IDS Report

Chuck Dermer (Naval Research Laboratory)
GLAST/SWG
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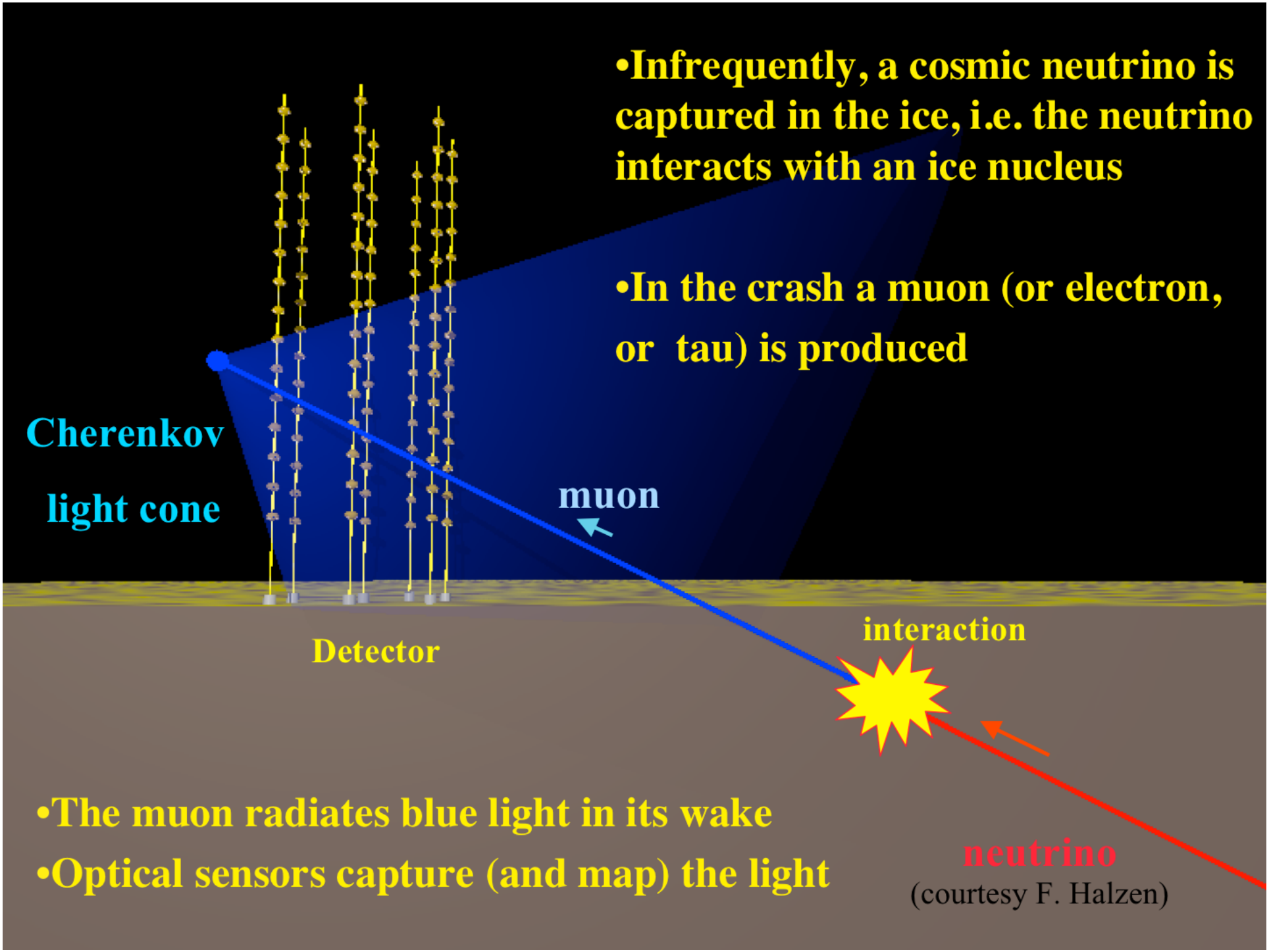
Collaborators:
Armen Atoyan (University de Montreal) Blazars, GRBs
Robert Berrington (NRL) Clusters of Galaxies
Markus Böttcher (Rice University) GRBs, Blazars
James Chiang (UMBC/SLAC) GRBs
Stuart Wick (NRL) Cosmic Rays, Neutrinos

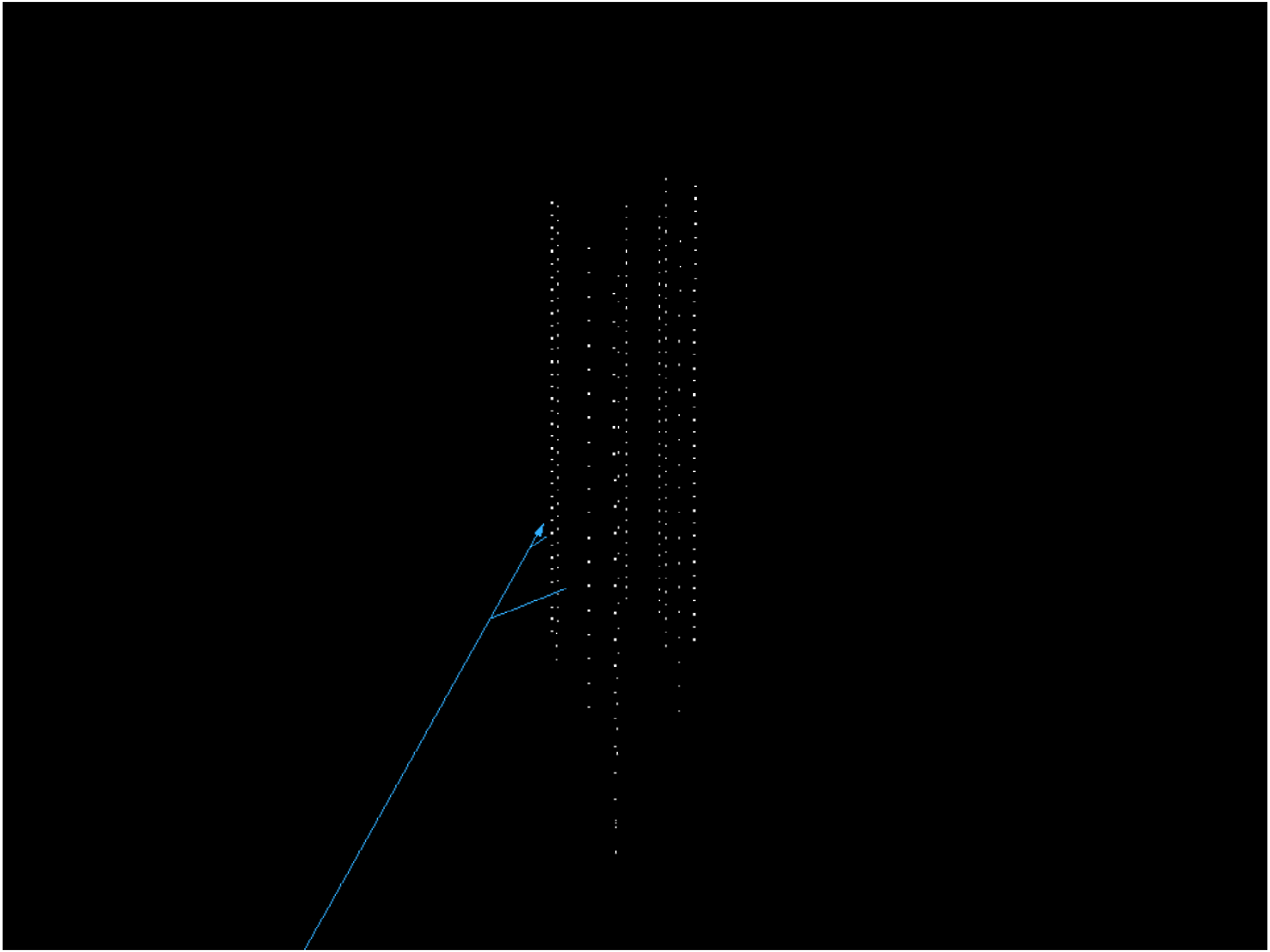
Gamma Ray/High Energy Neutrino Connection

