Firefly Mission to Study Terrestrial Gamma-ray Flashes

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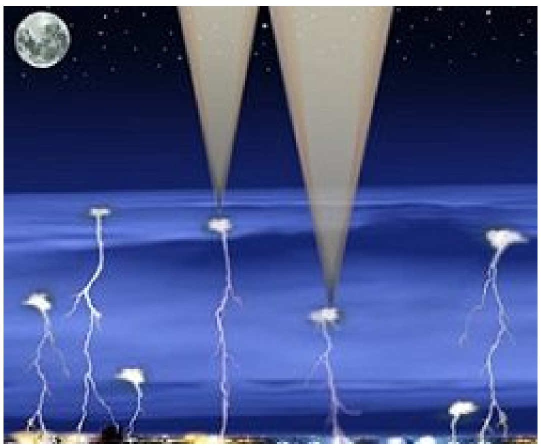

An artist's concept of TGFs. Credit: NASA/Robert Kilgore

High-energy bursts of gamma rays typically occur far out in space, perhaps near black holes or other high-energy cosmic phenomena. So imagine scientists' surprise in the mid-1990s when they found these powerful gamma ray flashes happening right here on Earth, in the skies overhead.

They're called Terrestrial Gamma-ray Flashes, or TGFs, and very little is known about them. They seem to have a connection with lightning, but TGFs themselves are something entirely different.

"In fact," says Doug Rowland of NASA's Goddard Space Flight Center, "before the 1990s nobody knew they even existed. And yet they're the most potent natural particle accelerators on Earth."

Individual particles in a TGF acquire a huge amount of energy, sometimes in excess of 20 mega-electron volts (MeV). In contrast, the colorful auroras that light up the skies at high latitudes are powered by particles with less than one thousandth as much energy.

At this stage, there are more questions about TGFs than answers. What causes these high-energy flashes? Do they help trigger lightning--or does lightning trigger them? Could they be responsible for some of the high-energy particles in the Van Allen radiation belts, which can damage satellites?

To investigate, Rowland and his colleagues at GSFC, Siena College, Universities Space Research Association, and the Hawk Institute for Space Sciences are planning to launch a tiny, football-sized satellite called Firefly in 2010 or 2011. Because of its small size, Firefly will cost less than $1 million — about 100 times cheaper than what satellite missions normally cost. Part of the cost savings comes from launching Firefly under the National Science Foundation's CubeSat program, which launches small satellites as "stowaways" aboard rockets carrying larger satellites into space, rather than requiring dedicated rocket launches.

An artist's concept of Firefly on the lookout for TGFs above a thunderstorm. Firefly will make simultaneous measurements of energetic electrons, gamma rays, and the radio and optical signatures of the lightning discharge.

If successful, Firefly will return the first simultaneous measurements of TGFs and lightning. Most of what's known about TGFs to date has been learned from missions meant to observe gamma rays coming from deep space, such as NASA's Compton Gamma Ray Observatory, which discovered TGFs in 1994. As it stared out into space, Compton caught fleeting glimpses of gamma rays out of the corner of its eye, so to speak. The powerful flashes were coming--surprise!--from Earth's atmosphere.

Subsequent data from Compton and other space telescopes have provided a tantalizingly incomplete picture of how TGFs occur:

In the skies above a thunderstorm, powerful electric fields generated by the storm stretch upward for many miles into the upper atmosphere. These electric fields accelerate free electrons, whisking them to speeds approaching the speed of light. When these ultra-high speed electrons collide with molecules in the air, the collisions release high-energy gamma rays as well as more electrons, setting up a cascade of collisions and perhaps more TGFs.

To the eye, a TGF probably wouldn't look like much. Unlike lightning, most of a TGF's energy is released as invisible gamma rays, not visible light. They don't produce colorful bursts of light like sprites and other lightning-related phenomena. Nevertheless, these unseen eruptions could help explain why brilliant lightning strikes occur.

A longstanding mystery about lightning is how a strike gets started. Scientists know that the turbulence inside a thundercloud separates electric charge, building up enormous voltages. But the voltage needed to ionize air and generate a spark is about 10 times greater than the voltage typically found inside storm clouds.

"We know how the clouds charge up," Rowland says, "we just don't know how they discharge. That is the mystery."

TGFs could provide that spark. By generating a quick burst of electron flow, TGFs might help lightning strikes get started, Rowland suggests. "Perhaps this phenomenon is why we have lightning," he says.

If so, there ought to be many more TGFs each day than currently known. Observations by Compton and other space telescopes indicate that there may be fewer than 100 TGFs worldwide each day. Lightning strikes millions of times per day worldwide. That's quite a gap.

Then again, Compton and other space telescopes before Firefly weren't actually looking for TGFs. So perhaps it's not surprising that they didn't find many. Firefly will specifically look for gamma ray flashes coming from the atmosphere, not space, conducting the first focused survey of TGF activity. Firefly's sensors will even be able to detect flashes that are mostly obscured by the intervening air, which is a strong absorber of gamma rays (a fact that protects people on the ground from the energy in these flashes). Firefly's survey will give scientists much better estimates of the number of TGFs worldwide and help determine if the link to lightning is real.

More information: firefly.gsfc.nasa.gov/

Source: Science@NASA, by Patrick Barry