

# GLAST Science at SLAC

**Tune Kamae**  
***SLAC/KIPAC***

**on behalf of the SLAC GLAST Team**

## Plan of Talk

- **Activity of GLAST Scientists at SLAC**
- **Overview of GLAST Science**
- **Two Key Features of the Instrument**
- **Dark Matter Search**
  - **Proton Interaction with Int. Stellar Matter**
- **Particle Acceleration in Universe**
- **Exploration of the Temporal Domain**
- **Summary**

# Activity of GLAST Scientists at SLAC

## SLAC scientists working on GLAST (as of January 2005):

- 3 faculty, 18 staff, 2 postdocs

## Activity scientists are heavily involved between 2003-2005:

- Verification of delivered hardware, Tracker, Calorimeter & DAQ.
- Development of Ground Support Equipment, on-line system.
- Development of the Geant4-based instrument simulator.
- Development of the instrument performance analysis software.
- Flight Instrument integration and testing.
- Development of the flight DAQ software and its “simulator”.
- Development of Science Analysis Software.
- Preparation for Beam Test at SLAC (Fall ‘06)
- **Science analyses related to GLAST. ← Focus of my talk**



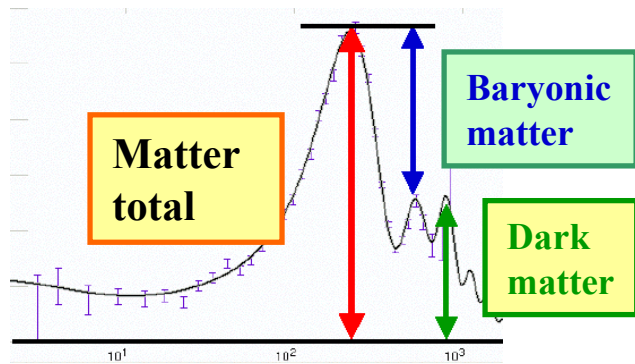
## Publications:

<b>Year 03,04,05</b>	<b>Refereed Journal</b>	<b>Conference Talks</b>
<b>Scientific topics</b>	<b>19 papers</b>	<b>17 talks</b>
<b>Instrumental topics</b>	<b>13 papers</b>	<b>9 talks</b>

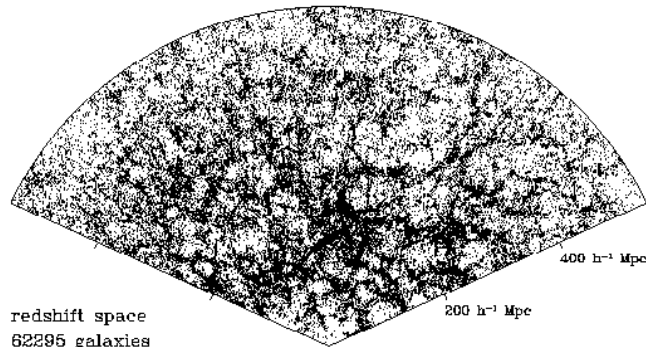
# GLAST will chase after Dark Matter

- There Are Signs of Dark Matter Everywhere -

## Big Bang (CMB)



## Evolution of Universe



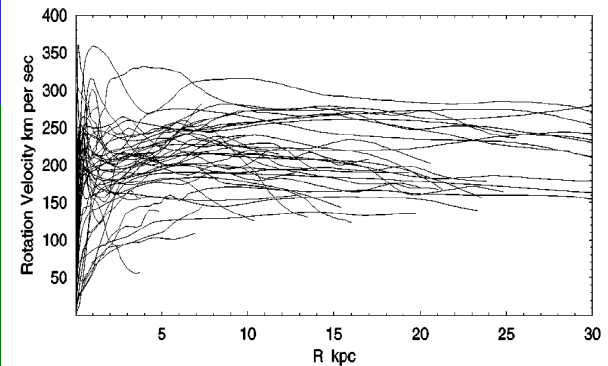
## SLAC User's Community

### GLAST Team

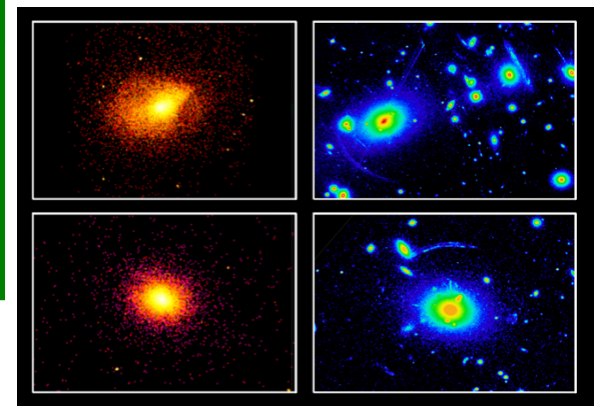


## KIPAC Stanford University

## Spiral Galaxies



## Galaxy Clusters



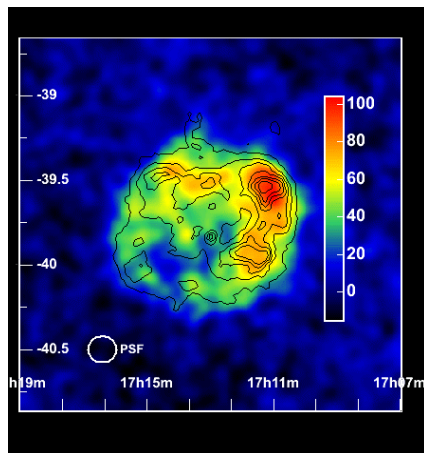
# GLAST will go after Particle Acceleration Sites

- Particles are accelerated at all scales -

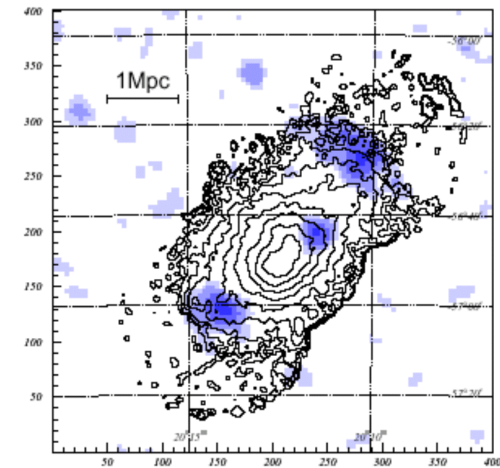
## Pulsars and Nebulae



## Super Nova Remnants



## Shocks in Merging Clusters



## Active Galactic Nuclei



SLAC  
User's Community

GLAST Team

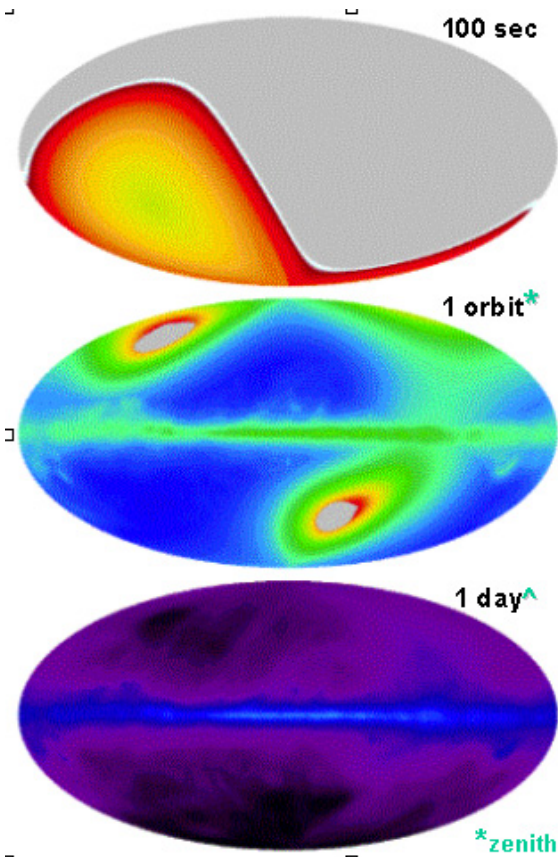


KIPAC  
Stanford University

# GLAST will survey the Universe Hourly

- Enormous Discovery Potential in the Dynamic Universe -

## GLAST's sensitivity



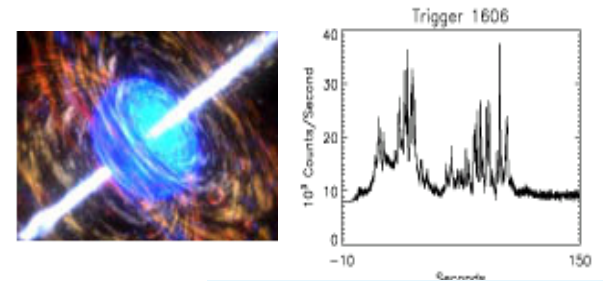
SLAC  
User's Community

GLAST Team

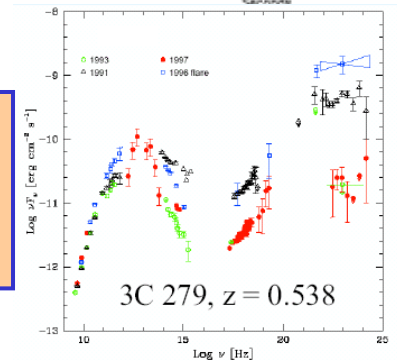


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## Gamma-Ray Burst



All  
kinds of  
flares



- Tests on **quantum gravity**
- Pulsar-nebula interaction
- **Strong lensing of AGN flares in time domain**