$$p + \gamma' \rightarrow n + \pi^+ \ , \ p + \pi^0 \rightarrow \gamma$$

$$\pi^+ \rightarrow e^+ + \nu_e + \nu_\mu + \bar{\nu}_\mu$$



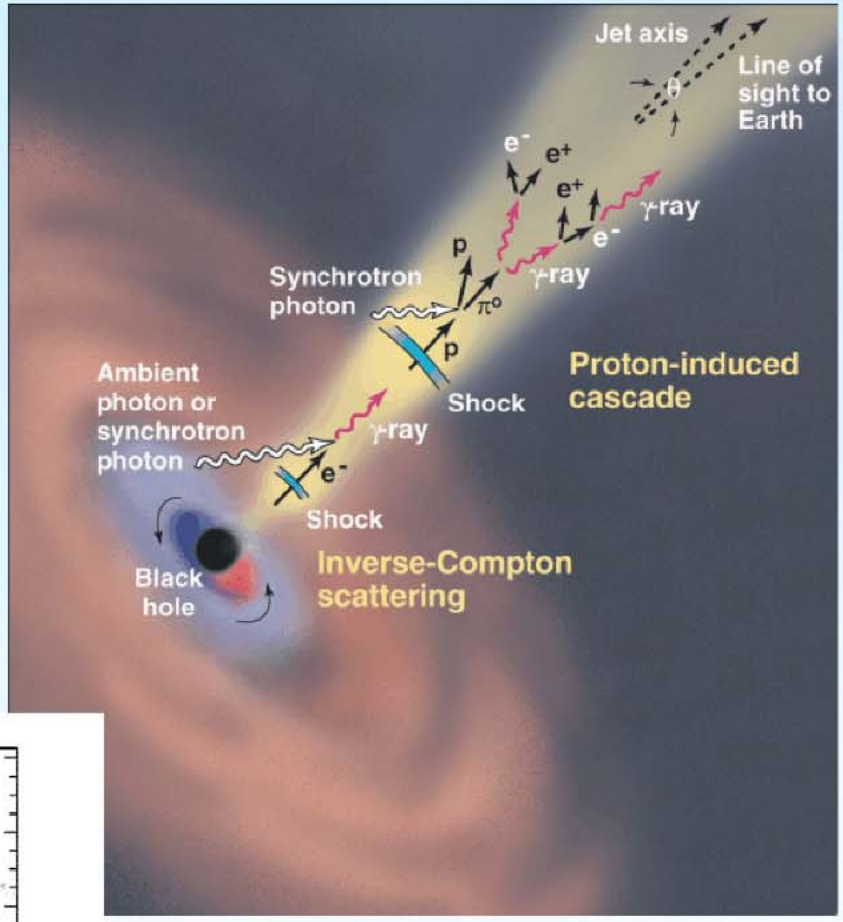
(courtesy F. Halzen)

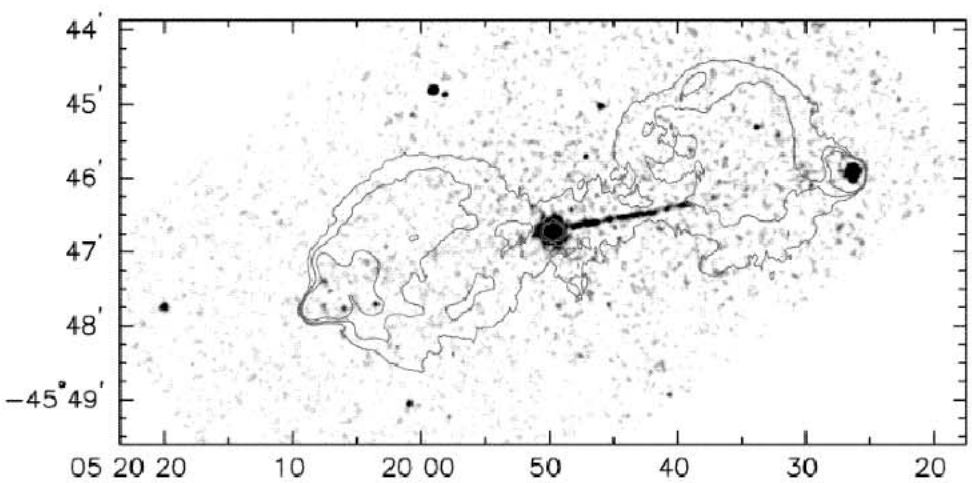


1. Neutral Beams from Blazar Jets

(March ApJ)

Combined lepton + hadron model
Importance of external radiation field
Neutron, neutrino, high-energy gamma-ray production
Evidence for UHECR acceleration

