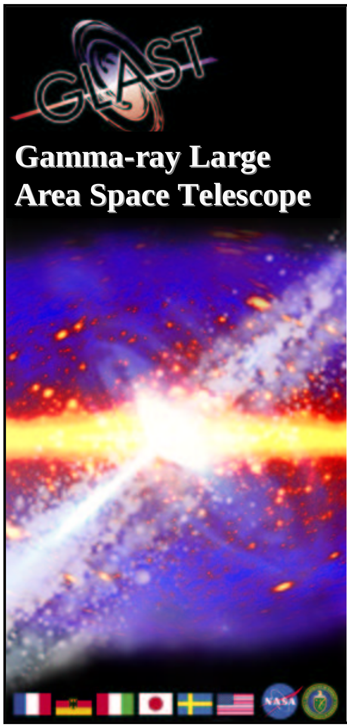


The GLAST Large Area Telescope (LAT)

Elliott Bloom
Stanford Linear Accelerator Center, Stanford University.

The New Cosmology Confronts Observation Conference
August 19-23,2002
ITP, UCSB

On behalf of the LAT collaboration

http://www-glast.stanford.edu/

1

Outline

- Introduction
  - Mission
  - Collaboration
  - Instrument
- Overview of the LAT Science capabilities
- Schedule

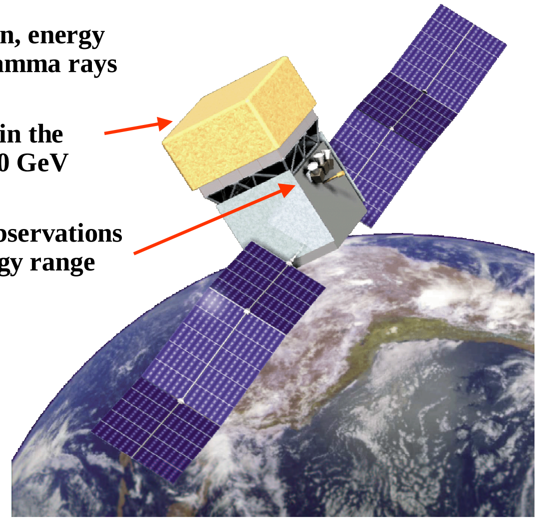
2

GLAST Mission

GLAST measures the direction, energy and arrival time of celestial gamma rays

- LAT measures gamma-rays in the energy range ~20 MeV - >300 GeV

- GBM provides correlative observations of transient events in the energy range ~20 keV – 20 MeV



Launch: September 2006

Orbit: 550 km, 28.5º inclination

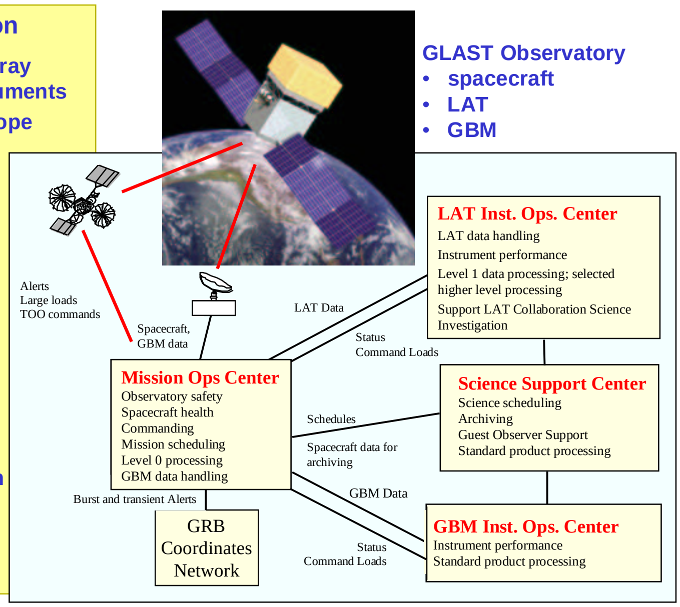
Lifetime: 5 years (minimum)

