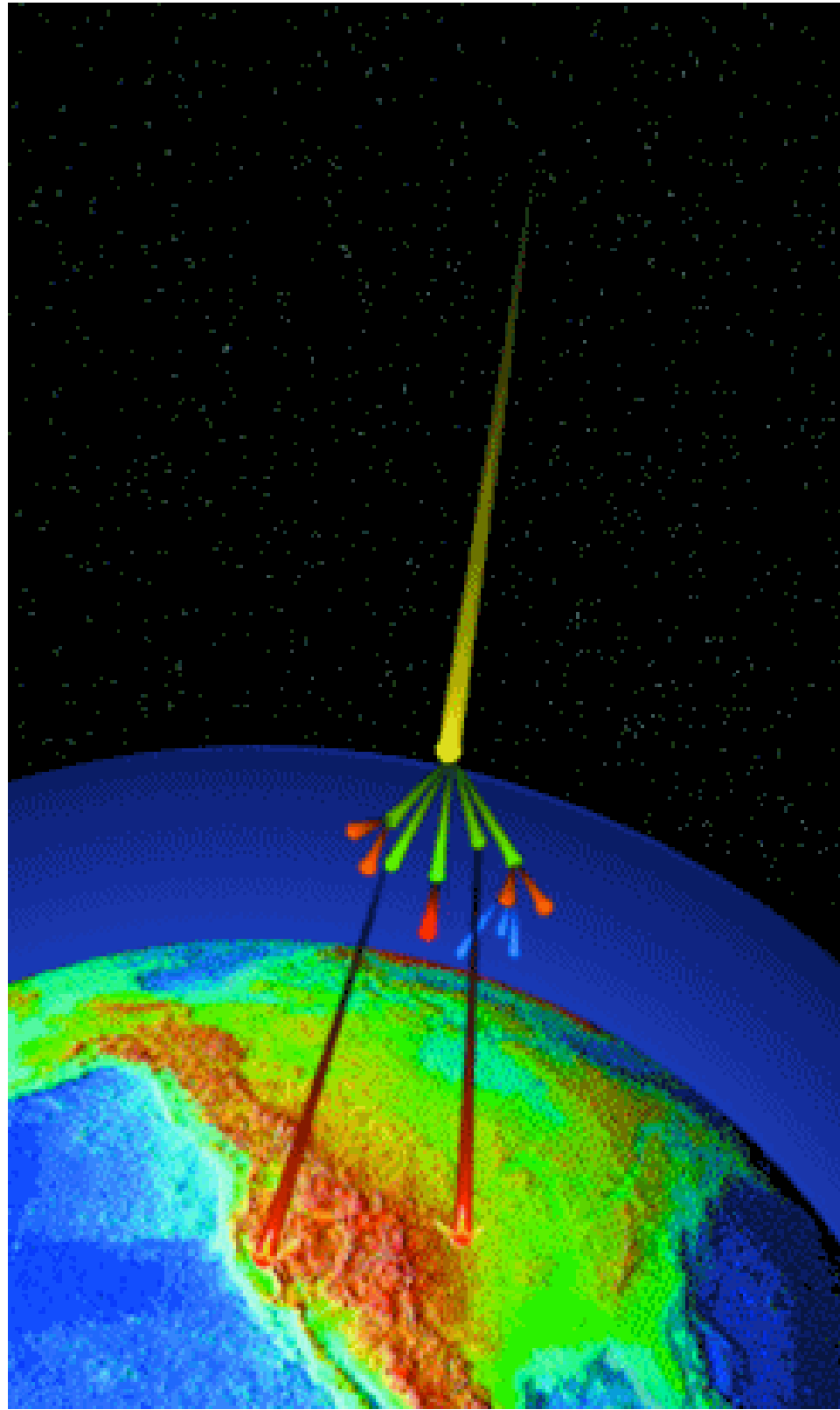


# COSMIC RAYS



<http://www2.slac.stanford.edu/vvc/cosmicrays/cratmos.html>

## What is a cosmic ray?

A cosmic ray is any particle, usually a proton, an electron, or an atomic nucleus, that comes to Earth from outer space. These particles interact with particles in the atmosphere, like oxygen and nitrogen, and the products of these interactions shower to Earth. There are two types of cosmic rays: primary and secondary. Primary cosmic rays are the particles that come from outer space, and secondary cosmic rays are the remnants of the primary when they break up in the atmosphere.

