LIVE INTERACTIVE LEARNING @ YOUR DESKTOP

NASA/NSTA Web Seminar Series

How Telescopes Have Changed Our View of the Universe

Webinar I: **Anti-matter Eyes on the Gamma-ray Skies**

Presenter: **Dr. Lynn Cominsky**

November 12, 2009

6:30p.m. – 8:00p.m. Eastern Time

Agenda:

1. Introductions
2. Tech-help info
3. Web Seminar tools
4. Presentation
5. Evaluation
6. Chat with the presenters

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Supporting the Presenting Team is…

For additional Tech-help call:

Elluminate Support,

1-866-388-8674 (Option 2)

Jeff Layman
Tech Support
NSTA
jlayman@nsta.org
703-312-9384

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Elluminate Live! - NSTA DEV

File Session View Tools Window Help

Participants

Participants

Paul Tingler (Moder...

1 Participant

Chat

Show All

Joined on September 17, 2009 at 9:37 AM

Send to This Room

Audio

Ctrl+F2

Teleconference available

Whiteboard - Main Room (Scaled 61%)

5/16 NSTA WS Staff

Follow Moderator

Roam

We would like to know more about you…

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In session for 2 minutes.

We would like to know more about you…

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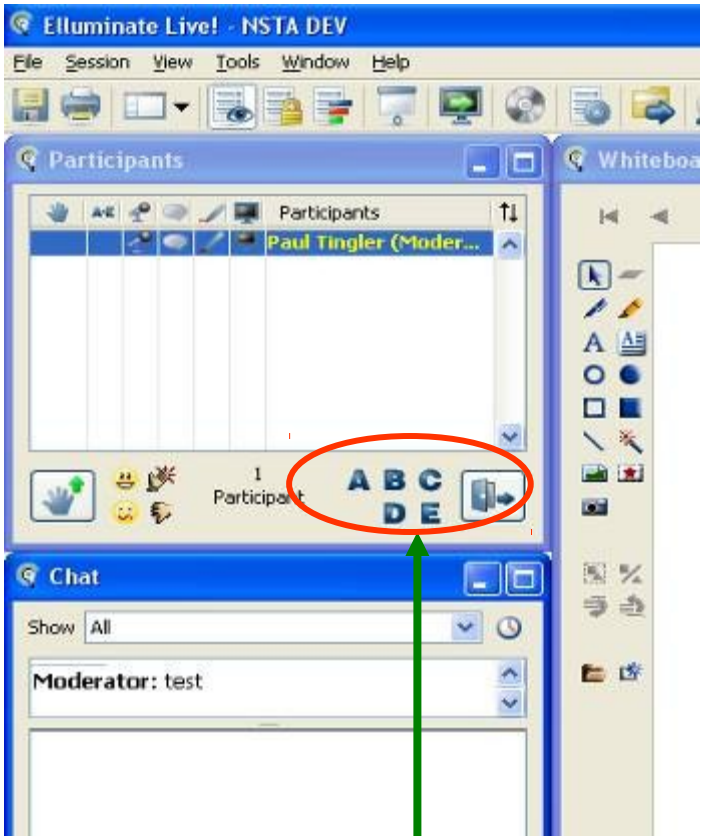
How many NSTA web seminars have you attended?



A. 1-3

B. 4-5

C. More than 5

D. More than 10

E. This is my first web seminar

Use the letters A-E located at the bottom right of the participant window to answer the poll.

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How many NSTA web seminars have you attended?

A. 1-3

B. 4-5

C. More than 5

D. More than 10

E. This is my first NSTA web seminar

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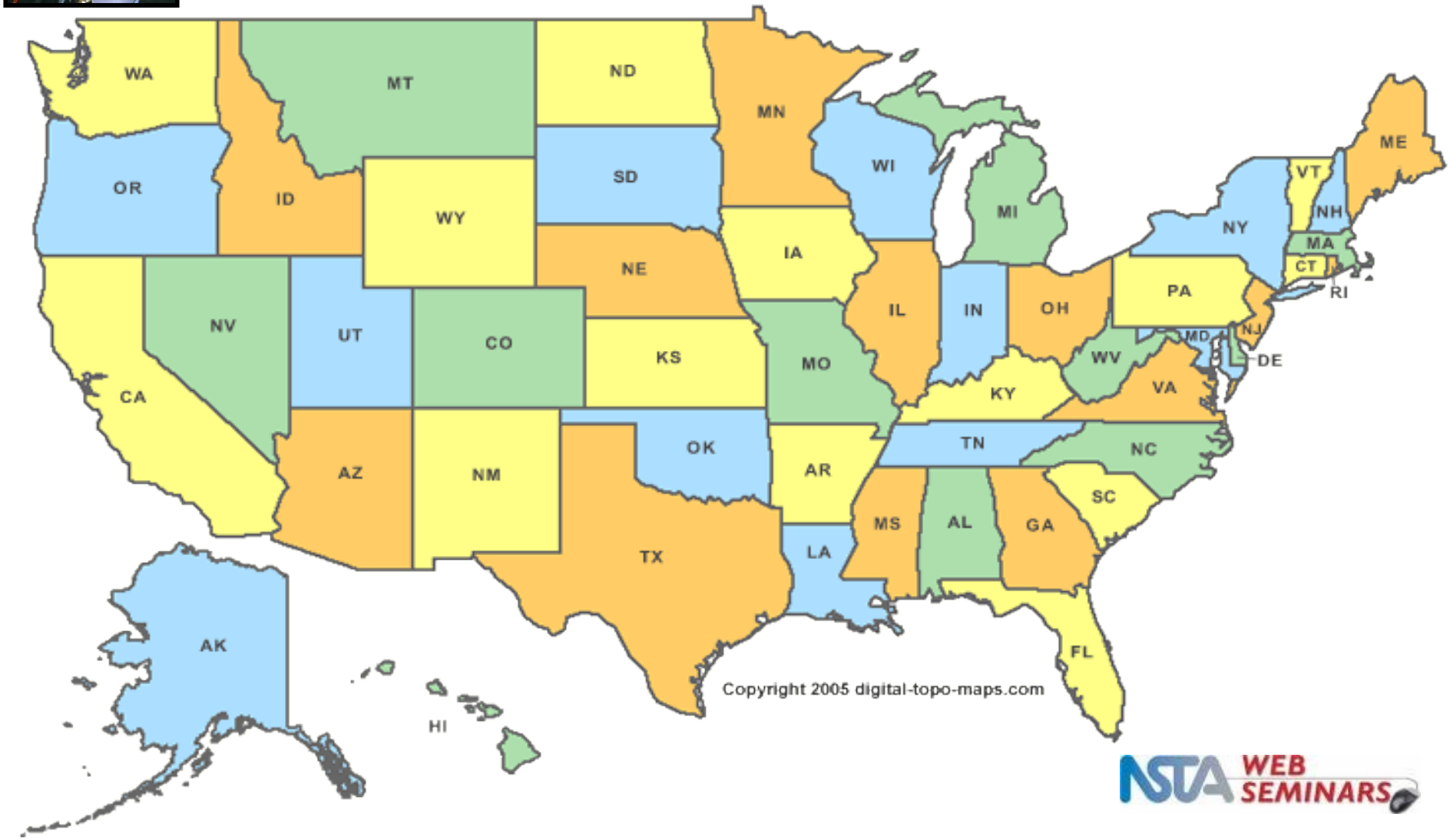
Where are you now?



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What grade level do you teach?

A. Elementary School, K-5.

B. Middle School, 6-8.

C. High School, 9-12.

D. I teach college students.

E. I am an Informal Educator.

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How Telescopes Have Changed Our View of the Universe

Webinar I: **Anti-matter Eyes on the Gamma-ray Skies**

Presenter: **Dr. Lynn Cominsky**

November 12, 2009

How Telescopes Have Changed Our View of the Universe

What this series offers you:

- use science from cutting edge NASA telescopes to illustrate to your students the process of discovery and scientific investigation;

- learn about telescopes across the electromagnetic spectrum and how advances in technology enable leaps in science;

- trace how our understanding of the physical universe has progressed over history.

Anti-Matter Eyes on the Gamma-Ray Skies

Have you ever wondered what $E=mc^2$ really means? Learn how anti-matter is used by the Fermi Gamma-ray Space Telescope to study the most energetic and exotic objects in the cosmos: blazing galaxies, intense stellar explosions and super-massive black holes. Fermi is changing our view of the Universe on scales from the infinite to the infinitesimal, and future observations may on the nature of dark matter.

Presented by:

Dr. Lynn Cominsky

Professor and Chair, Department of Physics and Astronomy

Director, NASA Education and Public Outreach Group

Sonoma State University

NASA

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Fermi Gamma-ray Space Telescope

Anti-matter Eyes on the Gamma-ray Skies

Prof. Lynn Cominsky

Sonoma State University

Director, Education and Public Outreach

NASA

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Classroom Connections

Fermi Gamma-ray Space Telescope

The Fermi Gamma-ray Space Telescope is opening a wide new window on the Universe, showing us the most extreme and exotic objects in the cosmos.

National Science Education Standards (partial list):

- Physical Science: Forces and Motions, Interactions of Energy and Matter
- Origin and Evolution of the Universe
- Science as a Human Endeavor
- Nature of Science Knowledge

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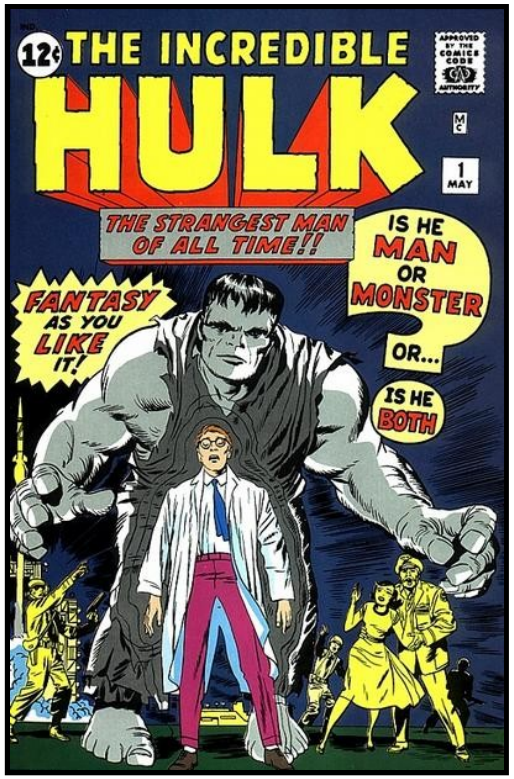
What turned Bruce Banner into the Hulk?

Fermi Gamma-ray Space Telescope



Use the poll buttons to answer:

A. Radio waves
B. Microwaves
C. Visible Light
D. X-rays
E. Gamma-rays

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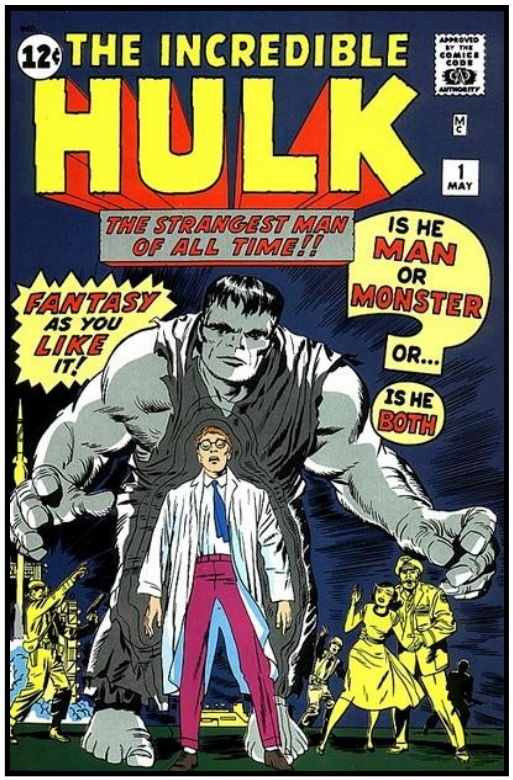
What turned Bruce Banner into the Hulk?