3

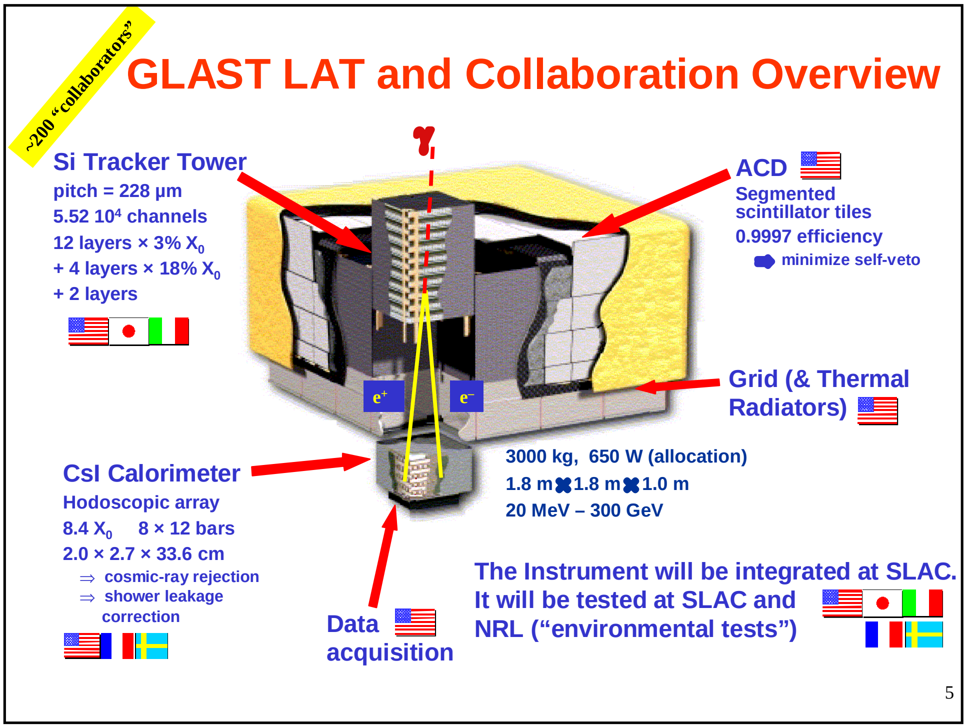
Gamma-ray Large Area Space Telescope

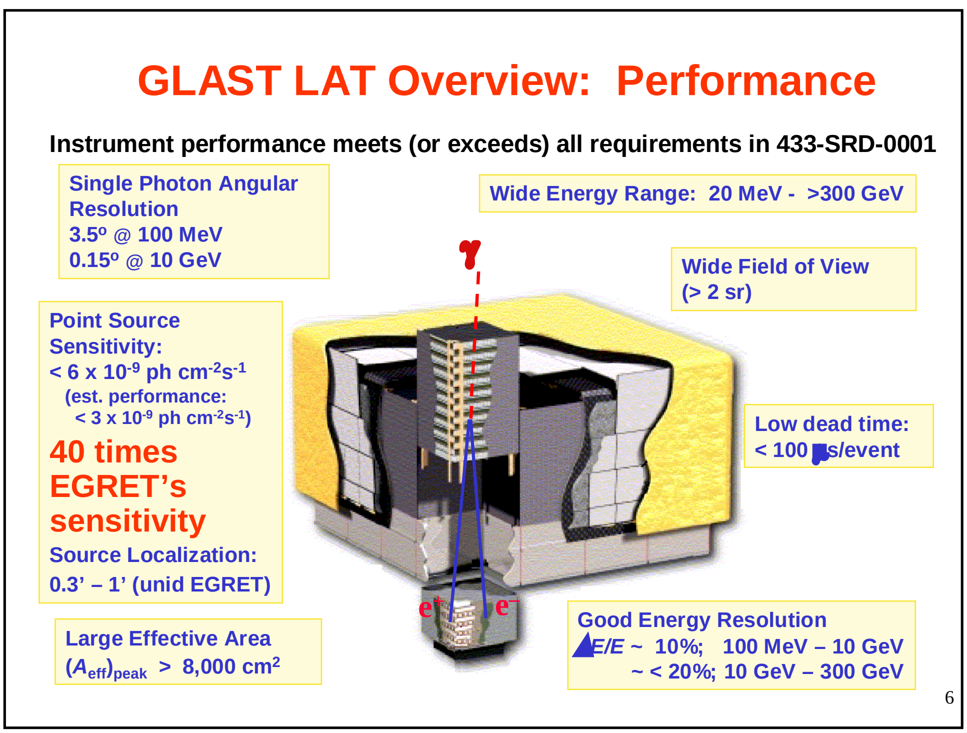
GLAST Mission

- high-energy gamma-ray observatory; 2 instruments
  - Large Area Telescope (LAT)
  - Gamma-ray Burst Monitor (GBM)
- launch (March 2006): Delta 2 class
- orbit: 550 km, 28.5º inclination
- mission operations
- science
  - LAT Collaboration
  - GBM Collaboration
  - Guest Observers
- lifetime: 5 years (minimum)

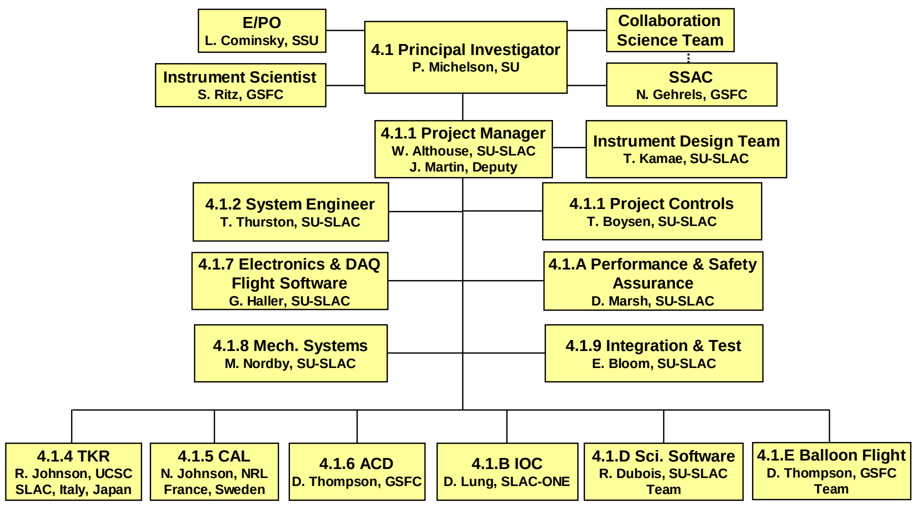


4


~200 "collaborators"
GLAST LAT and Collaboration Overview
Si Tracker Tower
pitch = 228 µm
5.52 10^4 channels
12 layers × 3% X_0
+ 4 layers × 18% X_0
+ 2 layers
ACD
Segmented scintillator tiles
0.9997 efficiency
minimize self-veto
Grid (& Thermal Radiators)
e^+
e^-
CsI Calorimeter
Hodoscopic array
8.4 X_0 8 × 12 bars
2.0 × 2.7 × 33.6 cm
⇒ cosmic-ray rejection
⇒ shower leakage correction
3000 kg, 650 W (allocation)
1.8 m × 1.8 m × 1.0 m
20 MeV – 300 GeV
The Instrument will be integrated at SLAC.
It will be tested at SLAC and NRL ("environmental tests")
Data acquisition
5


GLAST LAT Overview: Performance
Instrument performance meets (or exceeds) all requirements in 433-SRD-0001
Single Photon Angular Resolution
3.5° @ 100 MeV
0.15° @ 10 GeV
Wide Energy Range: 20 MeV - >300 GeV
Wide Field of View (> 2 sr)
Point Source Sensitivity:
< 6 x 10^{-9} ph $cm^{-2}s^{-1}$
(est. performance: < 3 x 10^{-9} ph $cm^{-2}s^{-1}$)
40 times EGRET's sensitivity
Source Localization:
0.3' – 1' (unid EGRET)
Low dead time:
< 100 µs/event
Large Effective Area
$(A_{eff})_{peak}$ > 8,000 cm^2
Good Energy Resolution
ΔE/E ~ 10%; 100 MeV – 10 GeV
~ < 20%; 10 GeV – 300 GeV
6

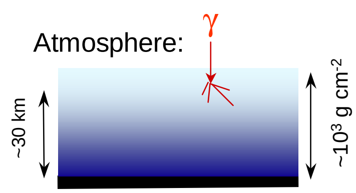
GLAST LAT Project Organization



7

Why do we need a satellite ?

