



# Fermi in Context

**Roger Blandford**  
**KIPAC**  
**Stanford**

# Historical Context

- **Early Prophets**

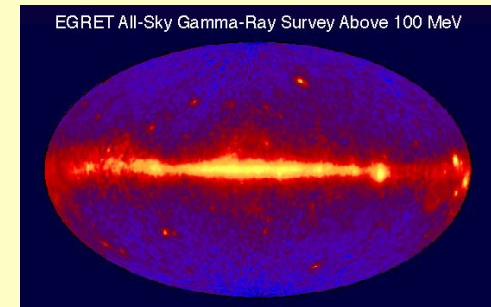
- Compton, Fermi, Feenberg, Primakoff...
- Hayakawa, Hutchinson, Jelley, Morrison, Fazio, Weekes...

- **Early Telescopes**

- OSO3, 7, SAS-2, COS-B, SMM, HEAO-1, 3...
- Vela, IPN, Venera, PVO, Beppo-SAX, HETE-2...
- Whipple, VERITAS
- CGRO, INTEGRAL, AGILE...

- **Early Sources**

- Earth, Sun, Galactic Plane, SNR, GRB, Blazars, Pulsars, Magnetars...



**Gamma-ray astronomy has a long history of successful instruments making discoveries and validating basic physics**

# Mission Context

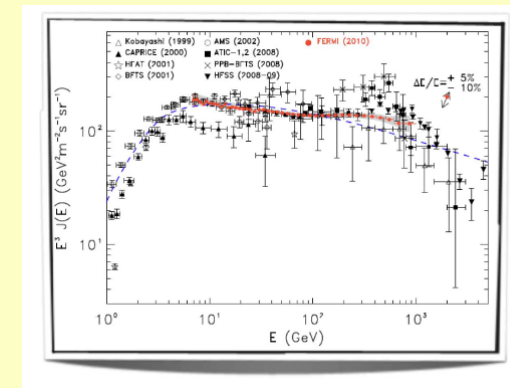
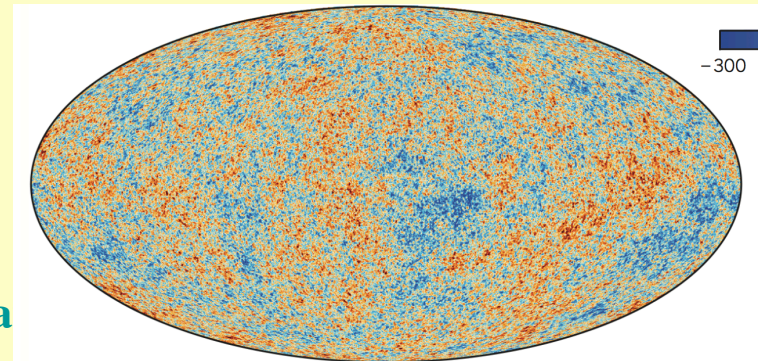
- **Launch June 2008**
  - “No drama” spacecraft
    - LAT/GBM/data systems robust
  - **Huge field of view**
    - 20,000 looks at sky, every 3hr
    - Survey mode like SDSS, LSST
  - **Long term monitoring**
    - (Quasi) Periodicity, eg PG1553+113
- **Pass 8 - June 2015 (upgrades already!)**
  - **30 percent acceptance increase**
    - New ROIs
  - **1-100 GeV transformed; no background > 50GeV**
    - impact <100 MeV



**Fermi planned, deployed and executed extraordinarily well**  
**Harmonious international collaboration**

# Cosmological Context

- **Discovery**
  - Expansion, Quasars, CMB...
- **Measurement**
  - Radio, Galaxy Surveys, CMB...
- **Standard Model**
  - Cosmological constant, dark matter, IGM, radiation
- **Dark Matter**
  - WIMPs, Axions, ALPs, gravity...
  - LHC, direct, indirect searches
  - Backgrounds, Galactic center, clusters, dwarf galaxies...
  - Galactic center too complex for confident detection?
  - 50->500 dwarfs?? Exclude simplest thermal relic model?
- **Extragalactic Background Light**
  - Gamma ray observations forced revision of galactic evolution models
  - Absorption seen and measuring EBL
  - Probe magnetic field, heat IGM?, seek new physics



**Accurate Fermi measurements electron (positron) spectra,  $\gamma$ -ray backgrounds and putative sources have contributed immensely to limiting the nature of dark matter**

# Survey Context

- Accurate catalogs last decades/centuries
  - Hipparchus, Messier, Herschel (NGC)...