Fermi Gamma-ray Space Telescope



Use the poll buttons to answer:

A. Radio waves
B. Microwaves
C. Visible Light
D. X-rays
E. Gamma-rays

Why? Because gamma-rays are powerful!

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How powerful?

Fermi Gamma-ray Space Telescope

Use the poll buttons to answer:

A. 100 times more energetic than visible light
B. 1000 times more energetic than visible light
C. 10,000 times more energetic than visible light
D. 100,000 times more energetic than visible light
E. 1,000,000 times more energetic than visible light

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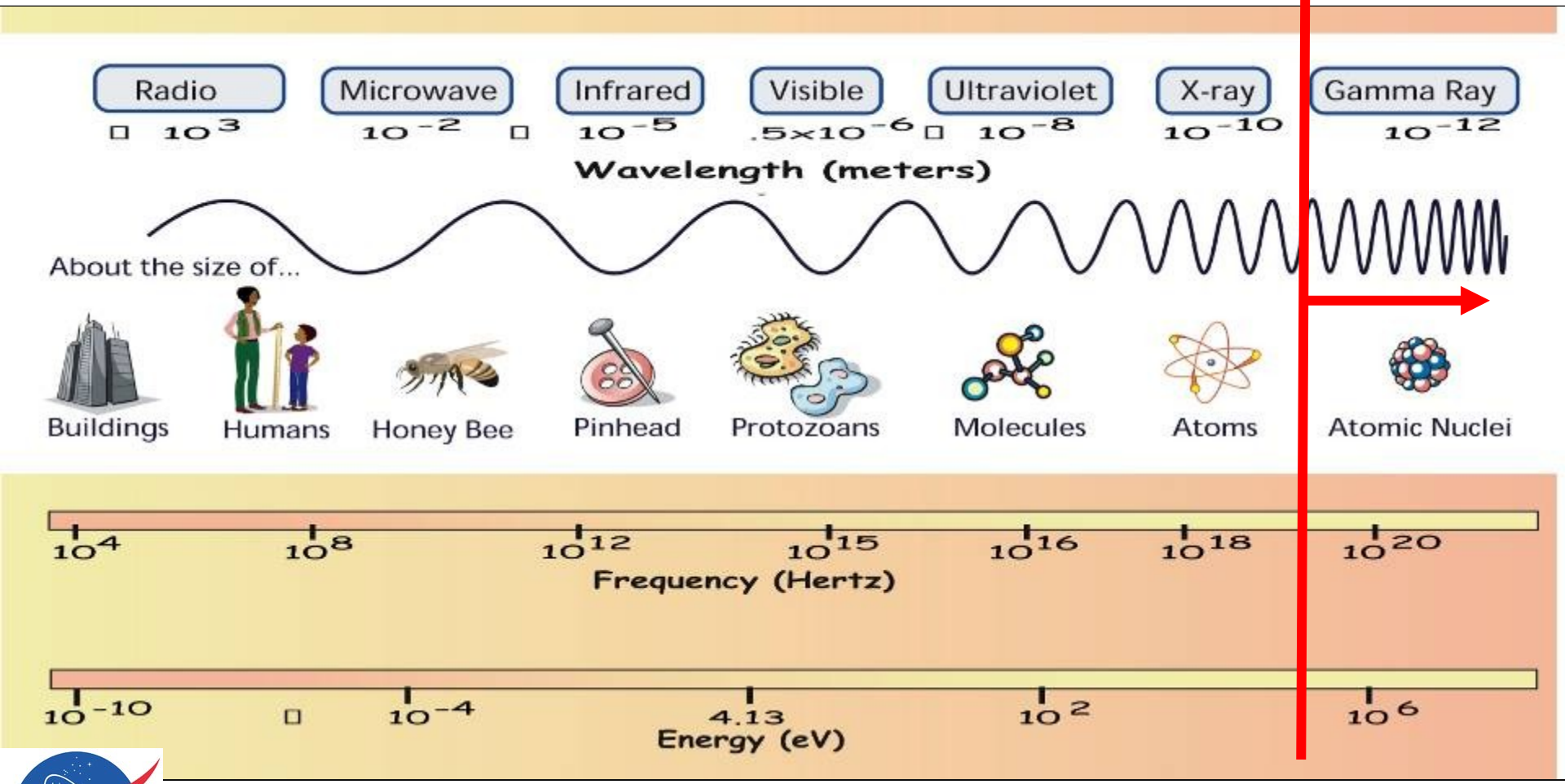
How powerful?

Fermi Gamma-ray Space Telescope



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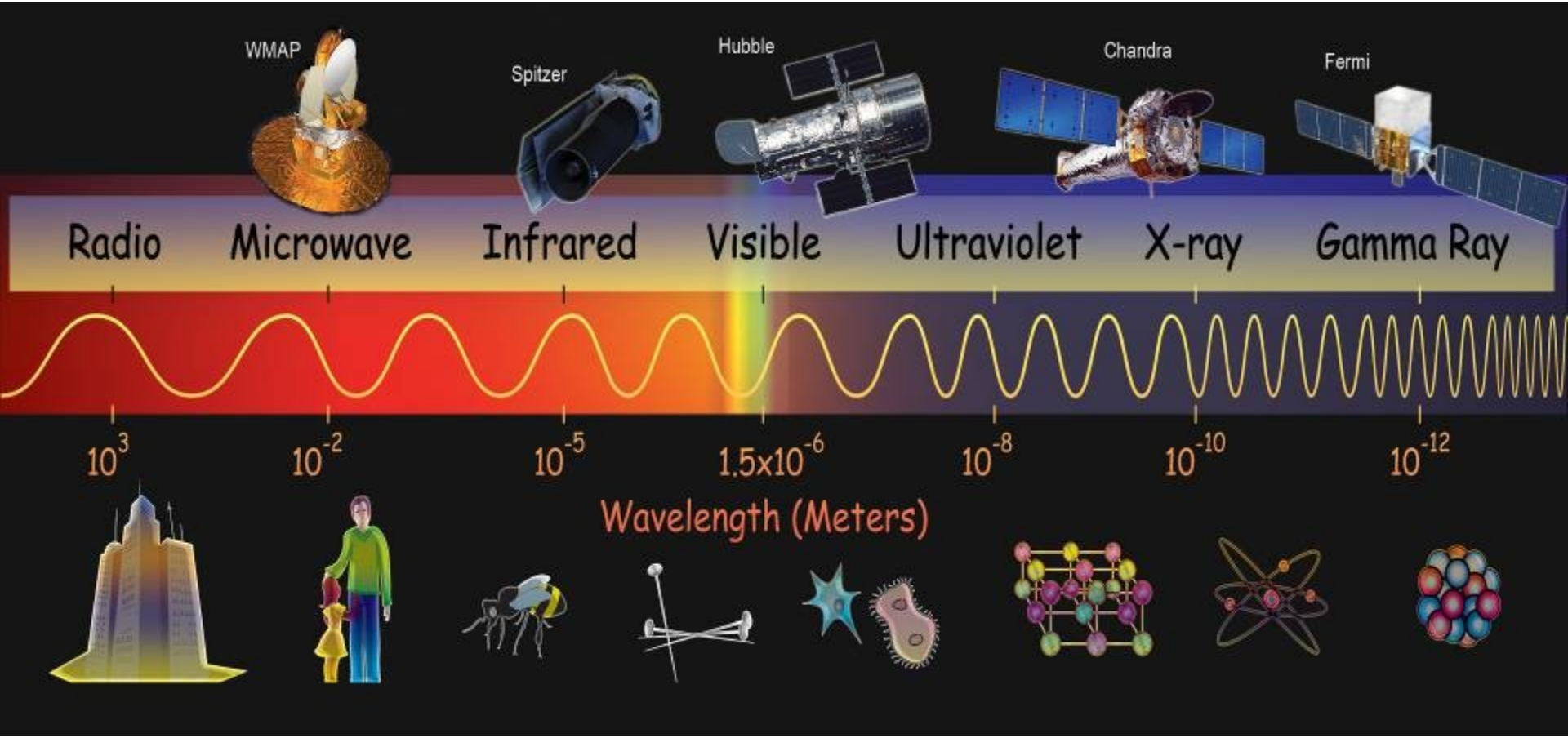
Telescopes Across the EM Spectrum

Fermi
Gamma-ray
Space Telescope



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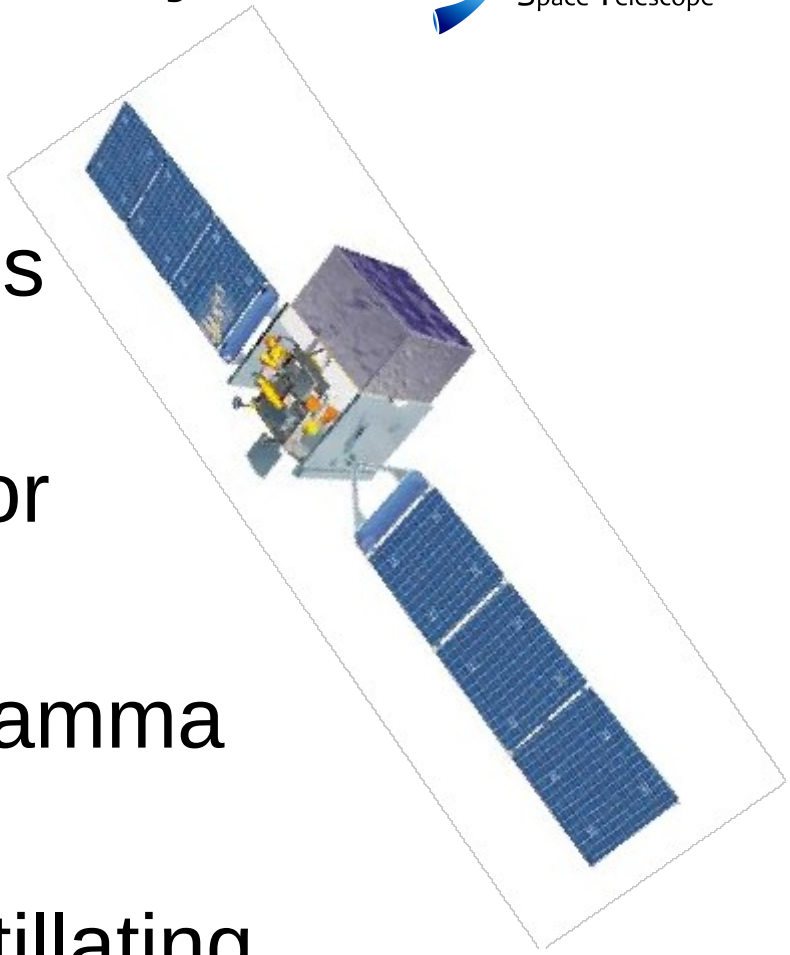
How to study gamma rays?