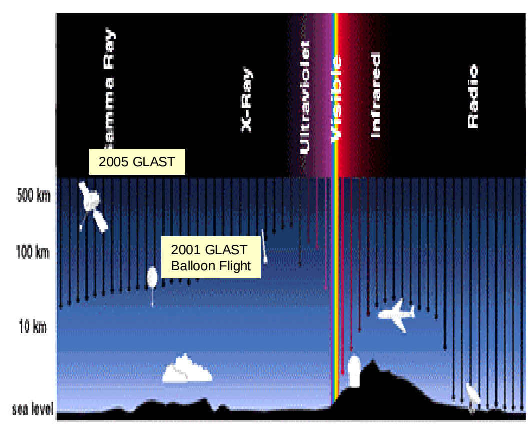
Atmosphere:



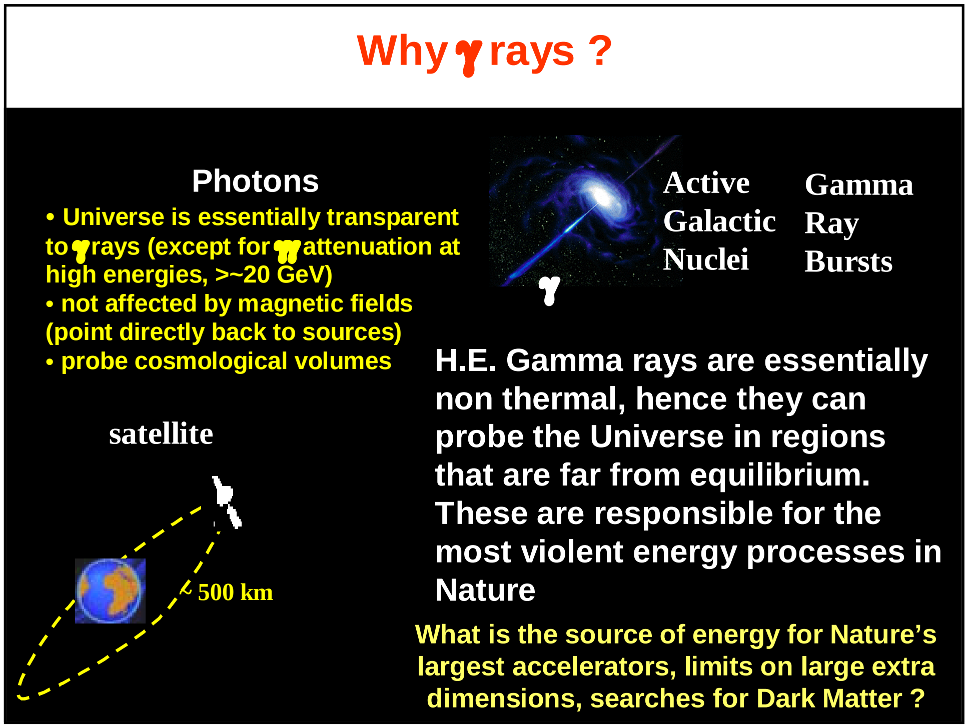
For E_γ < ~ O(100) GeV, must detect above atmosphere (balloons, satellites, rockets)

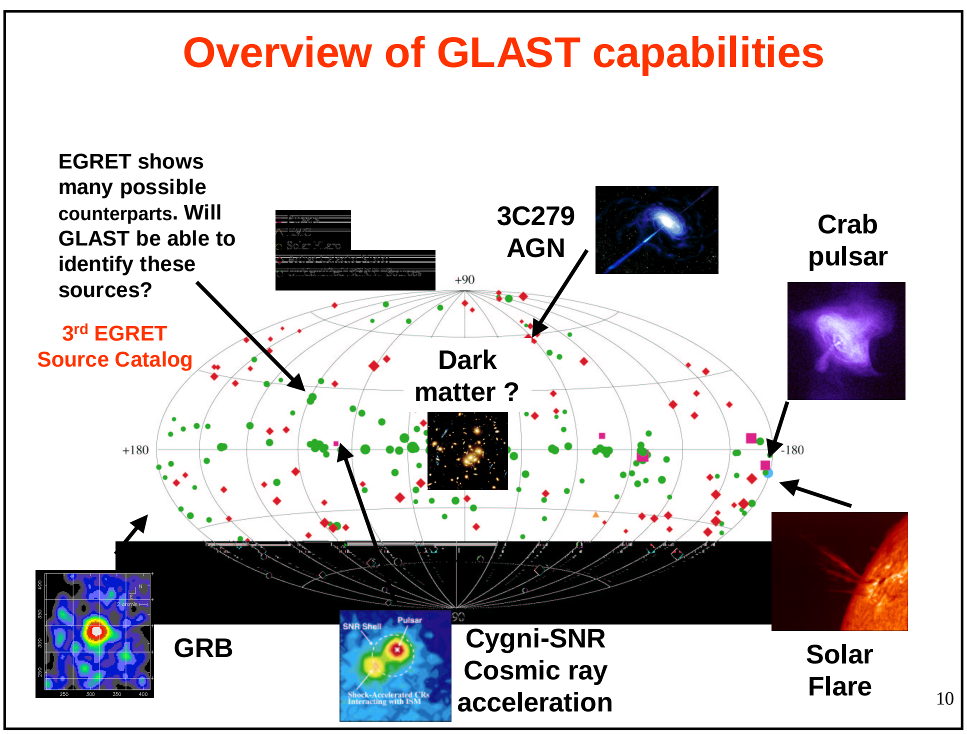
For E_γ > ~ O(100) GeV, information from showers penetrates to the ground (Cerenkov)

GLAST complements the capabilities of ground based observatories



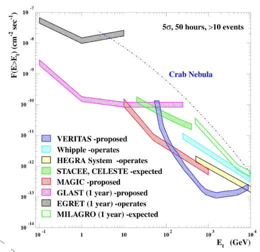
8


Why γ rays ?
Photons
• Universe is essentially transparent to γ rays (except for γγ attenuation at high energies, >~20 GeV)
• not affected by magnetic fields (point directly back to sources)
• probe cosmological volumes
Active Galactic Nuclei
Gamma Ray Bursts
γ
satellite
500 km
H.E. Gamma rays are essentially non thermal, hence they can probe the Universe in regions that are far from equilibrium. These are responsible for the most violent energy processes in Nature
What is the source of energy for Nature's largest accelerators, limits on large extra dimensions, searches for Dark Matter ?