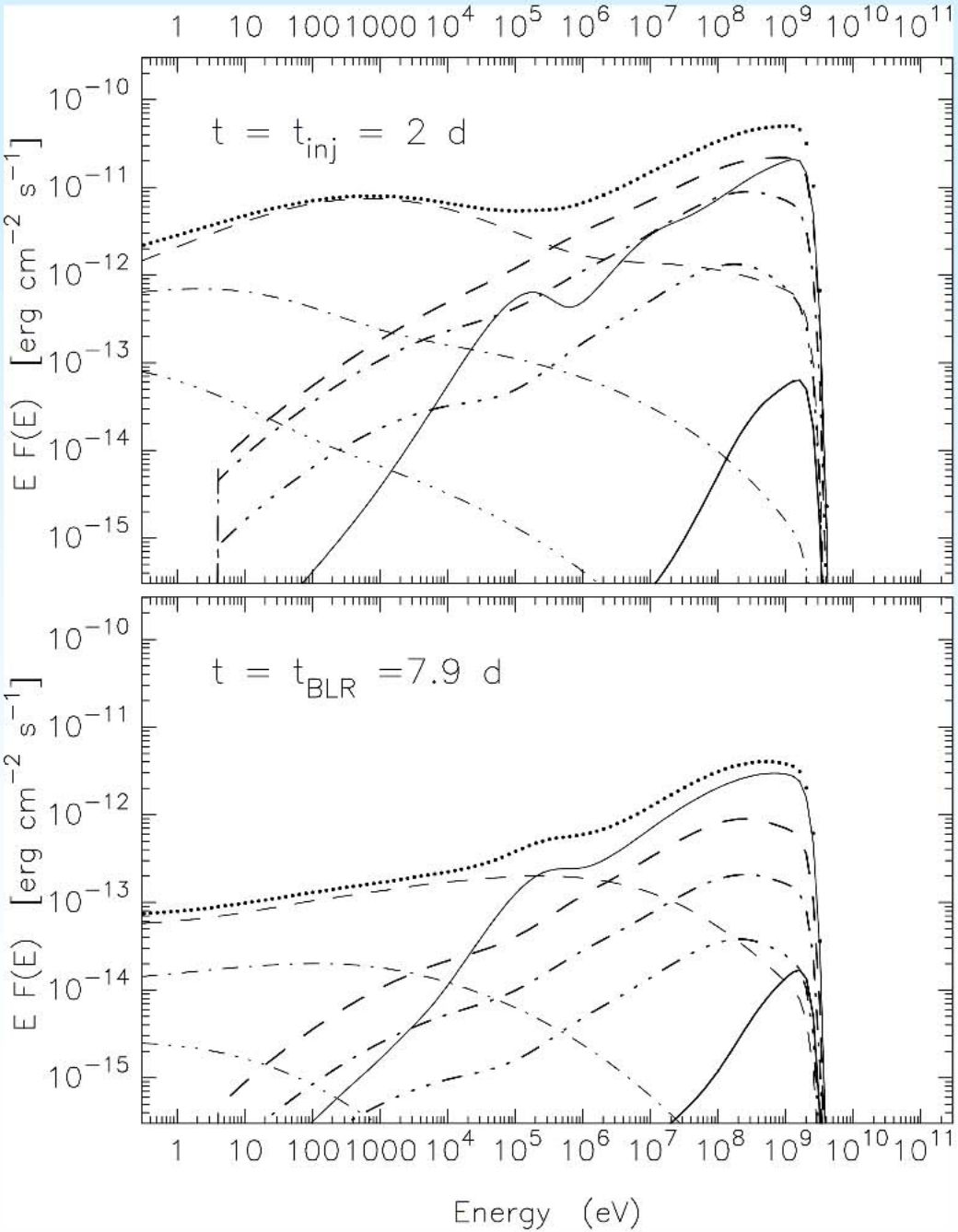




> 100 kps scale jet of Pictor A (Wilson et al. 2001, ApJ 547, 740)

Nonthermal gamma-rays ⇒ nonthermal particles
+ Intense photon fields

⇒ Strong photomeson production



Hadronic Cascade Radiation from 3C 279

(Limits proton/electron ratio)

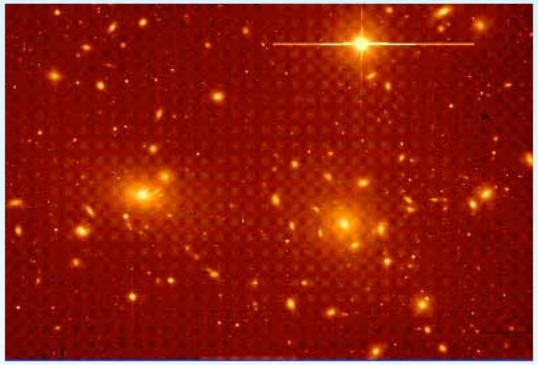
Predict detectable neutrino production from 3C 279 with a km-scale neutrino telescope; Hadronic gamma-ray emission detectable with GLAST

2. Nonthermal Particles and Radiation Produced by Cluster Merger Shocks

Thermal bremsstrahlung X-ray Emission of Galaxy Clusters traces gravitational well

Rich clusters (thousands of Galaxies; $\sim 10^{15}$ M_{sun}; kT ~ 5-10 keV, $L_X \sim 10^{43}$ - 10^{45} ergs s^{-1})

Velocity dispersions ~500-1000 km s^{-1}



Poor clusters (hundreds of Galaxies; $\sim 10^{14}$ M_{sun}; kT ~ 1-5 keV, $L_X \sim 10^{41}$ - 10^{43} ergs s^{-1})

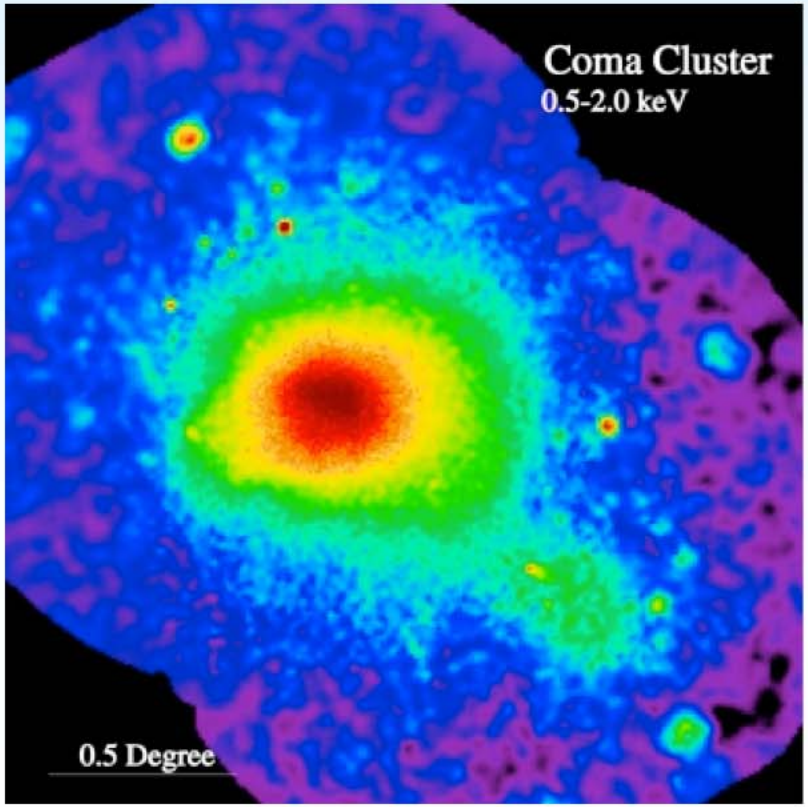
Velocity dispersions ~250-500 km s^{-1}

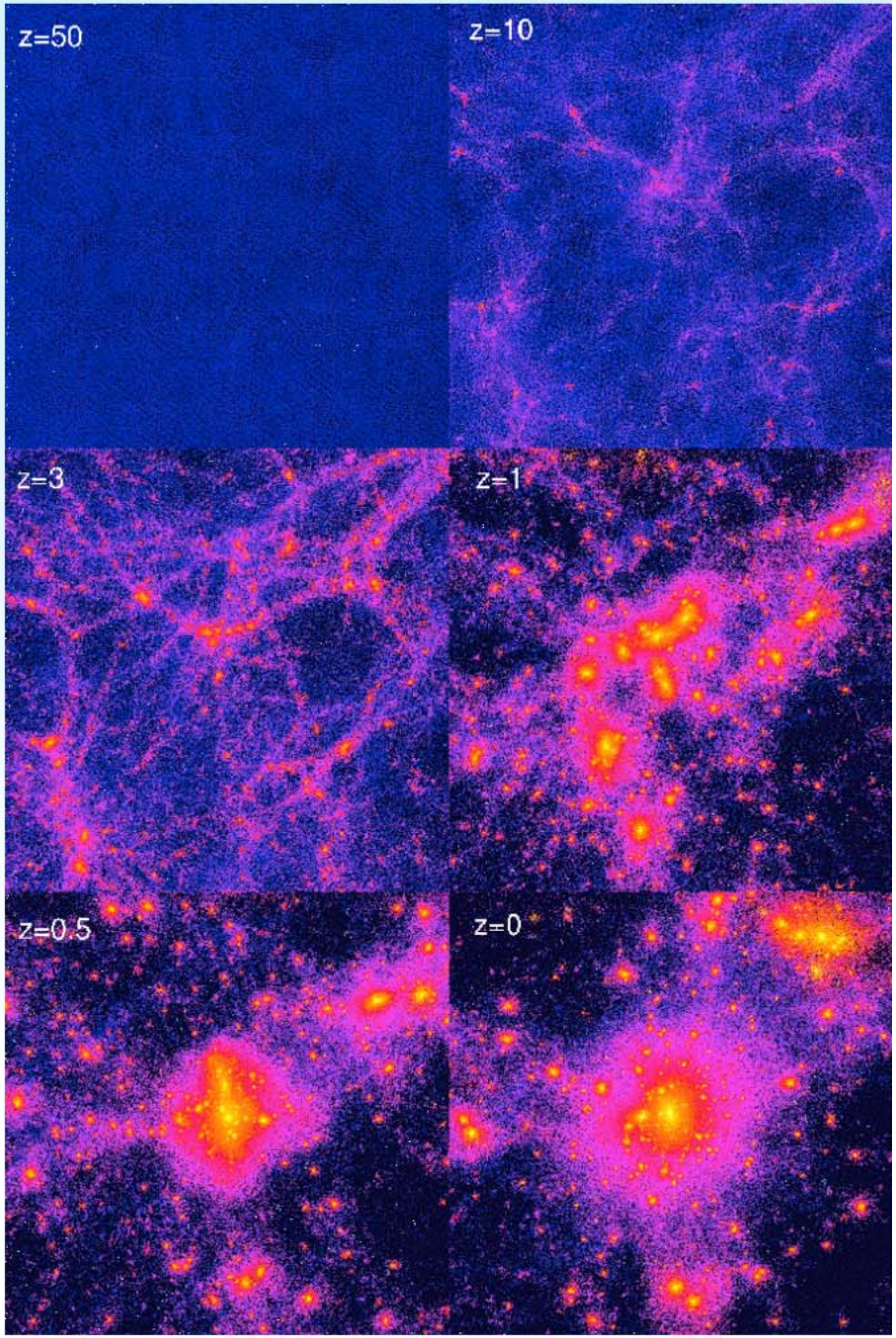
~5-10% of total mass of cluster; Orbital motion dominated by distribution of dark matter

