

Triton Fun Company

Science Newsletter April 2010

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April 2010

Lightning on other planets

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Lightning is a common phenomenon in planetary atmospheres. It is well-known on Earth, but also occurs on the outer planets, Jupiter, Saturn, Uranus and Neptune. Evidence of lightning was detected on these planets by the Voyager and Cassini spacecraft. Lightning has been well characterized on Earth (though some features of it are still not well known, including precise temperatures and state of the molecules in the lightning channel). However, lightning has been detected on the large outer planets from their radio emissions, for example, SEDs (Saturn electrostatic discharges), UEDs (Uranian electrostatic discharges), etc. Humans are familiar with the disruption and static in AM radio transmissions during lightning storms. This radio noise from discharges in the atmosphere is also called "sferics".

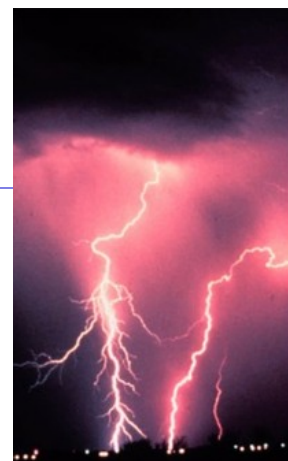
Lightning results from a discharge of electricity that gets created from a charge separation in clouds or between clouds and the ground. It can travel at 130,000 mph in our atmosphere. Estimates of the size of the lightning channel on Earth range from 1-20 cm. The luminous bright part of the bolt is narrower and is at very high temperatures of upwards of 30,000 K. The vapor pressure inside the channel can be as high as 13 atm, creating an outward moving shock wave which

will cause the pressure to drop in the channel to 0.87 atm in only 14 msec. There is a sharp temperature and pressure gradient in the channel which induces chemistry and changes the mix of species instantaneously. Lightning storms are incredibly powerful places for chemical transformation.

Bolts of lightning can last for 30-50 microseconds and have currents of 100 kAmps. The amount of current is able to heat up gaseous, liquid and solid objects in the air and on the ground very quickly. A bolt may have a power output of $\sim 10^{12}$ watts. It can be 20000-30000 degrees K in the center of the channel with an electron density of $\sim 1 \times 10^{24}$ e/m³.

The luminous core of the channel can cool down in a short time: microseconds. Despite what they say, lightning *can* strike twice in the same place, and in fact is much more likely to strike more than once down the conductivity channel established by the first stroke. Lightning will go down that channel again because it has been ionized on the first pass from cloud to ground and is the most conductive path available for the electrons at that time.

On Earth, most lightning is cloud-to-cloud lightning and only perhaps 1/6 to 1/2 of lightning is



Lightning storm

Ferocious on any planet

from cloud to ground. The downward stroke is followed by a more powerful upward stroke (the return stroke). The discharge from the return stroke and neutralization of the charges can occur down the channel at up to 0.2 times the speed of light. Each stroke occurs usually with around 40 microseconds between them. The length of the channels can be kilometers long.

This much energy dissociates molecules into atoms and ions. The associated shock wave expands outward and can heat the surrounding air outside the immediate channel to 2000-4000 K. The gases can cool quickly at a rate of a million degrees K per second. However, once the air cools, the reactions that would convert molecules to their low temperature forms may be 'kinetically inhibited' and so

Lightning on other planets: *continued*
 Photos/Info: NASA

the chemical compositions may be "frozen in" at the ratios that would occur at the higher temperatures. Elemental carbon from methane dissociation by lightning would convert back to methane at high temps but once the cooling takes place, the reaction is slowed down so much that there is a new equilibrium composition established. Therefore, carbon particles formed by lightning on Saturn, for example, should be able to be maintained due to the slowed conversion process.

Lightning bolts will have energies of up to 10^8 joules in Earth lightning storms. On the primitive Earth, discharge energies in sparks were estimated to be 0.9 cal/cm-yr and for corona in lightning was estimated to be around 3 cal/cm-yr. Later estimates gives 0.05 and 0.02 cal/cm-yr, respectively for the spark and corona discharges in lightning storms on the early Earth, still a lot of energy for dissociations and ionizations of atmospheric molecules.