Fermi Gamma-ray Space Telescope

- Absorbed by the Earth's atmosphere
- Use rockets, balloons or satellites
- Can't image or focus gamma rays
- Special detectors: scintillating crystals, silicon-strips



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The Fermi mission…

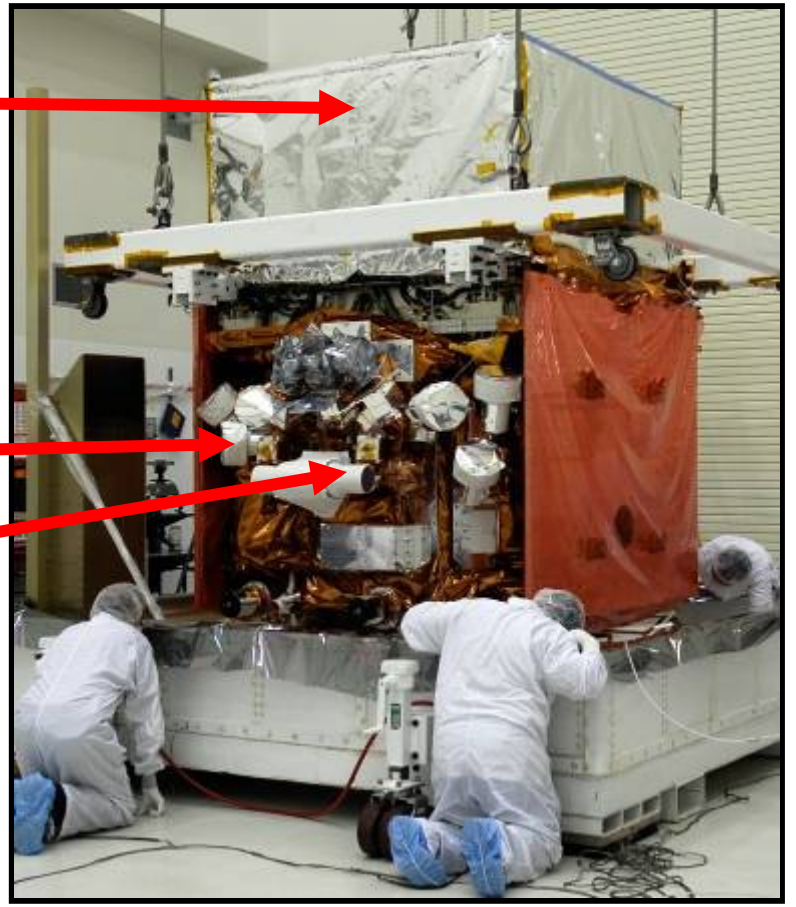
Fermi
Gamma-ray
Space Telescope

- First space-based collaboration between astrophysics and particle physics communities
- International partners from France, Germany, Italy, Japan & Sweden
- Launched June 11, 2008
- Expected duration 5-10 years

Before launch

Fermi Gamma-ray Space Telescope

- Large Area Telescope
- Gamma-ray Burst Monitor



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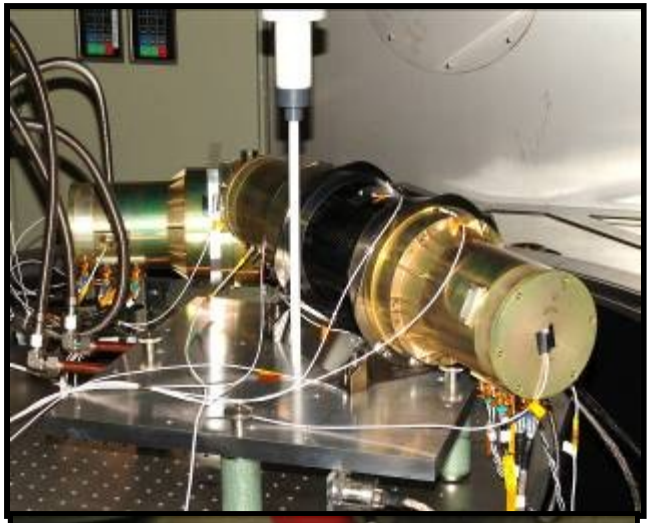
Gamma-ray Burst Monitor (GBM)

Fermi Gamma-ray Space Telescope

- PI Charles Meegan (NASA/MSFC)
- 12 sodium iodide scintillators
  - 10 keV to 1 MeV
  - Burst triggers and locations
- 2 bismuth germanate detectors
  - 150 keV to 30 MeV
  - Overlap with LAT



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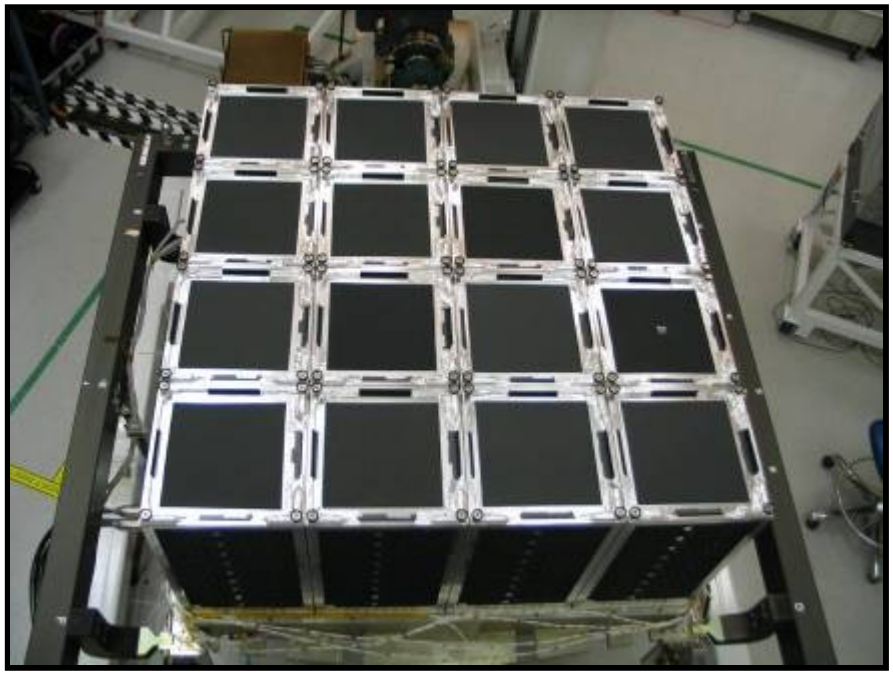
Large Area Telescope (LAT)

Fermi Gamma-ray Space Telescope

- PI Peter Michelson (Stanford)

- LAT is a 4 x 4 array of towers
- Each tower is a pair conversion telescope with calorimeter



- http://glast.stanford.edu

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What is the anti-matter partner of the electron?

Fermi Gamma-ray Space Telescope

Use the poll buttons to answer:

A. proton
B. neutron
C. positron
D. muon
E. neutrino

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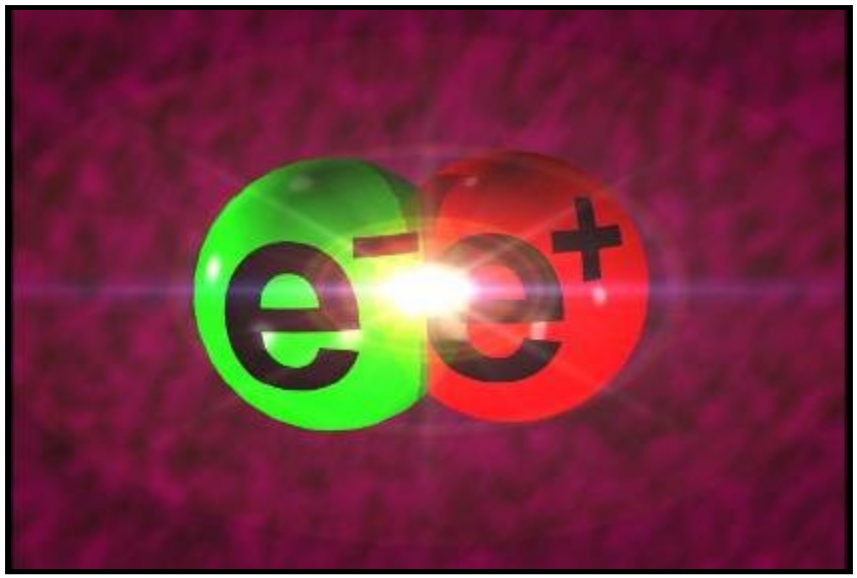
Pair-conversion

Fermi Gamma-ray Space Telescope



$E = mc^2$

m = mass of the electron or positron

E = energy of gamma ray

- Anti-matter partners of e- are **positrons** (e+)
- When they meet, they annihilate each other!

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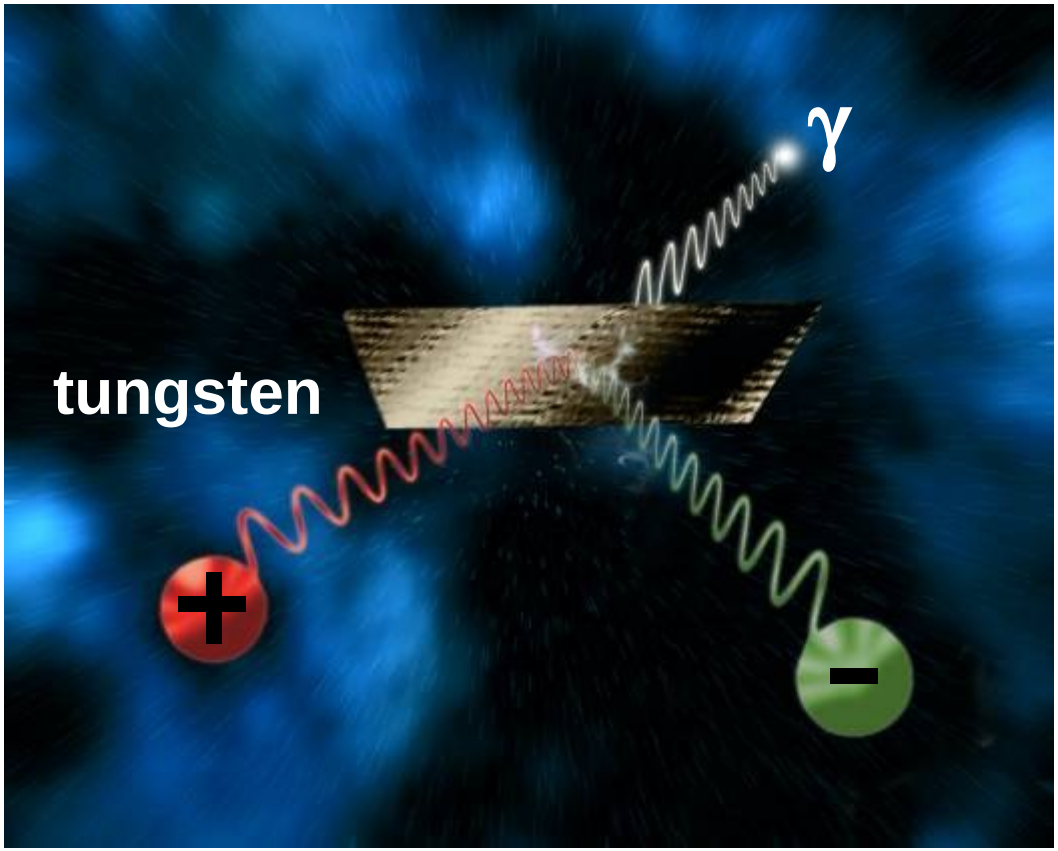
Now in reverse….