Which clusters are GLAST-bright?

Structure Formation

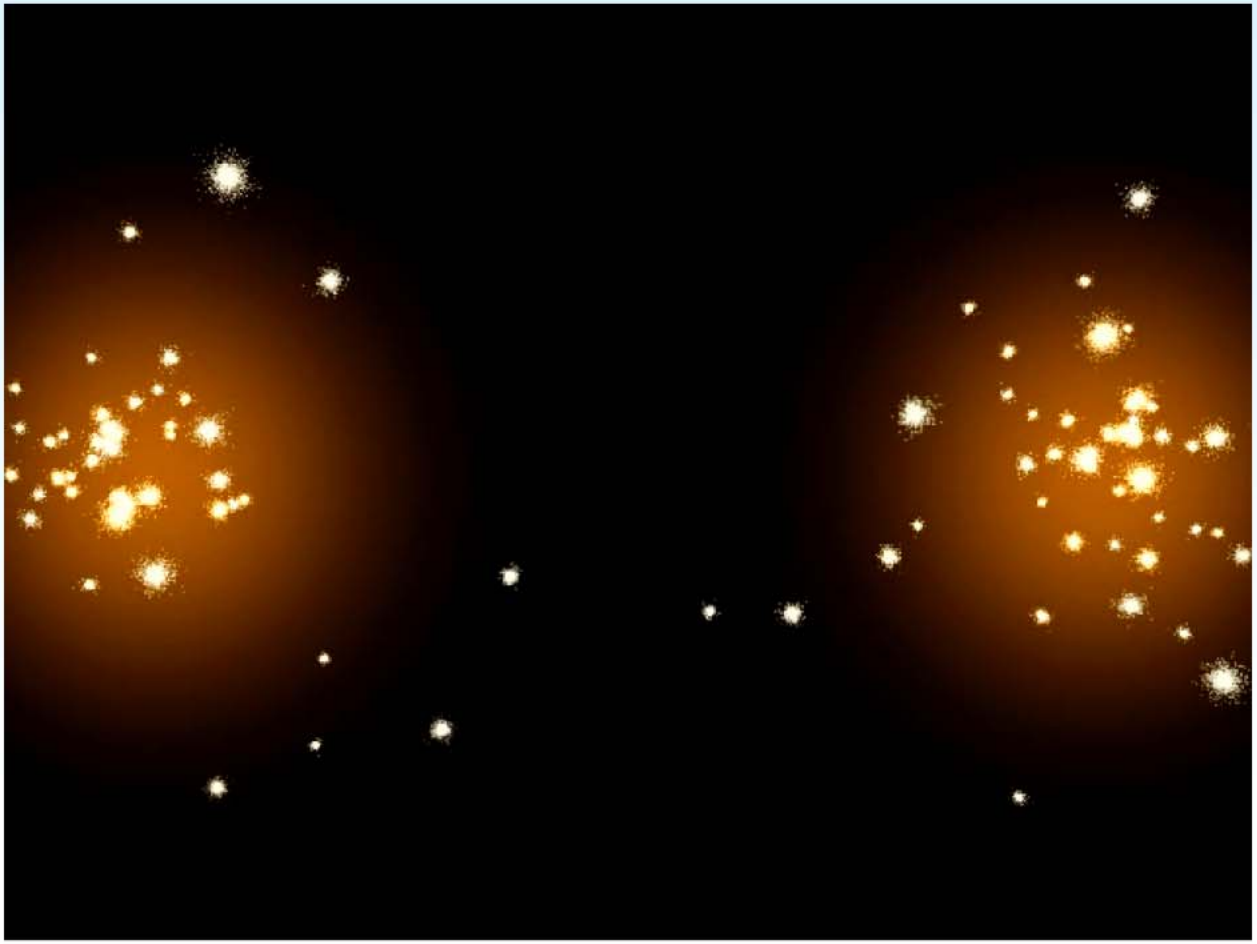
- Density fluctuations cause region to collapse.
  - **Magnitude of the density fluctuation determines the formation time**
  - **Larger structures form by accreting smaller clumps--hierarchical merging**
  - **Lumpy, continuous accretion**



