Gamma-ray Large Area Space Telescope

GLAST Mission, LAT Project, Science Opportunities

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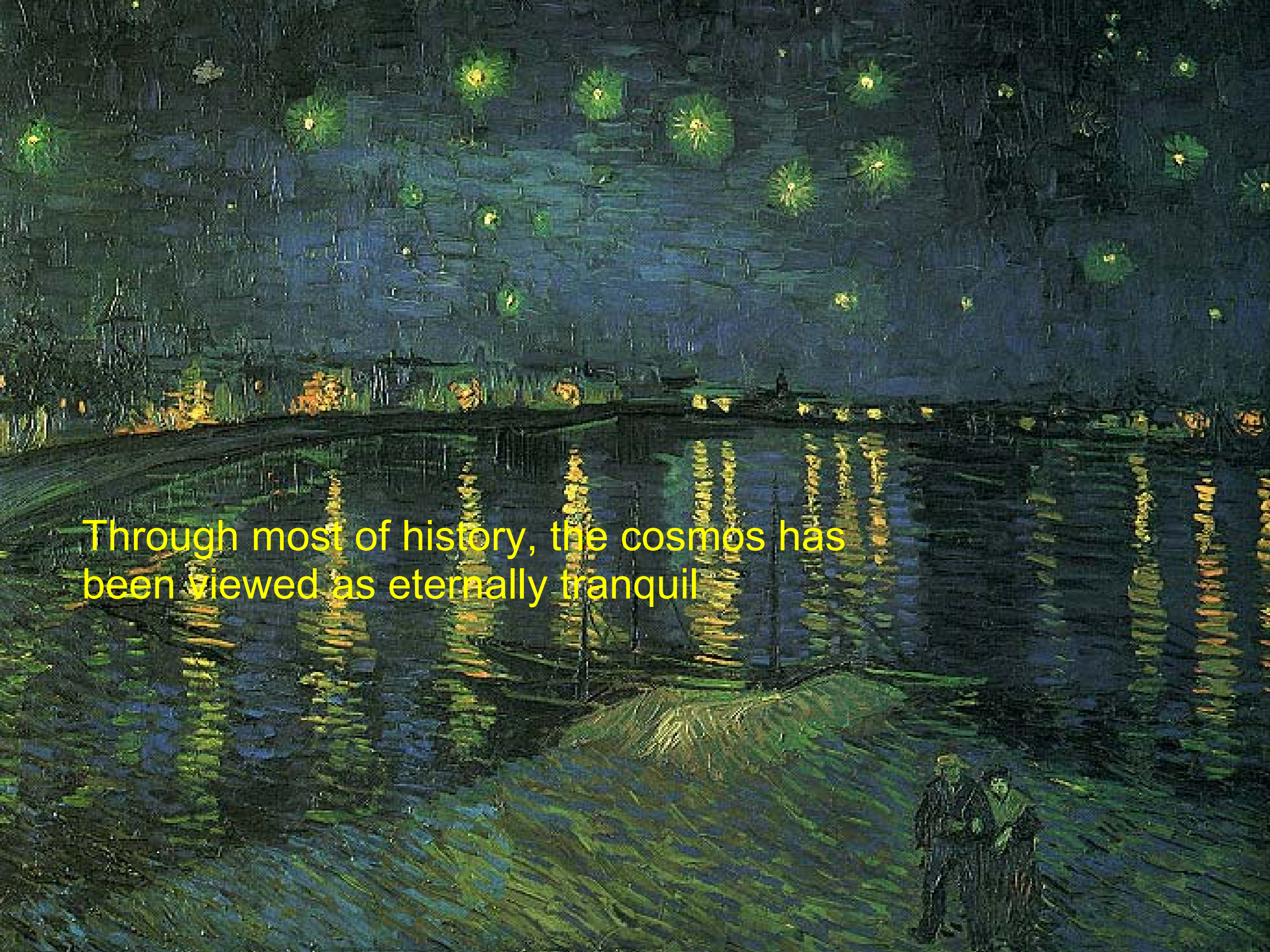
DOE Program Review
SLAC, Stanford University
April 9, 2003

Outline

- GLAST Mission overview
- Large Area Telescope (LAT) Project overview and status
- Science overview



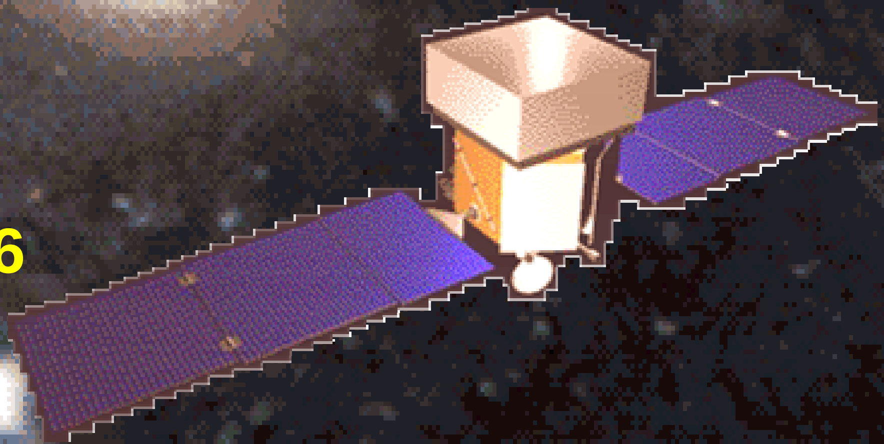
Through most of history, the cosmos has been viewed as eternally tranquil

During the 20th century the quest to broaden our view of the universe has shown us the vastness of the Universe and revealed violent cosmic phenomena and mysteries

GLAST is an important part of the continuing quest to broaden our view of the universe.

- observe, with unprecedented detail, cosmic arenas of extreme violence
- explore Nature’s highest energy processes (10 keV – 300 GeV)

LAUNCH: September 2006

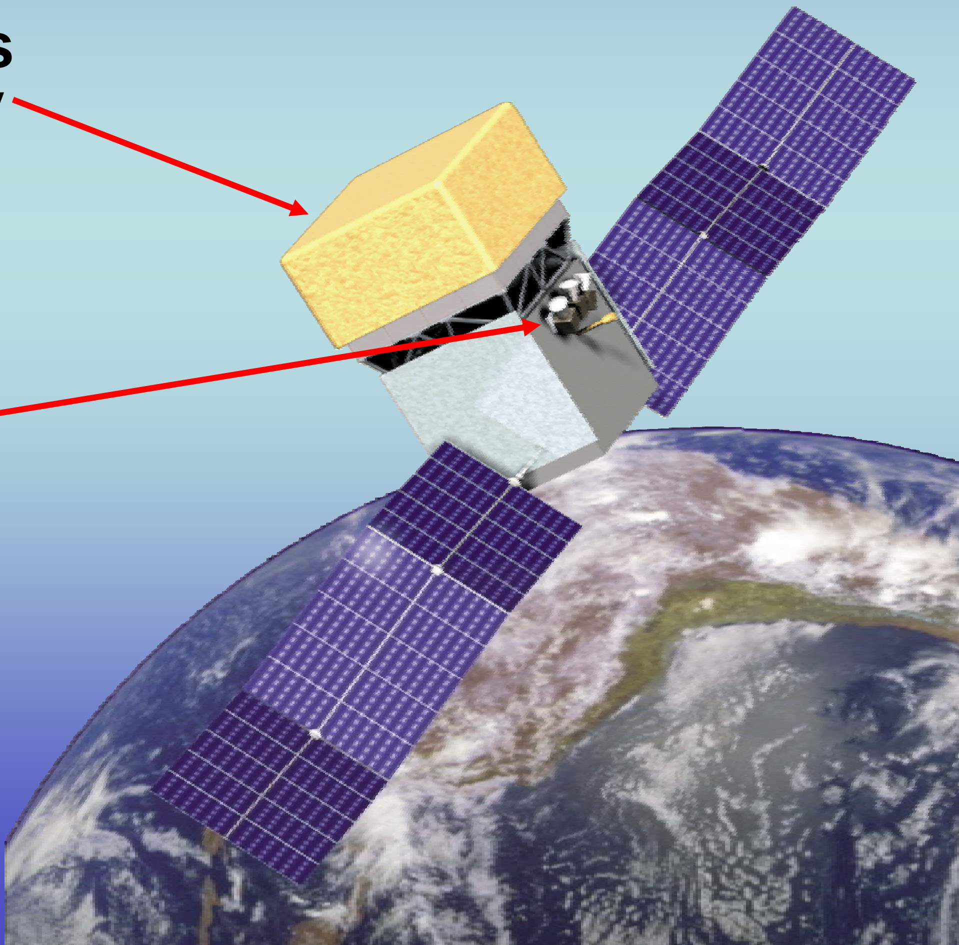


GLAST Mission

GLAST measures the direction, energy & 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

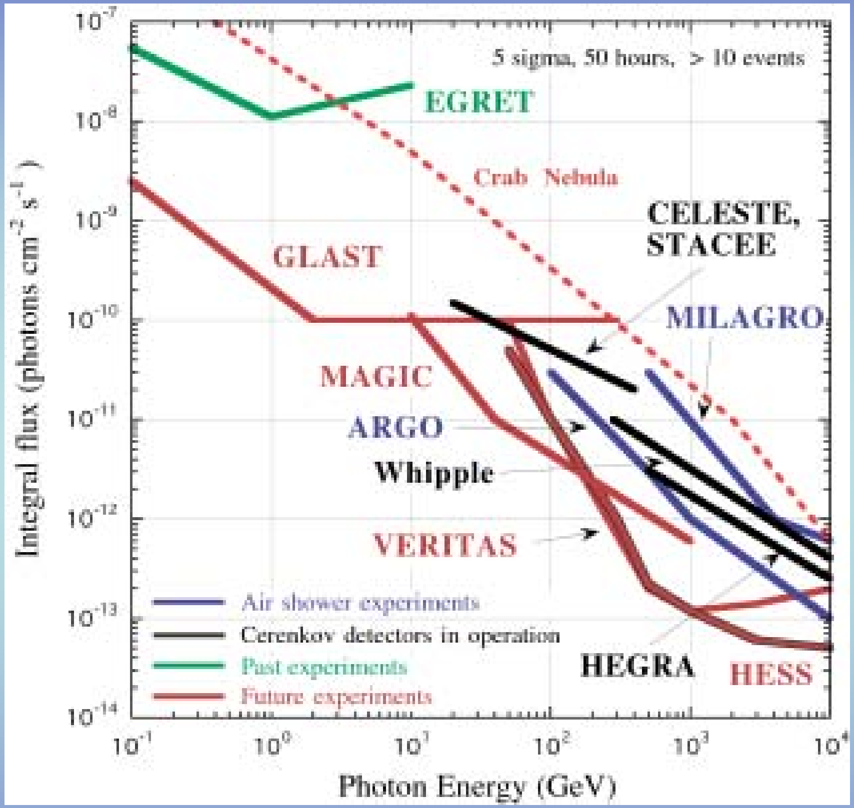


Summary of GLAST Project History

- **from its conception, GLAST developed by a collaboration of astrophysicists and particle physicists**
- **major leap in capability brought by modern detector technology**

- **LAT concept & technology in development by collaboration since 1992**
  - extensive beam tests of LAT elements, including high-altitude balloon flight of prototype LAT tower; validation of Monte Carlo model
- **GLAST endorsed by NASA Space Science Advisory Committee, Nov 1997**
- **Presented to DOE HEPAP, Jan 1997; submitted proposal for LAT to DOE, Feb 1998; reviewed by SAGENAP, April 1998**
- **Collaboration Proposal for LAT Flight Instrument accepted by NASA, Feb 2000**
  - proposal endorsed by CNES, CEA, IN2P3, ASI, INFN, JGC, SGC
  - subsequently, LoAs, MoAs signed or in final-draft form to formalize agreements
- **NRC Decadal Astronomy & Astrophysics Review ranks GLAST highest priority "moderate-size" space mission for next decade, Sept 2000**