- 3CR, IRAS, SDSS

- Fermi catalogs

- 3FGL 4 year ~ 3000 sources

- Pass 8

- 3LAC

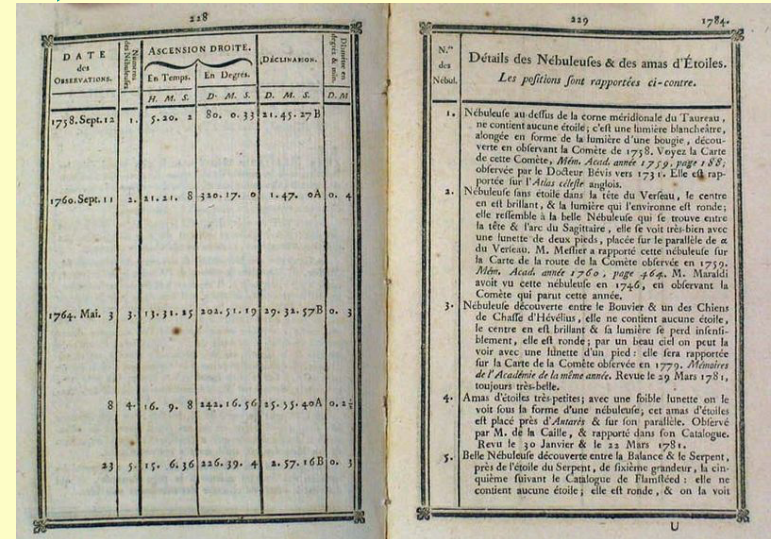
- ~ 1500 AGN

- 2FHL

- >50 GeV, 360 sources

- GRB

- GBM- 1000s, LAT -100

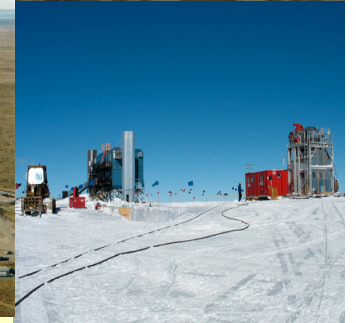
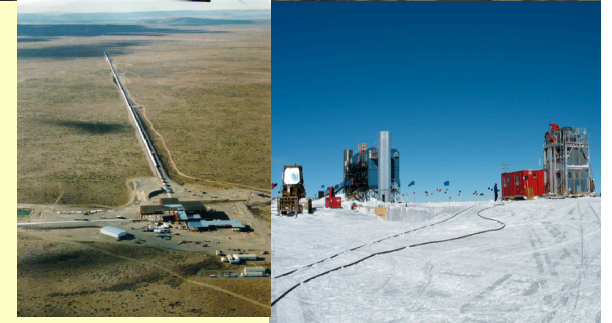


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00 03 25.8	+31 00 30.6	6.295	3.14e-10
00 03 33.6	+57 21 34.88	5.381	4.72e-10
00 03 50.09	-11 51 45.68	4.181	2.34e-10
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Careful, systematic cataloging by Fermi has brought gamma ray astronomy into mainstream

# High Energy Context

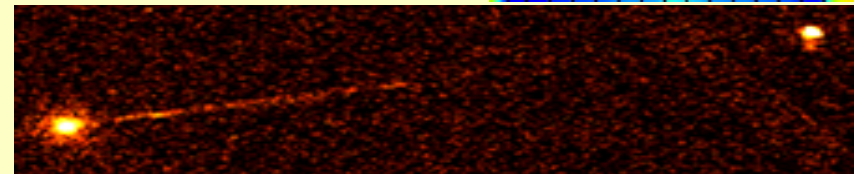
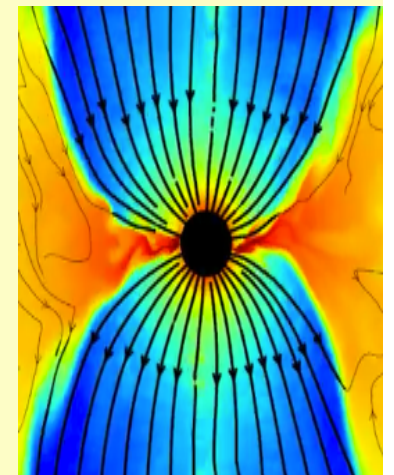
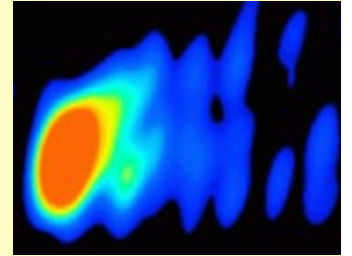
- **HESS, MAGIC, VERITAS** similar sources
  - Complementary observations of similar sources
  - Dark matter, new physics, extreme astrophysics
  - **HAWC**
    - Widefield, high energy
  - **CTA**
    - Two sites; low, medium high arrays; telescopes soon
- **IceCube**
  - **>100 x PeV cosmic neutrinos**
    - No statistical, positional, temporal identifications yet
- **Gravitational Radiation**
  - **A-LIGO, Virgo, Geo...**
    - Expecting to see NS-NS coalescences (short GRBs?), hoping for BH-BH