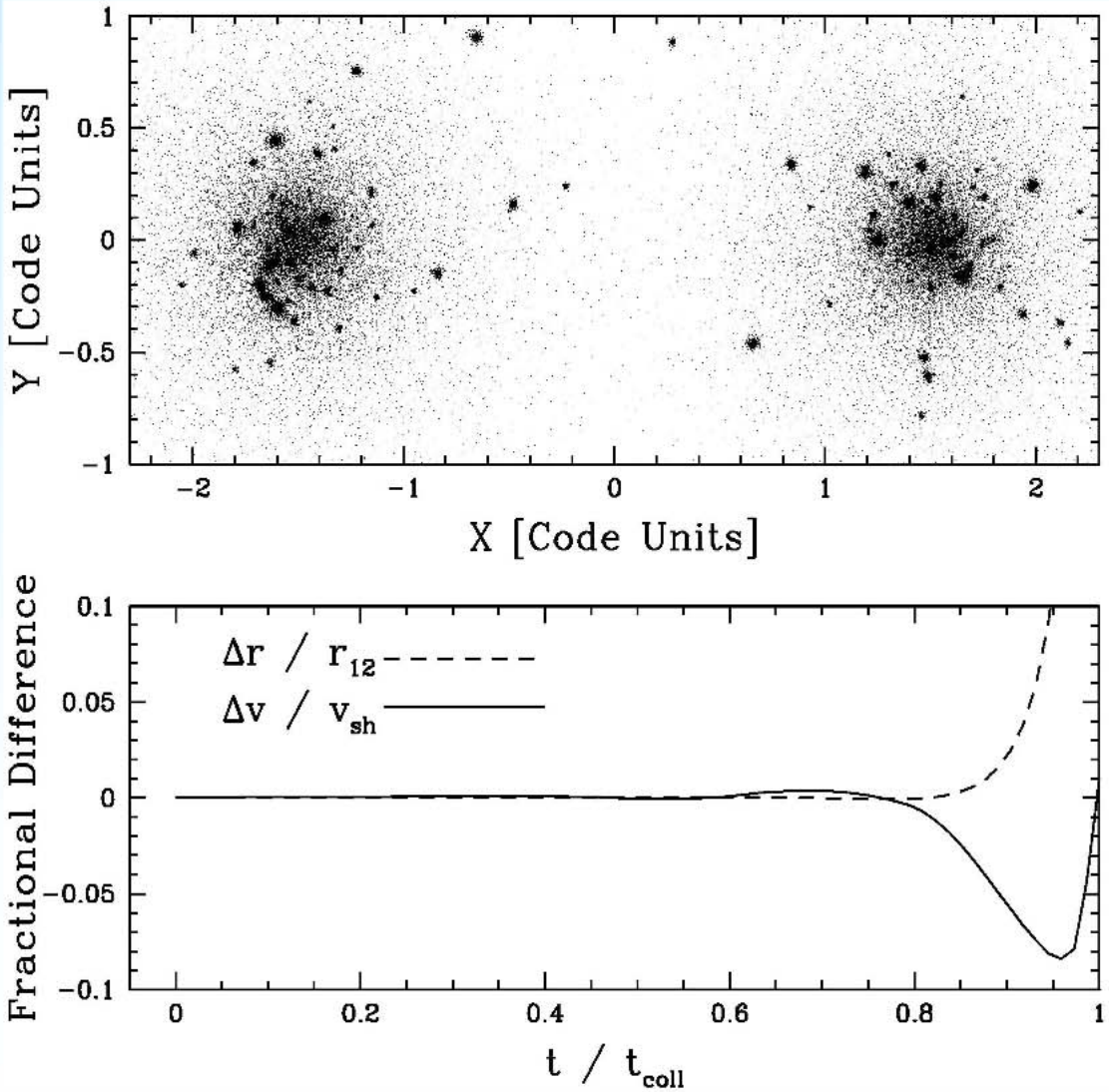


Cluster Merger

- Simulation of merging clusters of galaxies

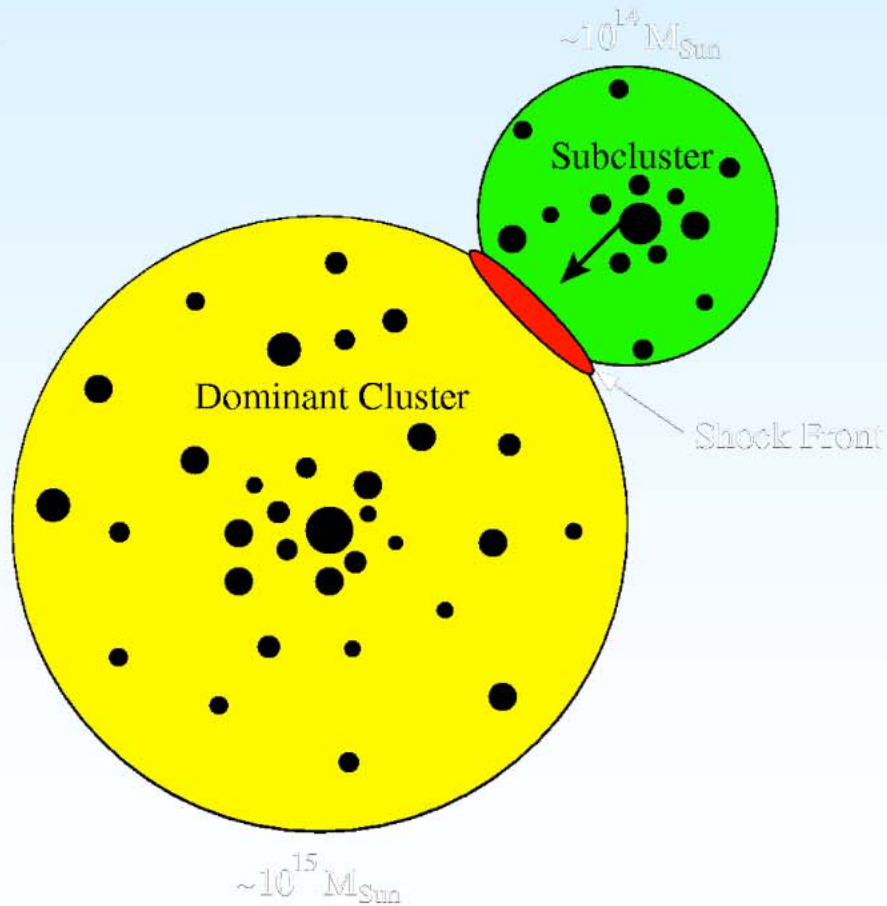


Infall Velocity



Shocks in Merging Clusters

- $(\Omega_0, \Omega_R, \Omega_\Lambda)$ (mass, curvature, and dark energy)= (0.3, 0.0, 0.7)
  - Redshift of cluster:
  - Cosmic Microwave Background (CMBR) dependence
    - $U_{CMBR}(z) = U_{CMBR}(z=0)\ (1 + z)^4$
    - Rich clusters from by accreting poor clusters
    - Shocks in Merging Clusters