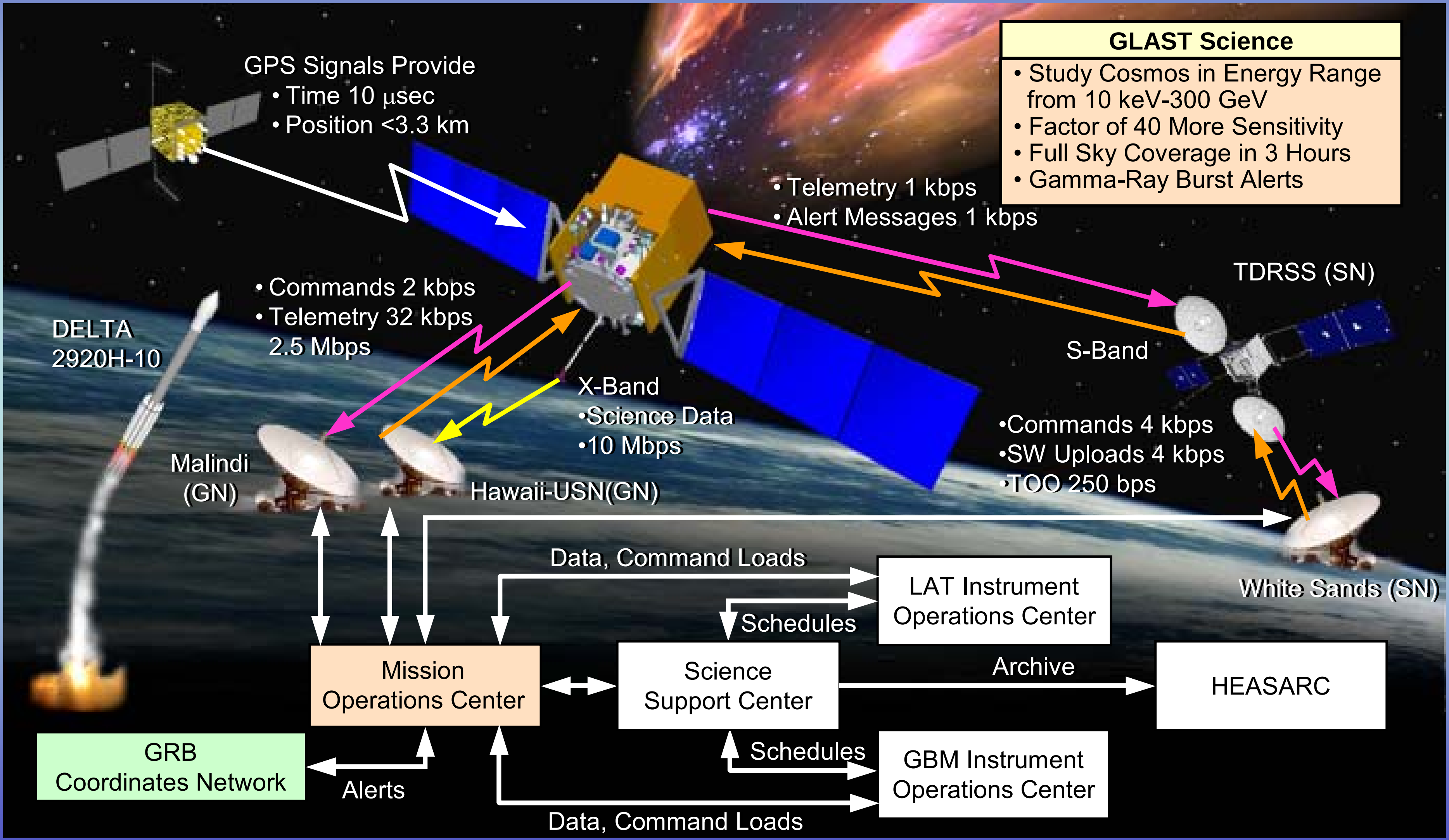
Complementary capabilities of GLAST and ground-based γ-ray observatories

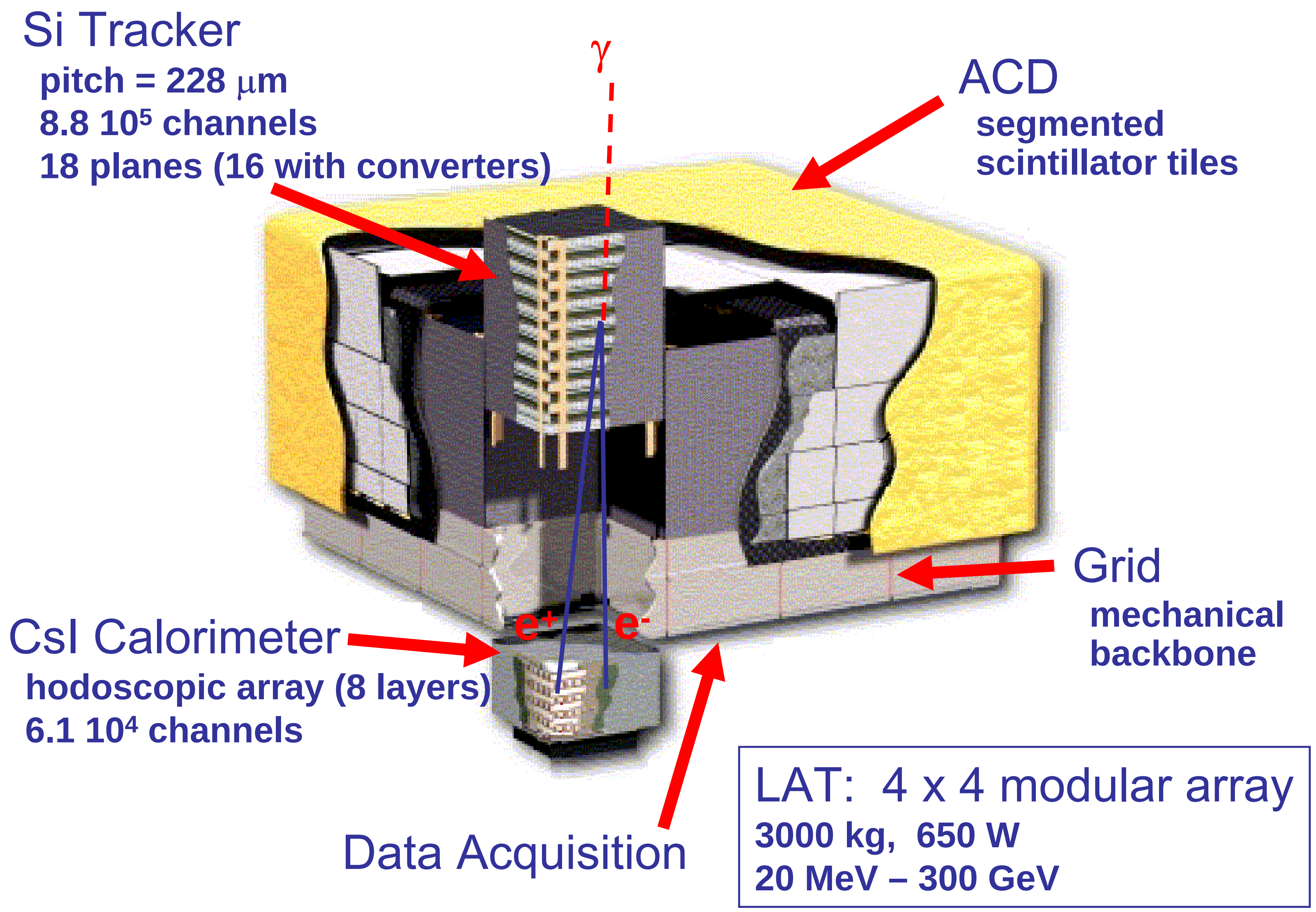


	ground-based		space-based
	ACT	EAS	Pair
angular resolution	good	fair	good
duty cycle	low	high	high
area	large	large	small
field of view	small	large	large+can reorient
energy resolution	good	fair	good, w/ smaller systematic uncertainties

The next-generation ground-based and space-based experiments are well matched.

GLAST Mission overview





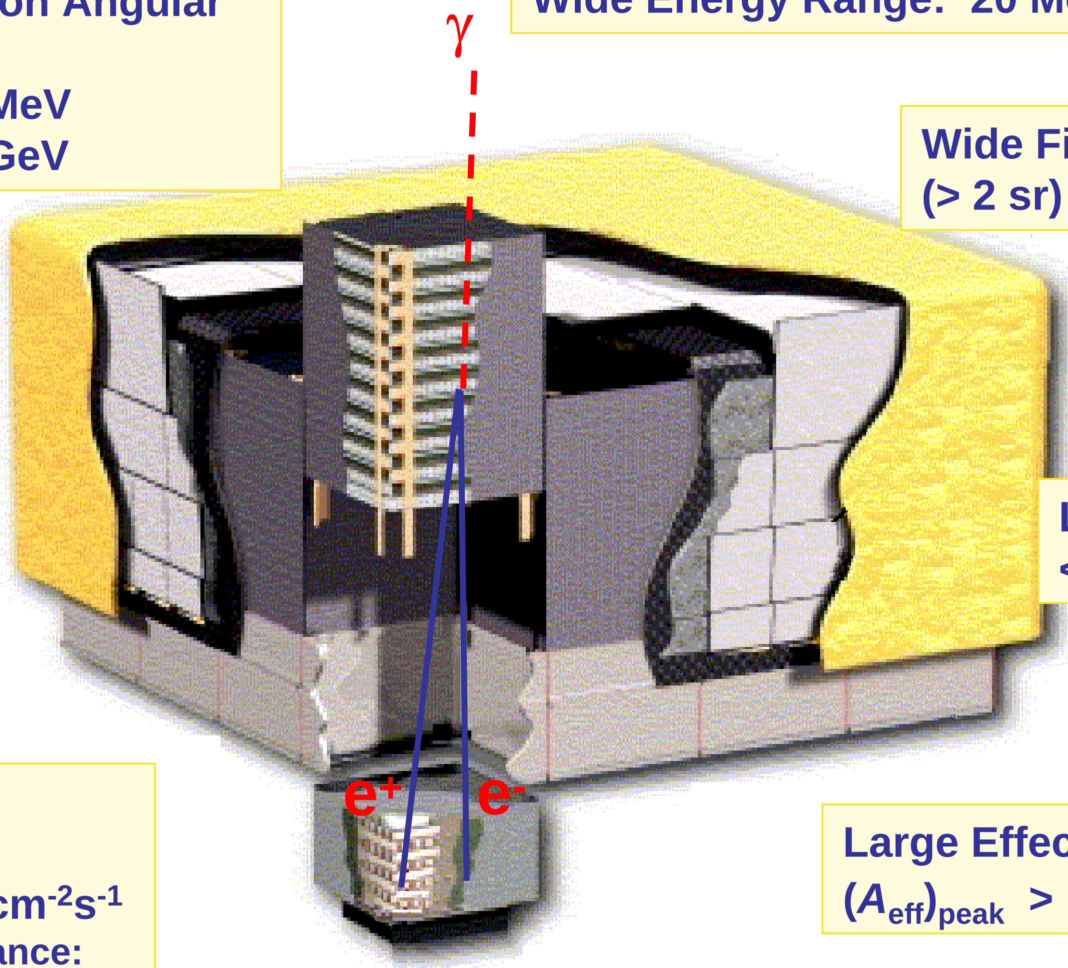
Si Tracker
pitch = 228 μm
8.8 10⁵ channels
18 planes (16 with converters)
γ
ACD
segmented
scintillator tiles
Grid
mechanical
backbone
e+
e-
CsI Calorimeter
hodoscopic array (8 layers)
6.1 10⁴ channels
Data Acquisition
LAT: 4 x 4 modular array
3000 kg, 650 W
20 MeV – 300 GeV

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)

40 times EGRET's sensitivity and extends energy range to 300 GeV



Low dead time:
< 100 μs/event

Large Effective Area
$(A_{eff})_{peak}$ > 8,000 cm^2

Point Source Sensitivity:
< 6 x 10^{-9} ph cm^{-2}s^{-1}
(est. performance:
< 3 x 10^{-9} ph cm^{-2}s^{-1})

Source Localization:
0.3' – 1'

Good Energy Resolution
$\Delta E/E$ ~ 10%; 100 MeV – 10 GeV
~ < 20%; 10 GeV – 300 GeV

GLAST LAT Collaboration

United States

- California State University at Sonoma
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Stanford University – Hanson Experimental Physics Laboratory
- Stanford University - Stanford Linear Accelerator Center
- Texas A&M University – Kingsville
- University of Washington
- Washington University, St. Louis