Fermi Gamma-ray Space Telescope

This process is called “pair conversion” as the incoming gamma-ray converts into an electron/positron pair



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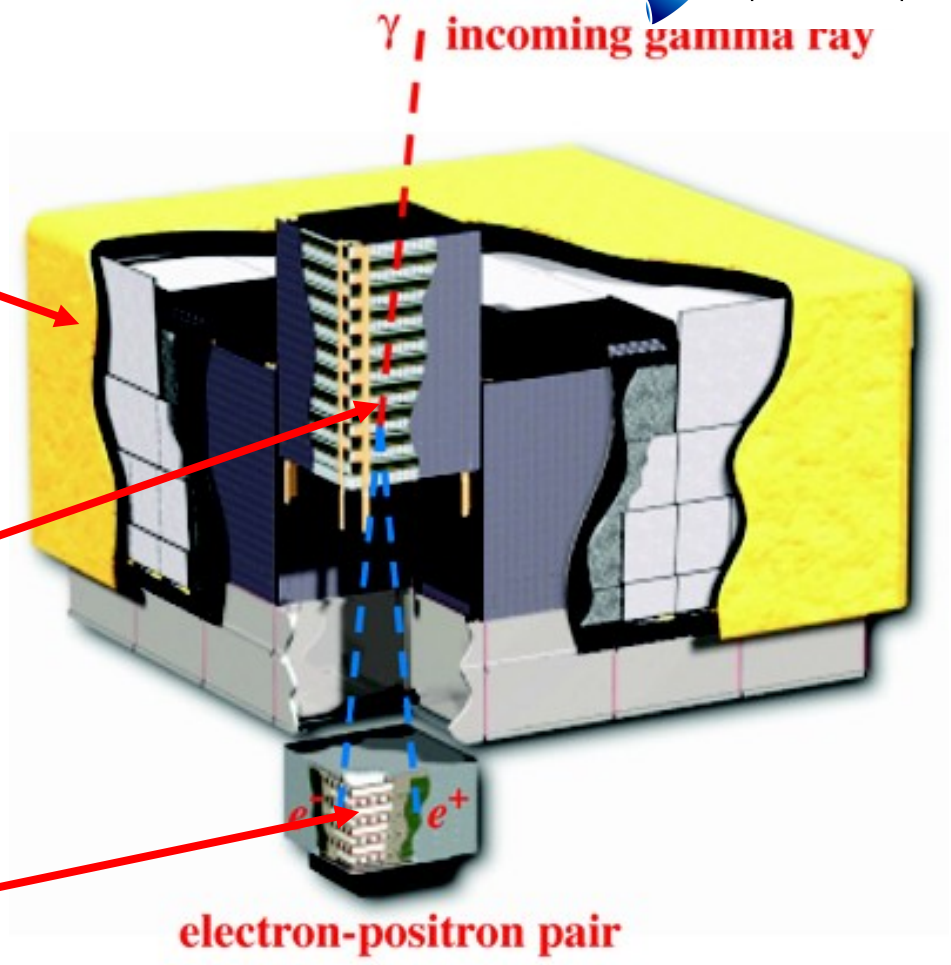
How does the LAT work?

Fermi Gamma-ray Space Telescope

- Anticoincidence Detectors – screen out charged particles
- Tungsten converts gamma rays into e+/e- pairs
- Calorimeter measures total energy



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Let's Pause for Two Questions from the Audience

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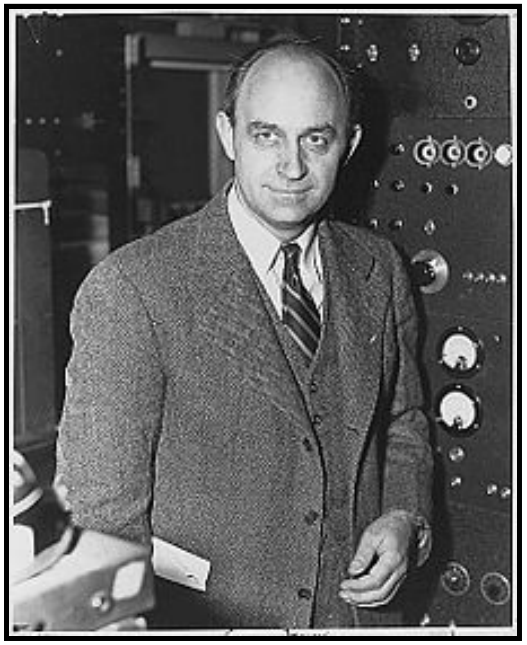
Launched!

- June 11, 2008
- Delta II Heavy (9 solid rocket boosters)
- Mass is 4300 kg
- 555 km circular orbit
- 1500 W total power
- 40 Mb/sec downlink

Renaming the satellite



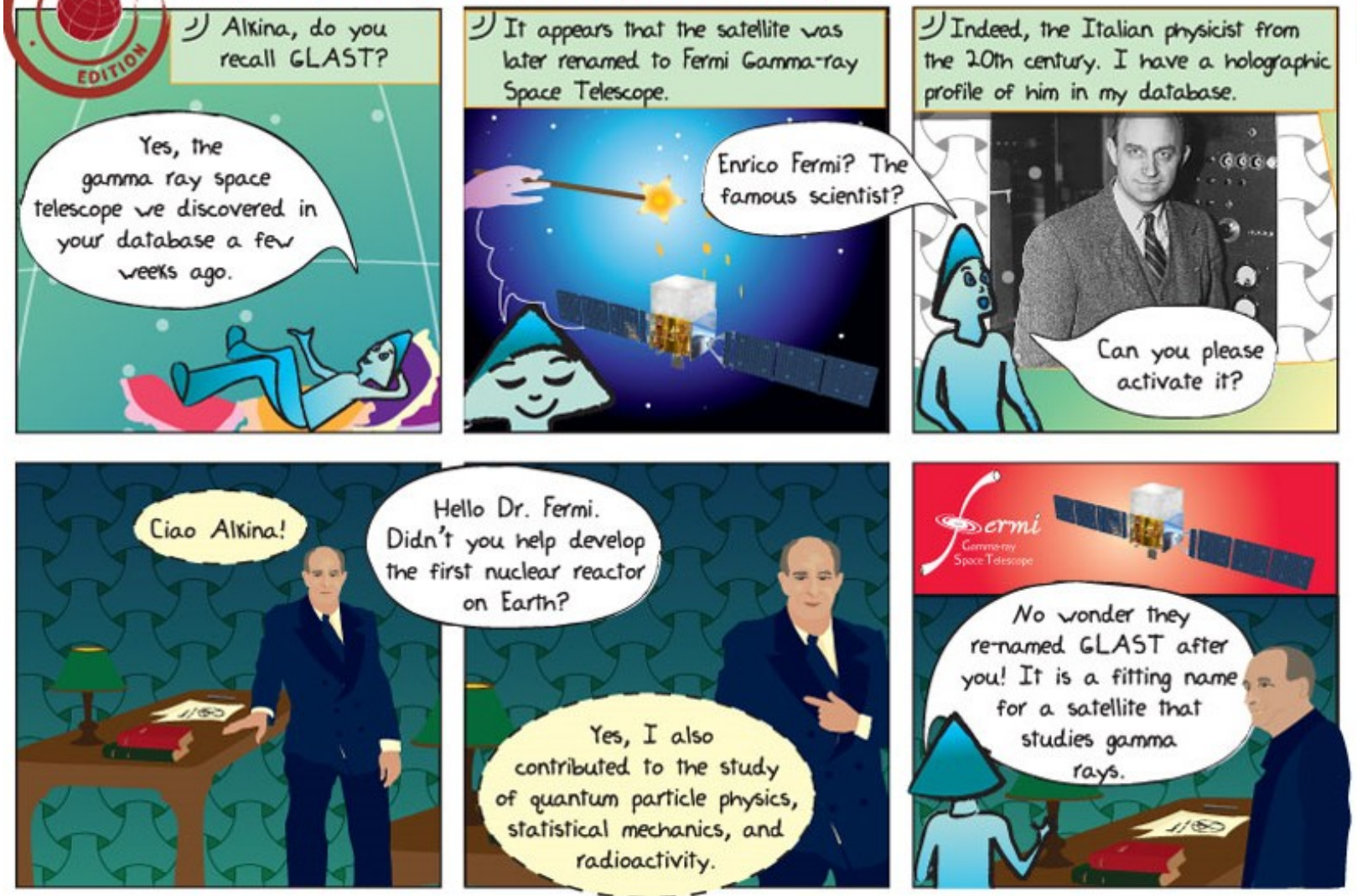
- We renamed the mission after Enrico Fermi, an Italian-American scientist on 8/26/08 when we announced our first results

Enrico Fermi
1901-1954
Nobel in 1938

Special "Eposode" of Epo's Chronicles

Fermi Gamma-ray Space Telescope

This special episode of Epo's Chronicles is not part of the main storyline.



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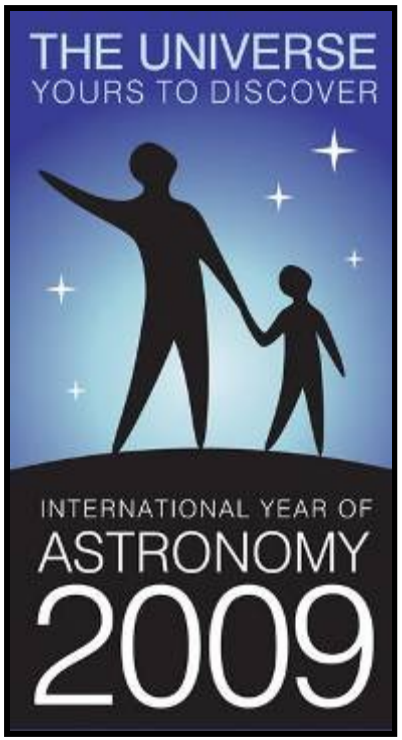
International Year of Astronomy 2009 (IYA)

World-wide celebration of astronomy, its contribution to society and culture

400th anniversary of first use of astronomical telescope by Galileo



NASA IYA objectives include:

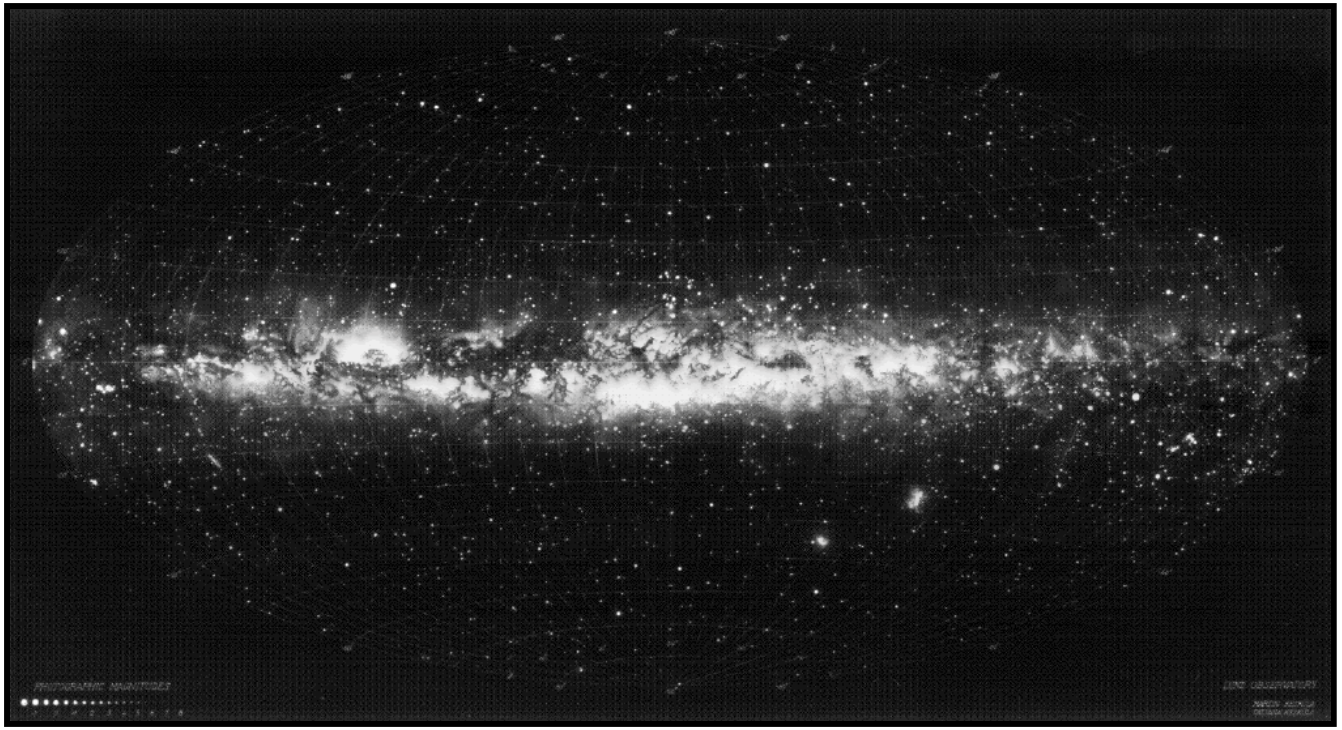
- strengthen interest in science and science education
- increase awareness of astronomy

•Special “eposodes” for IYA at:
http::://eposchronicles.org

Learn more at: astronomy2009.nasa.gov

Why study the gamma-ray Universe?