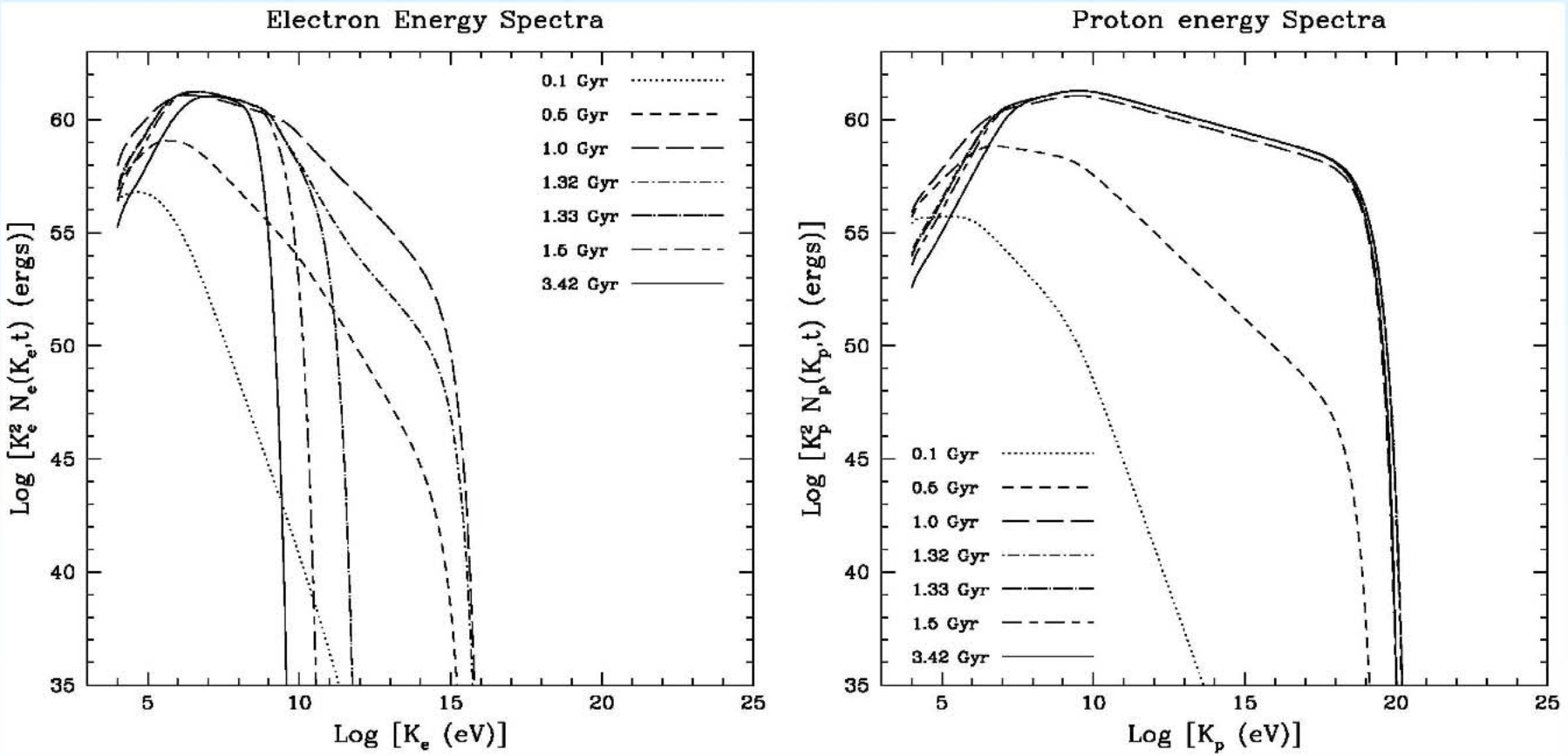
Particle Injection

- Power law distribution with exponential cutoff $$Q_{e,p}(E,t) = Q^0_{e,p}\left[\frac{(pc)^{-\alpha}}{\beta}\right]\exp\left[-\frac{E}{E_{\max}(t)}\right]$$
  - Occurs only if M ≥ 1.0
  - Occurs only during lifetime of shock
- Normalization

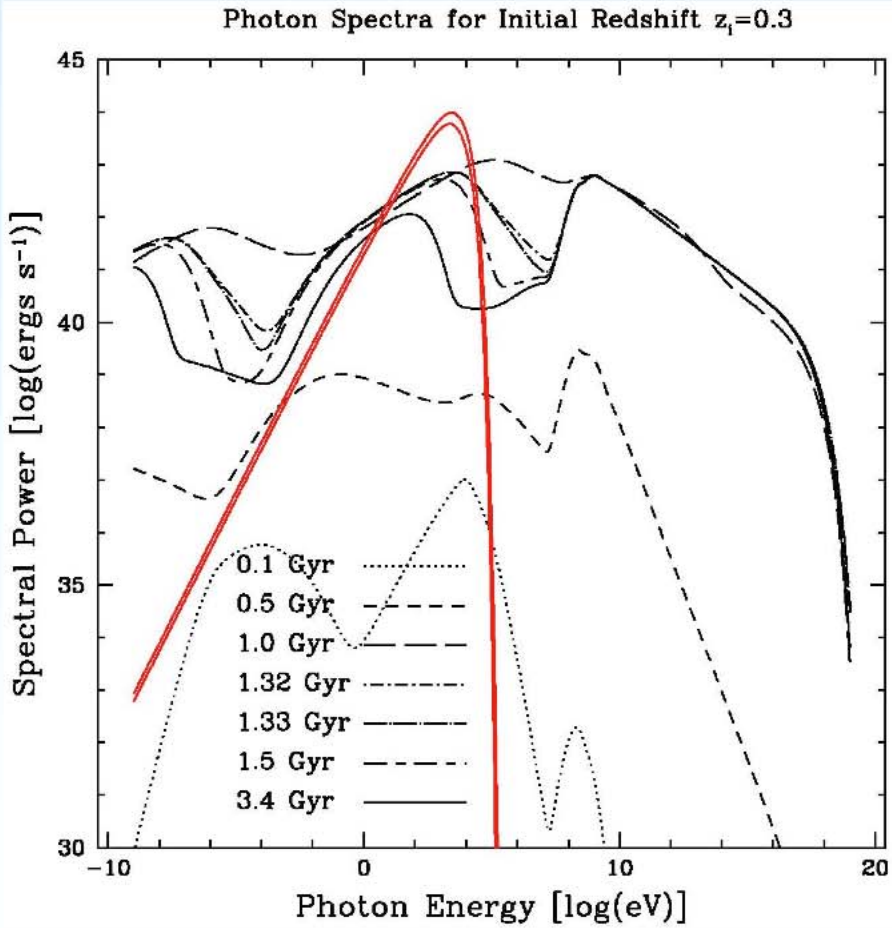
$$\int_{E_{\min}}^{E_{\max}} E_{e,p} Q_{e,p}(E,t)\,dE = \eta_{e,p}\left(\frac{1}{2}\langle n_{\mathrm{ICM}}\rangle \eta^{e}_{\mathrm{He}} m_p v_s^2\right)(A_s v_s)$$

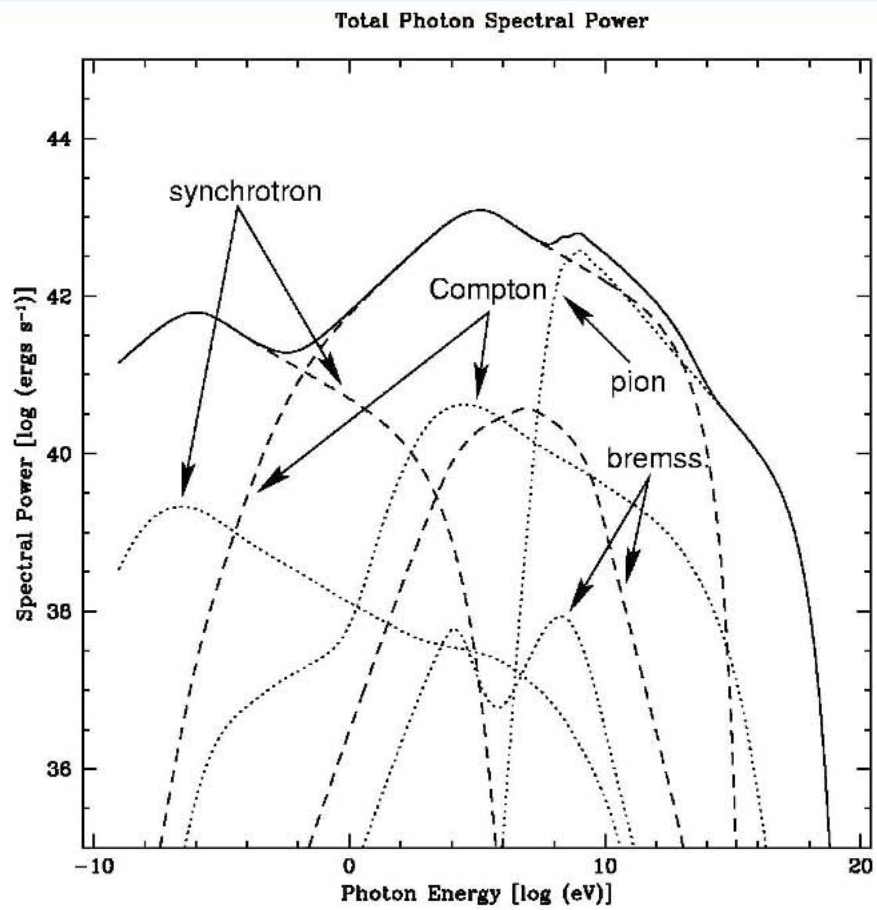
  - Where $\eta_{e,p}$ is an efficiency factor, and is set to 5%.
  - Typical values are $E_{tot} \approx 10^{63\text{-}64}$ ergs