Observations by spacecraft such as Voyager, Cassini and Galileo have confirmed lightning phenomena on the outer planets. The high frequency PRA receivers on Voyager observed *sferics*, and the PWA system detected *whistlers* (radio hiss). The imaging system was able to see optical evidence of lightning in Jupiter's atmosphere. The Galileo spacecraft could detect lightning optically and the imaging system had enough resolution to determine the location of a lightning flash to within a half of a degree of latitude on Jupiter. Galileo also had a lightning and radio emissions instrument (LRD) that could receive frequencies between 10 Hertz-100 kilo-Hertz. Voyager found that lightning strikes occur on Jupiter at $0.004 / \text{km}^2\text{-yr}$, much less than that of Earth which is around $6 / \text{km}^2\text{-yr}$. The energies of Jupiter's lightning bolts were estimated at 10^{12} Joules by Voyager.

The rate at Jupiter was calculated from the detection of whistlers on the planet. The Galileo spacecraft later confirmed the rate of $0.004 / \text{km}^2\text{-yr}$ (specifically $0.0042 / \text{km}^2\text{-yr}$). From modeling of storms on Jupiter, Yair et al (1995) determined the center of the storm cloud is at around 205-225 K. Yair assumed the channel was 20 km long and 2 km in diameter.

The absence of sferics in Voyager's observations of Jupiter were explained by the discharge times of Jupiter's lightning bolts being a few milliseconds, whereas on Earth they are shorter, around 10-100 microseconds.

Saturnian lightning was detected by Voyager's PRA instrument which picked up the Saturn electrostatic discharges, or SEDs. No whistlers were detected, and the lightning had not been detected optically. At least not until April 2010 when Cassini spotted visual evidence of lightning bolts in Saturn's storm clouds. However, copious data from Cassini has already shown the correlation of lightning with SED radio bursts in Saturn's atmosphere.

Lightning on Uranus was detected by Voyager from the UEDs (Uranian electrostatic discharges). Optical detection is not possible due to the depth of the lightning. Lightning is also present on Neptune, though it cannot be seen optically and there are only weak sferics. However, 16 whistlers were detected by Voyager which seems to be strong evidence of lightning on Neptune. The energies of the lightning could not be determined from the data but the frequency is calculated to be 1/19 that of Jupiter, so it is $\sim 2 \times 10^{-4} / \text{km}^2\text{-yr}$.

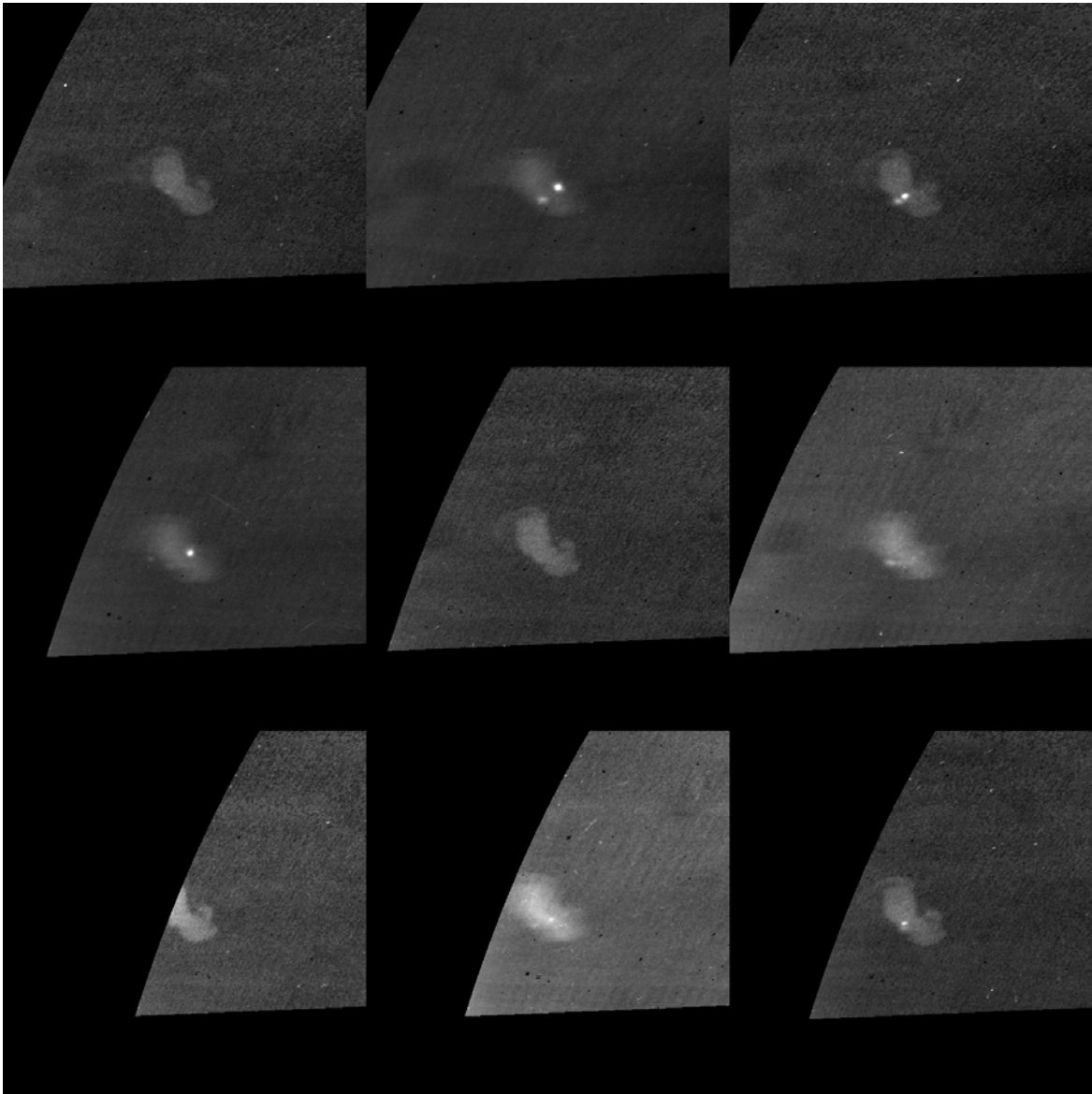
Until just this year, lightning on Saturn was not able to be seen visually, the reason being that the water level in Saturn's atmosphere where storms originate from is very deep; i.e. it is situated underneath many other cloud decks and layers of air so that the energy of the bolts of

