Natural Radio

News, Comments and Letters About Natural Radio

October 2013

Firestation Is Operational -- There's a new eye in the sky peering down on Thunderstorms from low earth orbit. The Firestation experiment was delivered to the ISS on August 3, 2013, by the Japanese robotic cargo vessel Kounotori-4. Shortly after, it was installed on the exterior of the ISS and by the end of August, its sensors and control systems were confirmed to be operational. Science data began flowing from the project at the beginning of September. Firestation will study the link between lightning and the mysterious events known as Terrestrial Gamma ray Flashes, or TGFs.

Lightning has both fascinated and struck fear into human beings since our origin. In mythology, it is the weapon Zeus gives to the Cyclops, it often appears in literature as an instrument of divine retribution and is used in contemporary culture as a symbol of quickness and power.

Ben Franklin in 1749 theorized the electrical nature of lightning and in 1752 performed his famous kite experiment to demonstrate and confirm that theory. Ben survived the dangerous experiment, but several others repeating the experiment weren't so lucky.

In his new book, *Earth Sound Earth Signal,* Douglas Kahn talks about how Thomas Watson, Alexander Graham Bell's assistant, heard the sounds of sferics, tweeks and whistlers through the first telephone, around 1876. This was probably the first reception of Natural Radio signals.

Other observations followed, and in the late 1920's, T. L. Eckersley published a series of papers and postulated the existence of a dispersive medium. His observations indicated that whistlers were associated with magnetic storms.

In a 1930 paper, Barkhausen offered two possible explanations for whistlers. The first, which is caused by a series of multiple reflections between the earth and the ionosphere, is the same method that produces tweeks. In the second, Barkhausen introduced the idea of a dispersive medium. He indicated that a remote lightning stroke, a direct current impulse that contains all frequencies, was the initiating event. He was at a loss, however, to explain the long duration and low amount of attenuation in whistlers. He concluded that more observation would be needed.

In the 1950's, L.R.O. Storey, in Cambridge, England, began a serious study of the nature and origin of whistlers. Through his observations of whistlers, he formed the basis of the "magneto-ionic" theory of their origin, and of a magnetic storm's effect on whistlers. Storey's research made an important contribution to the growing body of knowledge about whistlers by showing that whistlers followed the earth's magnetic field lines.

The floodgates were opened in the mid 1950's with the International Geophysical Year. The experiments of Robert Helliwell and others led to the development of theories of sferics, tweeks and whistlers and their relationship to lightning, as well as a much better understanding of the ionosphere. The Space Age began with the launch of Explorer I and the discovery of the Van Allen Belts and the beginning of the study of "Space Weather."

The nature of lightning got a bit more complicated with the discovery of Sprites. Sporadic visual reports of sprites go back at least to 1986, but they were first photographed on July 6, 1989 by scientists from the University of Minnesota. The term was coined around 1993. Elves were first observed in 1991 or 1992 and Blue Jets in 1994.

Even more mysterious than Sprites, Elves and Jets are Terrestrial Gamma Ray Flashes or TGFs. These were first discovered in 1994 by the Compton Gamma-Ray Observatory. A subsequent study from Stanford University in 1996 linked a TGF to an individual lightning strike occurring within a few milliseconds of the TGF. The newer RHESSI satellite has observed TGFs with much higher energies than those recorded by Compton, but the mechanism was still unknown.

The Fermi spacecraft was launched in 2008 and its Gamma Burst Monitor (GBM) detected gamma rays with energies of 511,000 electron volts. This signature indicates an electron has met its antimatter counterpart, a positron, and provides direct information about the source of the gamma rays.

What is interesting is that while most of the TGFs were detected when Fermi was orbiting directly over a thunderstorm, there were four cases Fermi was far away from any thunderstorm activity. In addition, sferics detected at the same time by a global monitoring network indicated the only lightning at the time was hundreds or more miles away. Further analysis of the data indicated that the high-energy electrons and positrons follow a field line, just like a whistler, and bounce back in a similar manner.

Considering the amount of positrons in the beam Fermi detected, the thunderstorm was briefly creating more radiation—in the form of positrons and gamma rays—than what hits Earth's atmosphere from all other cosmic sources combined,

Finally, as I wrote about in January, there is another interesting piece to the puzzle. Strong VLF bursts have been linked to TGFs for a long time, but researchers assumed that these signals were emitted by the lightning strokes associated with the gamma-ray emission. However, the improved data from Fermi GBM indicated that when a strong radio burst occurs almost simultaneously with a TGF, the radio emission is actually coming from the TGF itself.

Recently, a new theory has emerged to explain the generation of positrons and electrons that trigger the gamma-ray burst – Dark Lightning. What is hypothesized is that Dark Lightning may be a "competitor" to conventional lightning. Both act to neutralize the massive electrical charges that build up in thunderstorms.

What is proposed is that under certain conditions, the growing electrical field in a thunderstorm can precipitate a powerful avalanche of electrons, shooting upwards at near light speed. These electrons collide with air molecules and produce gamma-rays.