Particle Energy Spectra



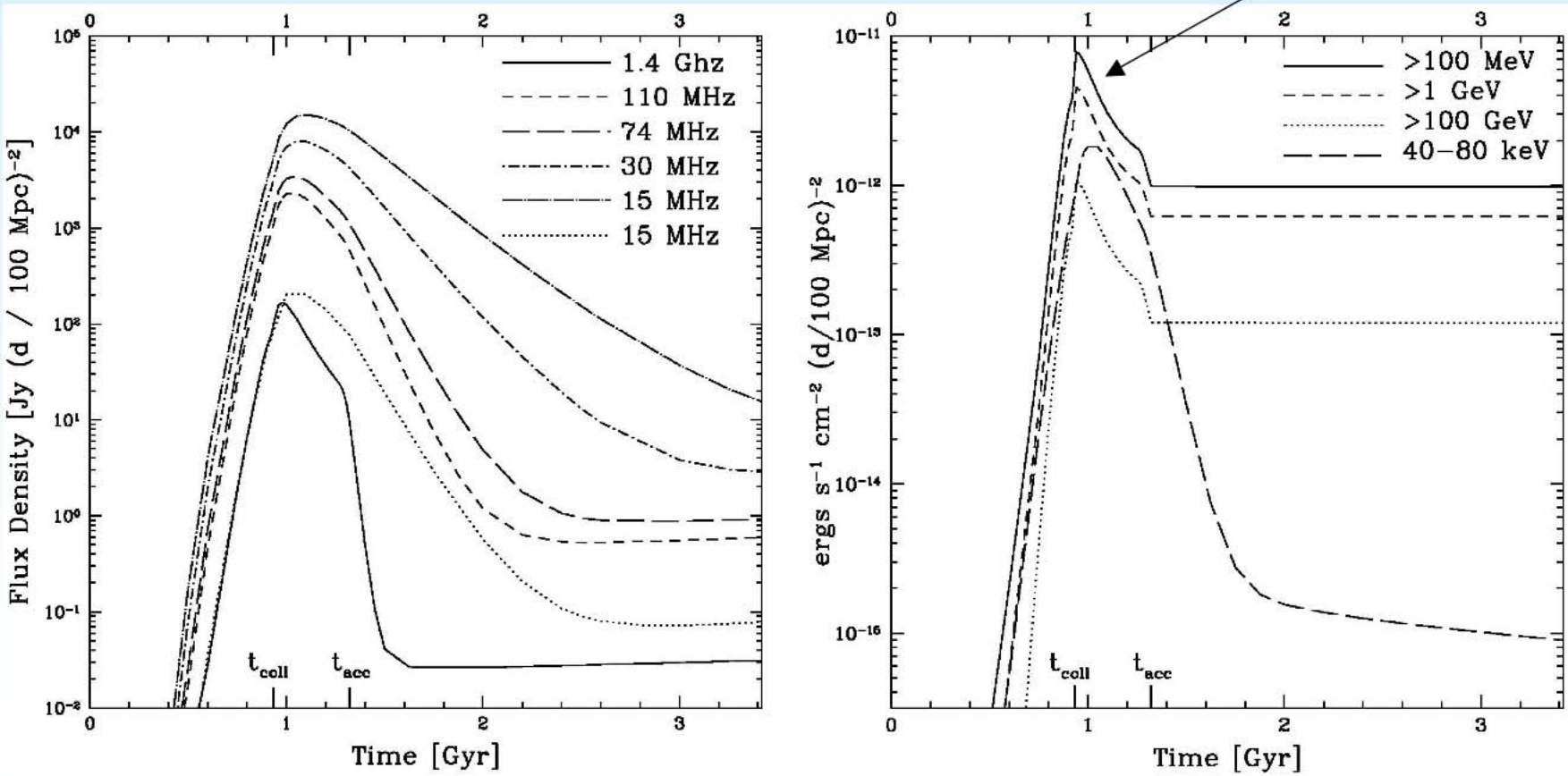
Nonthermal Particle Spectra





Galaxy Cluster Nonthermal Brightness

GLAST range



Nonthermal Emission from Cluster Merger Shocks

- Unidentified EGRET sources?
- Diffuse Extragalactic γ-ray Background?
- Nonthermal Particle Pressure
- Detectability with GLAST and LOFAR
  - Should be able to detect these features with the next generation of γ-ray observatories
  - Possible indicator of the dark matter profiles
  - Not a dominant contributor to the Diffuse Extragalactic γ-ray Background
  - Will significantly alter thermal X-ray emission

3. GRB-Supernova-Cosmic Ray Relationship

Gamma Ray Burst puzzle is far from solved

(Long Duration) GRBs Linked to Massive Stars

SN 1998bw/GRB 980425

X-ray Lines and Features in 5 GRBs

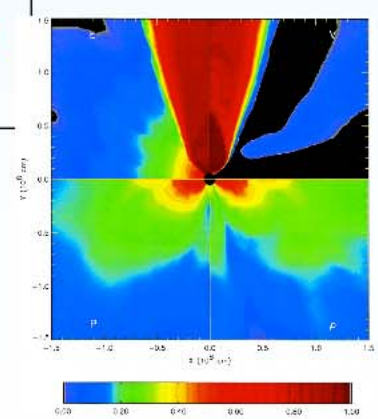
Supernova-Like Reddened Excesses in Optical Afterglows

Supranova Model
Two-step collapse to Black Hole

Constant Energy Reservoir Result ?

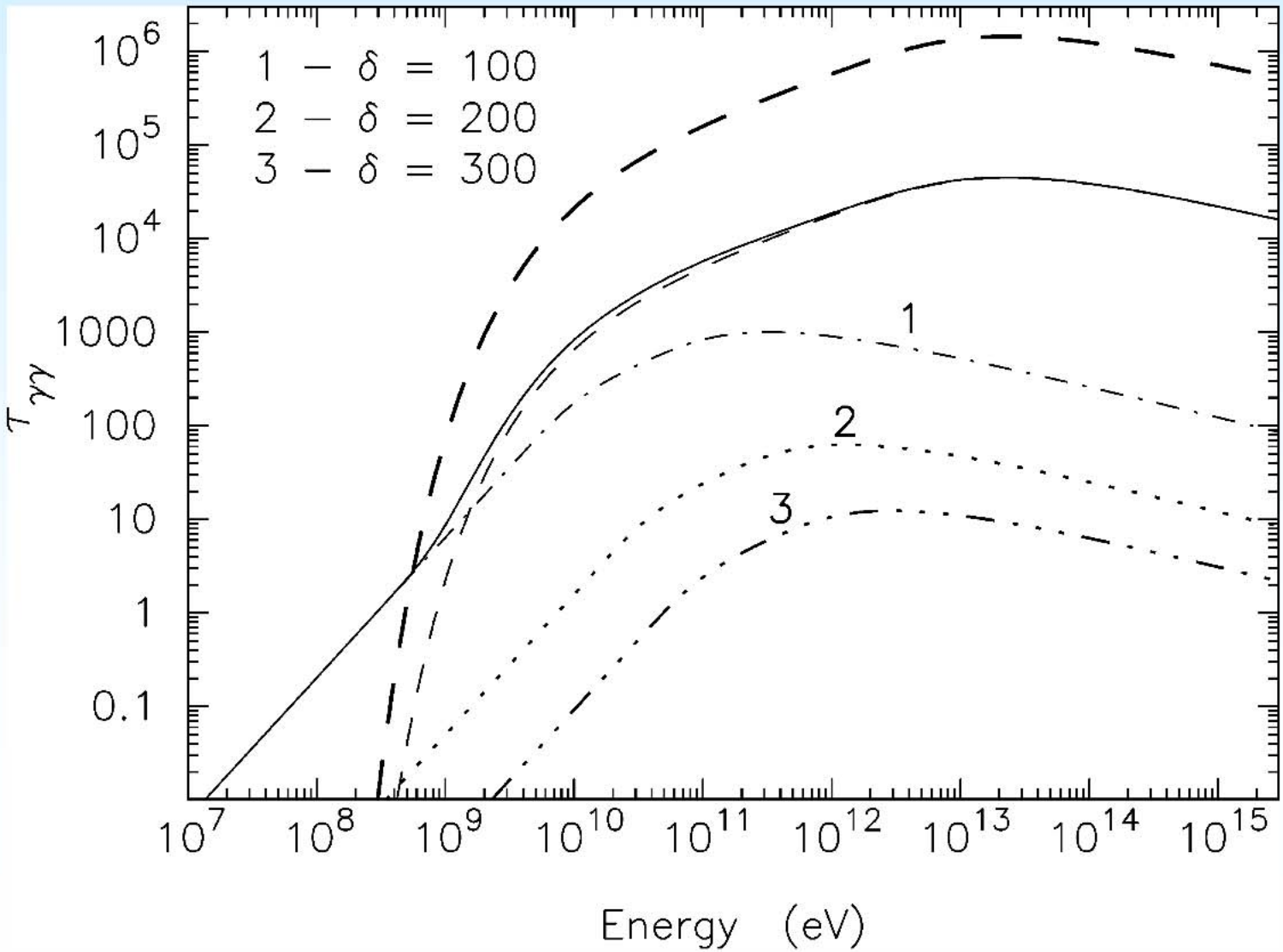
Collapsar Model
Direct collapse to Black Hole