# GLAST Detector Performance

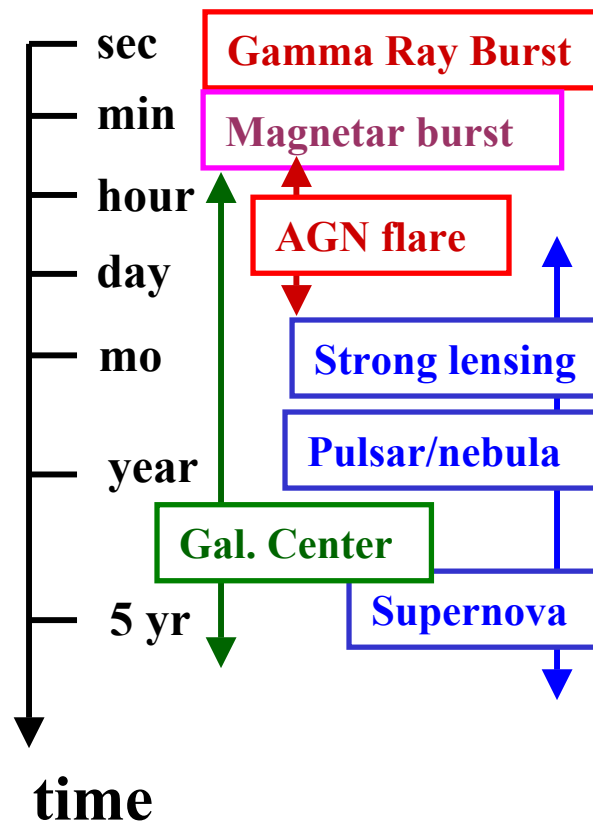
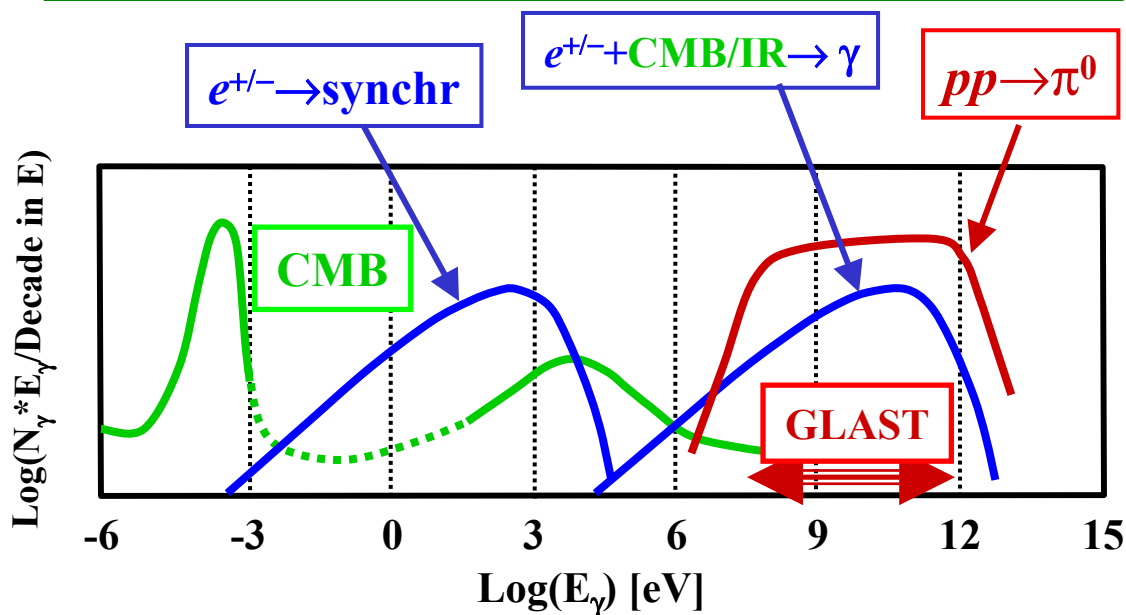
## - Two Most Notable Forte's -

**All-Sky Monitoring:** All variability btwn  
 ~ a few seconds to 5-10 years

**Energy Coverage:** Optimum to differentiate btwn  
 $pp \rightarrow \pi^0$  and  $e^{\pm} + \text{CMB/IR} \rightarrow \gamma$

**All-Sky Monitoring by GLAST**

**Energy Coverage of GLAST: 20MeV-300GeV**

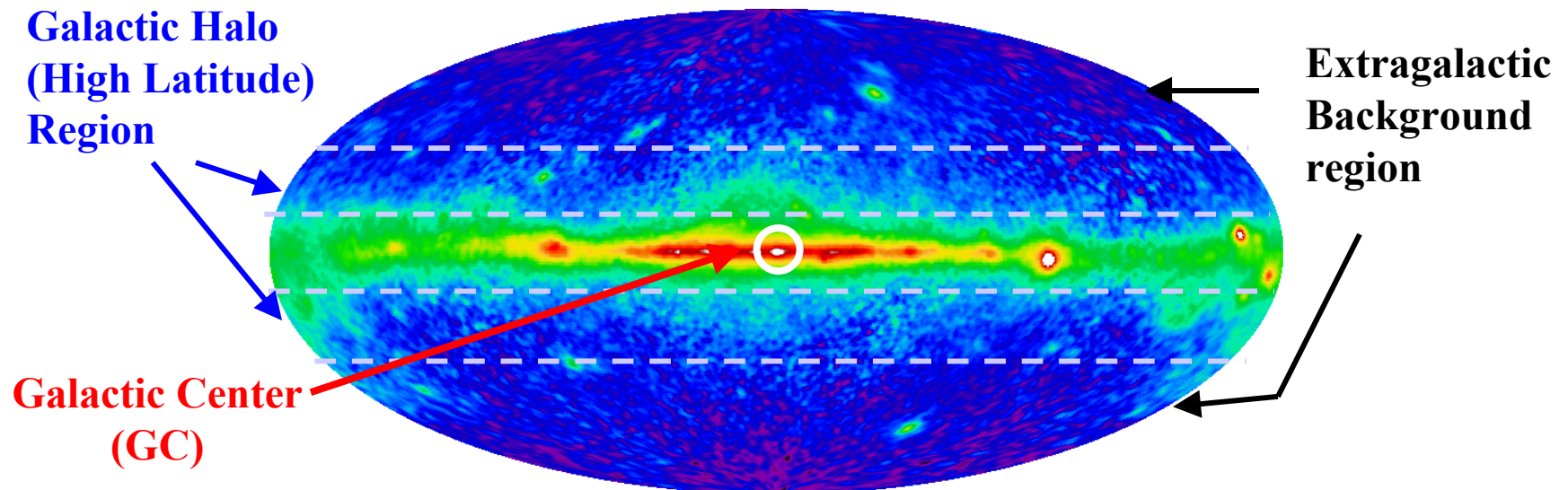


# Dark Matter Search

## - Introduction -

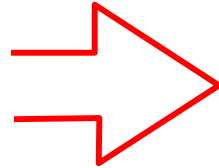
Search for an excess above the expected flux from the known processes.

Spectra	Galactic Center	Galactic Halo (High Latitude)	Extragalactic Background
Line	discussed #3		
Continuum		discussed #1, #2	discussed #4

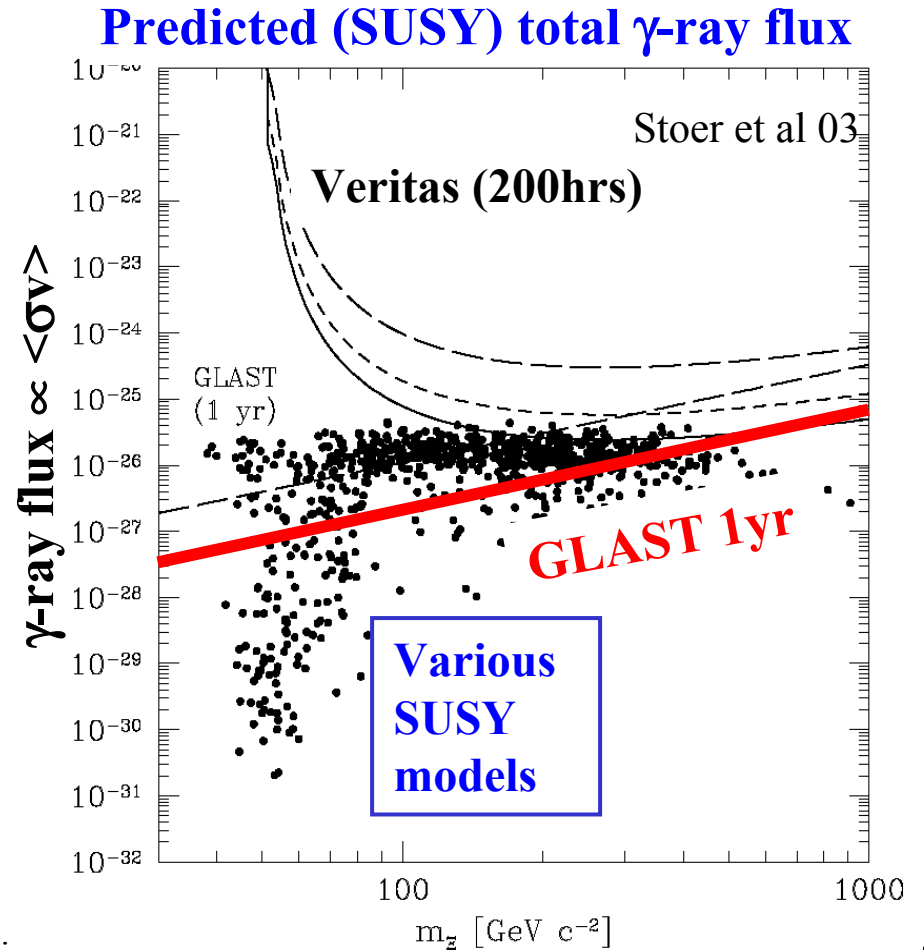
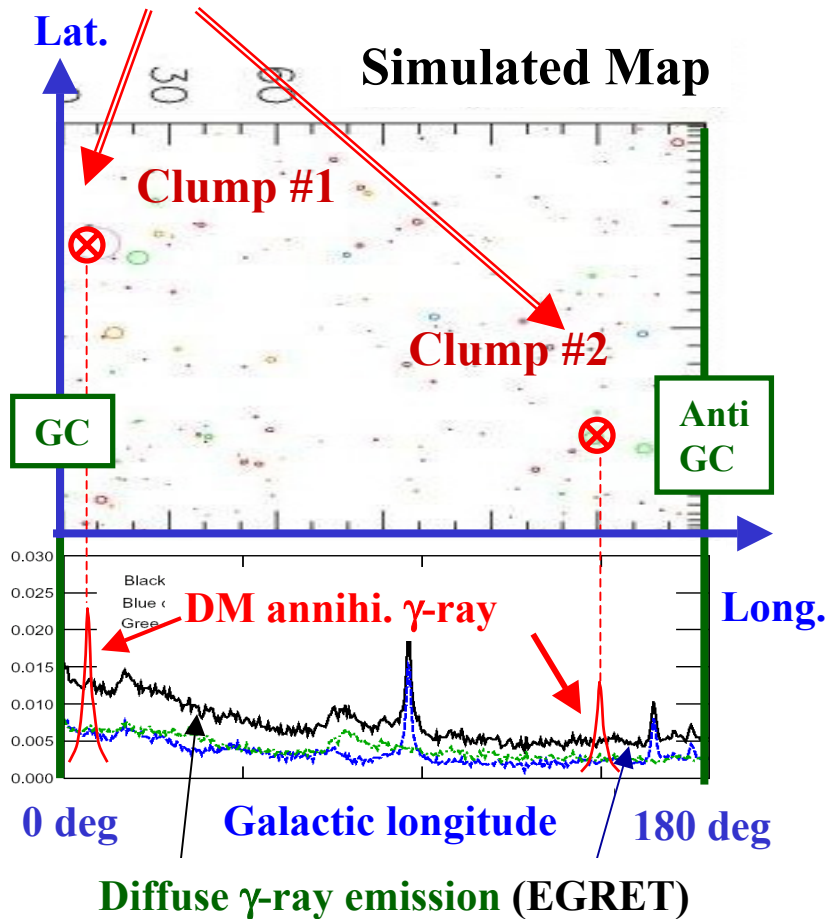