Fermi Gamma-ray Space Telescope



- Universe as seen by eye is peaceful

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But what if you had gamma-ray vision?

What does Fermi see in the Gamma-ray Sky?

Fermi Gamma-ray Space Telescope

Use the poll buttons to answer:

A. Moon
B. Sun
C. Pulsars
D. Milky Way Galaxy
E. Distant galaxies

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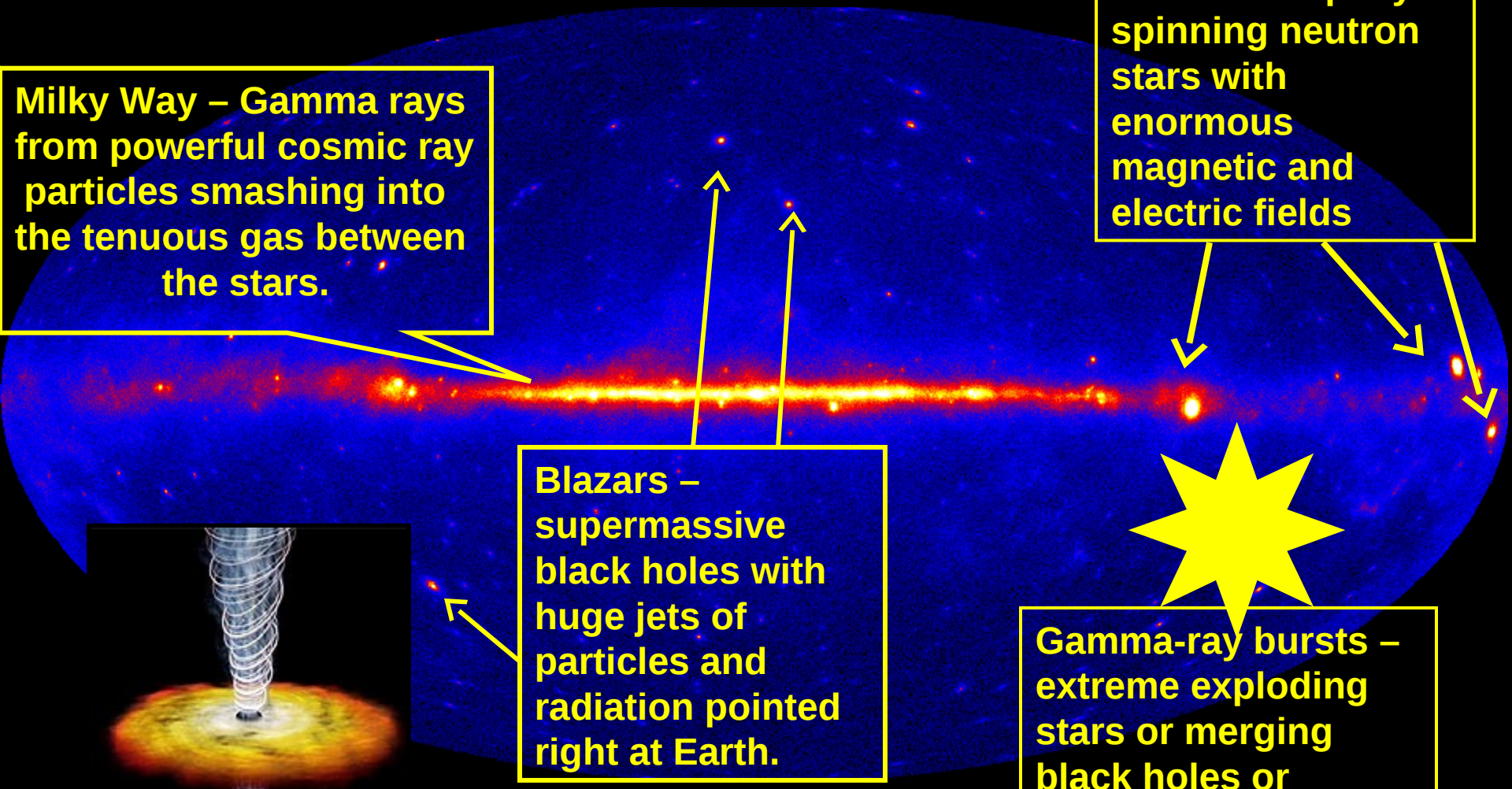
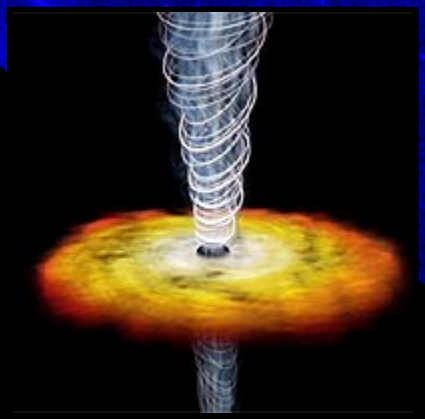
The Fermi Gamma-ray Sky in False Color



Milky Way – Gamma rays from powerful cosmic ray particles smashing into the tenuous gas between the stars.

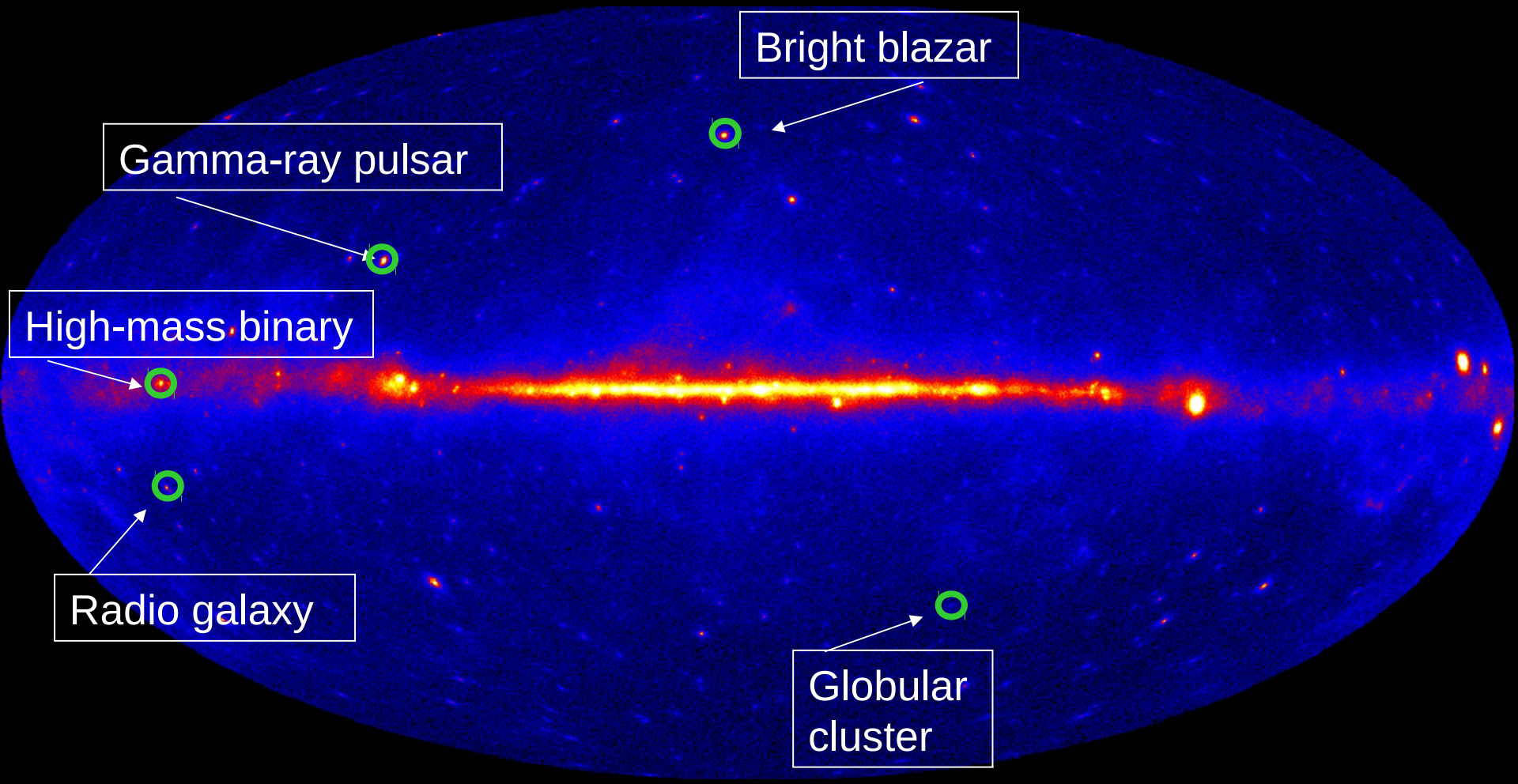
Pulsars – rapidly spinning neutron stars with enormous magnetic and electric fields

Blazars – supermassive black holes with huge jets of particles and radiation pointed right at Earth.



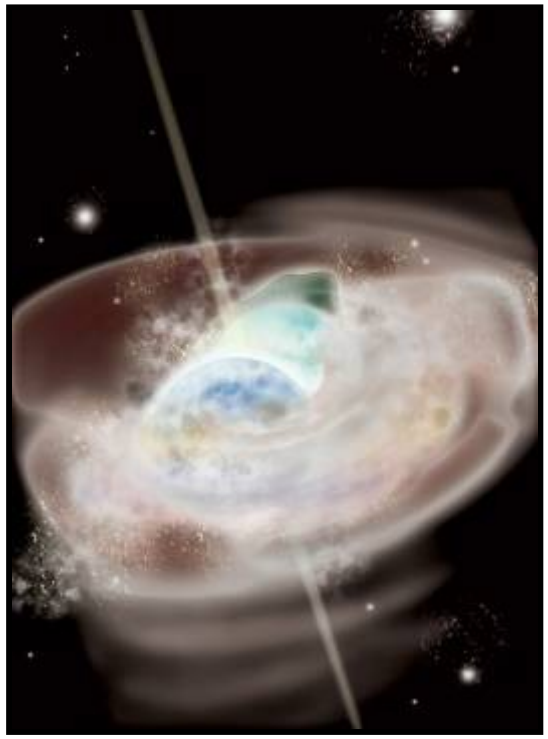
Gamma-ray bursts – extreme exploding stars or merging black holes or neutron stars.

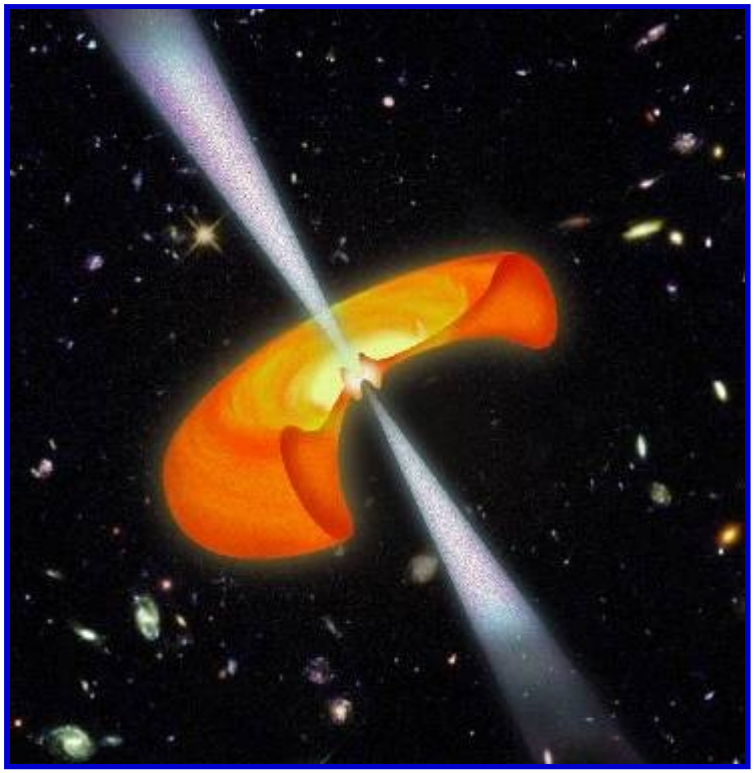
The Fermi Gamma-ray Sky – New discoveries



Gamma-ray Bursts

Fermi Gamma-ray Space Telescope





- Once a day, somewhere in the Universe a black hole is born!