France

- Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules
- Commissariat à l'Energie Atomique / Direction des Sciences de la Matière/ Département d'Astrophysique, de physique des Particules, de physique Nucléaire et de l'Instrumentation Associée

Italy

- Agenzia Spaziale Italiana (ASI), Science Data Center
- Istituto di Astrofisica Spaziale, (IASF, CNR)
- Istituto Nazionale di Fisica Nucleare (INFN)

Japan GLAST Collaboration

- Hiroshima University
- Institute for Space and Astronautical Science
- RIKEN

Swedish GLAST Consortium

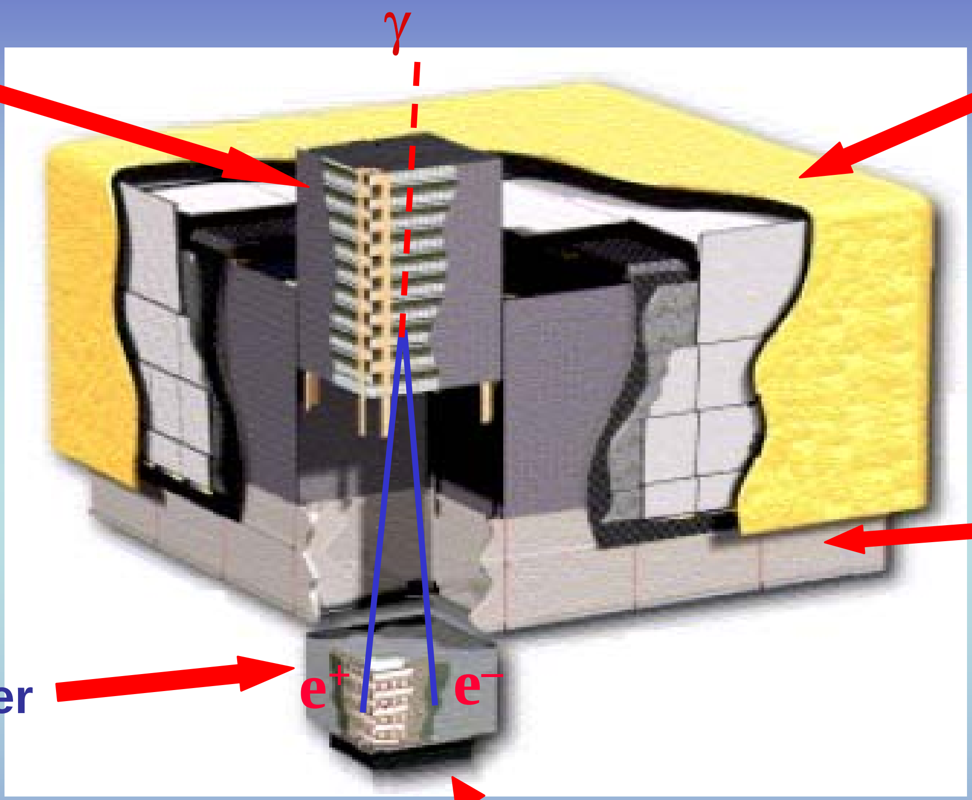
- Royal Institute of Technology (KTH)
- Stockholm University

126 Members (including 62 Affiliated Scientists)

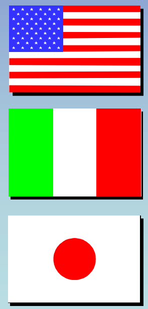
18 Postdoctoral Students

22 Graduate Students

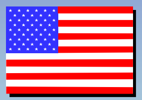
International contributions to the LAT



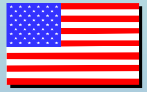
Si Tracker



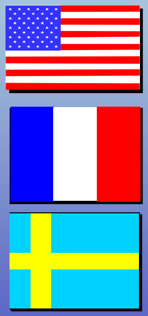
ACD



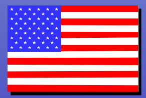
Grid (& Thermal Radiators)



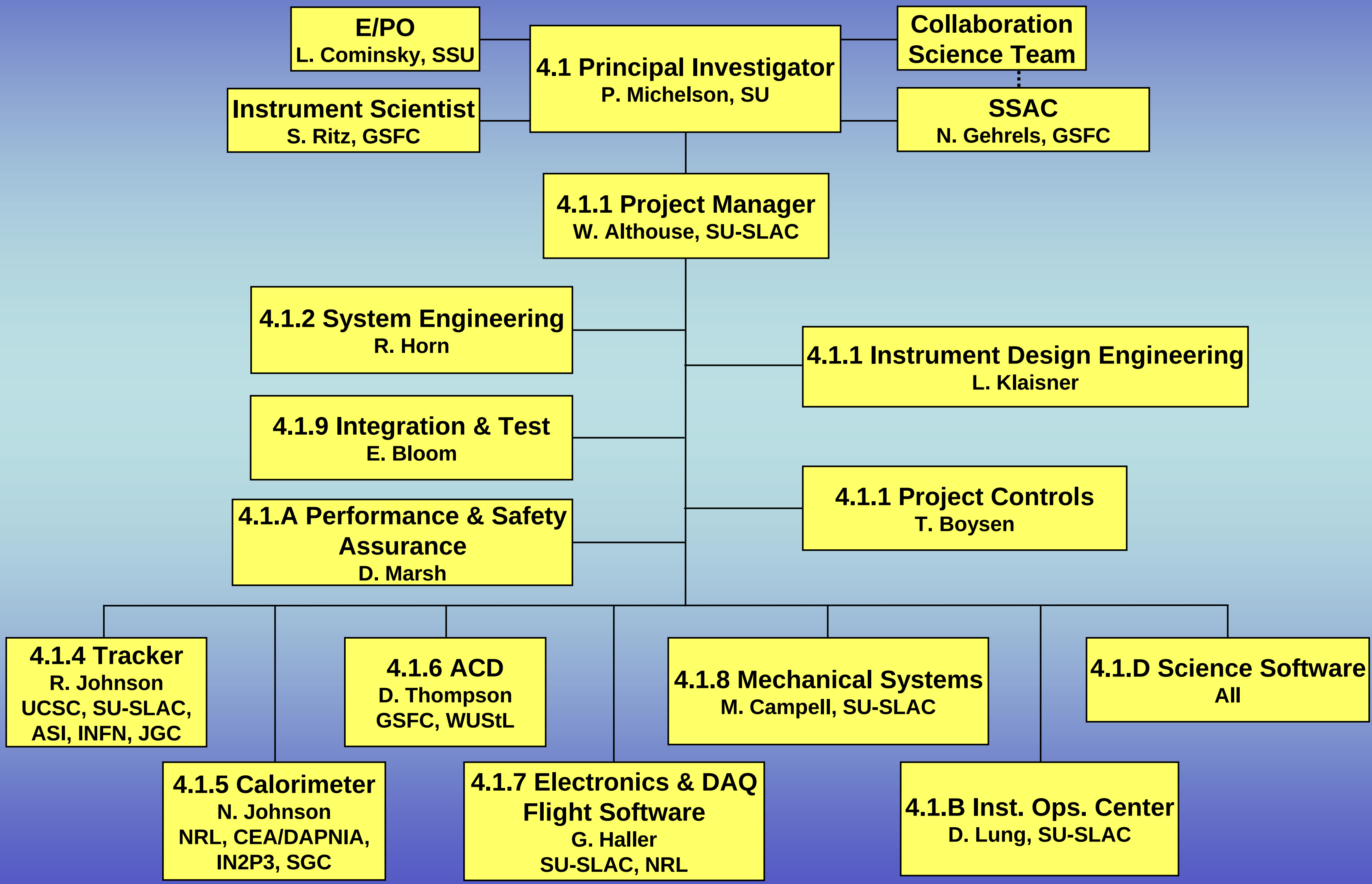
CsI Calorimeter



Electronics, Data Acquisition & Flight Software



GLAST LAT Organization



Collaboration Organization

Senior Scientist Advisory Committee

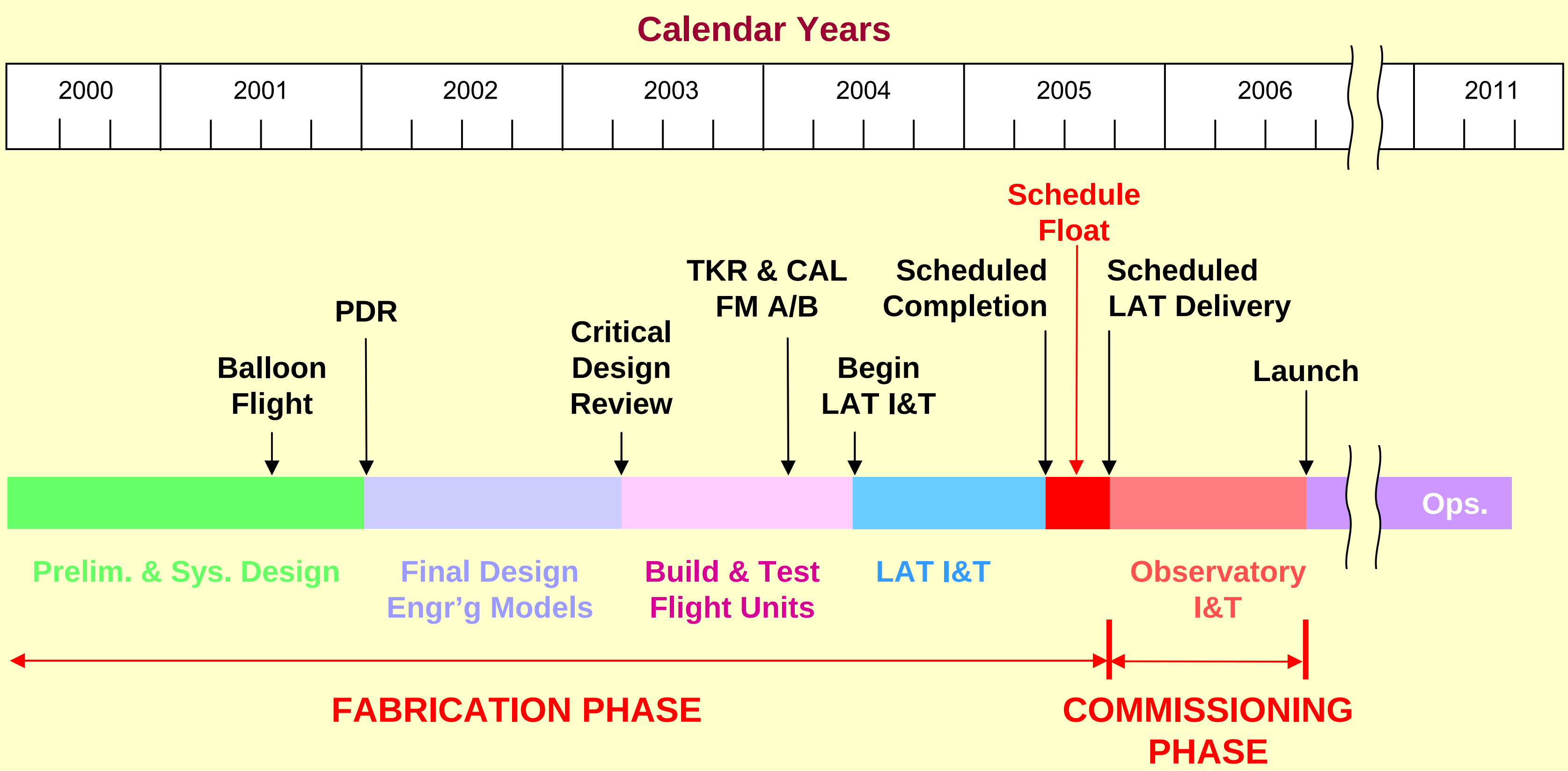
– membership

- N. Gehrels, Chair
- P. Michelson, PI/Spokesperson
- G. Barbiellini, Italy
- R. Bellazzini, Italy
- E. Bloom, U.S.
- T. Burnett, U.S.
- P. Carlson, Sweden
- R. Dubois, U.S.
- I. Grenier, France
- N. Johnson, U.S.
- R. Johnson, U.S.
- T. Kamae, Japan
- J. Ormes, U.S.
- S. Ritz, U.S.
- H. Sadrozinski, U.S.
- D. Smith, France
- D. Thompson, U.S.
- K. Wood, U.S.