**Scientific boundary between GeV and TeV astrophysics  
is rapidly disappearing  
Need stronger bridge to keV astrophysics through MeV**

# Relativistic Jet Context

- Commonly made by spinning BH, NS, AD
  - Fringes to  $\sim 10\text{m}$  in M87
    - EHT
  - Simulations validate extraction, collimation stability
    - $10^5\text{ m}$
  - EM dominated  $\rightarrow$  equipartition?
    - Where and how?
- Organized MW studies
  - Polarimetry
    - Infrared, circular?
  - Distributed emission along jet
    - Gammasphere
    - Gamma rays within radio



Fermi observations are "central" to understanding composition, speed and particle acceleration

# Particle Acceleration Context

- **Cosmic rays**

- TGF, Solar, Tevatrons, Pevatrons, Zevatrons

- Fermi 2, shocks

- SNR -> electrons, magnetic field, protons
- Hadronic vs Leptonic

- **Relativistic sources**

- Shocks, reconnection

- PIC simulations

- Electrostatic acceleration

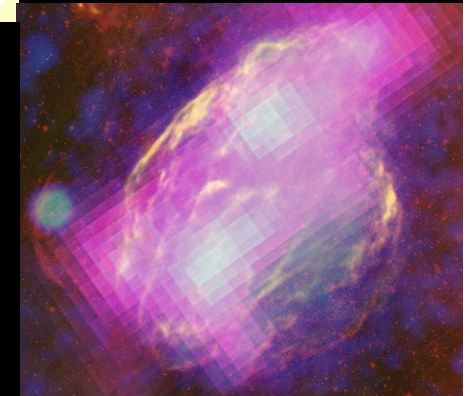
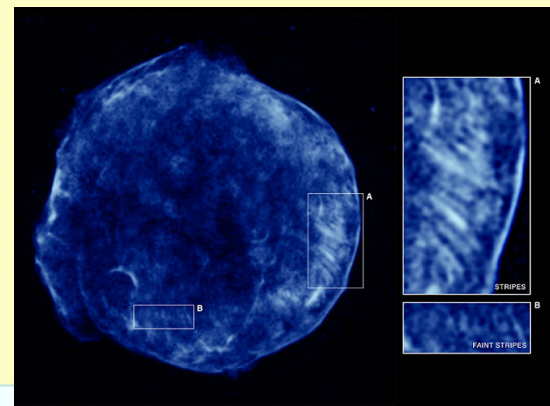
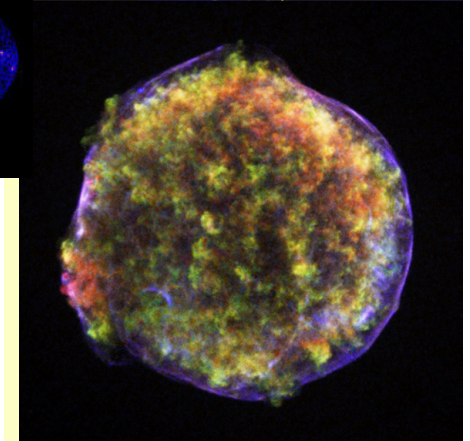
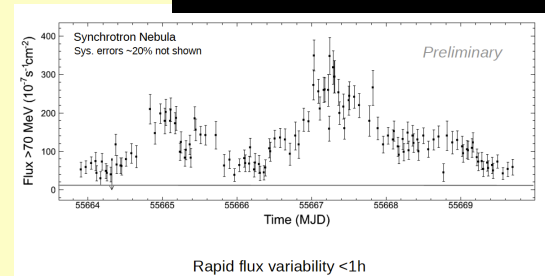
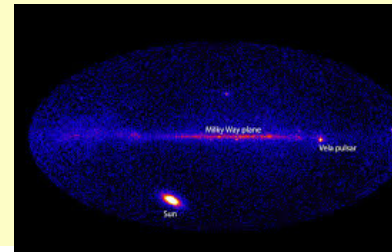
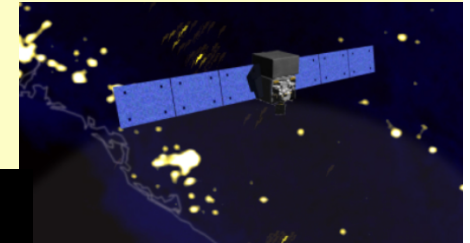
- Pulsars-PV, AGN-EV, GRB-ZV