Then, the gamma-ray radiation transforms into a positron and electron pair. Successive collisions between the new particles and air creates more positrons and electrons. Then the cycle repeats, like nuclear fission. Once this feedback loop gets going, it can quickly discharge parts of the thundercloud very quickly, just like a lightning stroke. Since this process generates a lot more gamma rays than light, it is practically undetectable in the visible spectrum.

Firestation will study the link between lightning and TGFs, and hopefully shed some light on the theory of Dark Lightning. Other questions to be answered are whether lightning triggers TGFs or whether TGFs trigger lightning and are TGFs responsible for some of the high-energy particles in the Van Allen belts.

"We know that lightning might be intimately linked to these flashes of gamma rays, but we don't know the cause and effect mechanisms just yet," said Doug Rowland, principal investigator for Firestation at NASA's Goddard Space Flight Center in Greenbelt, Md. "So one of Firestation's goals is to study many TGF and lightning events to see which types of lightning produce gamma rays and which kinds do not."

The Firestation Project is a knockoff of Firefly, a Cubesat project began by Rowland in 2008. The Firefly satellite, whose launch has been delayed several times, will hopefully also launch in 2013.

There are three sets of sensors aboard Firefly, combined in two instruments.

The prime instrument is the Gamma-Ray Detector instrument (GDR), developed by Dr. Joanne Hill at USRA/NASA GSFC. The GRD will measure the energy and time-of-arrival of incoming X-ray and gamma-ray photons associated with TGFs. The same instrument will also be able to detect energetic electrons in the hundreds of keV to few MeV range, to look for the relativistic electrons which are responsible for the gamma-ray emissions.

The other instrument is the VLF receiver / photometer experiment (VP), developed by Prof. Allan Weatherwax at Siena College. This experiment will combine multiple sensors to measure both the Very Low Frequency (VLF) radio waves emitted by lightning in the tens of Hz to tens of kHz range, and the optical emissions from lightning at high time resolution. These measurements will serve both to corroborate the occurrence of lightning when enhanced gamma-ray or electron fluxes are observed, as well as to help locate the parent lightning and determine some of its characteristics such as intensity, polarity, etc.

When lightning or TGFs are detected, and the signal strength is above a pre-set threshold, the system acquires 100ms of high time-resolution data from all three sensors, the optical, VLF, and GRD. The satellite is expected to observe up to 50 lighting strokes per day, and about 1 large TFG every couple of days.

Firestation was built primarily from spare pieces of the Firefly project with a redesigned housing for use on the ISS.

The instruments on both projects are similar, but they differ in some significant areas. The Firestation sensors operate over a wider measurement range. Firestation will also make use of a camera, also onboard the instrument pallet, to photograph lightning flashes so that the scientists can derive a precise location of their incidence. Firestation's data rate is about 3,000 times larger than Firefly's, so that the research team will be able to sample every lightning stroke, not just Firefly's carefully selected sample.

But, the biggest advantage is in mission duration. Firefly is expected to remain in low-Earth orbit for roughly a month, while Firestation will have a one-year mission flying on the ISS. Rowland says, "This represents orders of magnitude better coverage."

While no details have been published on the VLF receiver used in Firestation, it's probably safe to assume that it is the same or a very similar receiver to the one in the Firefly Cubesat. This receiver was developed by Professor Allan Weatherwax and his team of students at Siena College which measures single-axis electric fields in the 100 Hz. to 1 mHz. range.

In spite of the differences, both projects have the same mission. Using sensitive photometers to measure lightning flashes, VLF receivers to measure the strength and polarity of lighting, and combined gamma-ray and energetic electron detectors, both Firestation and Firefly will gather data to find out whether lightning triggers TGFs.

What Rowland finds most surprising about TGFs is their extreme energy."Gamma-rays are thought to come from the most violent events in the cosmos like stars colliding or exploding, what a surprise to find them shooting out of the cold upper atmosphere of our own planet."

While the mechanism of whistler creation is not a primary objective of this mission, it is likely that some information will emerge as to what type of lightning flashes create whistlers and if whistlers are also created by TGFs. Additionaly, is there a different VLF signature for a TGF burst and for Dark Lightning, if it actually exists?

This might allow us to discriminate among different types of whistlers, tweeks and sferics, depending on their source. This could make listening more interesting as we searched for the different type of emissions. Also, it could probably allow us to collect more potentially useful data. I'll post associated links and any mission updates on the Naturalradiolab.com website.

VLF_Group Updates – Google groups on Yahoo underwent an upgrade and facelift. The VLF_Group has a new look and somewhat smoother functionality.
The important thing is that the files section has been expanded to 2 Gigabytes of storage from 100 Meg. This will allow it to be a better information repository as in the past, we periodically had to purge non-essential files to keep from exceeding our limit and people were hesitant to post potentially useful files because of the space limitations.