Overview of GLAST capabilities
EGRET shows many possible counterparts. Will GLAST be able to identify these sources?
3rd EGRET Source Catalog
3C279 AGN
Crab pulsar
Dark matter ?
+90
+180
-180
GRB
Cygni-SNR Cosmic ray acceleration
Solar Flare
10

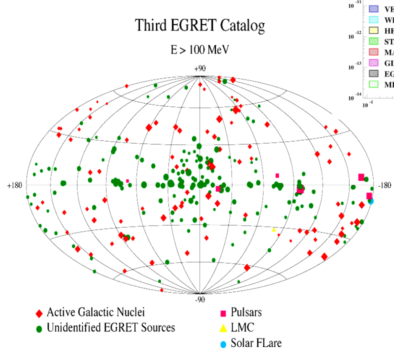
Gamma Ray Sky

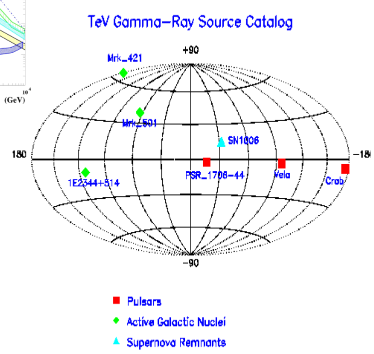
From space…



From the ground…

Why so few sources at TeV?



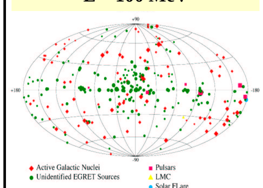


10 MeV ⟷ 30 GeV: EGRET

50-100 GeV ⟷ 10 TeV: Ground Telescopes

20 MeV ⟷ 300GeV: GLAST LAT

3rd EGRET Catalog
E > 100 MeV



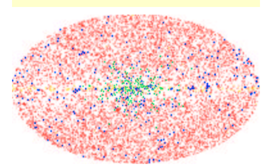
EGRET

1991-2001

GLAST

2006 - ?
5 yr operation requirement
10 yr operation goal

LAT Simulation
E > 100 MeV



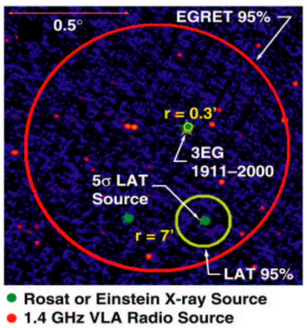
	EGRET	GLAST	Compare to EGRET
Energy	20 MeV - 30 GeV	20 MeV - 300 GeV	
Effective area	1500 cm²	> 10000 cm²	> 6
Field of view	0.5 sr	> 2.0 sr	> 4
Sensitivity (1yr)	~ 10^{-7} γ cm^{-2} s^{-1}	< 6 10^{-9} γ cm^{-2} s^{-1}	> 20
Localization	15 '	< 0.5 '	> 30
Deadtime	100 ms	< 100 μs	> 100

Large area
Low instrumental background

12

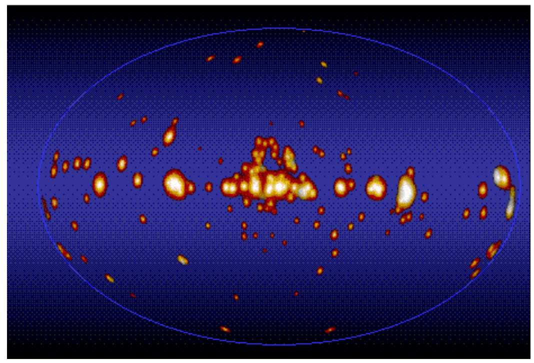
Science capabilities - resolution

Source identification requires a multiwavelength approach
- localization
- variability



Source localization (68% radius)

γ bursts	1 to tens of arcmin
Unidentified EGRET sources	0.3' to 1'

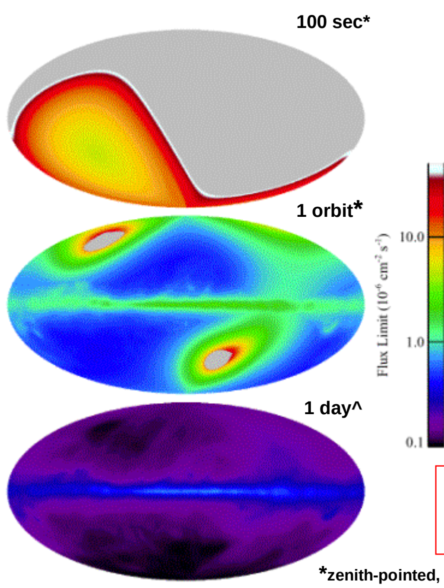


Unidentified EGRET Sources

Evidence for at least 2 unidentified Galactic populations:
- time-variable Galactic population
- persistent Gould Belt population

13

Science capabilities – transient sensitivity



wide field-of-view

EGRET Fluxes
- GRB940217 (100sec)
- PKS 1622-287 flare
- 3C279 flare
- Vela Pulsar

low deadtime (for light curve)

- Crab Pulsar
- 3EG 2020+40 (SNR γ Cygni?)

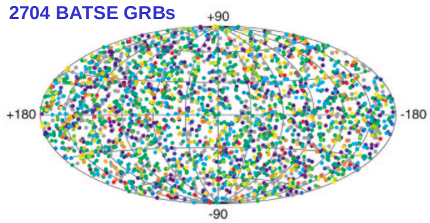
- 3EG 1835+59
- 3C279 lowest 5σ detection
- 3EG 1911-2000 (AGN)
- Mrk 421
- Weakest 5σ EGRET source

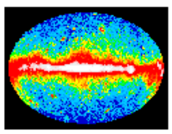
all 3EG sources + 80 new detected in 2 days
~200 γ bursts per year
AGN flares > few min

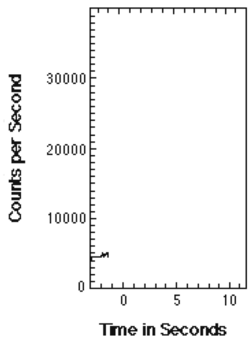
*zenith-pointed, ^"rocking" all-sky scan

14

Science capabilities - Gamma-Ray Bursts







The Gamma-Ray Burst mystery…

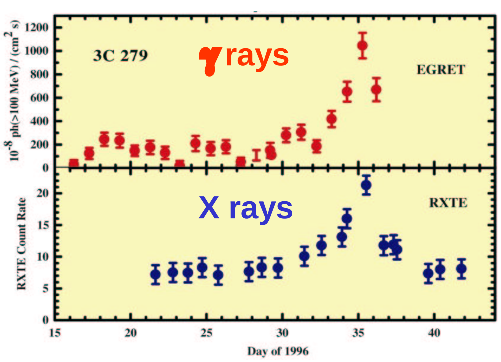
- Isotropic on sky (BATSE/ CGRO)
- Last from milliseconds to ~ 100 seconds
- Brightest transient phenomenon in the Universe
- ~ 1 per day - no repetitions
- Progenitors still not known

GLAST will….