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How much energy is in a gamma-ray burst?

Fermi Gamma-ray Space Telescope

Use the poll buttons to answer:

A. A billion (10^9) times the Sun's energy in 1 s
B. A trillion (10^{12}) times the Sun's energy in 1 s
C. A million billion (10^{15}) times the Sun's energy in 1 s
D. A billion billion (10^{18}) times the Sun's energy in 1 s
E. As much energy in 1 s as our Sun puts out in its entire lifetime

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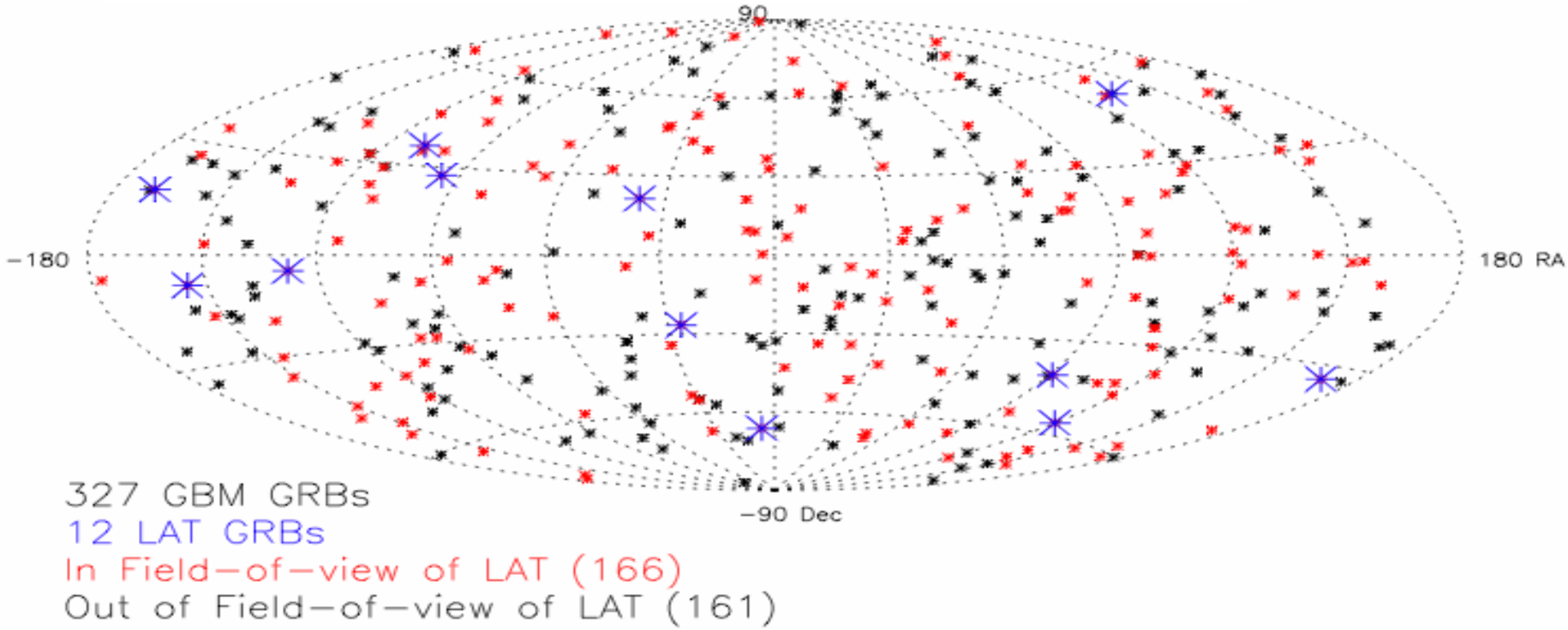
Fermi Bursts in first year

Fermi Gamma-ray Space Telescope

- As of 10/26/09



- About 4-5 bursts per week

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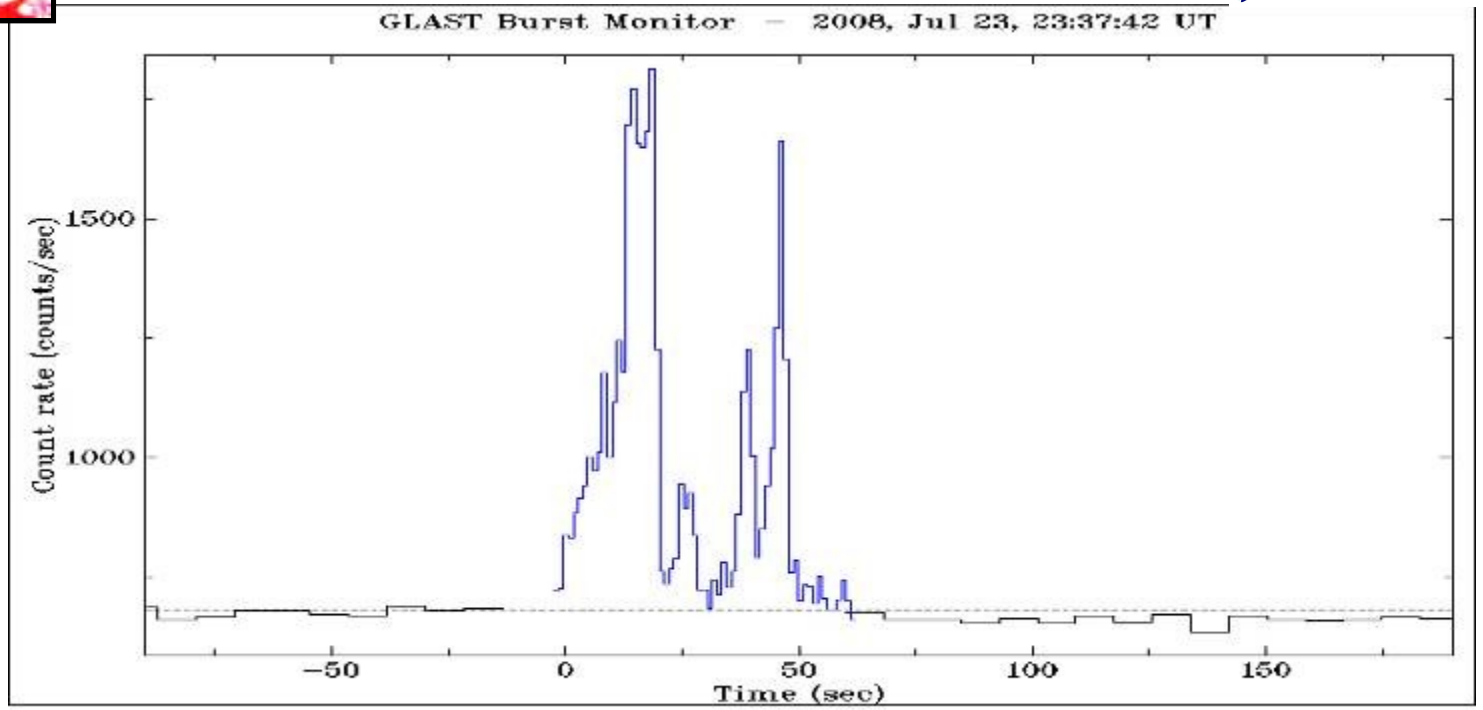
Typical strong GRB seen by GBM

Fermi Gamma-ray Space Telescope



- 325+ GBM bursts seen to date
- 12 LAT-GBM bursts seen in first 12 months

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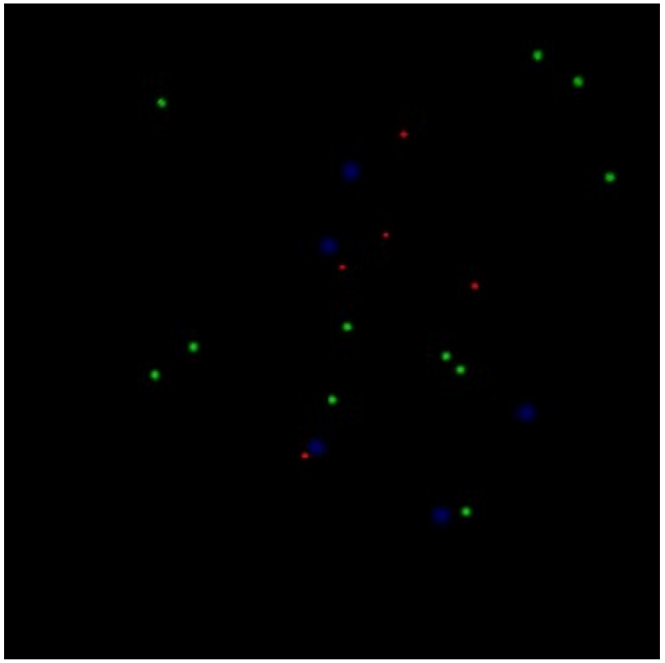
GRB080916C: most extreme GRB yet

Fermi Gamma-ray Space Telescope

- Greatest total energy, the fastest motions and the highest-energy initial emissions ever seen
- Studying the gamma rays tells us that the charged particles which made those gamma rays were moving at 99.9999% of light speed
- Observing the GRB using visible light tells us that it happened12.2 billion years ago



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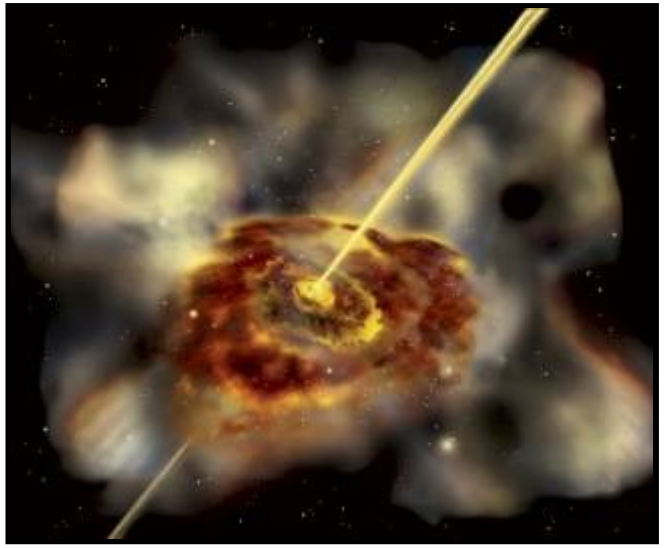
“Normal” galaxy

- A system of gas, stars, and dust bounded together by their mutual gravity
- Super-massive black hole in center, typically greater than 10^6 solar masses

Active Galaxy

Fermi Gamma-ray Space Telescope

- An galaxy with an intensely bright nucleus. At the center is a super-massive black hole that is feeding.
- Jets flare dramatically in gamma rays
- Galaxies that point their jets at us are called “blazars”
- How do the black holes send out jets?