lightning (that look so bright in Earth's atmosphere) would be scattered so much by the layers above that it would not be visible. On Jupiter, the water layer is not as deep as on Saturn and so Voyager was able to see optical flashes from the Jovian thunderstorms. The storms are also occurring too deep in the atmospheres of Uranus and Neptune to be seen optically. On these 3 planets where the storm layer is down deep, lightning was first detected by the static or crackle in the radio signals from the planet. However, as of 2010, new images from the Cassini spacecraft show optical images of Saturn lightning for the first time. This lightning was first recognized in the storm clouds that were coming over the horizon of Saturn and making lots of radio noise in Cassini's instruments. Now, the visual confirmation is a sweet result !

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 References

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- 2) Desch, S., Borucki, W., Russell, C.T., Bar-Nun, A., 2002. Progress in planetary lightning, *Rep. Prog. Phys.* 65, 955-997.
- 3) Rakov, V.A., Uman, M.A., 2003. *Lightning: Physics and Effects*, Cambridge University Press
- 4) Yair, Y., Levin, Z. Tzivion, S., 1995. Lightning generation in a Jovian thundercloud: Results from an axisymmetric numerical cloud model, *Icarus* 115, 421-434.
- 5) Lightning observed on Saturn:
<http://saturn.jpl.nasa.gov/news/newsreleases/newsrelease20100414/>
- 6) NASA video about Saturn storms:
<http://www.youtube.com/watch?v=ZVWI3I-KpwA&NR=1>

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Cassini sees Saturn lightning for the first time

These images show the characteristic curlicue Saturnian storm clouds occurring in the 35 degree South latitude band, also known as “storm alley”. Now bright flashes have been detected visually in these storms, confirming the presence of lightning. Previously, only *static* or *crackles* in the natural radio signals from the planet would give evidence of the presence of lightning as the storm came over the horizon.

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Superfluous Questions:

- 1) Rigil Kentaurus is another name for *what* familiar star system ?
 a) Rigel b) Beta Aurigae c) Alpha Centauri d) Canus Major
- 2) From Earth, the center of our galaxy appears to be in *what* constellation ?
 a) Gemini b) Sagittarius c) Scorpio d) Taurus
- 3) In the TV show *Star Trek*, an alien named Sargon temporarily inhabits Capt. Kirks body. Who is Sargon's wife?
 a) Estella b) Quino c) Eleena d) Thalassa
- 4) What is the state bird of New York ?
 a) Eastern bluebird b) Goldfinch c) White wren d) Eastern sparrow

→ ANSWERS in next months issue of the Science Newsletter ! ←---

** ANSWERS to March's Superfluous Questions: 1. b) 6000 2. c) race car driver 3. c) goldenrod 4. c) South Dakota