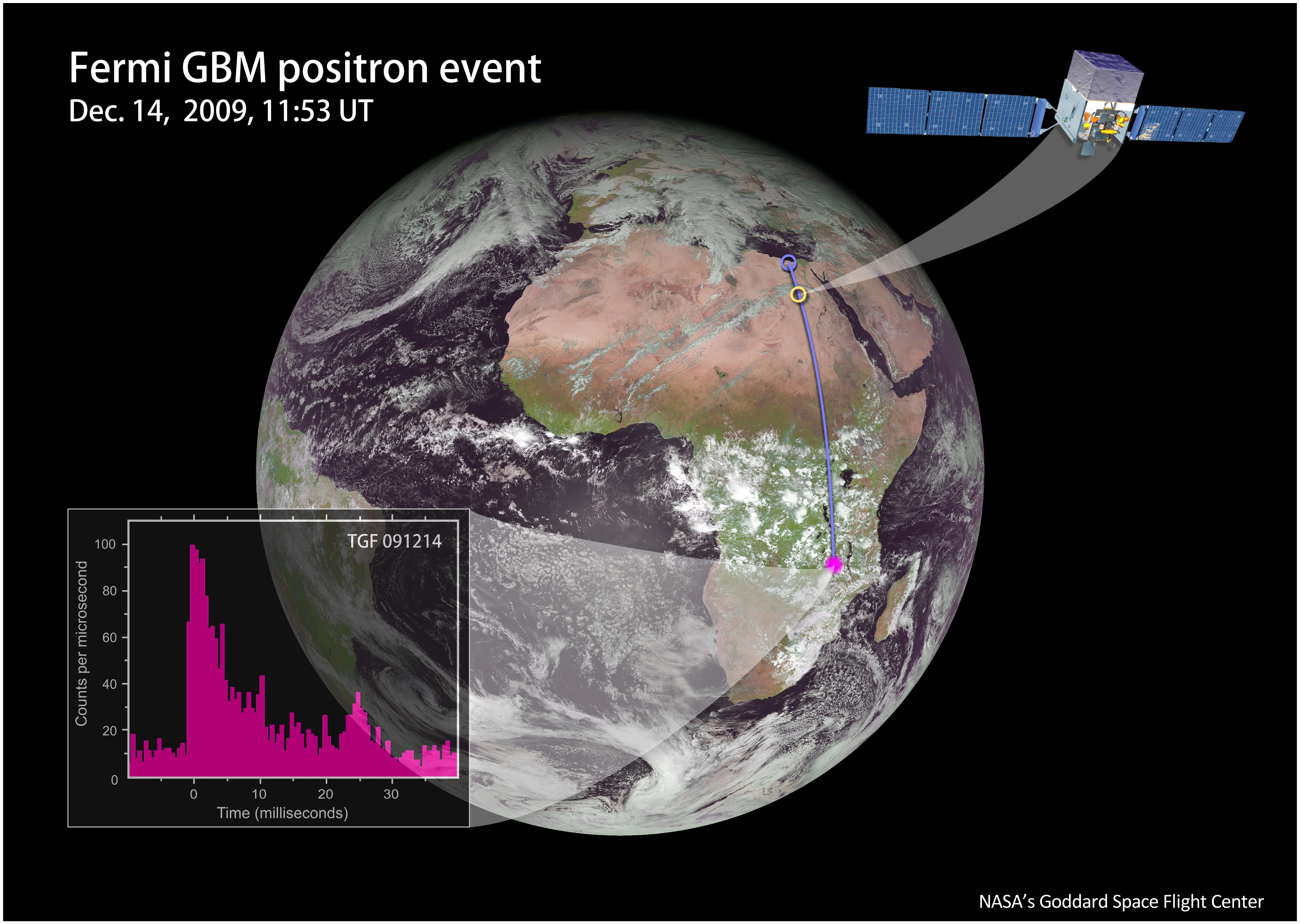
Fermi Gamma-ray Space Telescope

Terrestrial Gamma-ray Flashes

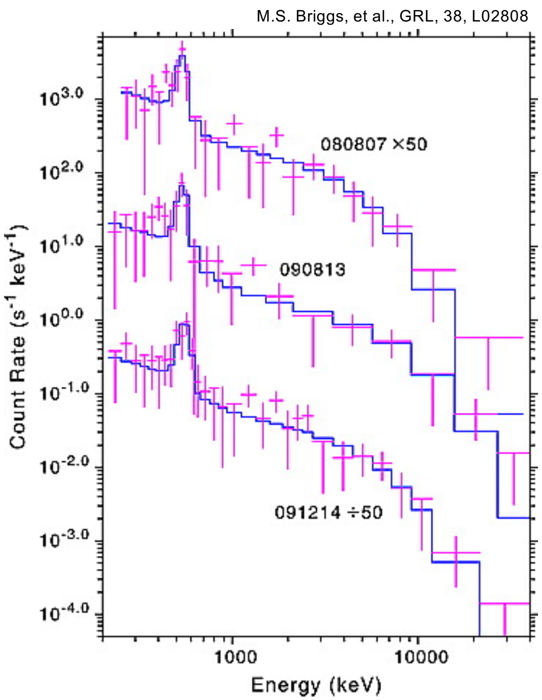


Terrestrial Gamma-ray Flashes seen by Fermi spark surprise

Terrestrial Gamma-ray Flashes (TGFs) are **intense sub-millisecond bursts of MeV gamma rays** produced in active thunderstorm regions and temporally associated with lightning events. These events were discovered in 1994 by the Compton Gamma Ray Observatory, and they have been detected by RHESSI, AGILE, and both instruments on Fermi – the Gamma-ray Burst Monitor (GBM) and the Large Area Telescope (LAT). The rate of TGFs is estimated to be 500 per day worldwide (~10^{-4} of the lightning rate), but most go undetected, and this rate is uncertain. Recent estimates are higher.