# Dark Matter in Galactic Halo: **Continuum $\gamma$**

$\Lambda$ CDM predicts **many DM clumps** in Galactic Halo



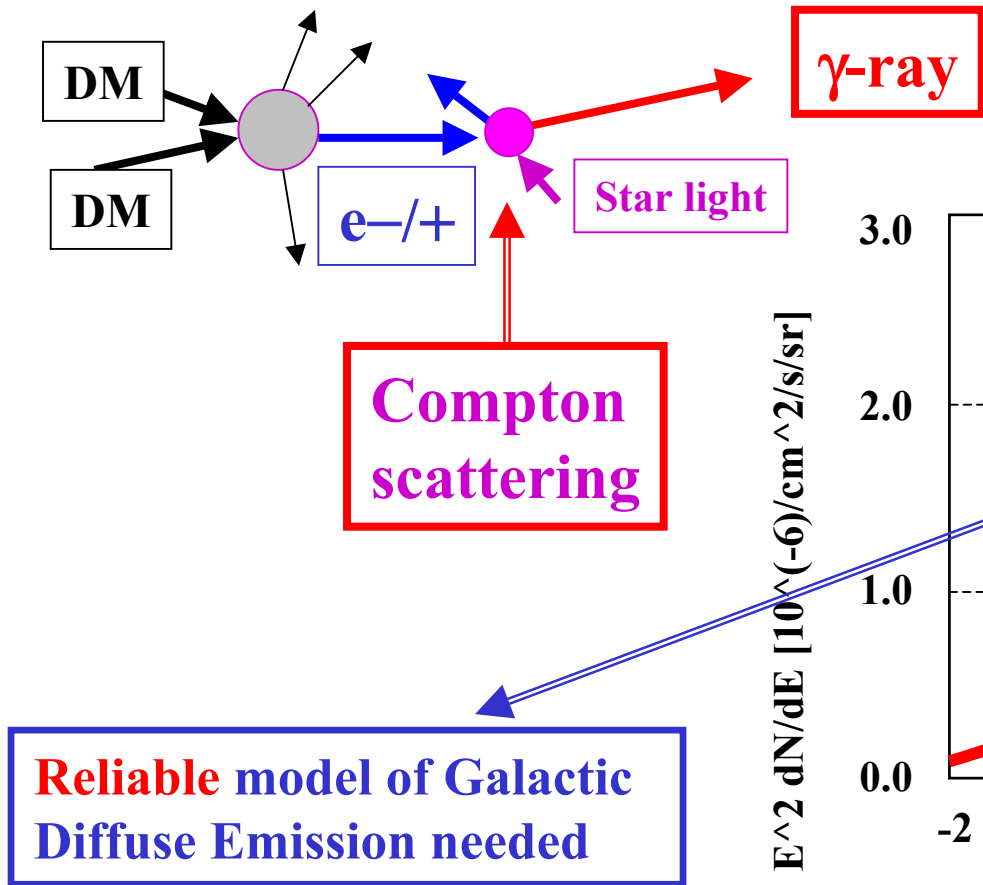
**Excess in diffuse  $\gamma$ -ray flux:**  
Pronounced in  $E_\gamma \gg \text{GeV}$



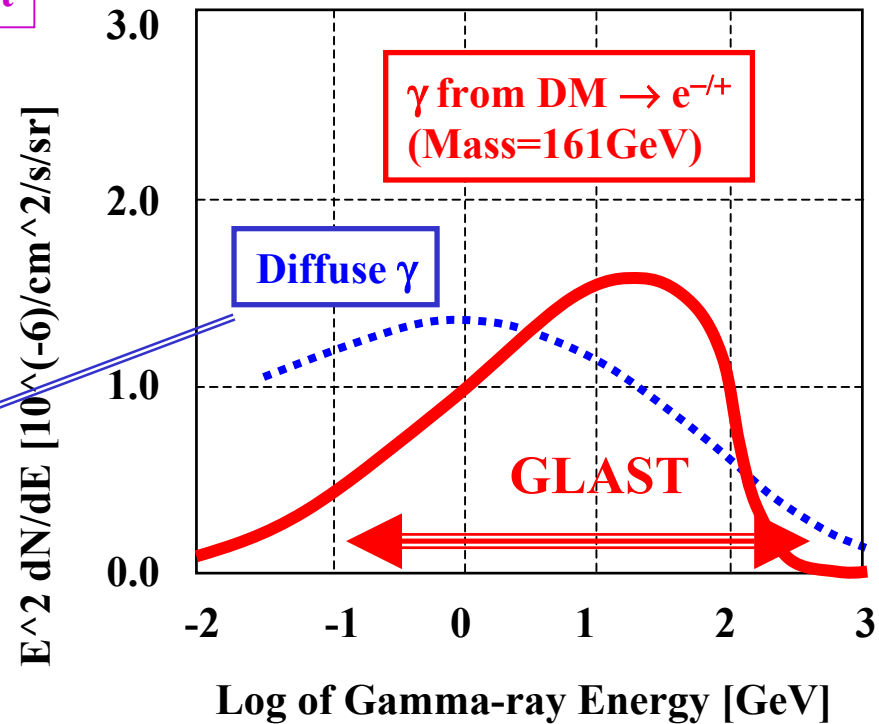


# Dark Matter in Galactic Halo: Compton-Scatt. $\gamma$

## - Best Strategy for GLAST -

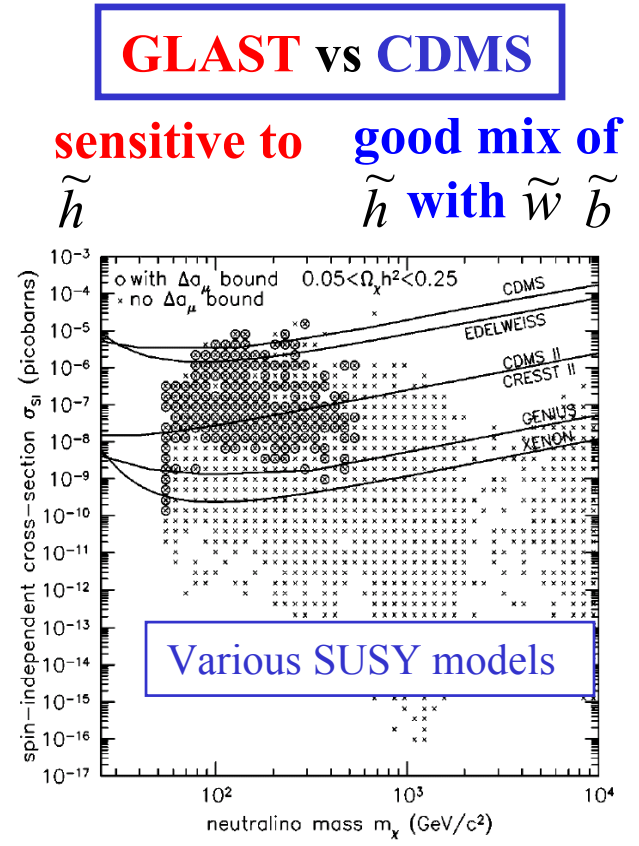
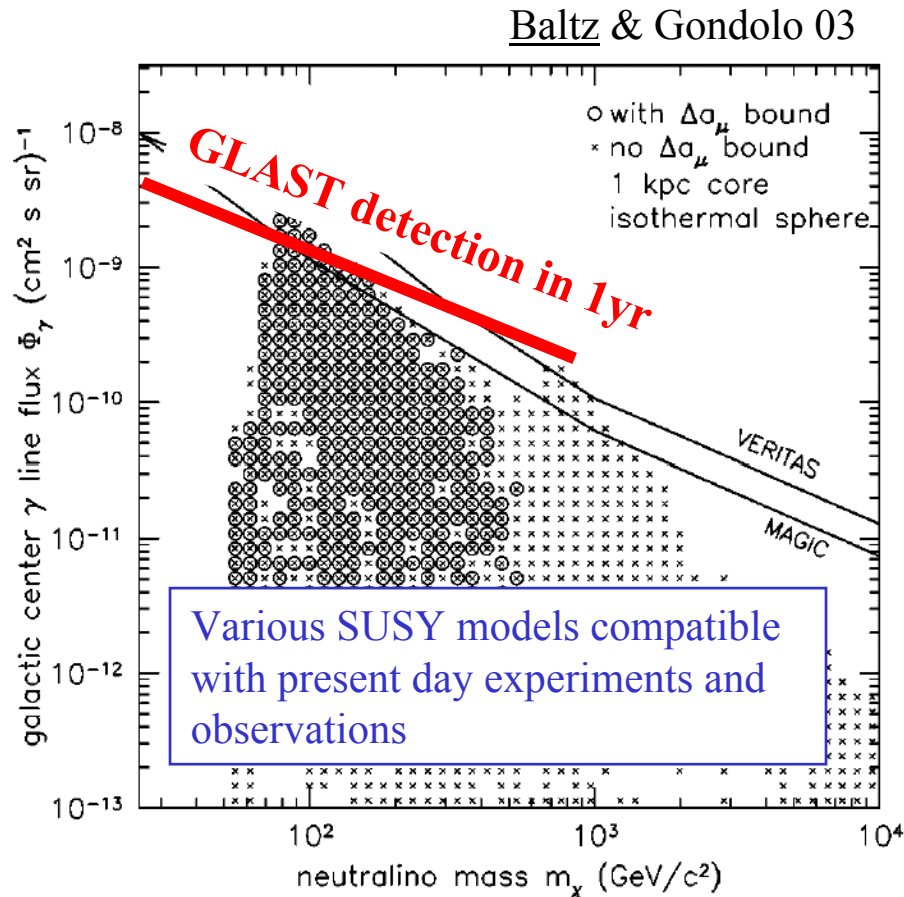