## Low Energy Cosmic Rays

Low Energy Cosmic Rays consist of protons and electrons with very low energy from solar winds, which are produced by solar flares. Almost all of these are deflected by the Earth's magnetic field and absorbed in the atmosphere. However, they do possess enough energy to ionize gases in the atmosphere. This produces the Aurora Borealis in the Northern Hemisphere and the Aurora Australis in the Southern Hemisphere. Still, these cosmic rays do not reach the Earth's surface.

## High Energy Cosmic Rays

High Energy Cosmic Rays, also known as Galactic Cosmic Rays (GCR), come from interstellar space. These rays are composed of 85% protons (hydrogen nuclei), 12% alpha particles (helium nuclei), and 3% electrons and nuclei of heavier atoms. The average life span of a GCR is 10 million years. Some of these particles come from outside our galaxy, and typically have energies of several billion electron-volts. One possible source for the high energy of these particles is supernova explosions. The GCR's are also affected by the sun. The solar wind, which consists of plasma and loose protons and electrons, creates the heliosphere that extends past Pluto. When the GCR's pass through this heliosphere, they lose some of their energy, and the lowest energy GCR's never reach the Earth. When cosmic rays reach the atmosphere, they collide with atmospheric gas molecules. Some of the secondary particles produced in these collisions eventually decay into muons.

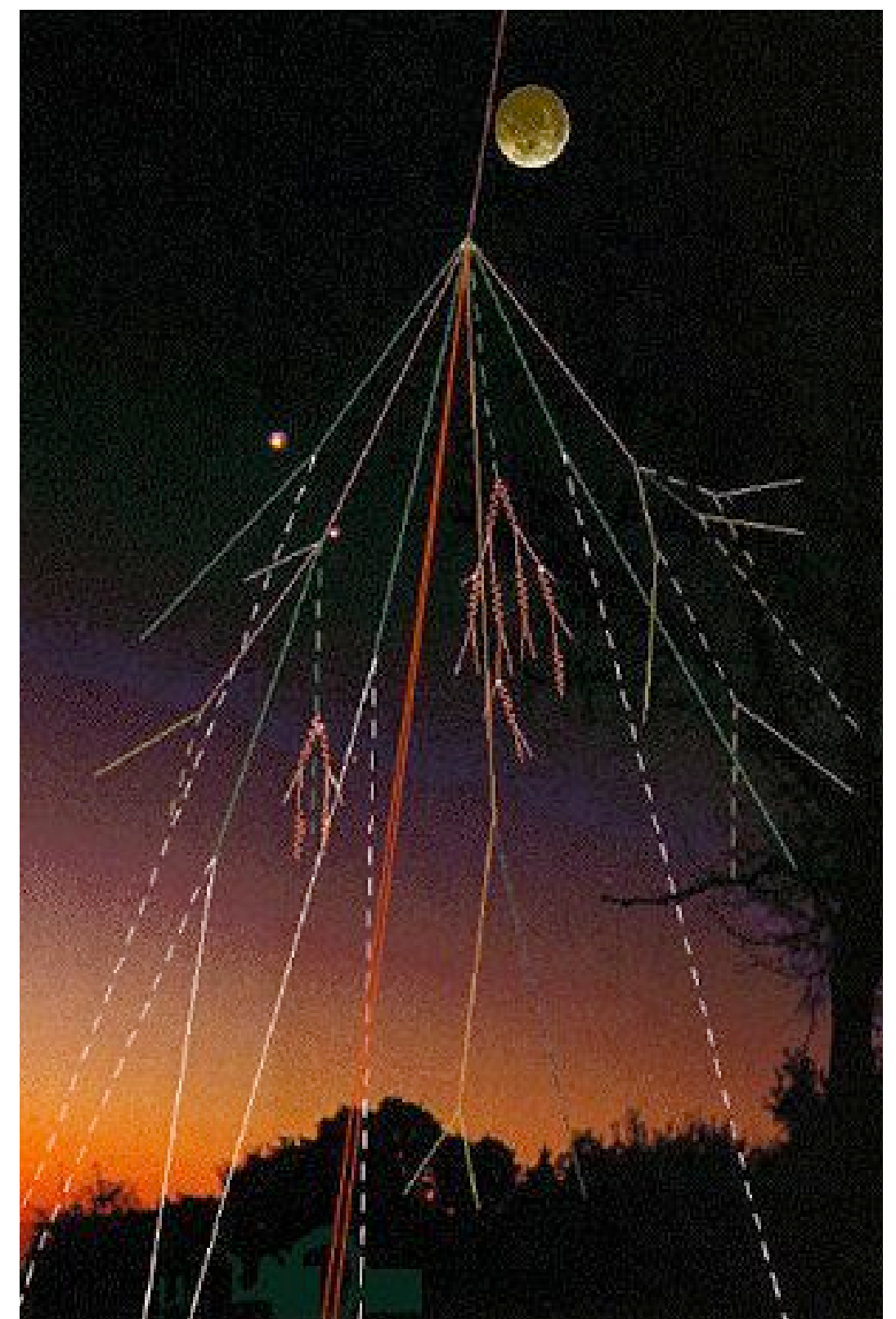
## What is a muon?