- place strong constraints on physical conditions within the source region (because GeV photons are strongly susceptible to absorption via gamma-gamma pair conversion..)
- detect a GRB about once every 2 days, quite possibly including bursts from the first generation of stars

15

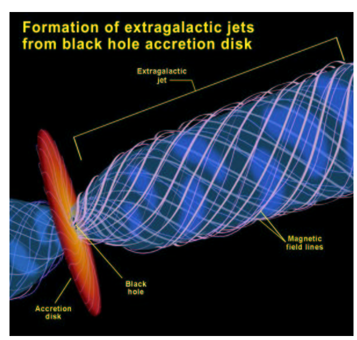
AGN - Supermassive Black Holes ?



Up to 10000 times the luminosity of typical galaxy in a volume of one cubic parsec ! (1 pc = 3.1 x 10^{18} cm ~ 3 light years) (assuming isotropic emission)

Accretion processes can explain huge output power since they are very efficient

Changes in Luminosity in a fraction of a day !
Variability constrains the size of the emitting source

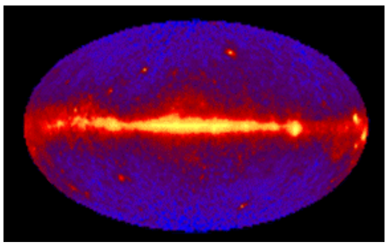


16

Diffuse Background Emission

• Galactic (falls rapidly at higher latitudes, away from the plane we have less gas, backgrounds are instrumental, extragalactic diffuse and point sources such as pulsars)
• Extragalactic- |b| > 10 deg (backgrounds are instrumental, galactic diffuse and point sources such as AGN)

EGRET Gamma Ray Emissions > 100 MeV



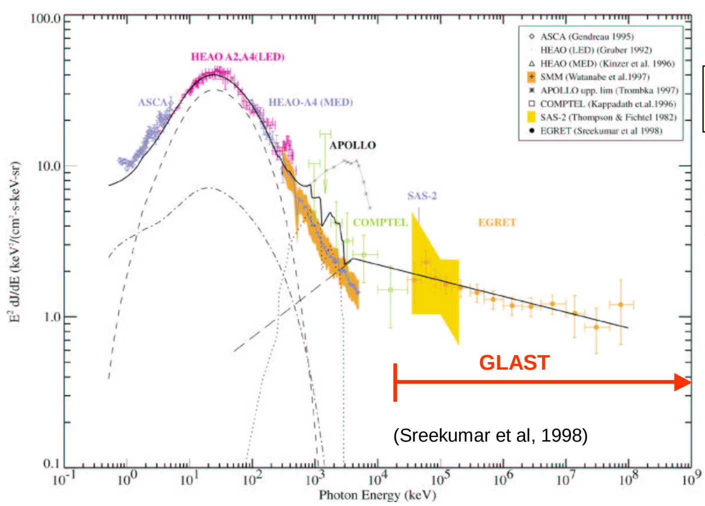
Diffuse Model includes
•Cosmic ray nucleon interactions with nucleons in the interstellar gas, which dominates for E > 70 MeV (via pizero decays)
•Bremstrahlung of cosmic ray electrons which dominates below ~ 20 MeV
•Inverse Compton interactions between relativistic cosmic ray electrons and soft photons in the interstellar gas (100 MeV photons appear from interactions between 1 – 100 GeV e- with MW to UV photons). More significant at high latitudes.

Hunter et al (1997), showed that there is generally a good agreement between EGRET observations of the gamma ray diffuse radiation in the Galactic Plane and model calculations

17

Extragalactic Diffuse Background

Could the EGRET diffuse background have a larger contribution of extragalactic point sources, such as AGN (blazars), which were not completely resolved ?



EGRET estimated

$$\frac{dF}{dE} \propto \frac{1}{E^{-2.10 \pm 0.03}}$$

after subtraction of point sources and emission from the galactic disk and the galactic center

(model dependent)

18

EGRET Limits on Large Extra Dimensions

VOLUME 87, NUMBER 5 PHYSICAL REVIEW LETTERS 30 JULY 2001

New Supernova Limit on Large Extra Dimensions: Bounds on Kaluza-Klein Graviton Production

Steen Hannestad
NORDITA, Blegdamsvej 17, 2100 Copenhagen, Denmark

Georg G. Raffelt
Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), Föhringer Ring 6, 80805 München, Germany
(Received 22 March 2001; published 11 July 2001)

If large extra dimensions exist in nature, supernova (SN) cores will emit large ßuxes of Kaluza-Klein gravitons, producing a cosmic background of these particles with energies and masses up to about 100 MeV. Radiative decays then give rise to a diffuse cosmic **γ-ray background** with $E_\gamma < 100$ MeV which is well in excess of the observations if more than 0.5% – 1% of the SN energy is emitted into the new channel. For two extra dimensions we derive a conservative bound on their radius of $R < 0.9 \times 10^{-4}$ mm; for three extra dimensions it is $R < 1.9 \times 10^{-7}$ mm.