Baltz & Wai 04



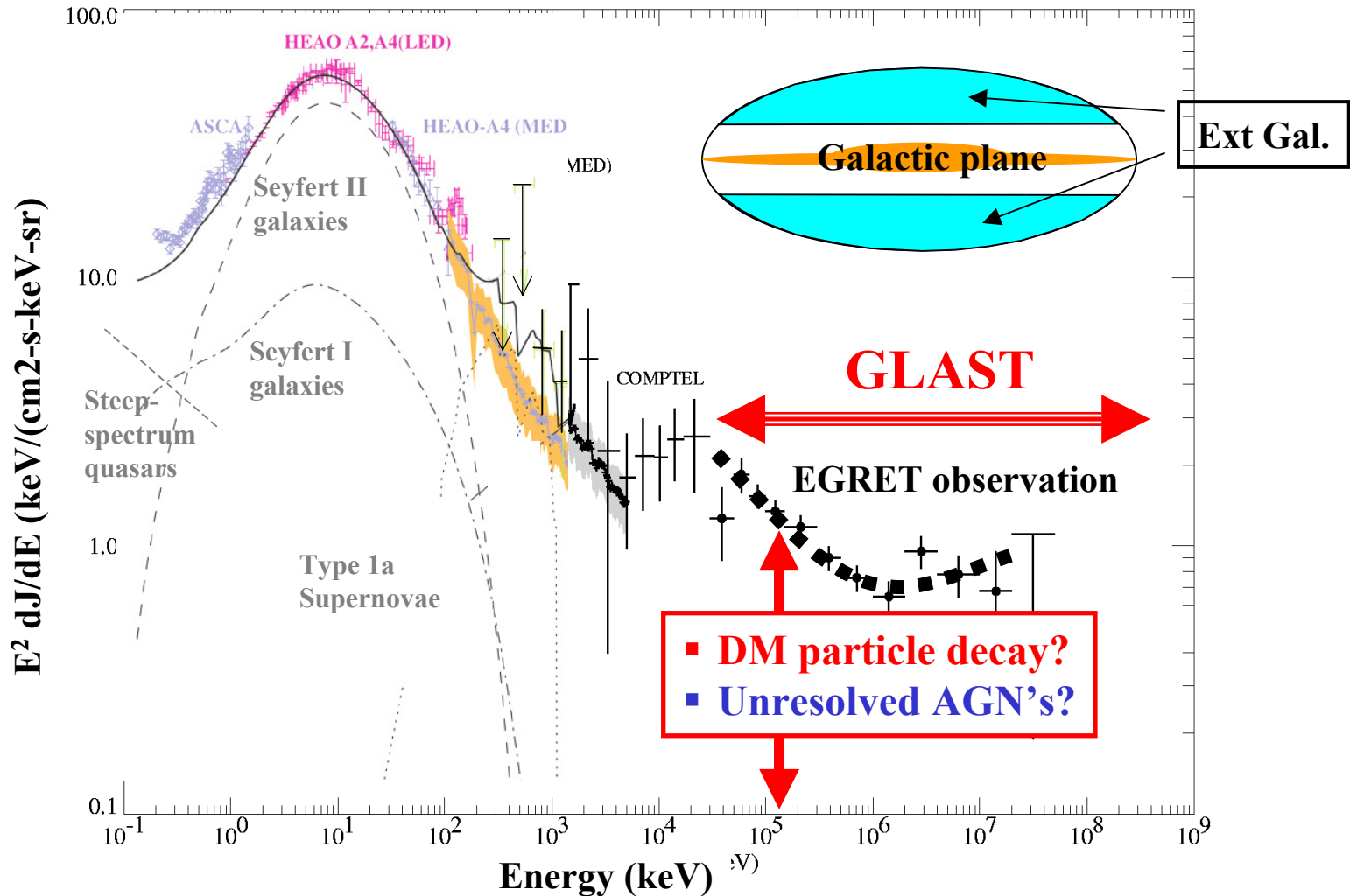
# Galactic Dark Matter: Line $\gamma$ at Galactic Center

Line  $\gamma$ -ray from DM annihilation in Gal. Center: **Hopeful** but requires careful analyses.

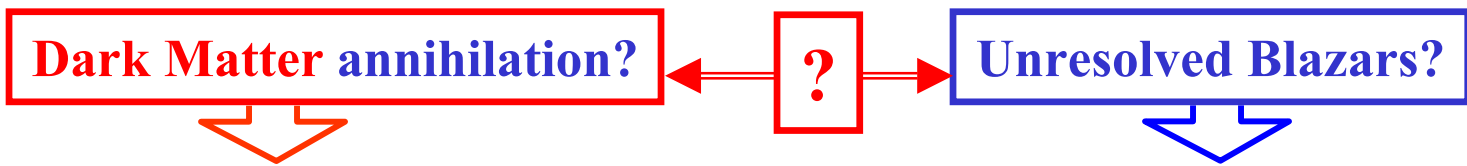


# Extragalactic Background: Dark Matter?

## Extragalactic Background Spectrum: from UV to TeV $\gamma$ -ray

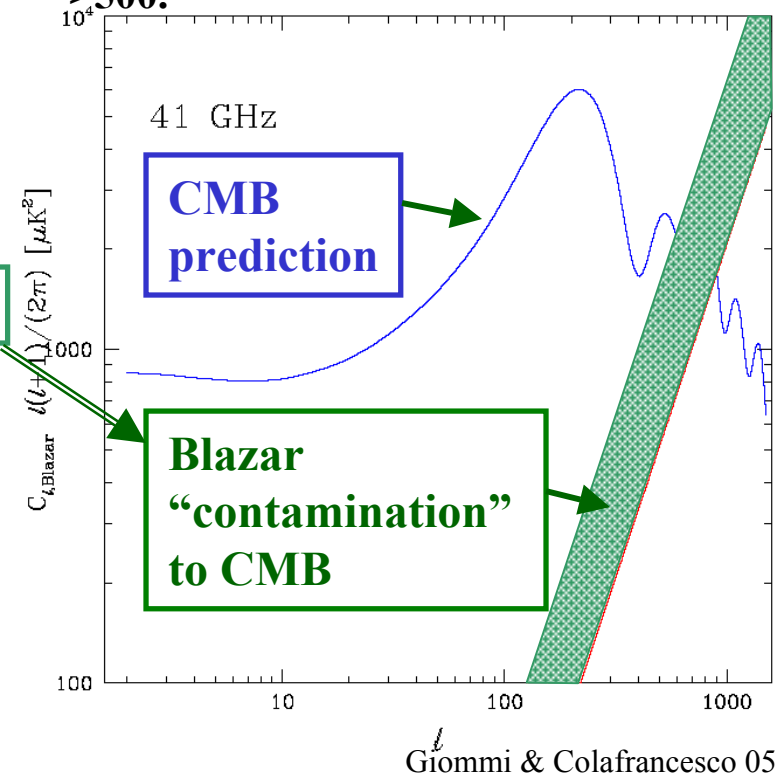
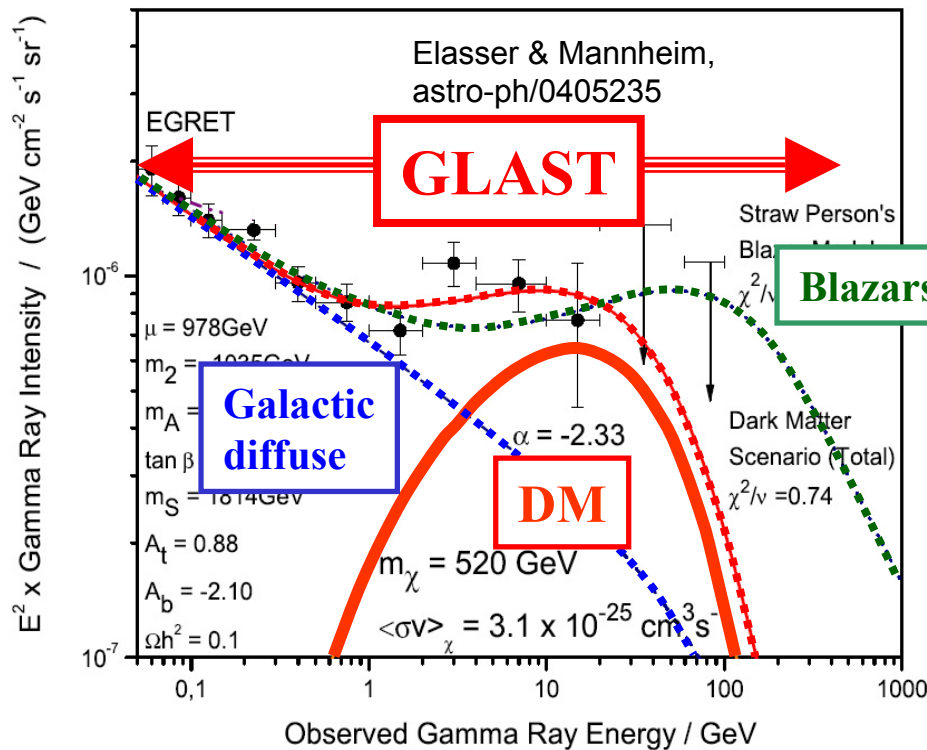


# Extragalactic Background: **DM vs Blazars**



Annihilation of **DM particles** with mass  $\sim 500\text{GeV}$ . We need **Blazar survey data** from surveys in radio.

