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
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
We would like to know more about you...
We would like to know more about you...
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.
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
Where are you now?
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.
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=mc² 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 shed light 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
Anti-matter Eyes on the Gamma-ray Skies

Prof. Lynn Cominsky
Sonoma State University
Director, Education and Public Outreach
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
What turned Bruce Banner into the Hulk?

Use the poll buttons to answer:

A. Radio waves
B. Microwaves
C. Visible Light
D. X-rays
E. Gamma-rays
What turned Bruce Banner into the Hulk?

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!
How powerful?

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
How powerful?

100 MeV
Telescopes Across the EM Spectrum
How to study gamma rays?

• Absorbed by the Earth’s atmosphere
• Use rockets, balloons or satellites
• Can’t image or focus gamma rays
• Special detectors: scintillating crystals, silicon-strips
The Fermi mission...

- 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

- Large Area Telescope
- Gamma-ray Burst Monitor
Gamma-ray Burst Monitor (GBM)

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

- 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
What is the anti-matter partner of the electron?

Use the poll buttons to answer:

A. proton
B. neutron
C. positron
D. muon
E. neutrino
Pair-conversion

E = mc²

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!
Now in reverse....

This process is called “pair conversion” as the incoming gamma-ray converts into an electron/positron pair.
How does the LAT work?

• Anticoincidence Detectors – screen out charged particles
• Tungsten converts gamma rays into e+/e- pairs
• Calorimeter measures total energy
Let’s Pause for Two Questions from the Audience
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

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

Alkina, do you recall GLAST?

Yes, the gamma ray space telescope we discovered in your database a few weeks ago.

It appears that the satellite was later renamed to Fermi Gamma-ray Space Telescope.

Enrico Fermi? The famous scientist?

Can you please activate it?

Hello Dr. Fermi. Didn’t you help develop the first nuclear reactor on Earth?

Yes, I also contributed to the study of quantum particle physics, statistical mechanics, and radioactivity.

No wonder they re-named GLAST after you! It is a fitting name for a satellite that studies gamma rays.
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 “episodes” for IYA at: http://eposchronicles.org

Learn more at: astronomy2009.nasa.gov
Why study the gamma-ray Universe?

- Universe as seen by eye is peaceful
But what if you had gamma-ray vision?
What does Fermi see in the Gamma-ray Sky?

Use the poll buttons to answer:

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

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

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

Gamma-ray bursts – extreme exploding stars or merging black holes or neutron stars.
The Fermi Gamma-ray Sky – New discoveries
Gamma-ray Bursts

• Once a day, somewhere in the Universe a black hole is born!
How much energy is in a gamma-ray burst?

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
Fermi Bursts in first year

- As of 10/26/09

- About 4-5 bursts per week
Typical strong GRB seen by GBM

- 325+ GBM bursts seen to date
- 12 LAT-GBM bursts seen in first 12 months
GRB080916C: most extreme GRB yet

- 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 happened 12.2 billion years ago
“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

- 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
Monitoring Flares from “Blazars”

- 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
Global Telescope Network

- 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
Let’s Pause for Two Questions from the Audience
Pulsars

• Stellar corpses - size of a city, mass of the Sun, spinning up to 1000 times per second
Fermi discovers the 1\textsuperscript{st} gamma-ray only pulsar

0.3 s pulsations

- Pulsar is not at center of SNR
Radio pulsar model

- Radio beams are emitted from polar caps
- Magnetic poles are not aligned with rotation axis
How do gamma ray pulsars work?

- Pulsars are not simply lighthouses anymore
- Gamma rays come from outer magnetosphere
The Pulsing Sky (Romani)

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

• 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?
Searching for Dark Matter

- 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
Many places to look!

Galactic Center

Satellite Galaxies

Milky Way Halo

Spectral Lines

Extra-galactic

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

No detections so far, but the search continues…
Conclusions

• 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
Fly the Gamma-ray Skies: Online materials

• Space Mysteries:
  – Solar Supernova
  – Galactic Doom

• LAT Simulator
  – http://www2.slac.stanford.edu/vvc/

• Black Hole Rescue
  http://spaceplace.nasa.gov/ames
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](http://epo.sonoma.edu) – see Events tab for PD near you
- [http://fermi.sonoma.edu](http://fermi.sonoma.edu)
- [http://swift.sonoma.edu](http://swift.sonoma.edu)
- [http://gtn.sonoma.edu](http://gtn.sonoma.edu)
- [http://eposchronicles.org](http://eposchronicles.org)
- [http://mystery.sonoma.edu](http://mystery.sonoma.edu)
Thank you to the sponsor of tonight's Web Seminar:
Welcome to Your Professional Development

The Learning Center is NSTA’s e-professional development portal to help you address your classroom needs and busy schedule. You can gain access to more than 3,300 different resources that cater to your preference for learning. Over 925 resources, such as journal articles, science objects and web seminars are available for free. A suite of practical tools such as My Library, My Transcript, and My Professional Development Plan and Portfolio tool help you organize, personalize, and document your growth over time. If desired, you may review an archived Web Seminar overview of the NSTA Learning Center, or download the “How to Guide” PDF (2.7 MB).

Explore Learning Opportunities

See all FREE Resources

By Subject
- Earth & Space Science
- Life Science
- Physical Science

By Grade Level
- Elementary
- Middle School
- High School
- College

Select your state to begin:

Choose a state

Do-It-Yourself Learning

Learn at your own pace online with these 1-2 or 6-10 hour interactive activities.

Live Online Seminars & Classes

Learn online from certified instructors with your colleagues. 1-2 hour seminars, week and month long courses are available. Earn state

http://learningcenter.nsta.org
http://www.elluminate.com
National Science Teachers Association
Dr. Francis Q. Eberle, Executive Director
Zipporah Miller, Associate Executive Director
Conferences and Programs
Al Byers, Assistant Executive Director e-Learning

NSTA Web Seminars
Paul Tingler, Director
Jeff Layman, Technical Coordinator

LIVE INTERACTIVE LEARNING @ YOUR DESKTOP
How Telescopes Have Changed Our View of the Universe

Web seminar series:

A Century of Cosmic Surprises

December 08, 2009

From Sound Waves to Microwaves: "Listening" to the Oldest Light of the Universe with the Planck Mission

December 16, 2009
- **NOAA: Global Climate Change Impacts in the Eastern United States**
  November 17, 2009
- **FDA/CFSAN International Affairs**
  November 18, 2009
- **FDA: Applications of Nanotechnology in Cosmetics and Foods**
  November 24, 2009
Web Seminar Evaluation:

Click on the URL located on the Chat Window