A muon is the same as an electron except it is 200 times heavier. Muons reach the Earth's surface because they possess three important properties: they decay relatively slowly compared to other particles produced through the decay (like pions), they can penetrate large amounts of material without reacting due to their lack of strong interaction properties, and unlike electrons, they are too massive to be significantly affected by electric fields. Interestingly, based on the muon's half-life of 1.4 microseconds, they should have all decayed long before they reached the Earth. We are able to detect them because of the effects of Special Relativity; the particles undergo a time dilation due to their high velocity (close to the speed of light), allowing some to survive the journey to Earth without decaying.

## Effects of Cosmic Rays

When a muon ionizes a gas molecule, it strips away an electron, making the molecule a positive ion. The electron then recombines with a nearby positive ion. The balance between this ionization and recombination results in a fairly constant density of positive and negative ions in the atmosphere. Due to differences in the properties of negative and positive ions, an electric field is created with a potential difference of 100 volts per meter. In a thunderstorm, the negative ions are pushed up and the positive ions are pushed down by a not-completely-understood mechanism. This changes the electric field strength to tens of thousands volts per meter, which results in a discharge of particles, commonly known as lightning. Based on this, it may be concluded that cosmic rays may have a direct influence on the types of weather we can have on Earth.

Another effect of cosmic rays is the ability to use carbon dating in determining the age of organisms. Collisions of primary cosmic rays with the nuclei of atmospheric molecules can cause a change in the makeup of these molecules. For example, if a high energy neutron collides with a nitrogen nucleus, there is a charge exchange. This is when one of the nitrogen's protons is replaced with the incoming neutron. This leaves the nucleus with 6 protons and 8 neutrons, an isotope known as Carbon-14. This isotope is unstable and decays with a half-life of 5730 years. Organisms then take in this carbon from the atmosphere and when they die, their age can be determined through analysis of the amount of Carbon-14 left in their bodies. This process is known as carbon dating.



[www.rsc.ccc.tn.us/obs/Cosmic%20ray%20shower.jpg](http://www.rsc.ccc.tn.us/obs/Cosmic%20ray%20shower.jpg)