SSAC Charter

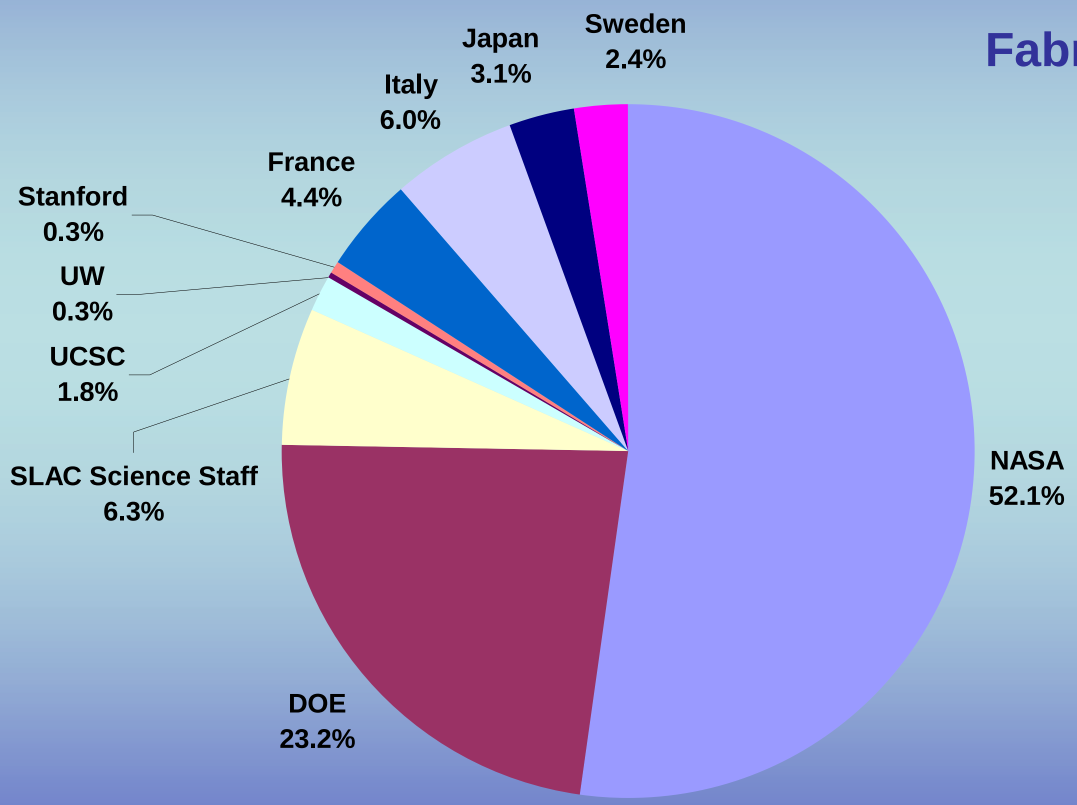
- **Advise PI/Spokesperson on the conduct of the LAT Science Investigation**
- **Implement collaboration membership policy and publication policy**
- **Advise PI and LAT Management on LAT design issues that critically impact science performance**
- **Meet monthly**

LAT Schedule highlights



GLAST scheduled for launch in September 2006

Fabrication Phase funding contributions



Fabrication Funding

TOTAL	=	$159.7M
DOE	=	$37.0M
NASA	=	$83.3M
US/Japan	=	$1.0M
Subtotal	=	$121.3M

International Memoranda of Agreement

MoAs between Stanford Univ-SLAC and:	Status
• INFN, ASI, Italy	pending signature
• IN2P3, France; NRL	√ signed
• CEA/DSM/DAPNIA, France; NRL	√ signed
• Royal Inst. of Technology & Stockholm Univ., Sweden; NRL	√ signed
• Hiroshima Univ., ISAS & RIKEN, Japan; UCSC/SCIPP	√ signed

Purposes of Agreements

- establish areas of responsibility and commitments to LAT Project (e.g. deliverables, science participation,)
- establish International Finance Committee to review status of commitments

Agreements available on Web:

www-glast.slac.stanford.edu/LAT-Details/MOAs/MOAList.htm

Status of Agency Level Agreements

Agreement:	Status
• NASA – Department Of Energy	√ signed
• NASA – CNES Agreement	pending signature
• NASA – ASI Agreement	pending signature
• NASA – Japan	draft in process
• NASA – Sweden	draft in process

LAT Project status summary and highlights for the next year

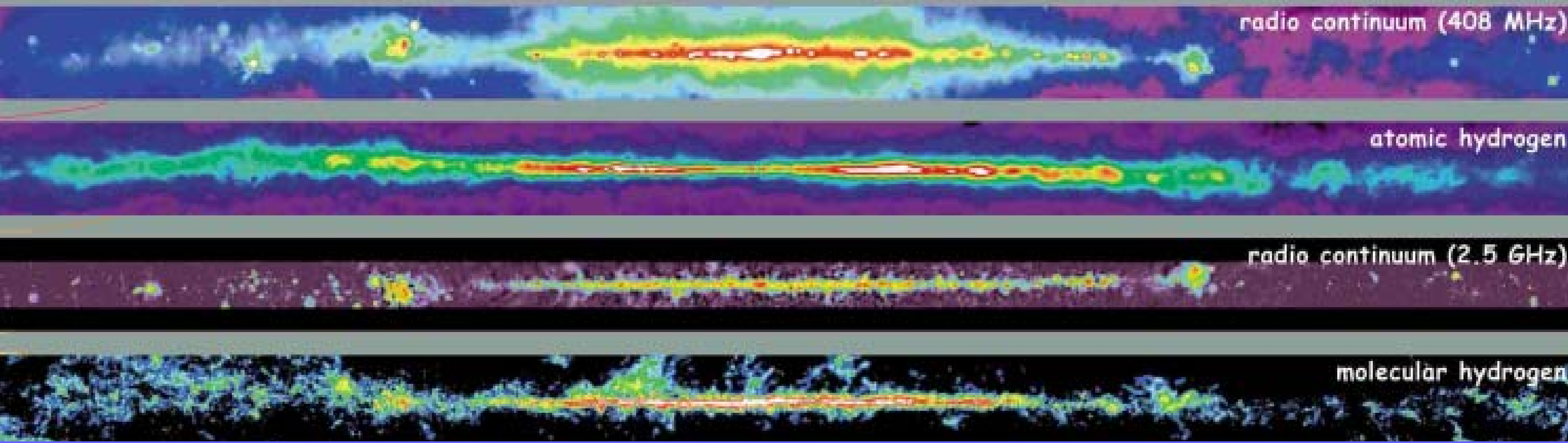
- **DOE Baseline Review / NASA PDR Review, January 2002**
  Delta Baseline–PDR Review, July 2002
  - LAT Project baselined; CD-2 approval (Nov 2002)

- **the transition from design to flight fabrication is currently underway**
  – engineering models being completed and evaluated
  – preparing for CDR/CD-3 DOE/NASA Review, May 12-16, 2003
    - completed subsystem peer reviews

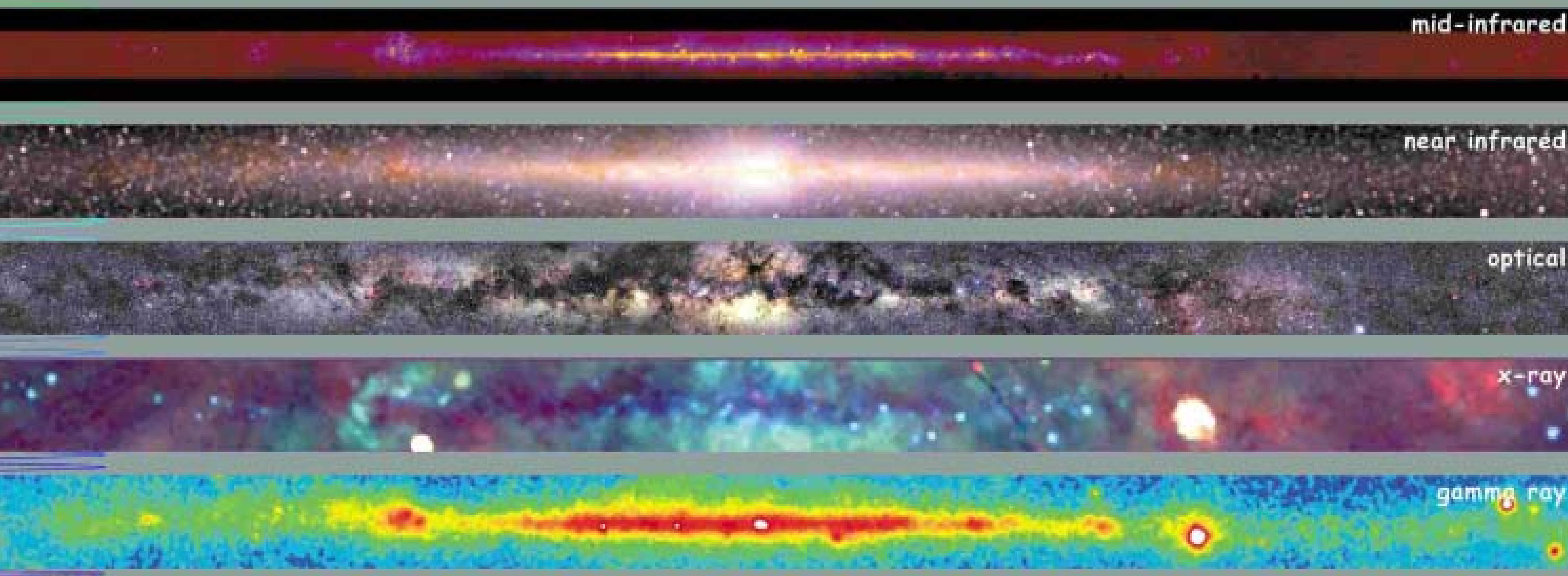
- **International Finance Committee formed to regularly review funding agency commitments – 1st meeting, February 18-19, 2003; next meeting scheduled for September 2003**
  – international partners have been delivering on commitments
  – 03' funding commitments are particularly critical to maintaining schedule

- **first flight hardware deliveries to SLAC scheduled for February-March, 2004**
  – first 4 calorimeter and tracker modules will be integrated into Calibration Unit (CU)
  – LAT Grid delivered June 2004 – LAT integration begins

- **collaboration meeting planned for Sept 15-19, 2003 in Rome, Italy**
  – meeting will concentrate on collaboration plan for operations phase: instrument operations, science data analysis, etc.



GLAST Science Opportunities



Questions addressed by high-energy gamma-ray observations

- What are the mechanisms and sites of cosmic-ray generation (acceleration)?
- What are the unidentified sources of high-energy radiation revealed by the Compton Observatory?
- What are Gamma-Ray Bursts?
- What is the origin of the apparently isotropic, diffuse extragalactic gamma-ray background?