If Diffuse  $\gamma$ -ray Background (EXB) is large and due to **Blazars**, they may dominate over primordial CMB for  $l > 500$ .



# Diffuse Emission Model: $pp$ Interaction

## Old $pp$ interaction models

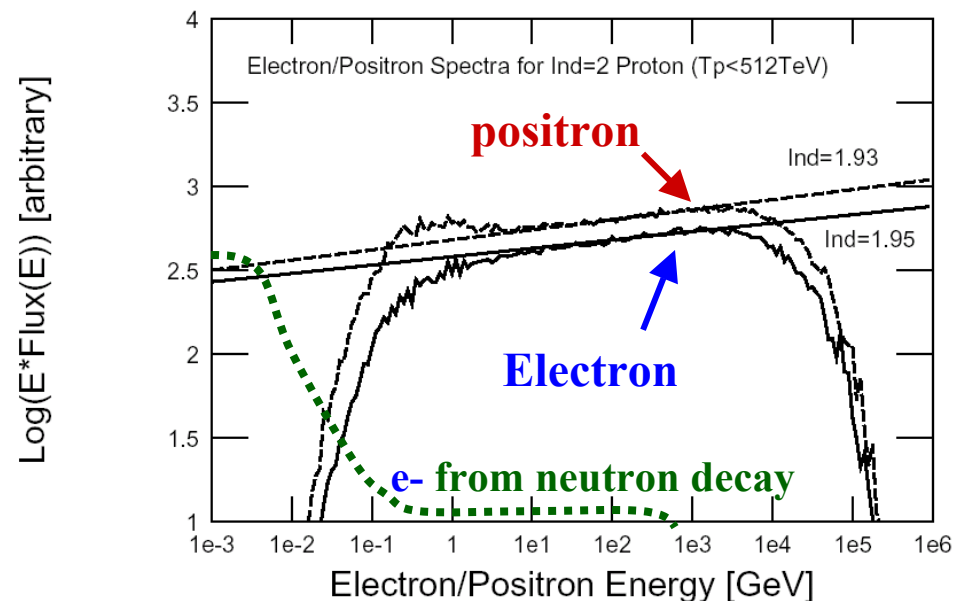
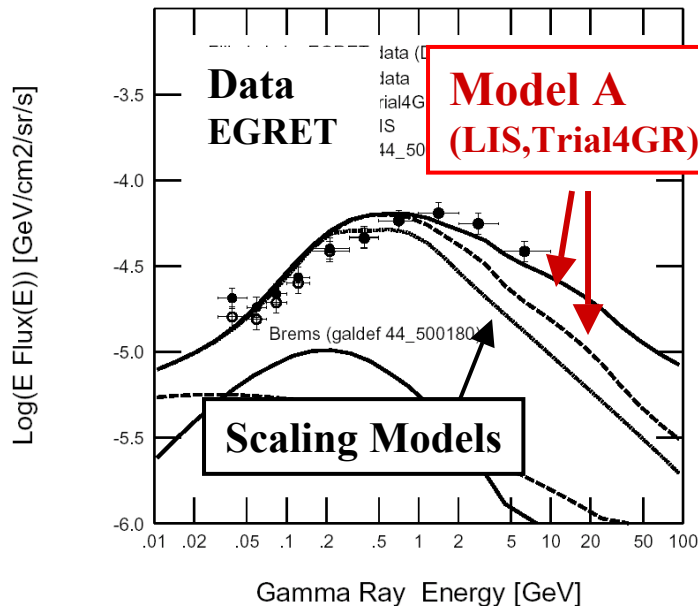
- Constant inelastic cross-section
- Feynman scaling
- No diffraction dissociation

## New $pp$ interaction model

- Rising cross-sections
- Scaling violation: Pythia + CDF Tune A
- Diff. dissociation: CDF Goulios

“GeV Excess” >50% explained

“Positron excess” predicted



Kamae et al. 05, Kamae, Karlsson, Mizuno et al. 05, Kamae, Karlsson, Cohen-Tanugi Mizuno et al.05

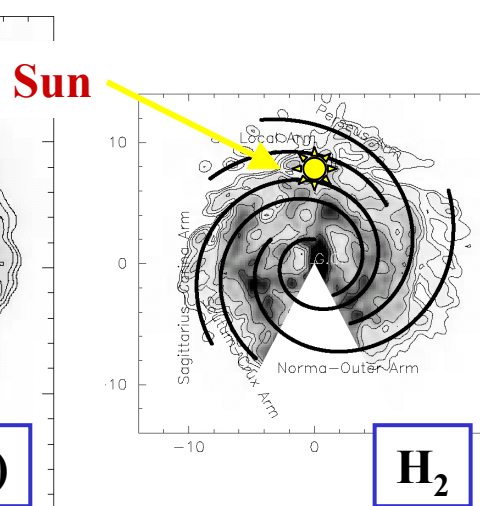
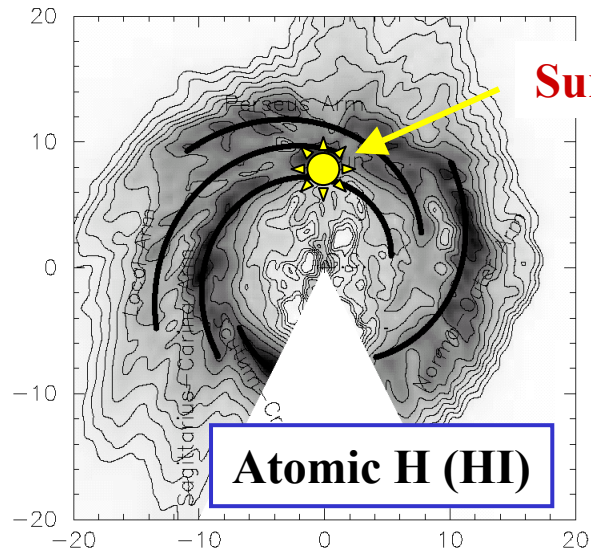
# Diffuse Emission Model: Modeling of Galaxy

GALPROP: a reliable 3D model of Galaxy, “Geant 4” of Milky Way

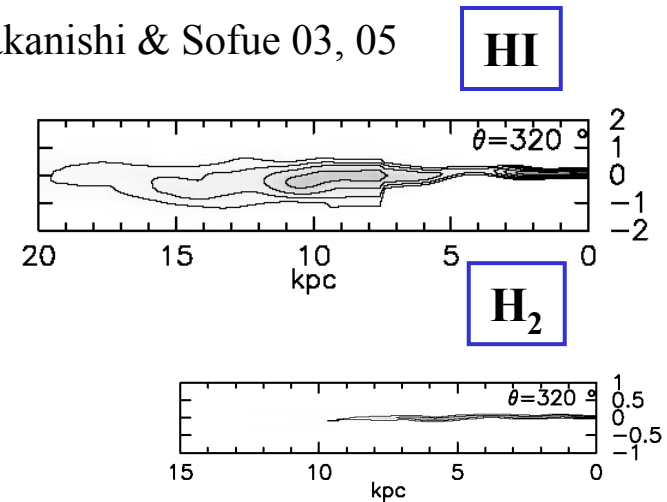
- ❑ Several improvements in progress
  - Add the **up-to-date *pp* interaction model**: Mizuno, Kamae et al. (in progress)
  - Improve **cosmic-ray source distribution**: Strong, Digel, et al. 04
- ❑ One author (**Igor Moskalenko**) of GALPROP is now at **Stanford Campus**

New data and new analyses

- ❑ **High Galactic latitude clouds**: Diego, Digel, et al. 05
- ❑ **3D Matter distribution based on CO, HI, and  $\gamma$ -ray distribution**: SLAC-Tokyo-Nagoya