While TGF gamma rays have not been well-imaged, many TGFs are **coincident with a lightning event** near the sub-satellite point, suggesting that TGFs are associated with lightning processes. Detailed RF imaging of a few of these events suggests that the source of the gamma rays is ~10-15 km in altitude, well within the thundercloud and deep in the atmosphere. Thunderstorms are the most powerful natural terrestrial particle accelerators.

Recently the Fermi GBM has detected the signature of antimatter produced in these intense gamma ray flashes, a phenomenon never before seen.



GBM spectra (magenta crosses) for three different TGFs showing the characteristic 511 keV line produced by positron annihilation (modeled in blue).

How Thunderstorms Launch Particle Beams Into Space

Intense electric fields (>100 kV/m) within thunderclouds can create an upward-moving, **runaway avalanche** of relativistic electrons. When those relativistic electrons are deflected by air molecules, they emit bremsstrahlung gamma rays.

Many of those gamma rays Compton-scatter off electrons in air molecules and **eject relativistic electrons**. Other gamma rays pass close enough to the nuclei of atoms in air to pair-produce, transforming into a relativistic electron and positron pair.

These **high-energy electrons and positrons** escape into space, confined and spiraling along Earth's magnetic field lines in a relatively narrow beam, where they can be intercepted by spacecraft traveling overhead.

Finding Antimatter with the GBM

When the spacecraft intercepts a positron beam produced in a TGF, the positrons annihilate with electrons in the spacecraft and detectors, producing a pair of gamma rays with energy equal to the rest mass of the electron, 511 keV. The GBM detects gamma rays in the 10 keV to 40 MeV range, which puts the 511-keV electron-positron annihilation line well within its range of sensitivity. The GBM, then, detects the antimatter beam as a brief spike of gamma rays at that specific energy.

For more information, visit http://fermi.gsfc.nasa.gov/

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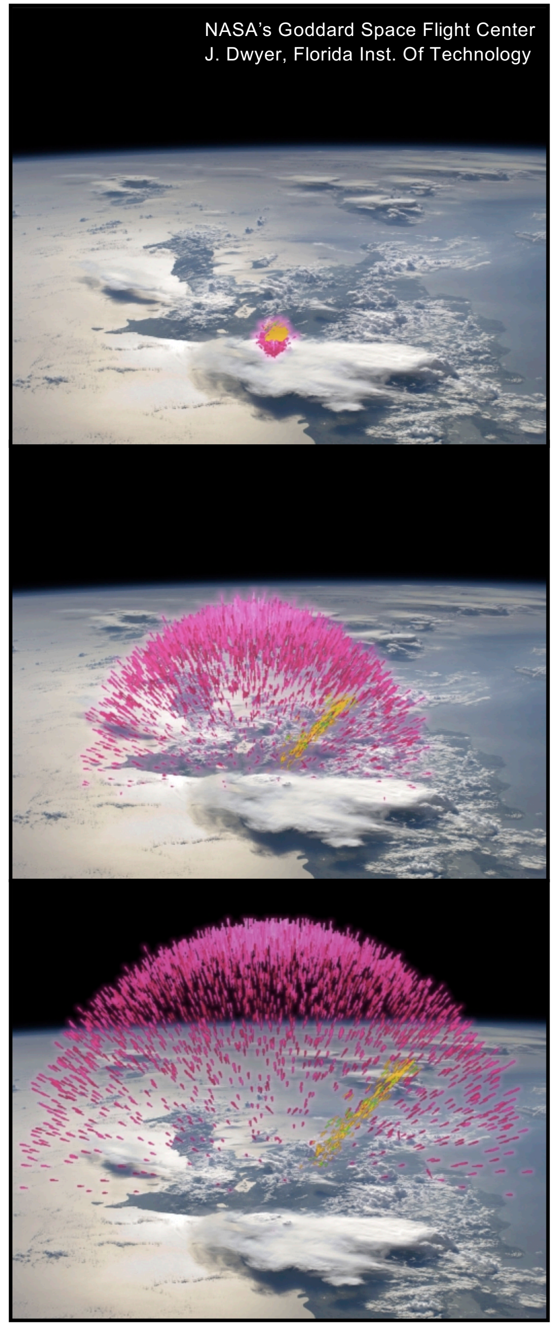
NASA's Fermi mission is an astrophysics and particle physics partnership managed by NASA's Goddard Space Flight Center in Greenbelt, Md., and developed in collaboration with the U.S. Department of Energy, with important contributions from academic institutions and partners in France, Germany, Italy, Japan, Sweden and the United States.

A set of snapshots of a model TGF forming at an altitude of 15 km (9.3 mi). The frames show the extent of the TGF at 0.2, 1.4 and 1.98 milliseconds after the trigger time.



A gamma-ray shower from the TGF is shown in magenta, and the electron/positron beam is in yellow.