Collaboration Science Working Groups

I. <u>Working Group I: Extended Sources and Diffuse Radiation</u>
Galactic Diffuse Radiation and Emission from Normal Galaxies
Gamma-ray Emission from Molecular Clouds
Cosmic Ray Acceleration and Gamma-ray Emission from SNR shells and Plerions
High-Energy Emission from Galaxy Clusters

II. <u>Working Group II: Galactic Sources and Unidentified Sources</u>
Particle Acceleration and Gamma-ray Emission in Pulsars and Binary Systems
Unidentified Sources: Population Studies
Unidentified Sources: Radio/optical/X-ray identifications
High-Energy Emission from Stellar-Mass Galactic Black Hole Candidates
The Galactic Center

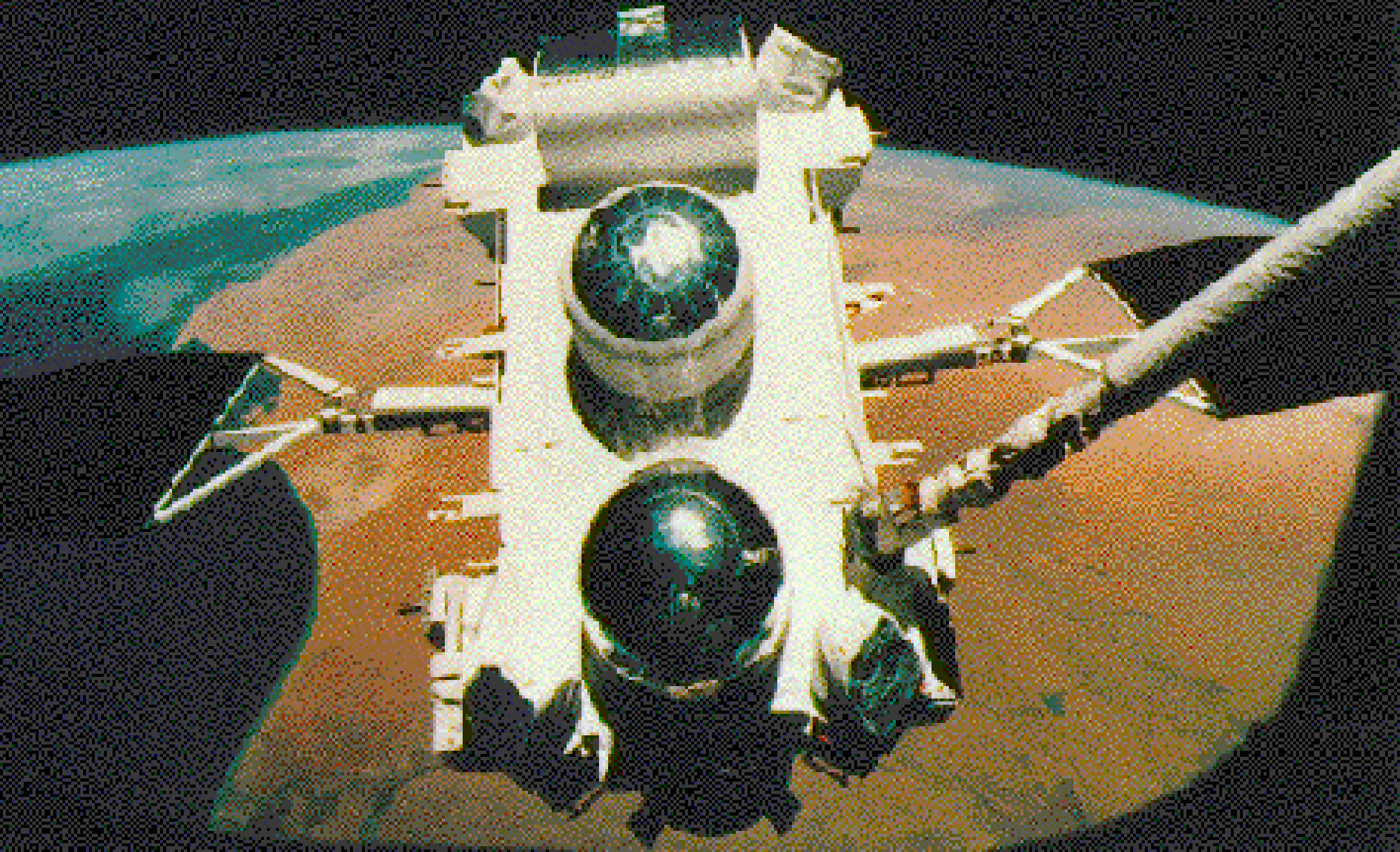
III. <u>Working Group III: Extragalactic Sources</u>
Extragalactic Diffuse Radiation and LogN-LogS of Extragalactic Sources
Gamma-ray Emission Mechanisms in Blazar AGNS
Cosmic Evolution of AGN Blazars and Spectral Cutoffs: Population and EBL Studies
High-Energy Emission from Seyfert galaxies and Radio galaxies

IV. <u>Working Group IV: Searches for New Physics</u>
Searches for Dark Matter
Search for Signatures of Quantum Gravity
Search for Primordial Black Hole Evaporation

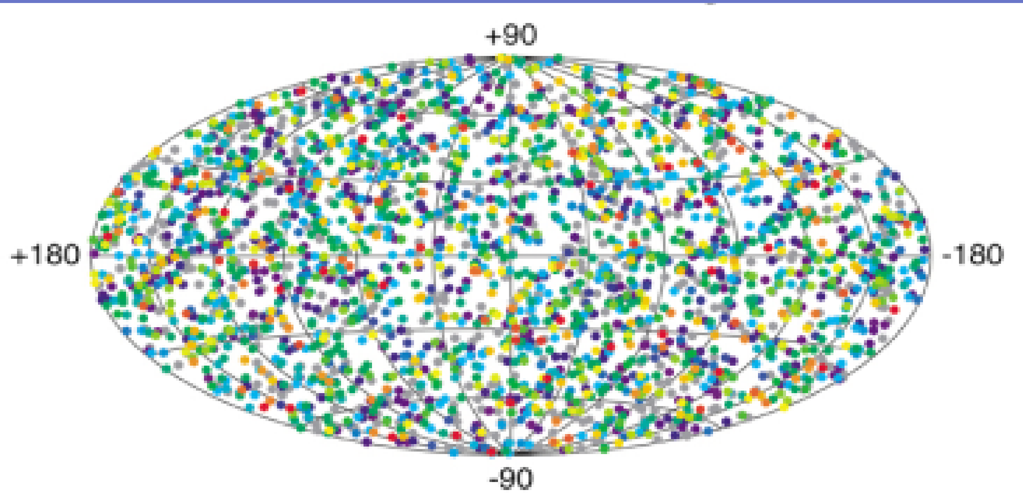
V. <u>Working Group V: GRBs and Solar Flares</u>
Gamma-Ray Bursts: Testing emission models; afterglows and multiwavelength observations
Solar Flares

Compton Gamma-Ray Observatory

April 5, 1991 - June 4, 2000



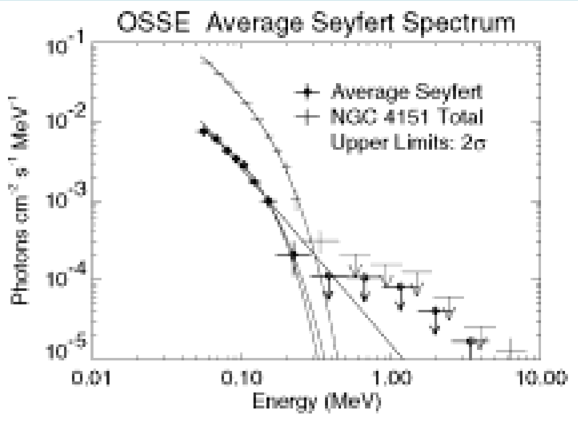
CGRO – Science Legacy



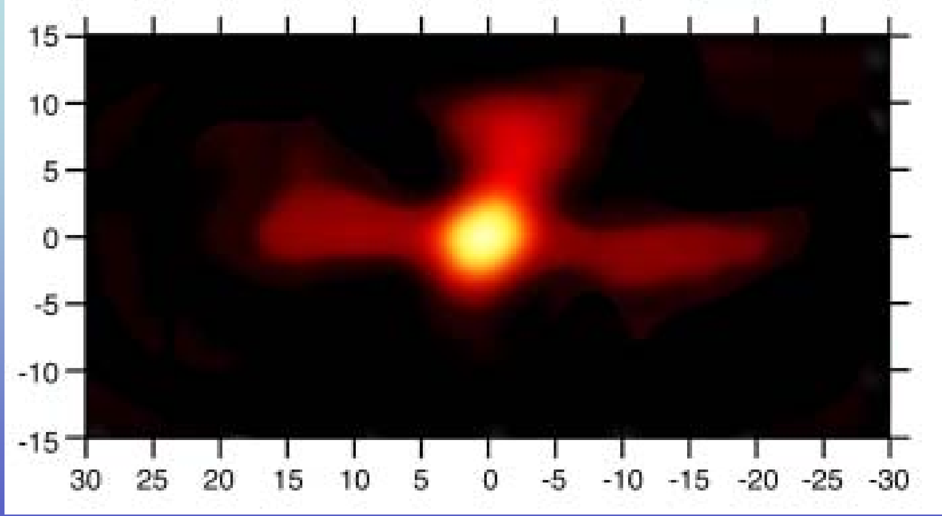
BATSE

2704 gamma-ray bursts: isotropic distribution

OSSE



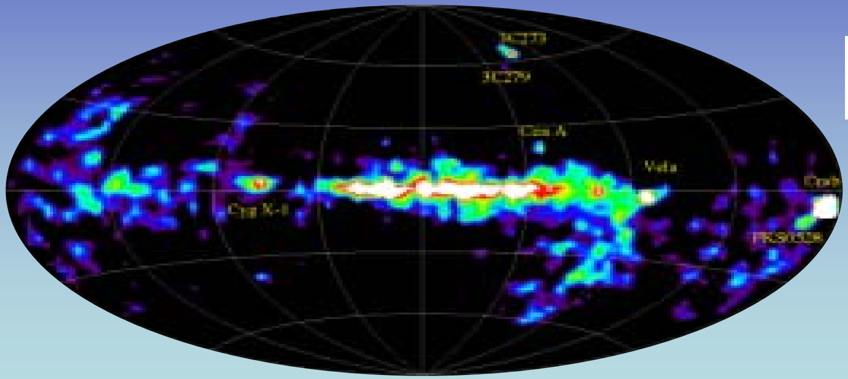
average spectrum of Seyfert galaxies



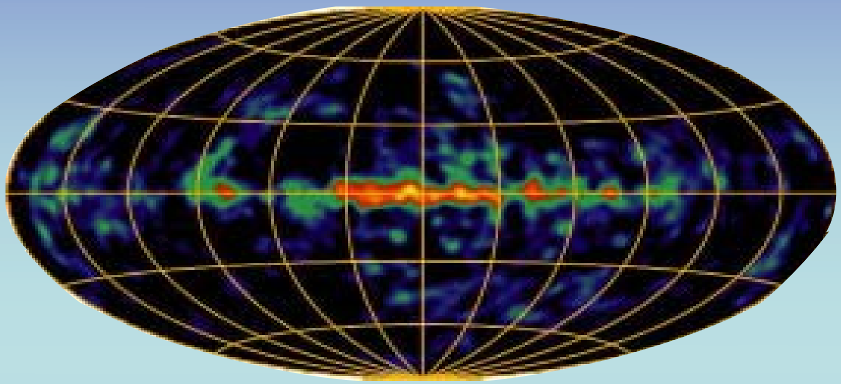
map of the Galactic center at 511 keV

CGRO – Science Legacy

COMPTEL

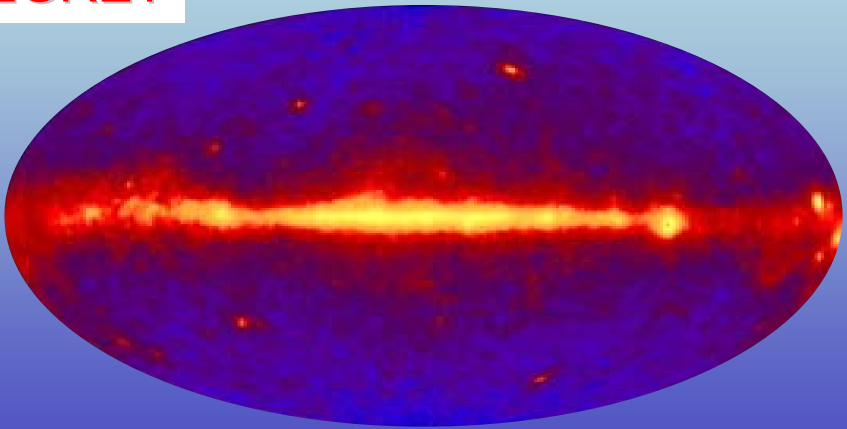


1-30 MeV map of Galaxy



Al^{26} map of Galaxy - 1.809 MeV relic of Galactic nucleosynthesis over past few million years