Nakanishi & Sofue 03, 05

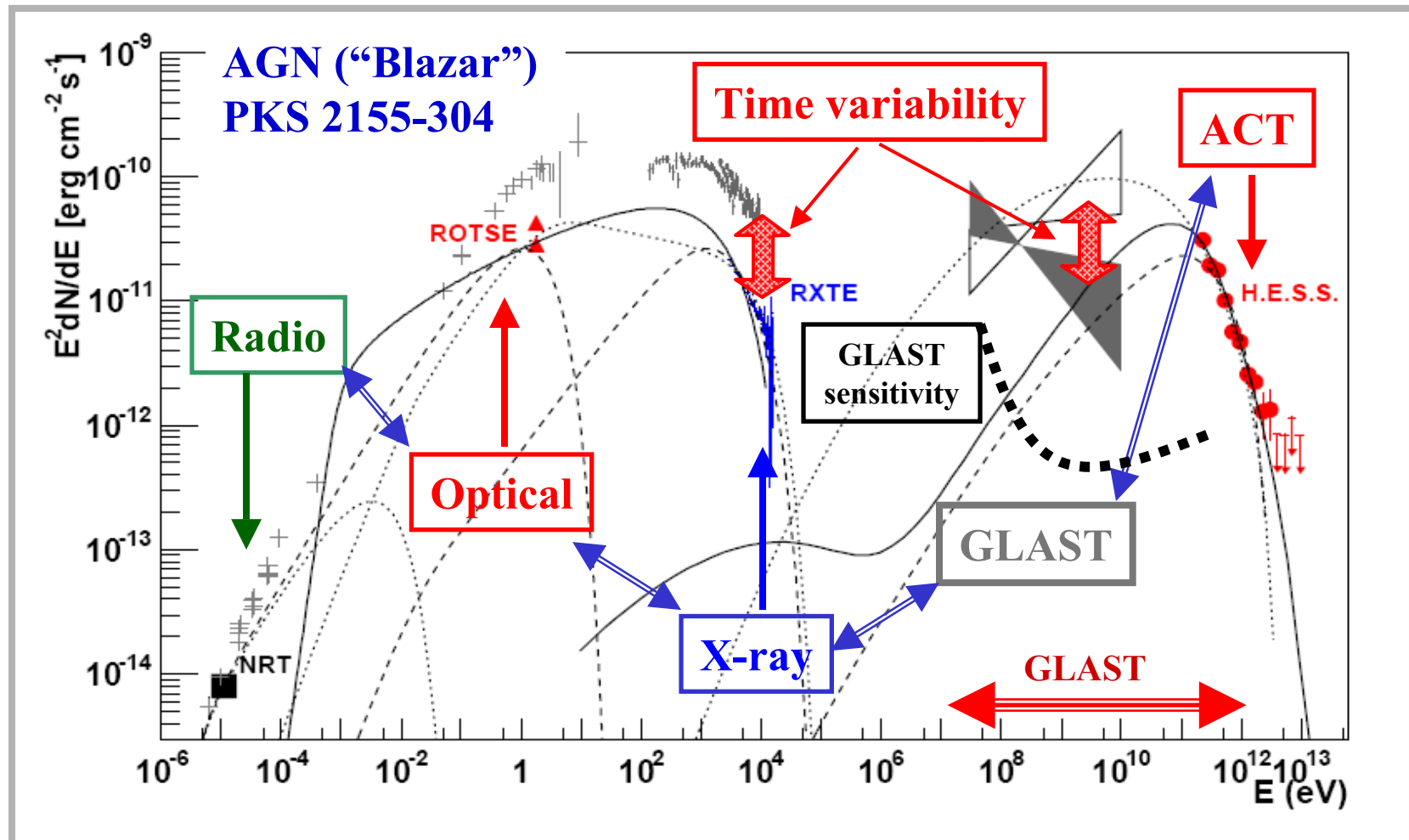


# Particle Acceleration: Introduction

- Acceleration mechanism?
- Sign of **proton (nuclei) acceleration**?



- Time variability study
- Multiwavelength



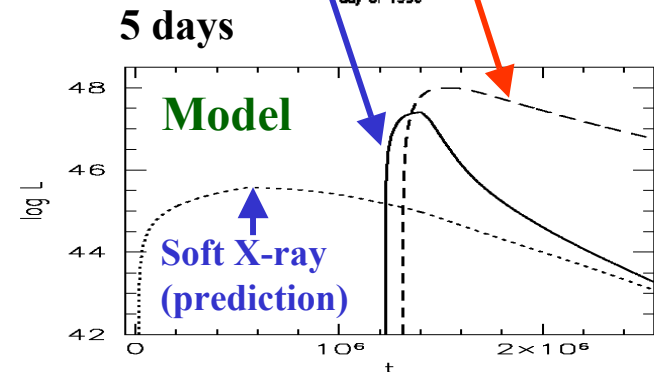
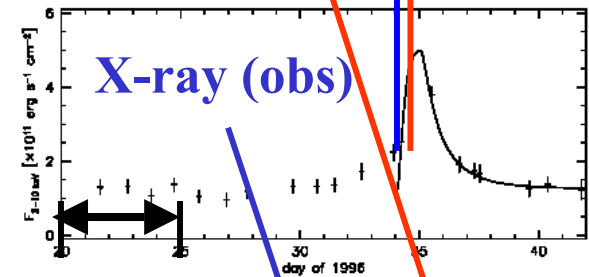
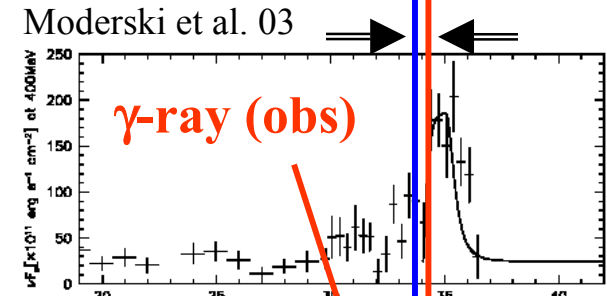
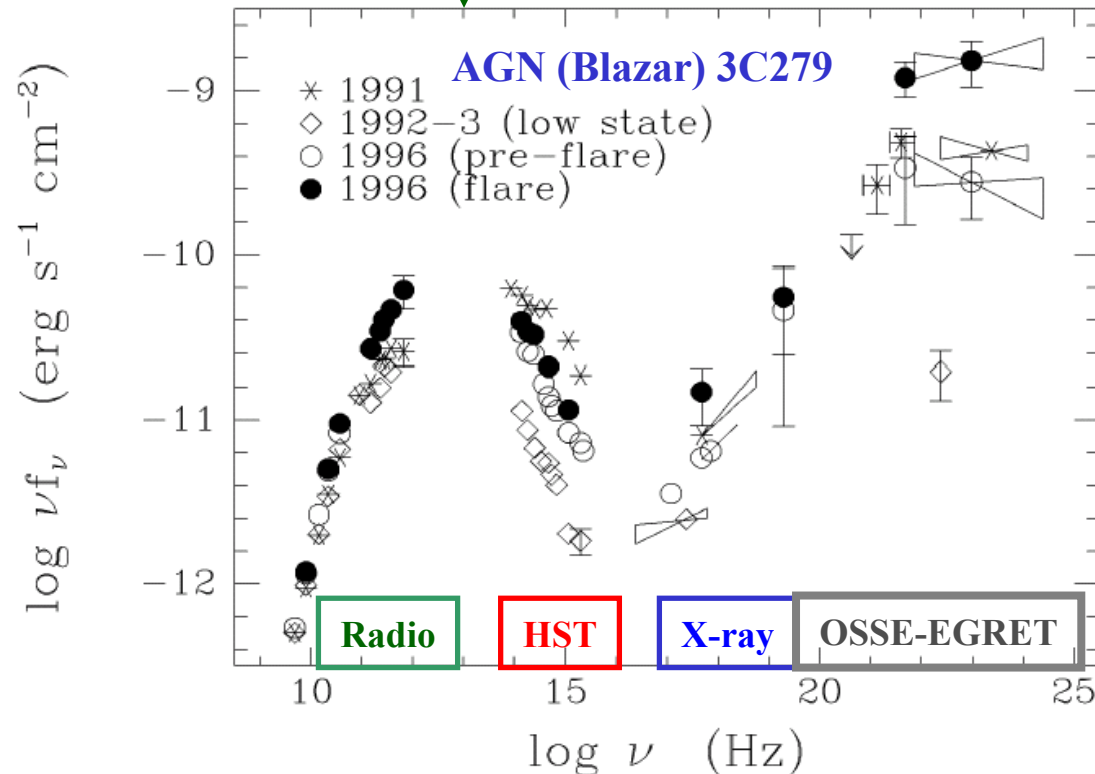
# Particle Acceleration: Time Variability

**Multiwavelength observation:**  
An example on 3C279 [AGN(Blazar)]

Variability over 5 years

One flare

Time lag of a few hrs



Madejski, Kamae et al. 04



# Particle Acceleration: Site for UHE protons?

Large scale shock ( $\sim 1\text{Mpc}$ ): Slow accel. over  $>1\text{Gy} \Rightarrow$  Only  $p$  reaches UHE