External or Internal Shock Model for Prompt GRB Emission



γγ Optical Depth

Photon attenuation strongly dependent on δ in collapsar model



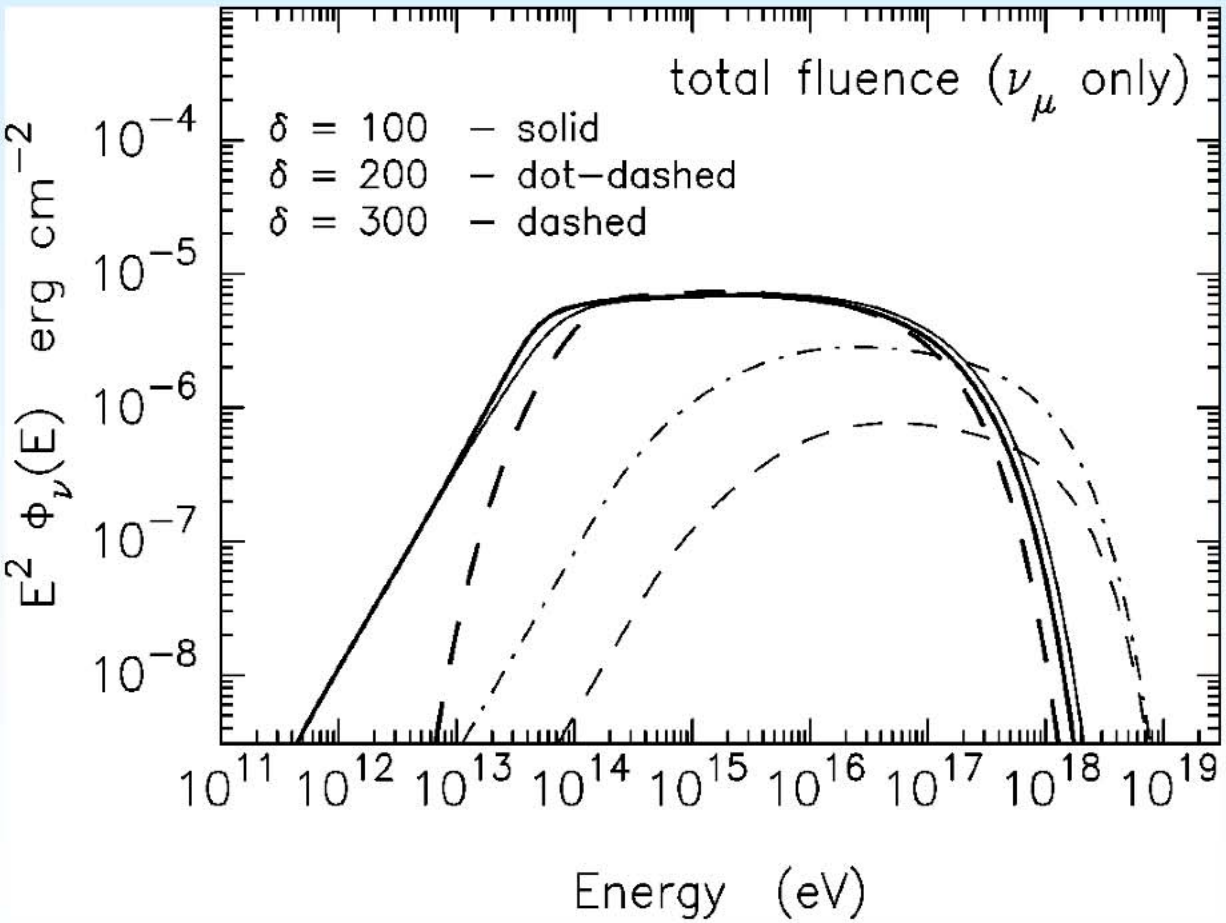
Energy Fluence of Photomeson Muon Neutrinos

For a fluence of 3×10^{-5} ergs/cm^2,

N_ν predicted by IceCube:

$N_\nu \approx 0.0032$, 0.00015, 0.00001 for $\delta = 100$, 200, and 300, respectively in collapsar model

$N_\nu \approx 0.09$ for $\delta = 100$ and 300 in supranova model



$t_{var} = 1$ sec

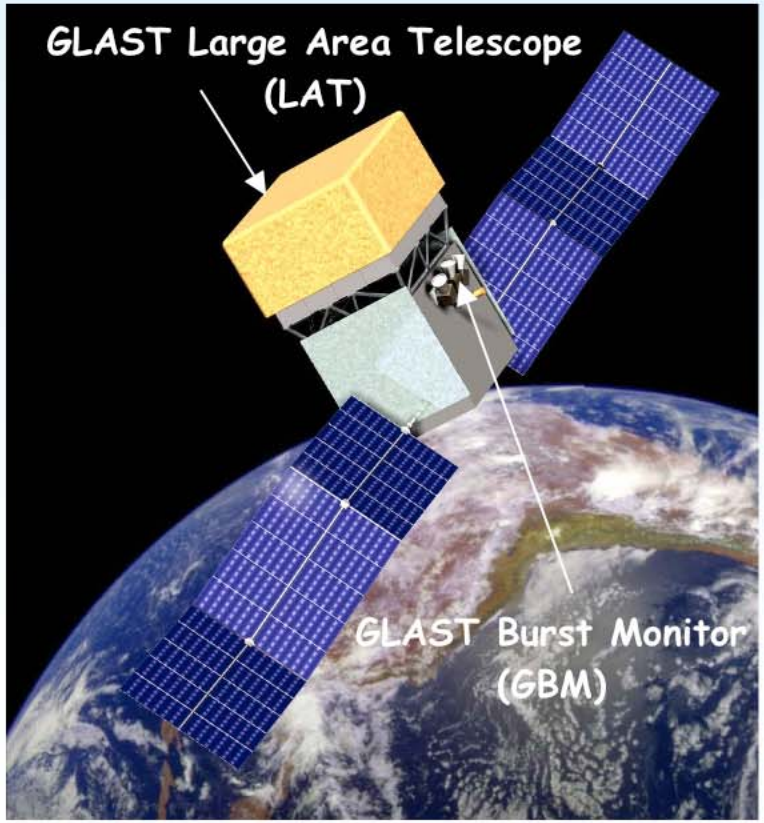
Gamma Ray and High-Energy Neutrino Observations

Neutrinos ⇒ Cosmic Ray Sources

Gamma-rays: Sites of cosmic ray acceleration in Galaxy

Gamma-rays: Clean fireball bursts/supranova model

Gamma-rays + Neutrinos: test collapsar and supranova models



Cosmic Rays originate from the stars that produce the subclass of SNe whose core collapses a second time to a black hole and makes a GRB

GLAST detection of enhanced radiation from GRB remnant