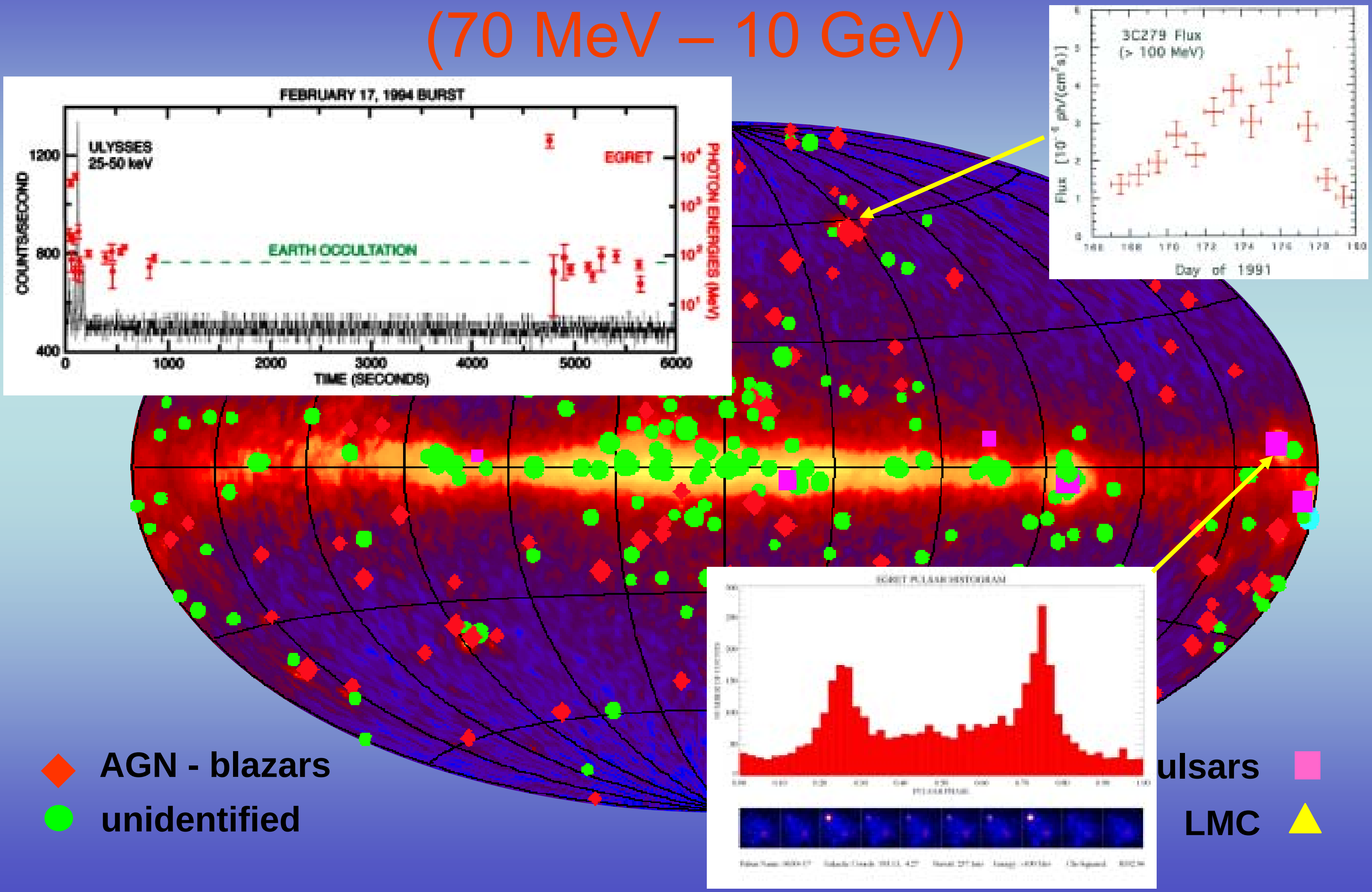
EGRET



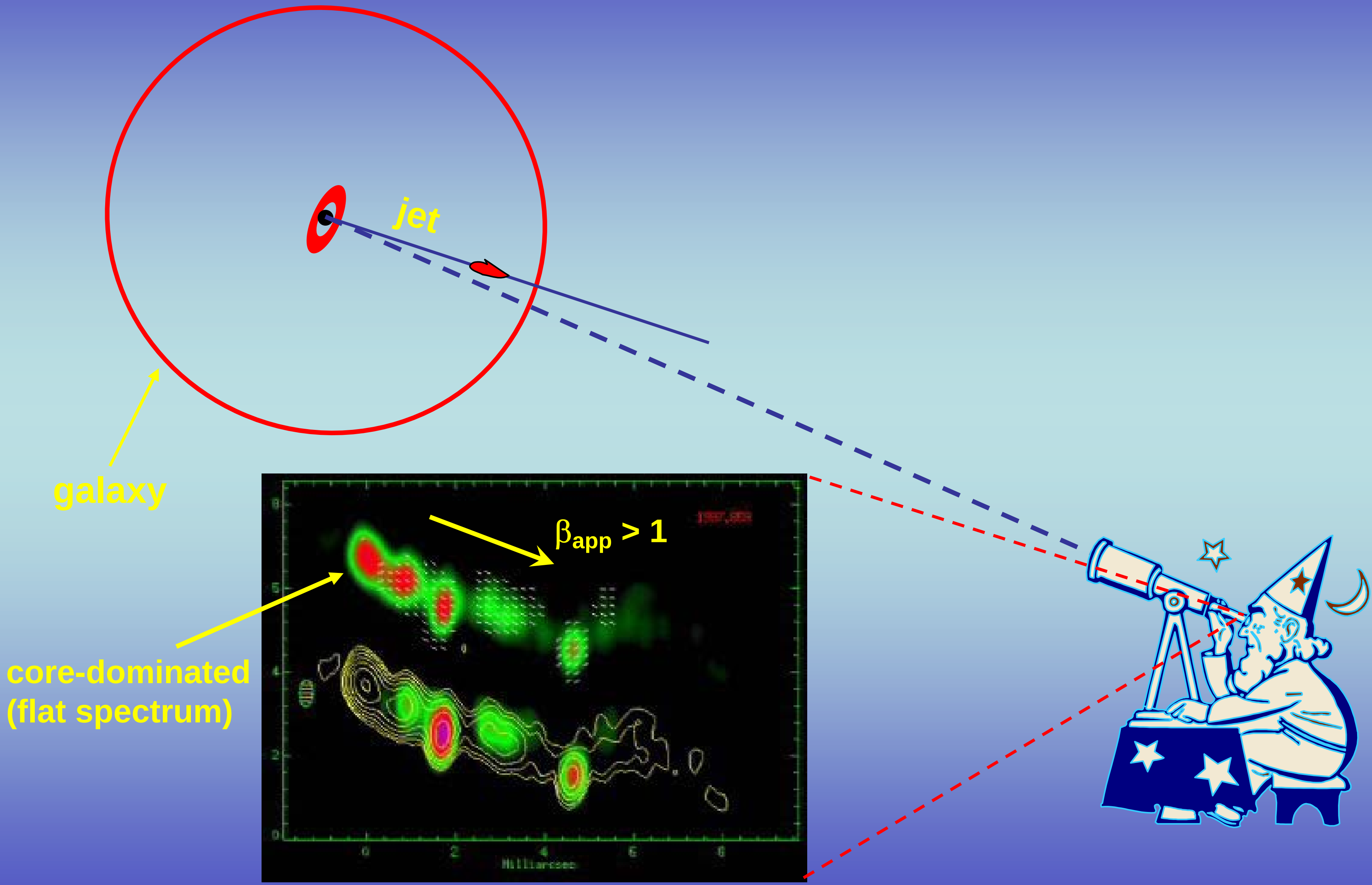
All-sky survey
(70 MeV – 10 GeV)

EGRET all-sky survey

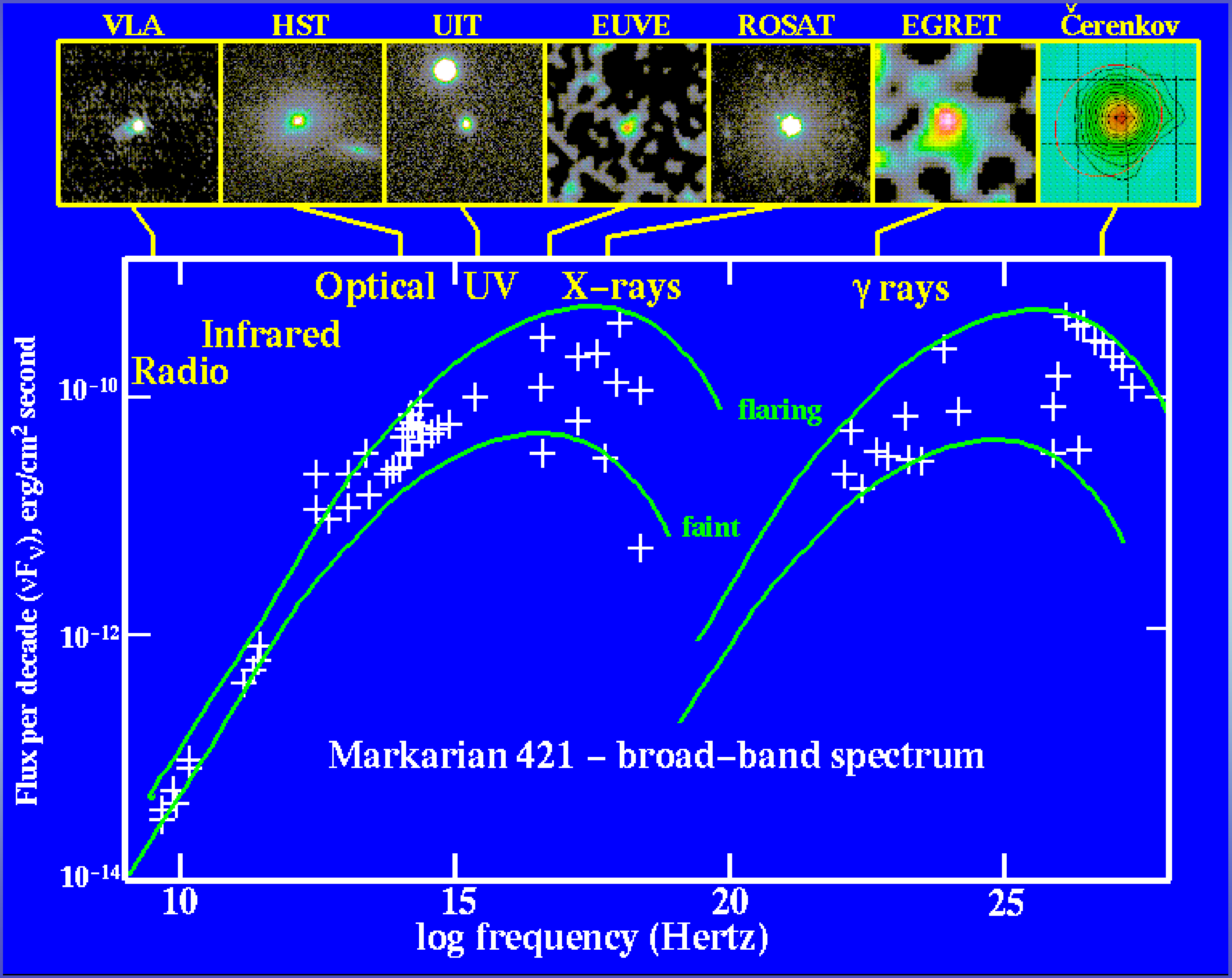
(70 MeV – 10 GeV)



AGN-Blazar geometry

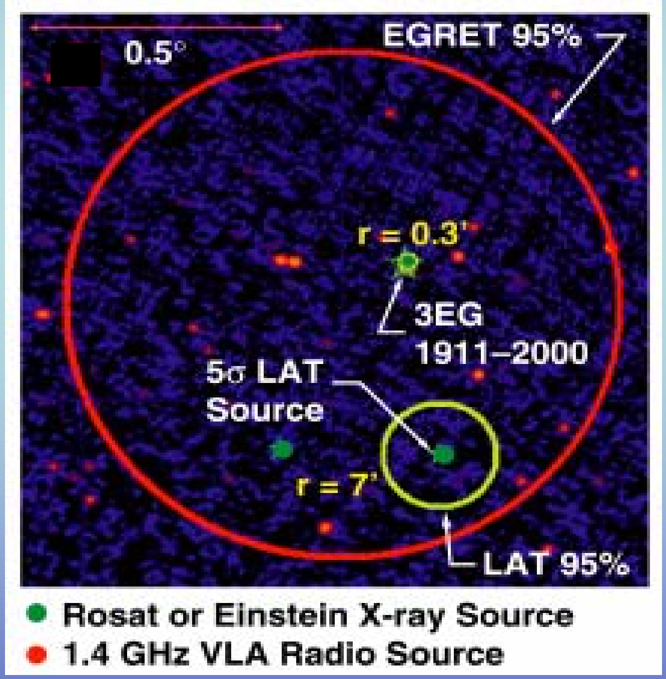


VLBA Observations of 3C120 (Gomez, et al)