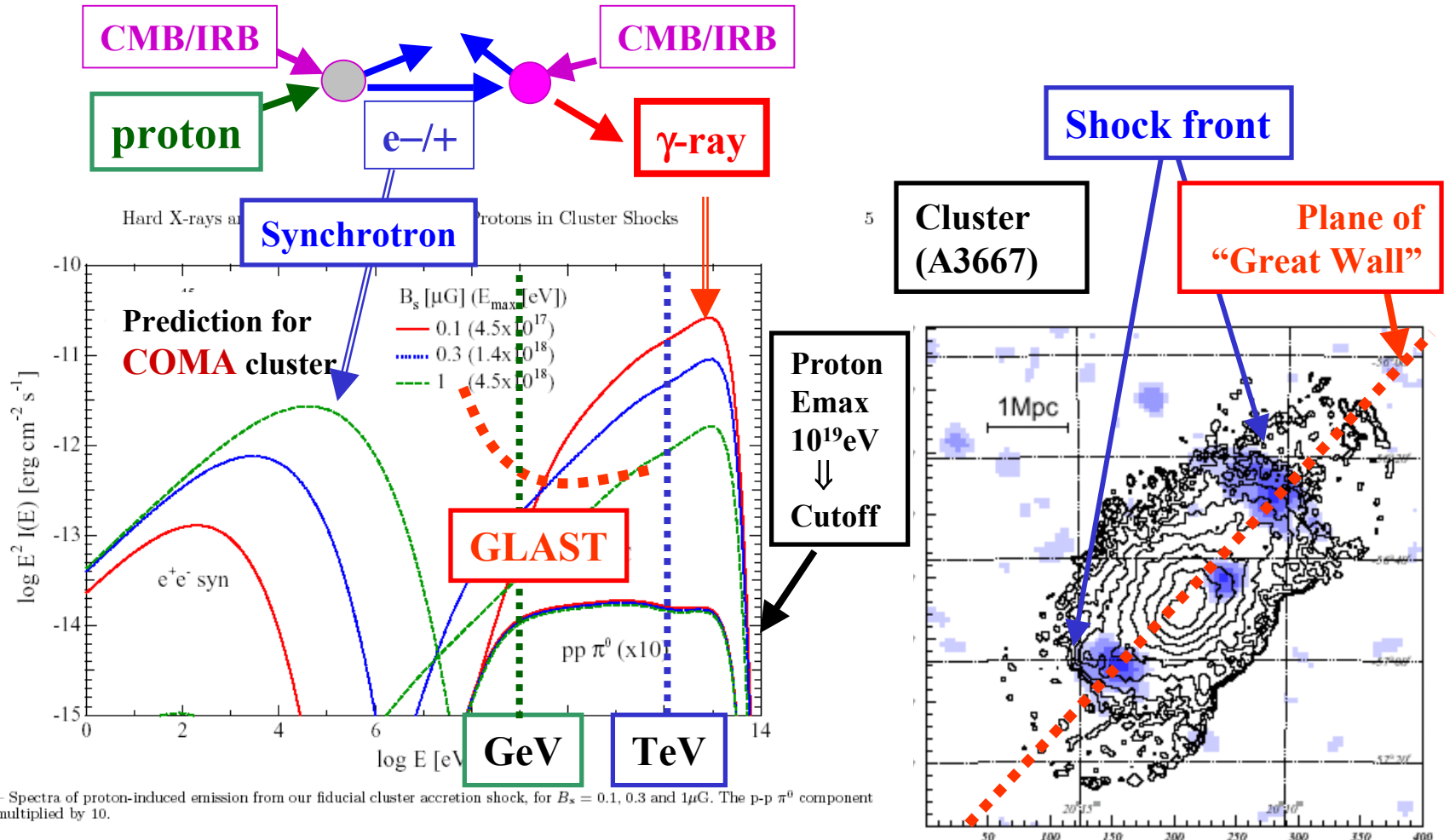


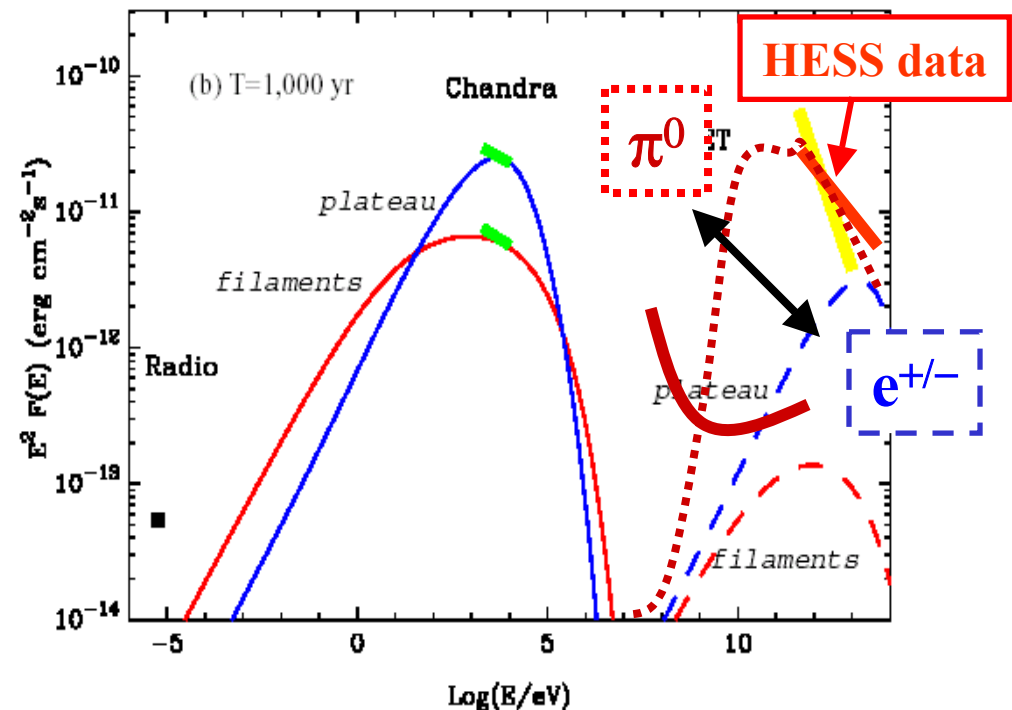
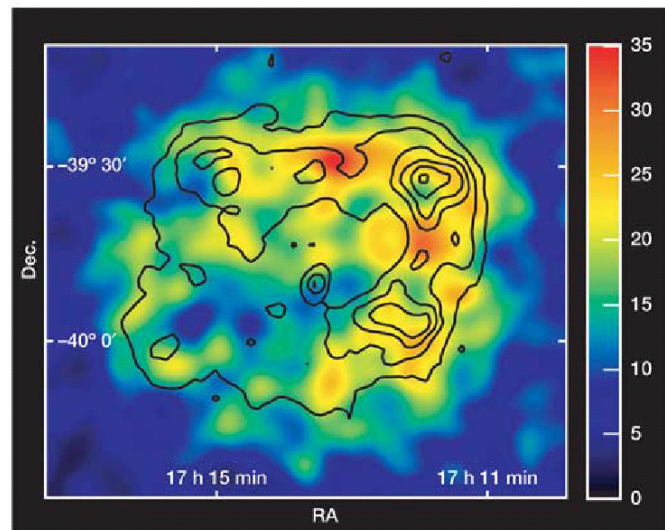
FIG. 1.— Spectra of proton-induced emission from our fiducial cluster accretion shock, for  $B_s = 0.1, 0.3$  and  $1\mu\text{G}$ . The  $p$ - $p \pi^0$  component has been multiplied by 10.

# Particle Acceleration: Sign of protons?

## Supernova Remnants: Favored Galactic cosmic ray sources

- Recent detection of TeV  $\gamma$ -rays by HESS and other ACT's
- HE electron + CMB  $\rightarrow$  TeV  $\gamma$ -ray may not reproduce data (Inoue et al 05)
- GLAST measurement in 100MeV-100GeV is crucial to resolve the origin,  $p$  vs  $e^{\pm}$

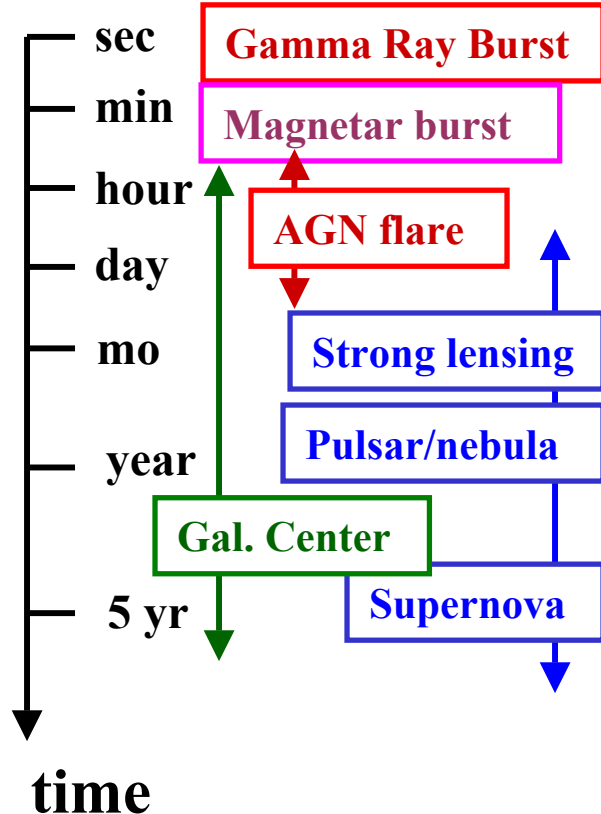
Supernova remnant RX J1713  
HESS 04 + ASCA



# Exploration of **Temporal Domain**

GLAST is **the first** to monitor all-sky from **a few sec** to **5-10 yrs**

**Onset times of bursts and flares** detected elsewhere will be compared those of **GLAST**.



We are linked to **Astro-E2**, **NuStar**, Radio (AGN/CO/HI), HESS/Veritas/Cangaroo, etc.

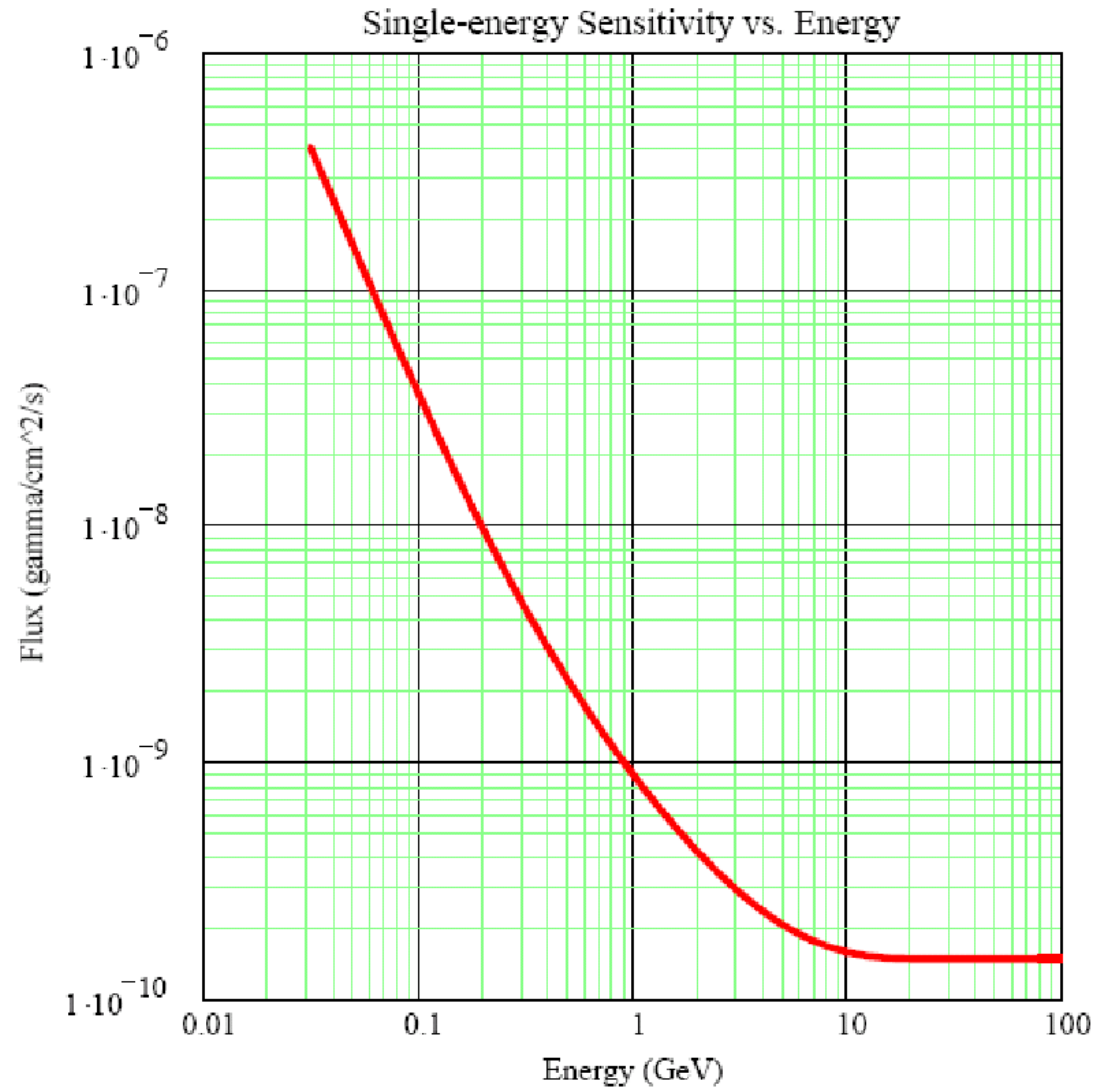
Careful instrument characterization, calibration, and monitoring are required **on ground** and **in orbit** to detect subtle variability.