DOI: 10.1103/PhysRevLett.87.051301 PACS numbers: 97.60.Bw, 04.50.+h, 11.10.Kk, 11.25.Mj

19

Dark Matter

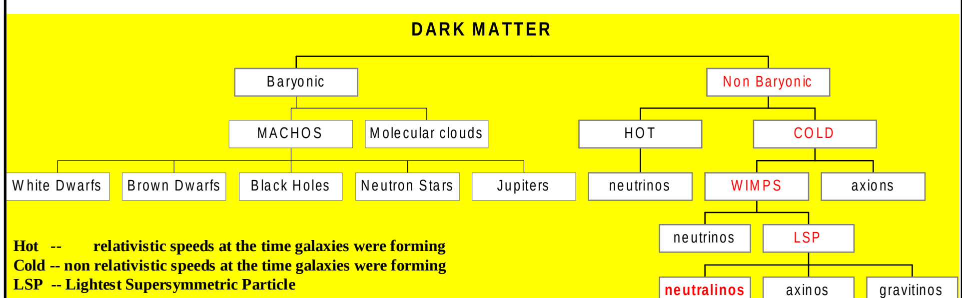
- Ω Energy matter density/critical density
- Contributions from
  - Ω_M matter
  - Ω_Λ cosmological constant
  - Ω_B baryonic matter
  - Ω_{NB} non-baryonic matter

$$\underset{1}{\Omega} = \underset{0.3}{\Omega_M} + \underset{0.7}{\Omega_\Lambda}$$

$$\downarrow$$

$$\underset{0.05}{\Omega_B} + \underset{0.25}{\Omega_{NB}}$$

~ 90% of matter in the universe is non luminous

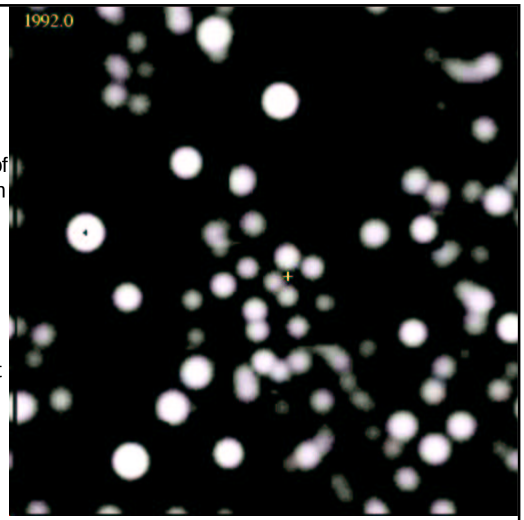


20

The Nature of the Dark Mass in the Center of the Milky Way

REINHARD GENZEL, ANDREAS ECKART, THOMAS OTT, FRANK EISENHAUER

Derivation of stellar proper motions within 3" of the compact radio source Sgr A*obtained from 0".15 astrometric K-band maps in five epochs between 1992 and 1996. Allow whose infrared counterpart may have been detected, for the first time, in a deep image in June 1996. All available checks including a first comparison with high resolution maps now becoming available from other groups support our conclusion that there are several fast moving stars ($\geq 10^3$ km/s) in the immediate vicinity (0.01 pc) of Sgr A*.

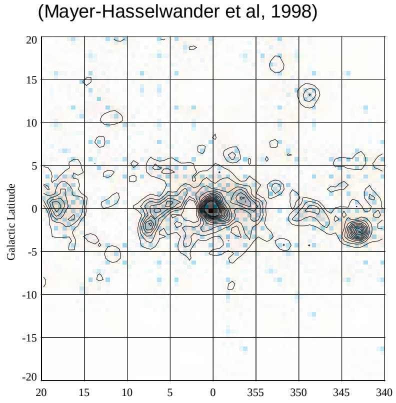


From the stellar radial and proper motion data, we infer that a dark mass of 2.61 ($\pm 0.15_{stat}$) ($\pm 0.35_{stat+sys}$) $\times 10^6$ M_o) must reside within about a light week of the compact radio source. Its density must be 2.2×10^{12} $M_o pc^{-3}$ or greater. There is no stable configuration of normal stars, stellar remnants or sub-stellar entities at that density. From an equipartition argument we infer that at least 5% of the dark mass ($\geq 10^5$ M_o) is associated with the compact radio source Sgr A* itself and is concentrated on a scale of less that 15 times the Schwarzschild radius of a 2.6×10^6 M_o black hole. The corresponding density is 3×10^{20} $M_o pc^{-3}$ or greater. If one accepts these arguments it is hard to escape the conclusion that there must be a massive black hole at the core of the Milky Way.

21

Gamma Ray Excess from the Galactic Center

(Mayer-Hasselwander et al, 1998)



Residual count map of the galactic center after subtraction of diffuse background model

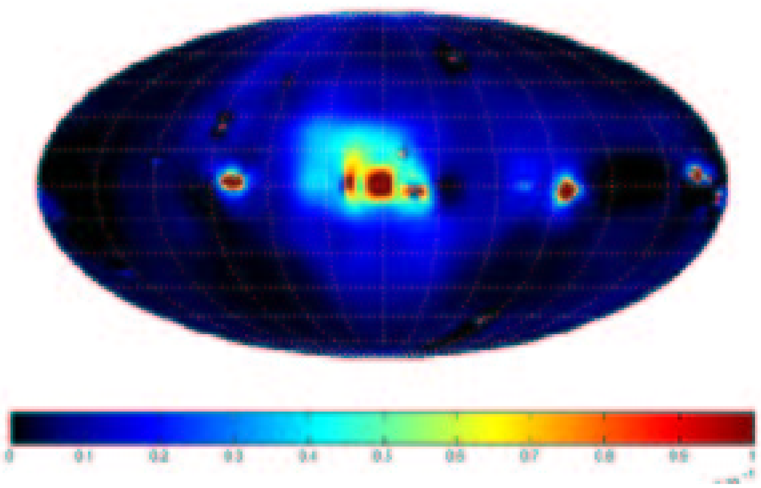
(excess is model dependent)

EGRET analysis revealed an excess of γ rays from a position consistent with the galactic center

The EGRET team (Mayer-Hasselwander et al, 1998) have seen a convincing signal for a strong excess of emission from the galactic center, with $I(E) \times E^2$ peaking at ~ 2 GeV, and in an error circle of 0.2 degree radius including the position $l = 0^o$ and $b = 0^o$. In their paper it was speculated that among other possible causes, this excess could be due to the continuum γ-ray spectrum from WIMP annihilation. With the dramatically improved angular resolution and effective area of GLAST, this effect should become both more localized and pronounced if it is a Galactic Center phenomenon.

22

Is There a Galactic Halo that Glows in High Energy Photons Photons?



Contours of photon intensity in units of 10^{-5} ph cm^{-2} sec^{-1} sr^{-1} for $E\gamma > 1$ GeV, after subtraction of "best estimate" of Galactic diffuse model. Data indicates presence of a galactic halo (Dixon et al. 1998).