Art by Aurore Simonnet

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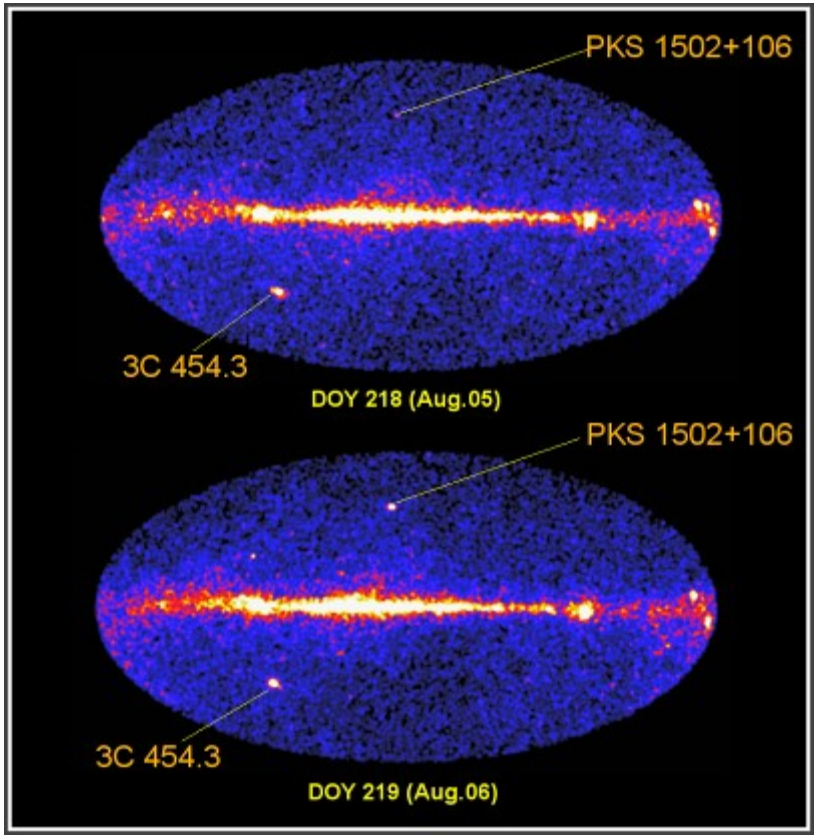
Monitoring Flares from "Blazars"

Fermi Gamma-ray Space Telescope

- Fermi scans the entire sky every 3 hours – can see short flares
- Coordinated campaigns with ground-based telescopes are giving us information about how the jets work



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Global Telescope Network

Fermi Gamma-ray Space Telescope

- Students do ground-based visible-light observations using remote telescopes
- GRBs and flaring blazars
- Coordinated with Fermi and other satellite data

GORT at Pepperwood

http://gtn.sonoma.edu

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Let's Pause for Two Questions from the Audience

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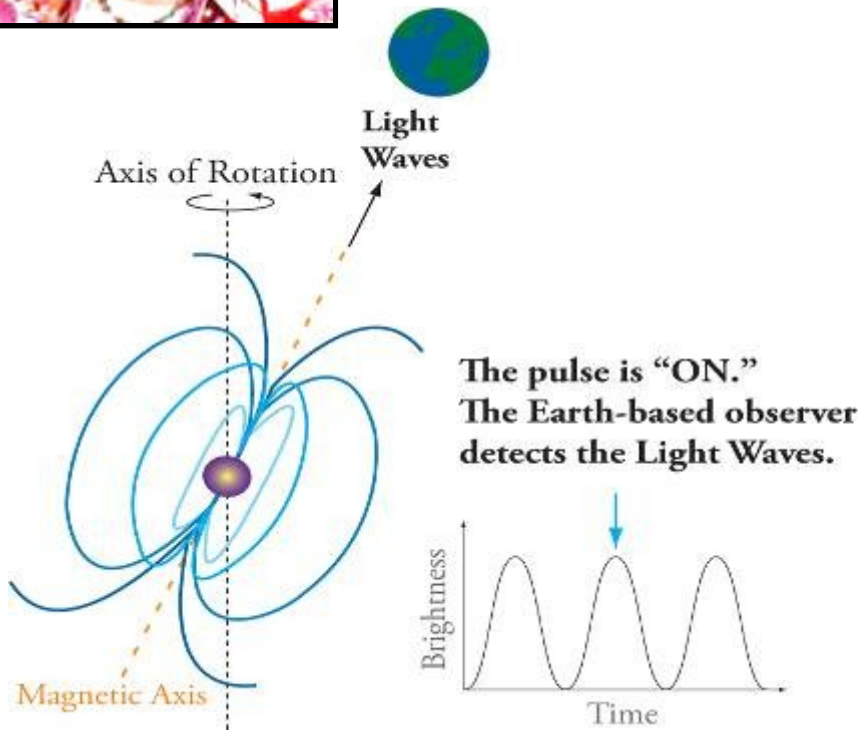
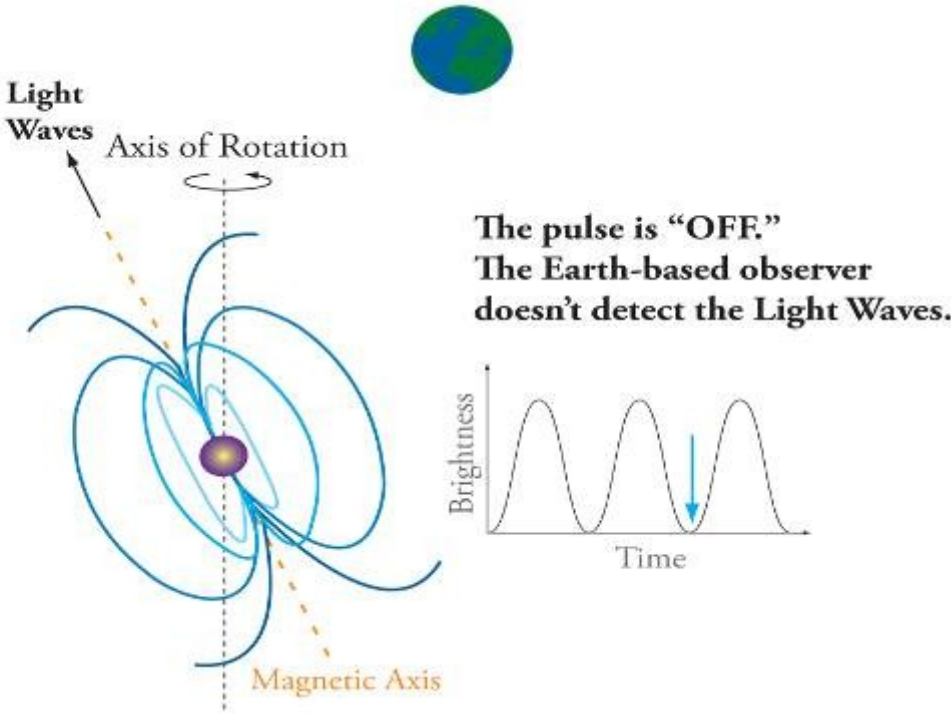
Pulsars

Fermi Gamma-ray Space Telescope





- Stellar corpses - size of a city, mass of the Sun, spinning up to 1000 times per second

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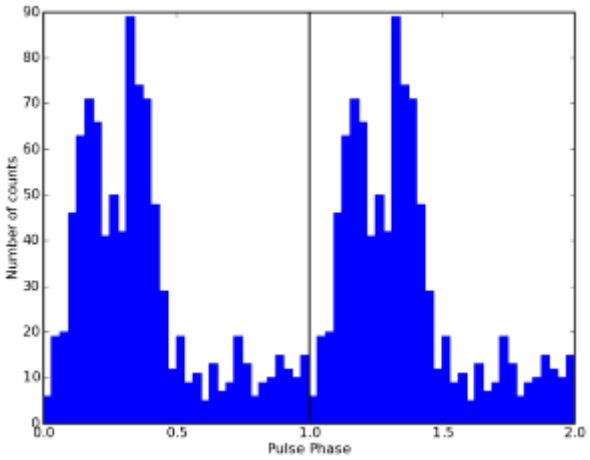
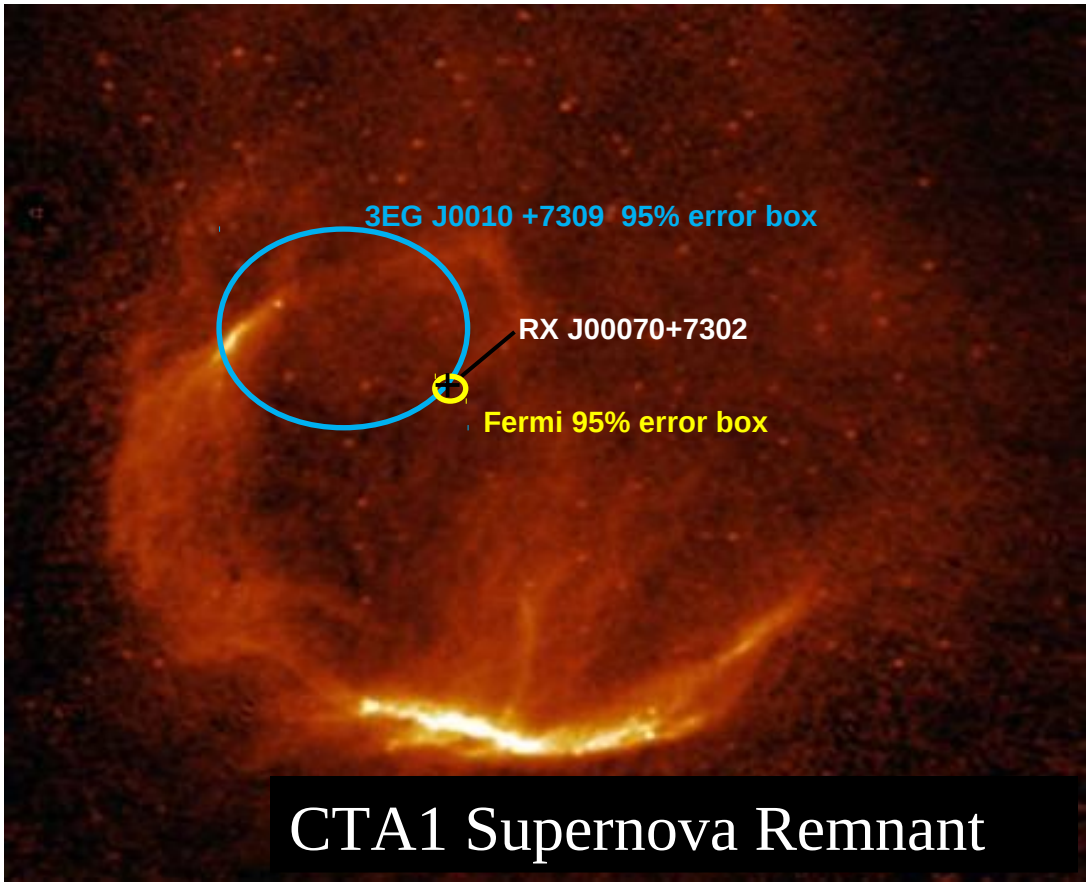
Fermi discovers the 1st gamma-ray only pulsar

Fermi Gamma-ray Space Telescope

0.3 s pulsations



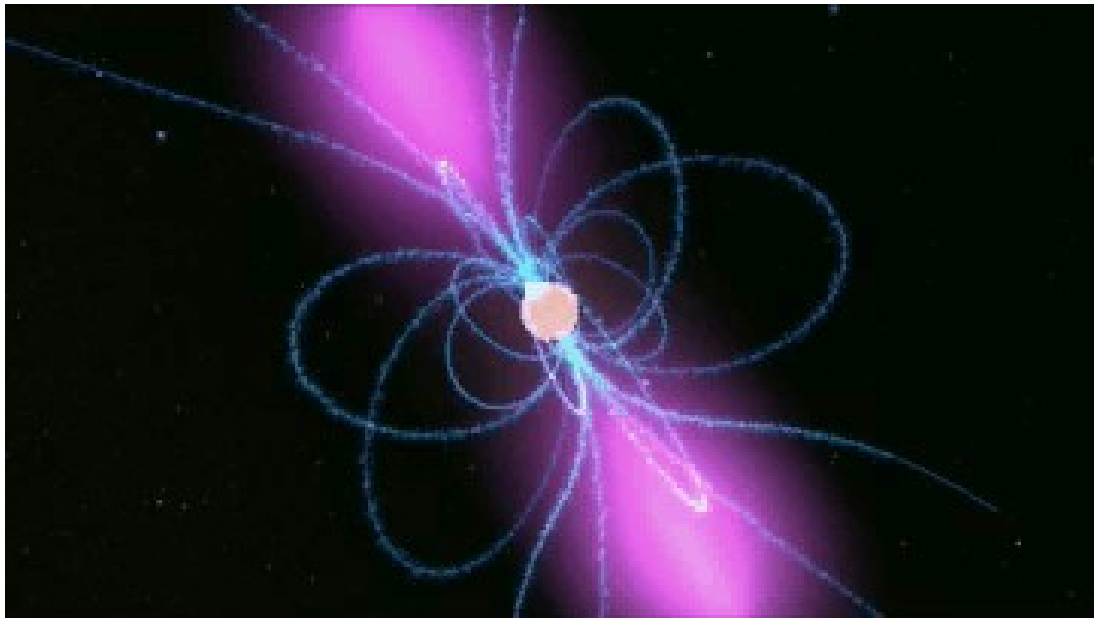
- Pulsar is not at center of SNR



Radio pulsar model

Fermi Gamma-ray Space Telescope

- Radio beams are emitted from polar caps
- Magnetic poles are not aligned with rotation axis



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How do gamma ray pulsars work?