**Instrument Team and ISOC**

# Summary

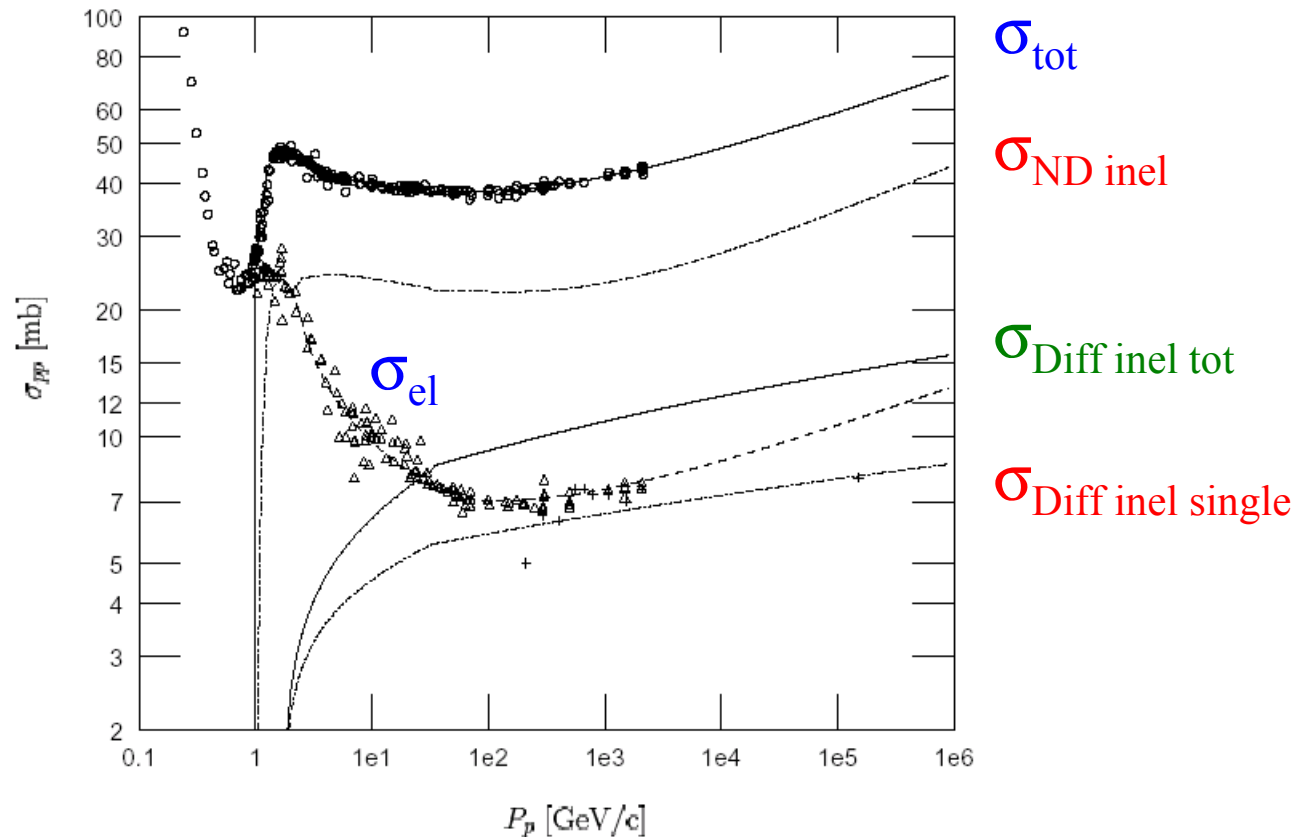
- ❑ **GLAST scientists at SLAC are playing leading roles in production and integration of the **Flight Instrument**.**  
(Talks by Bloom and Cameron)
- ❑ **We are analyzing observational data and building theoretical models as parts of preparation for GLAST science, in close collaboration with SLAC-HEP and KIPAC.**
- ❑ **Expert knowledge on the instrument accumulated at SLAC will help us in detecting important but subtle signals and their temporal variability.**
- ❑ **We are actively establishing links to radio, X-ray and air-Cherenkov telescope experiments.** (Talk by Madejski)
- ❑ **We would like to **share many exciting science with broader HEP community**.**

# Backup Slide: GLAST-LAT Sensitivity



# Backup Slide: $pp$ Cross-Sections

Parameterized model (Kamae, Karlsson et al. 2005)



# Backup Slide: Parameterized $\gamma$ -ray Spectrum

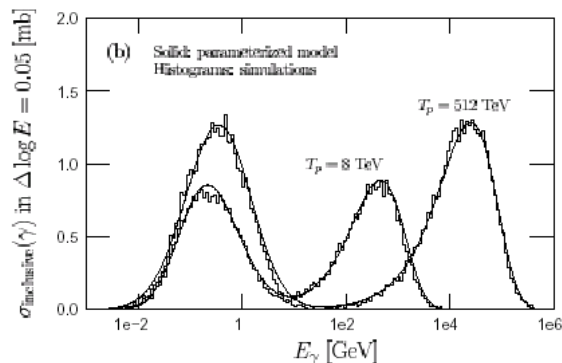
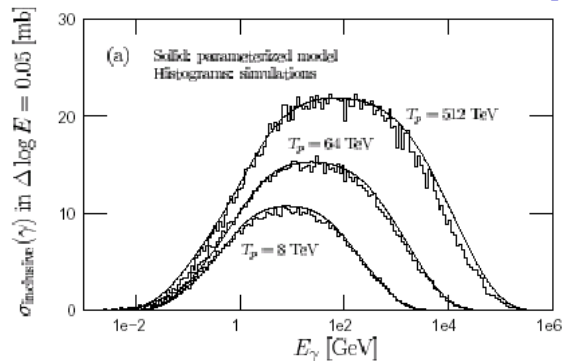
Parameterized model (Kamae, Karlsson et al. 2005)

$$x = \log_{10}(E_\gamma)$$

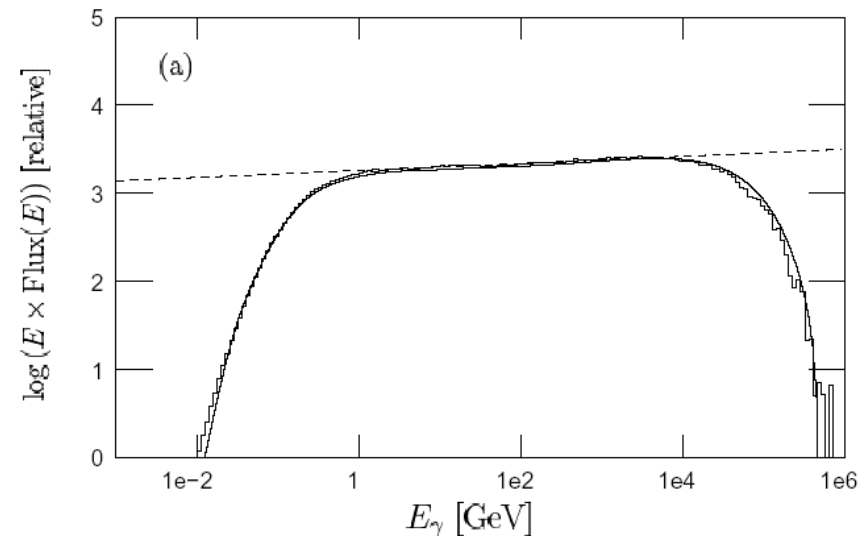
$$F_{\text{ND}}(x) = a_0 \exp(-a_1(x - a_3 + a_2(x - a_3)^2)^2) + a_4 \exp(-a_5(x - a_8 + a_6(x - a_8)^2 + a_7(x - a_8)^3)^2)$$

$$F_{\text{Diff}}(x) = b_0 \exp(-b_1((x - b_2)/(1.0 + b_3(x - b_2)))^2) + b_4 \exp(-b_5((x - b_6)/(1.0 + b_7(x - b_6)))^2)$$

$\gamma$ -ray spctr for Non-Diff. for 3  $T_p$



$\gamma$ -ray spctr for ND+Diff for protons w/ power-law spctr. (ind=2.0)



# Backup Slide: Angular Distribution off the Proton Beam

For narrow a proton beam g-ray spectrum may appear totally different depending on the viewing angle.

Karlsson, Kamae, Cohen-Tanugi, et al. (in progress)

