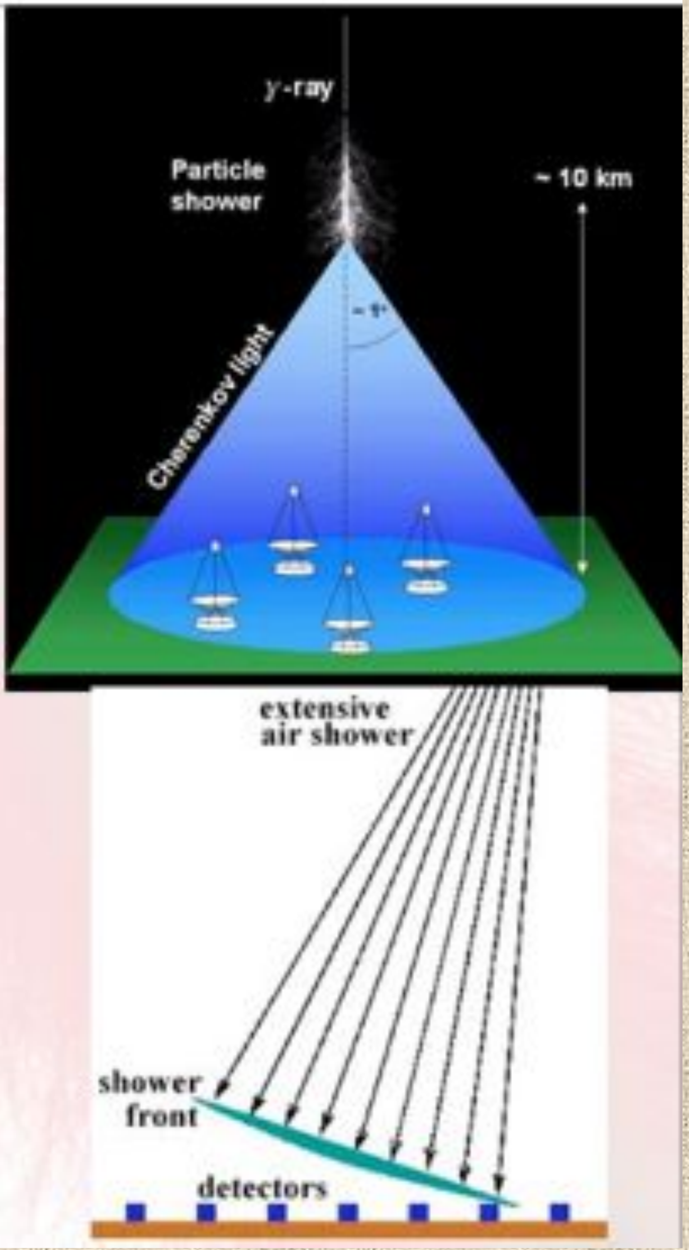
Radiation is fun (and mostly not too dangerous)

From Andy

How to see gamma rays at ground level

Lexicon

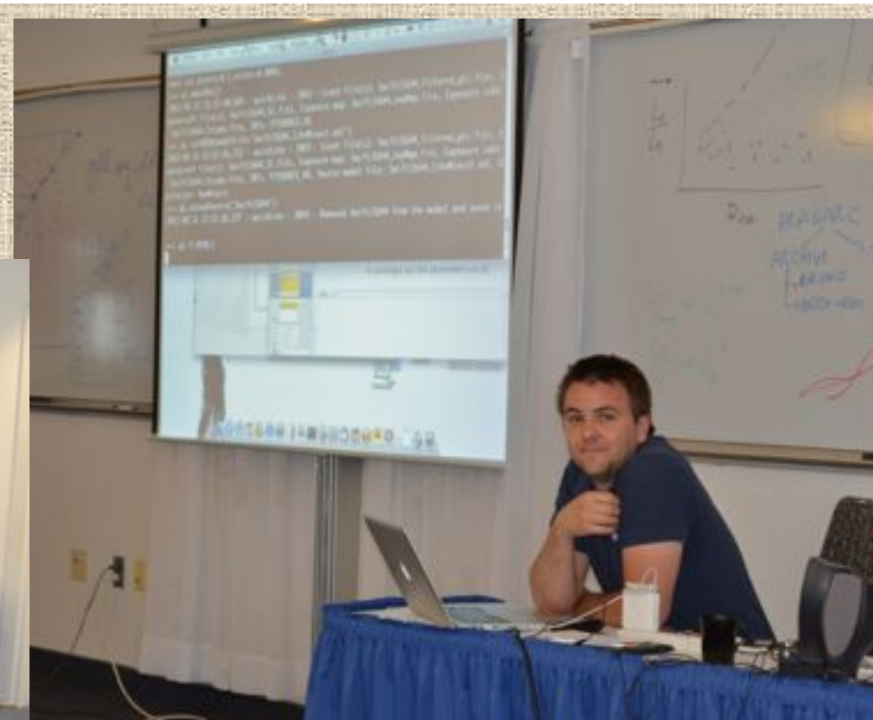
- IACT - Imaging Atmospheric Cherenkov Telescope (detector includes both the fancy mirror and camera, but also includes the atmosphere, which is used as a detector volume.
- EAS Array - Extended air shower detector. Detects particles at the ground.



From Jamie et al.

Cherenkov telescopes…Even a toddler can do it!

Analysis can be tough, but it’s worth it. Keep at it!



Thank you!