- **Flares**

- Crab Nebula hr variation

- TeV blazars minute variation

- GRB 10 ms variation

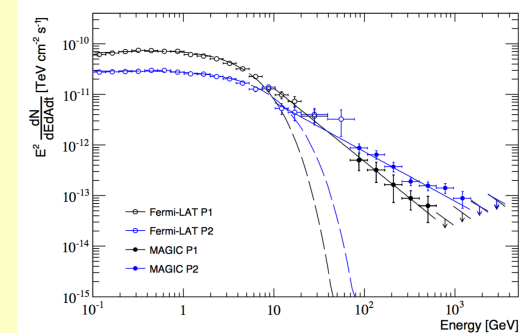
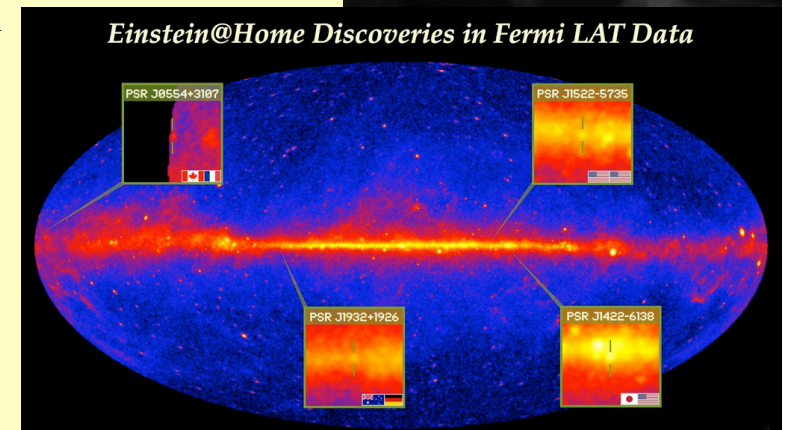
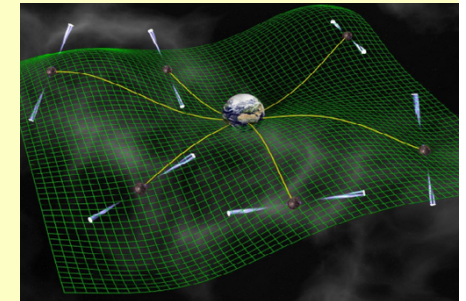


**Dramatic flares observed by Fermi, TeV telescopes demand radically new particle acceleration mechanisms**



# Neutron Star Context

- X-ray binaries and radio pulsars
  - Astrophysical sources and tools
    - MSPs, magnetars/AXPs, black widows/reddbacks, Be binaries
    - Radio tests of general relativity
    - Pulsar timing array for gravitational radiation
    - Hard equation of state
- Pulsar finder and timer
  - ~200 Pulsars
    - Pass 8 observing to high energy
- Probe of magnetosphere physics
  - Most of pulsed power
  - Infer emission sites
    - Near light cylinder
  - Crab pulses to 1.5 TeV
    - Emission mechanism



**Fermi's multiple contributions to neutron star physics have been its biggest surprise relative to expectations**

# Public Context

- Public outreach never more important than today
  - Widespread confusion and mistrust about science
    - Problem solver not fashion statement
- Fermi is easy to “communicate”
  - MBH, GRB, Pulsars, Sun...
- Great teaching tool
  - K through gray
    - Dark matter
    - Electromagnetic spectrum
    - Extreme astrophysics
    - Gravity
- Public participation in science increasing
  - Monitoring, Galaxy zoo, Einstein@ home, database fishing...



**Imperative that this activity continue to be supported**

# Future Context

- **Transients**
  - **Gravitational waves, VHE vs, FRBs, optical transients**
    - Temporal associations as well as positional
- **TeV connection**
  - **HAWC, CTA...**
    - Bridged gap, integrated studies
- **Dwarf Galaxies**
  - **DES, LSST >300?**
    - Best prospects for upper limits, discovery, follow up
- **Discovery Space**
  - **New source classes from catalogs**
  - **New physics – LI/QED, DM, acceleration...**



**Gamma-ray astronomy is still a young science and most discovery in physics and astronomy was unscripted**