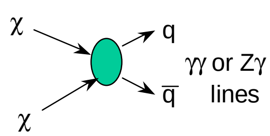
23

Neutralino Annihilations

Good particle physics candidate for galactic halo dark matter is the LSP in R-parity conserving SUSY

$$\chi_1^0 = a_{11}\tilde{B} + a_{12}\tilde{W}^3 + a_{13}\tilde{H}_1^0 + a_{14}\tilde{H}_2^0$$

If true, there may well be observable halo annihilations



Example: χ^0 from Standard SUSY, annihilations to jets, producing an extra component of multi-GeV γ flux that follows halo density (not isotropic) peaking at ~ 0.1 Mχ^0 or lines at Mχ^0. Background is galactic γ ray diffuse.

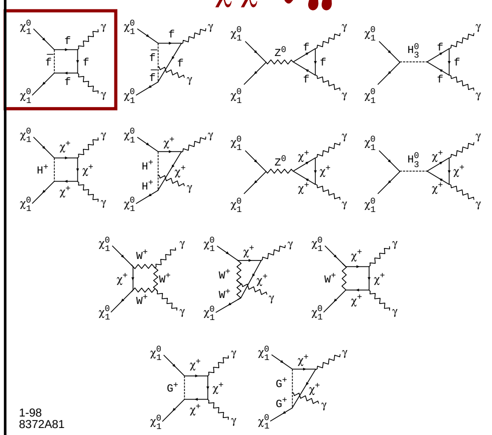
Although calculation for γ-rays is less uncertain than for other signals (multi-GeV antiprotons, positrons) a null result will not likely constrain SUSY parameter space.

If SUSY uncovered at accelerators, GLAST may be able to determine its cosmological significance quickly.

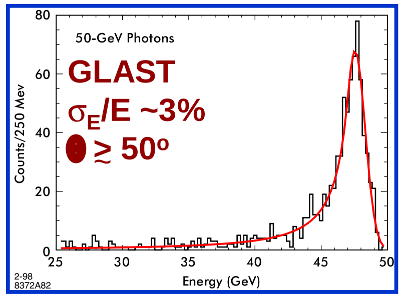
24

SUSY LSP Halo Annihilation

$\chi\chi \rightarrow \gamma\gamma$



\+



\+ **Navarro, Frenk & White Halo (No Clumps) Central Core** =

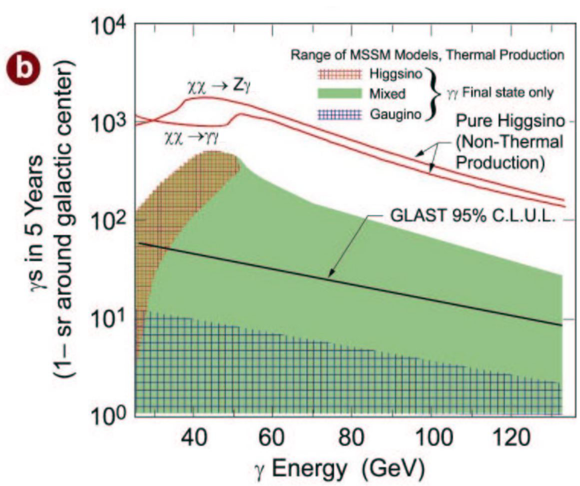
$$\rho(r) = \frac{\rho_0}{(r/r_0)(1+r/r_0)^2}$$

$$r_0 = 3.4\,kpc,\ \rho_0 = 0.4\,GeV/cm^3,\ R_0 = 8.5\,kpc$$

(Bergström & Ullio 1997; Bern, Gondolo, Perelstein 1997)