VLA
HST
UIT
EUVE
ROSAT
EGRET
Čerenkov
Optical
UV
X–rays
γ rays
Infrared
Radio
flaring
faint
Markarian 421 – broad–band spectrum
Flux per decade (νFν), erg/cm² second
10⁻¹⁰
10⁻¹²
10⁻¹⁴
10
15
20
25
log frequency (Hertz)

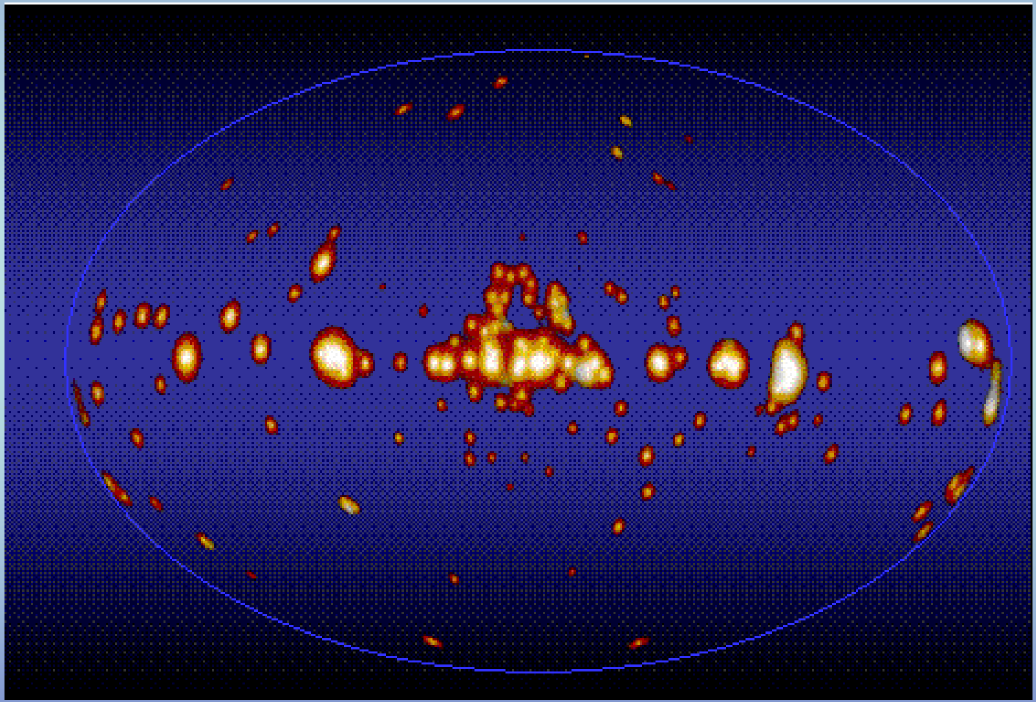
LAT science capabilities - resolution

source identification requires a multiwavelength approach
- **localization**
- **variability**



source localization (68% radius)

- γ-ray bursts: 1 to tens arcminutes
- unid EGRET sources: 0.3' – 1'

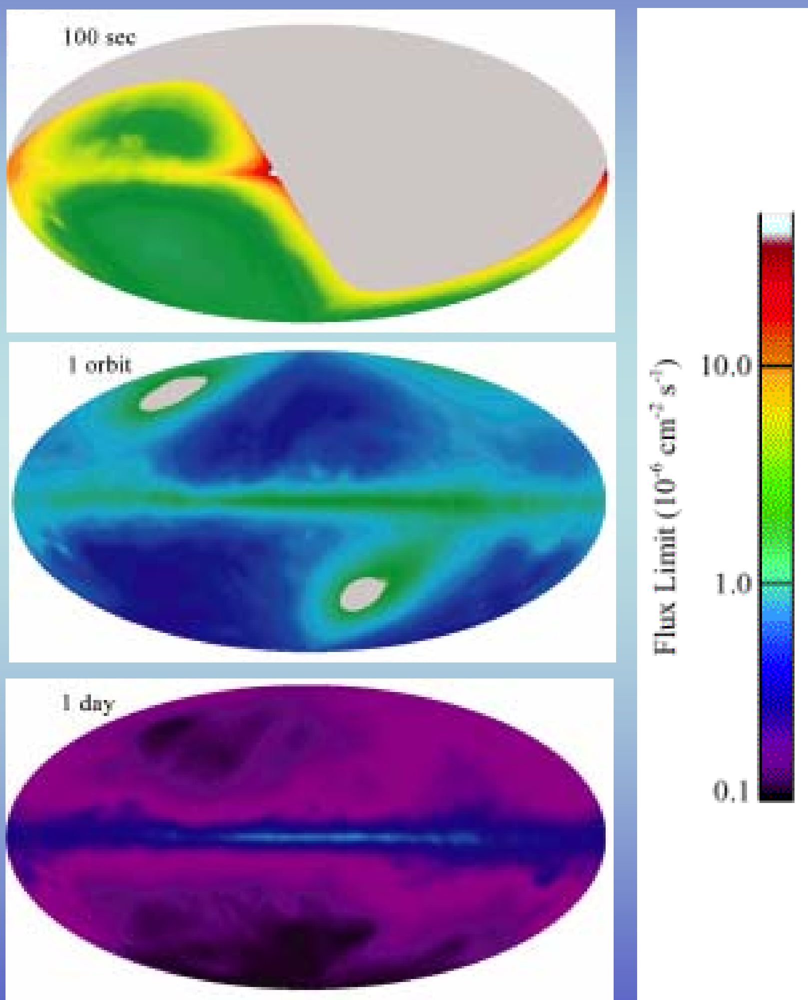


Unidentified EGRET sources

evidence for at least 2 unidentified Galactic populations
time variable Galactic population
persistent Gould belt population

LAT science capabilities – transient sensitivity

enabling LAT capabilities
- **wide field-of-view**
- **low deadtime (for light curve)**



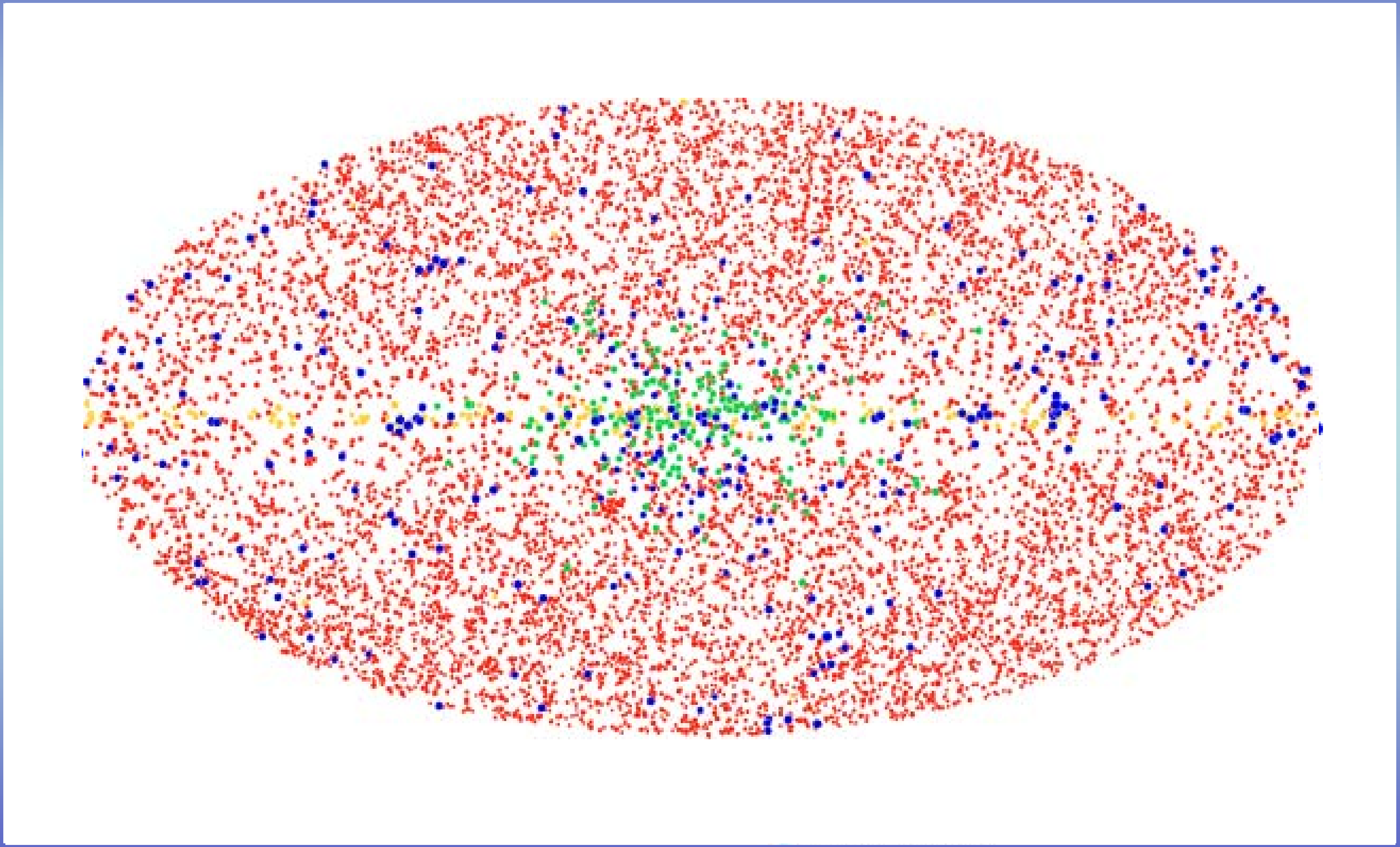
- **GRB940217 (100sec)**
- **PKS 1622-287 flare**
- **3C279 flare**
- **Vela Pulsar**

- **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**

detect all EGRET sources after ~day
~200 γ-bursts/year
AGN flares >few minutes

GLAST Survey: ~10,000 sources (2 years)

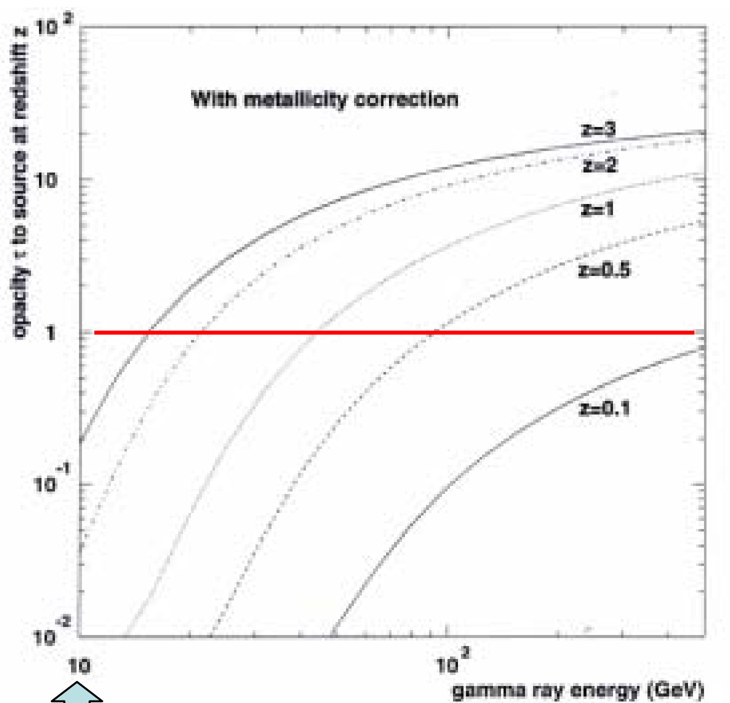


Constraints on extragalactic background light (EBL) from high-redshift γ-ray blazars