Fermi Gamma-ray Space Telescope

- Pulsars are not simply lighthouses anymore
- Gamma rays come from outer magnetosphere

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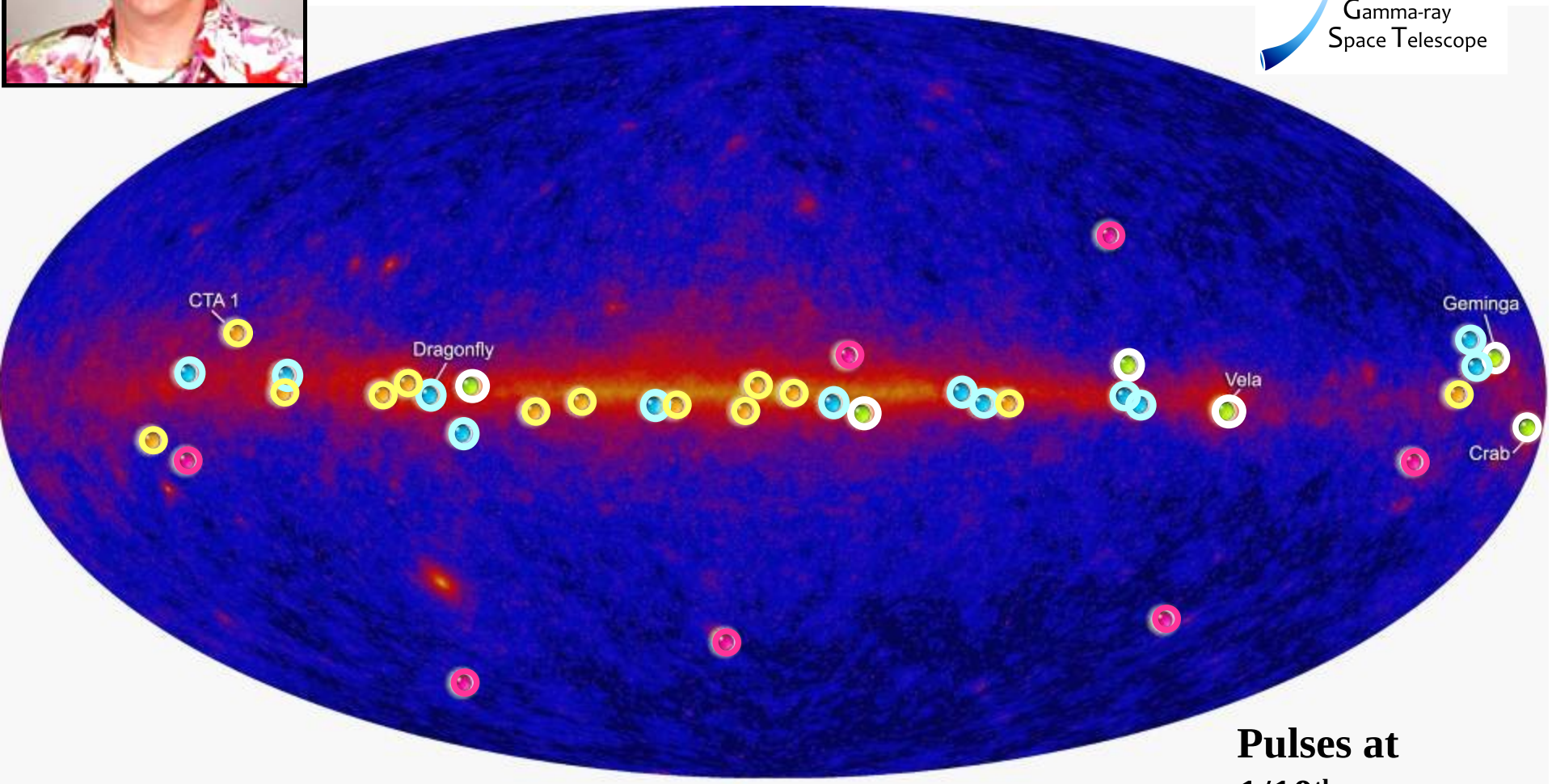
The Pulsing Sky (Romani)

Fermi Gamma-ray Space Telescope



Pulses at 1/10th true rate

Fermi Pulsar Detections

- New pulsars discovered in a blind search
- Millisecond radio pulsars
- Young radio pulsars
- Confirmed pulsars seen by Compton Observatory EGRET instrument

Sixth interactive

Fermi Gamma-ray Space Telescope

- Use the chat box to report your observations of the pulsing gamma-ray sky shown in the previous slide
- Do you notice anything that puzzles you?

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Searching for Dark Matter

Fermi Gamma-ray Space Telescope

- Dark matter makes up 80% of the matter in the Universe
- The leading particle candidate for dark matter is theorized to self-annihilate, creating gamma-ray lines in the energy range 30 GeV - 10 TeV
- Fermi could see these lines up to 300 GeV (if they exist)
- More lines are expected near the center of our Galaxy

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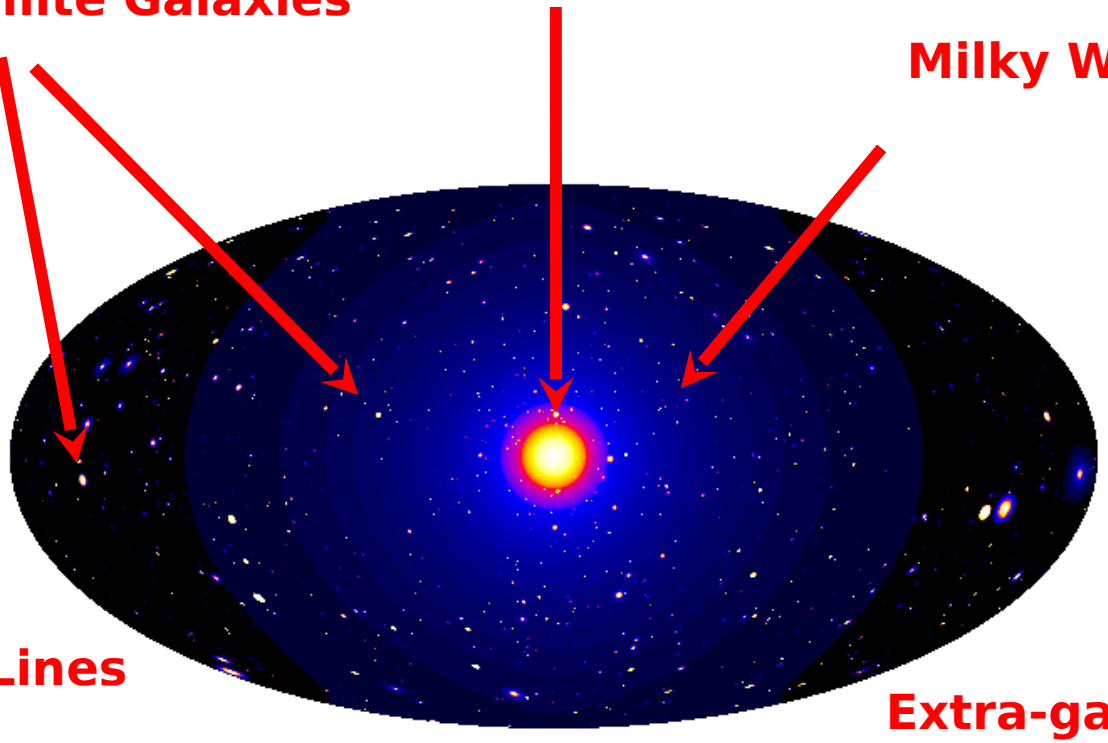
Many places to look!

Fermi Gamma-ray Space Telescope

Galactic Center

Satellite Galaxies

Milky Way Halo



All-sky map of simulated gamma ray signal from DM annihilation (Baltz 2006)

Spectral Lines

Extra-galactic

No detections so far, but the search continues…

Conclusions

Fermi Gamma-ray Space Telescope

- Fermi is using a telescope based on anti-matter to map the high-energy Universe at energies millions of times higher than visible light
- Fermi has opened wide a new window on the Universe – which may yet show us connections between the infinite and the infinitesimal
- Stay tuned – the best is yet to come!
- For more info: http://www.nasa.gov/fermi

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Fly the Gamma-ray Skies : Online materials

Fermi Gamma-ray Space Telescope

- Space Mysteries:
  - Solar Supernova
  - Galactic Doom
- LAT Simulator

  –http://www2.slac.stanford.edu/vvc/
- Black Hole Rescue

  http://spaceplace.nasa.gov → ames

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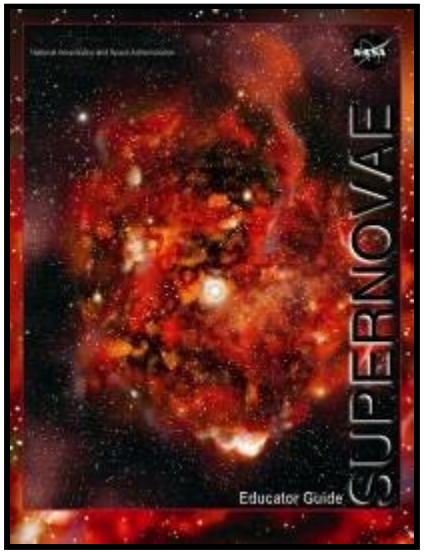
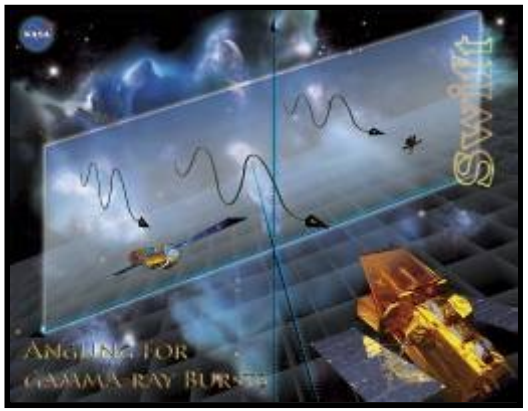
Free Printed Materials

- 3 TOPS curriculum guides
- Active Galaxy Educator's Guide
- Active Galaxy Pop-up book
- Supernova Educator's Guide
- GRB Educator's Guide





For more information:

- **http://epo.sonoma.edu – see Events tab for PD near you**
- http://fermi.sonoma.edu
- http://swift.sonoma.edu
- http://gtn.sonoma.edu
- http://eposchronicles.org
- http://mystery.sonoma.edu

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