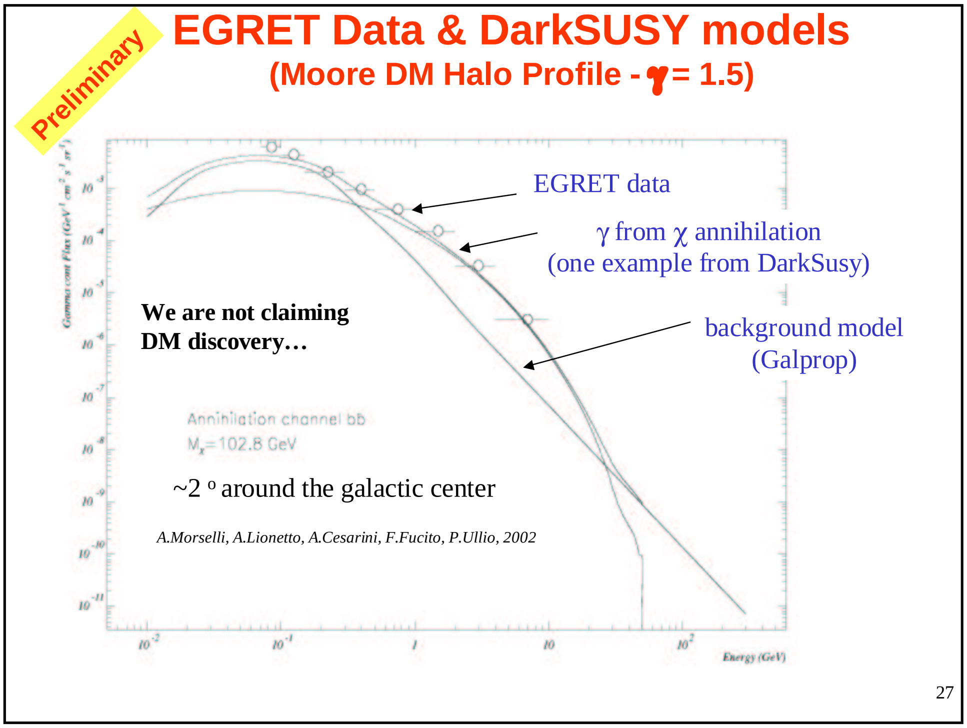
25

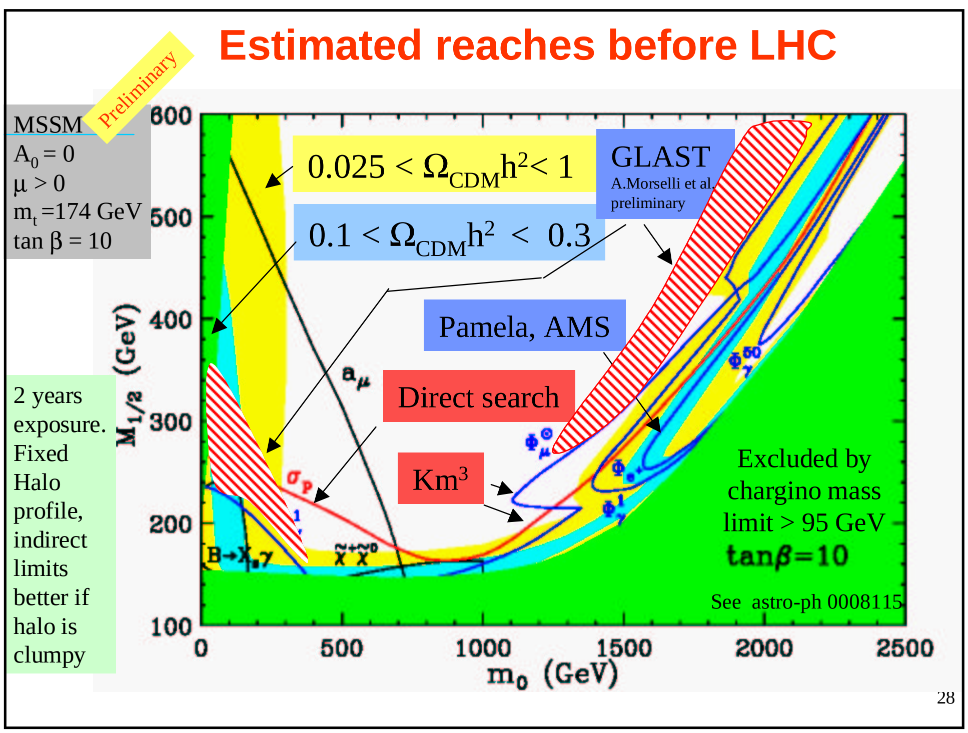
GLAST MC Limits on MSSM from γ lines



GLAST monenergetic γ "line" sensitivity (95 % CLUL) vs E_γ. Colored areas are a range of MSSMs within a restricted parameter space from standard assumptions and thermal relic abundance calculations. Red lines are rates assuming a non-thermal origin with Higgsino accounting for the bulk of the Galactic halo.

26


Preliminary
EGRET Data & DarkSUSY models
(Moore DM Halo Profile - γ= 1.5)
EGRET data
γ from χ annihilation
(one example from DarkSusy)
background model
(Galprop)
We are not claiming
DM discovery…
Annihilation channel bb
M_χ=102.8 GeV
~2 º around the galactic center
A.Morselli, A.Lionetto, A.Cesarini, F.Fucito, P.Ullio, 2002
Energy (GeV)
27


Estimated reaches before LHC
Preliminary
MSSM
A_0 = 0
μ > 0
m_t =174 GeV
tan β = 10
0.025 < Ω_CDM h² < 1
0.1 < Ω_CDM h² < 0.3
GLAST
A.Morselli et al.
preliminary
Pamela, AMS
Direct search
Km³
2 years exposure. Fixed Halo profile, indirect limits better if halo is clumpy
Excluded by chargino mass limit > 95 GeV
tanβ=10
See astro-ph 0008115
M_1/2 (GeV)
m_0 (GeV)
28

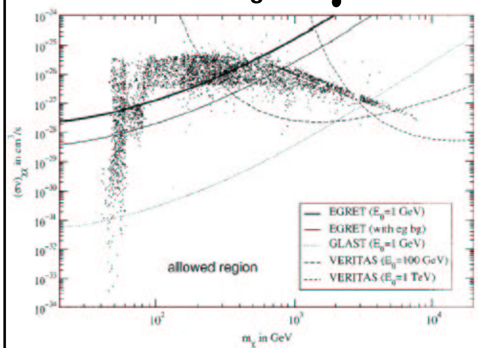
Particle dark matter constraints from the Draco dwarf galaxy

C. Tyler, PHYS. REV D **66**, 023509 (2002)

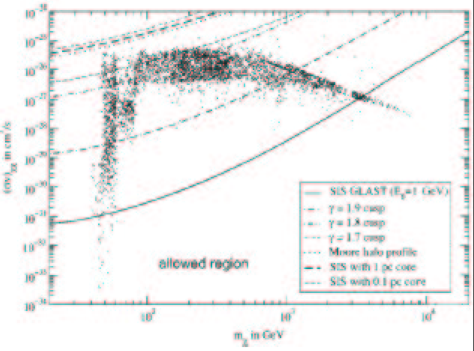
Draco dwarf spheroidal galaxy, 79 kpc from Earth,
$M/L = 440 \pm 240\ M_{solar}/L_{solar}$, $M \sim 8.6 \times 10^{7}\ M_{solar}$.

Draco has the mass of a dwarf galaxy and the starlight of a globular cluster

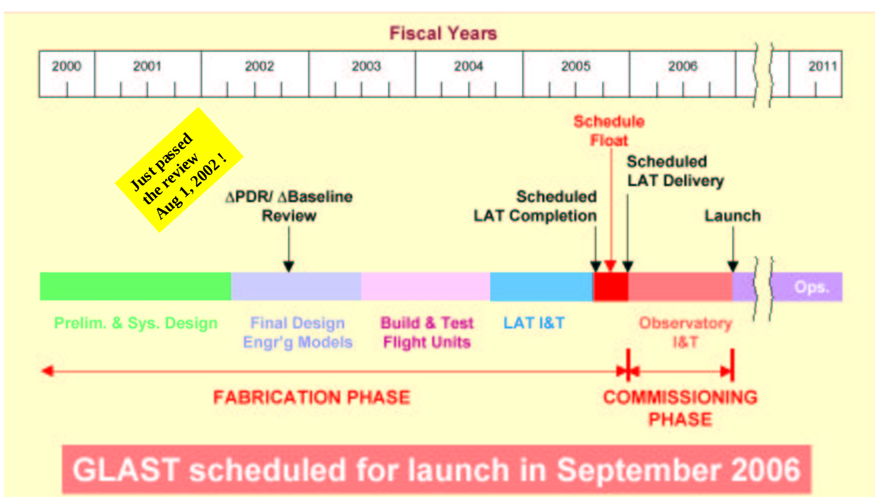
γ limits from EGRET and GLAST assuming SIS - γ = 2



γ limits from GLAST assuming a number of Halo models



Schedule



30