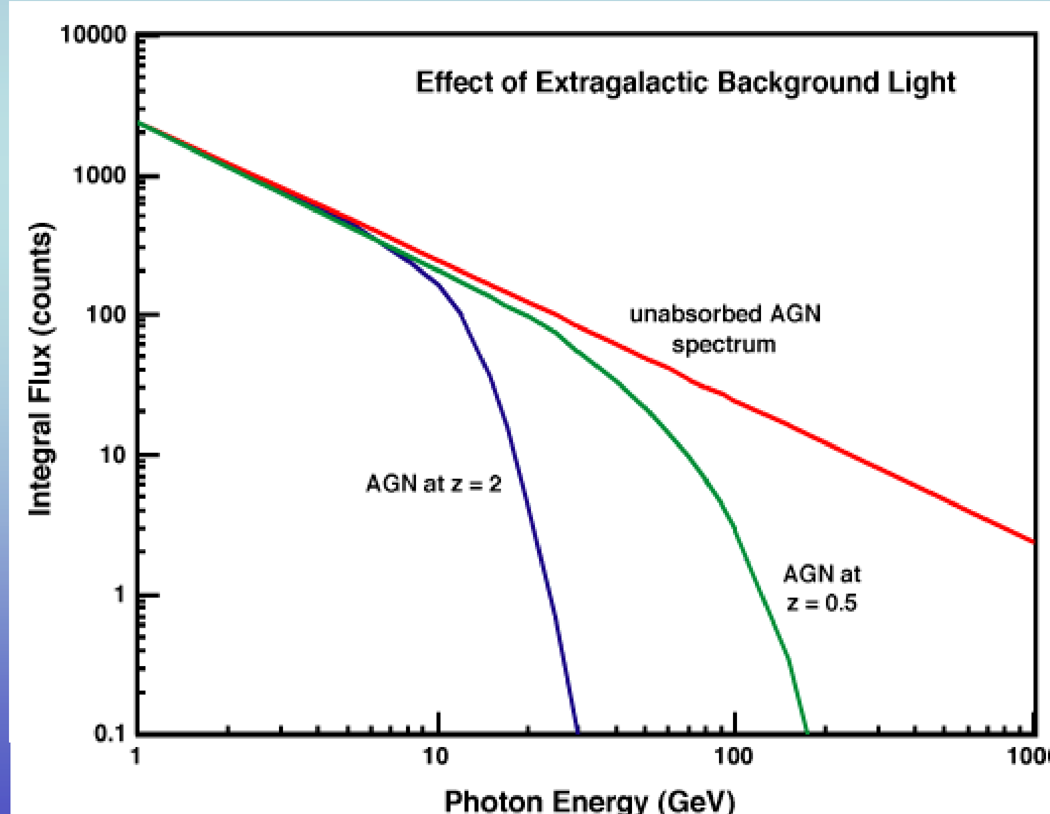
EBL: - indicator of integrated luminosity of the universe
- can provide unique information on origin of structure at early epochs

photons with E>10 GeV are attenuated by the diffuse field of UV-Optical-IR extragalactic background light (EBL) $\gamma + \gamma \rightarrow e^+ + e^-$

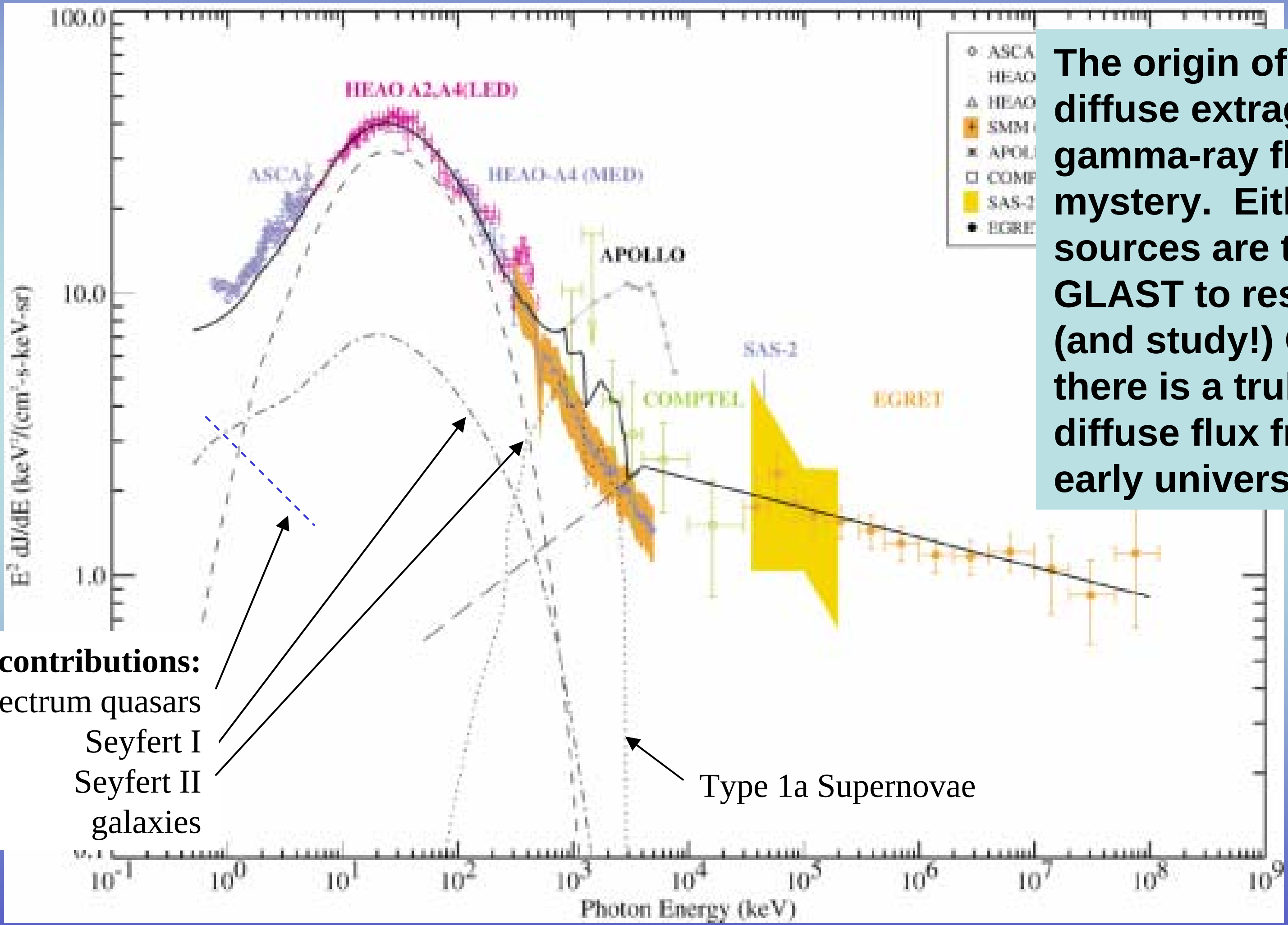
Salamon & Stecker, ApJ 493, 547 (1998)



No significant attenuation below 10 GeV



high-energy isotropic diffuse radiation from x-rays to gamma-rays



The origin of the diffuse extragalactic gamma-ray flux is a mystery. Either sources are there for GLAST to resolve (and study!) OR there is a truly diffuse flux from the early universe

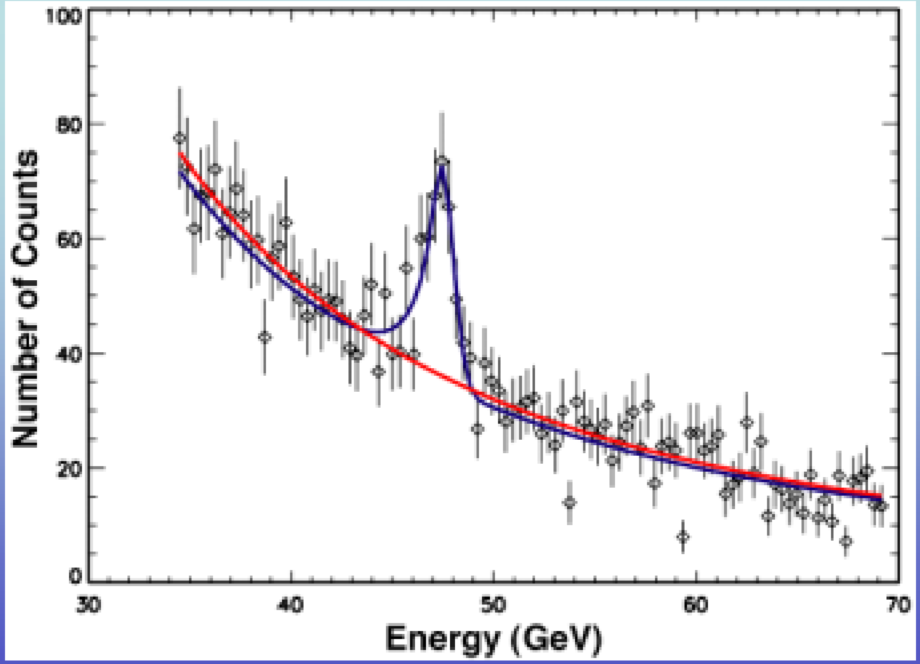
Estimated contributions:
Steep-spectrum quasars
Seyfert I
Seyfert II galaxies

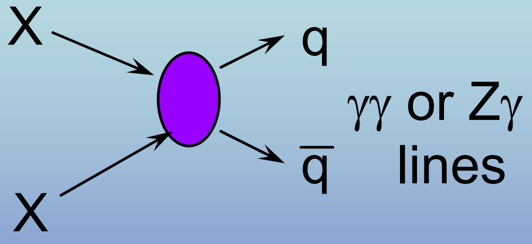
Type 1a Supernovae

discovery potential: dark matter

Some important models in particle physics could also solve the dark matter problem in astrophysics. If correct, these new particle interactions could produce an anomalous flux of gamma rays.

- Identify relatively narrow spectral lines
  - Requires energy range with response to at least 300 GeV
  - Requires spectral resolution:
    5% at energies above 10 GeV (goal of 3%)





e.g. halo WIMP annihilation

discovery potential: large extra dimensions

"GLAST is a new dimension search engine"

- Savas Dimopoulos, March 1, 2003

- theories with large (submillimeter) extra dimensions: alternative way to solve the hierarchy problem of particle physics
  - move the Planck scale to near the weak scale
  - observed weakness of gravity due to presence of *n* new spatial dimensions large compared to electroweak scale

    (Arkani-Hamed, Dimopoulos & Dvali 1998)

- Recently, Hannestad & Raffelt (2002) pointed out that SNe would produce Kaluza-Klein gravitons that are generic for these theories
  - produced non-relativistically, so many are gravitationally bound to SN core (i.e, neutron star) $\rightarrow$ KK particle halo
  - KK gravitons decay ($\tau \sim 10^9$ years) to $\nu\nu$, e^+e^-, and $\gamma\gamma$

discovery potential: large extra dimensions

- Constraints from EGRET observations (Hannestad & Raffelt 2002):

  γ-ray flux limits for nearby NS limit compactification scale
  ≥ 500 TeV (n=2)
  ≥ 30 TeV (n=3)

- GLAST will have point source sensitivity of ~ 1.5 x 10^{-9} ph cm^{-2} s^{-1}

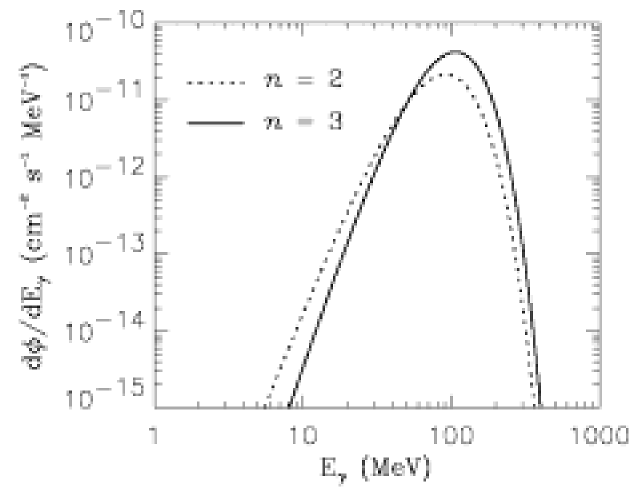


FIG. 2. The γ-flux from RX J185635-3754 for $f_{KK} = 10^{-7}$ and an assumed SN core temperature of 30 MeV.

corresponds to $f_{KK} = 10^{-7}$, where f_{KK} is the fraction of SN energy emitted as KK gravitons

GLAST:

Exploring Nature's Highest Energy Processes

September 2006 launch