Cosmic Rays

and

The Cloud Chamber

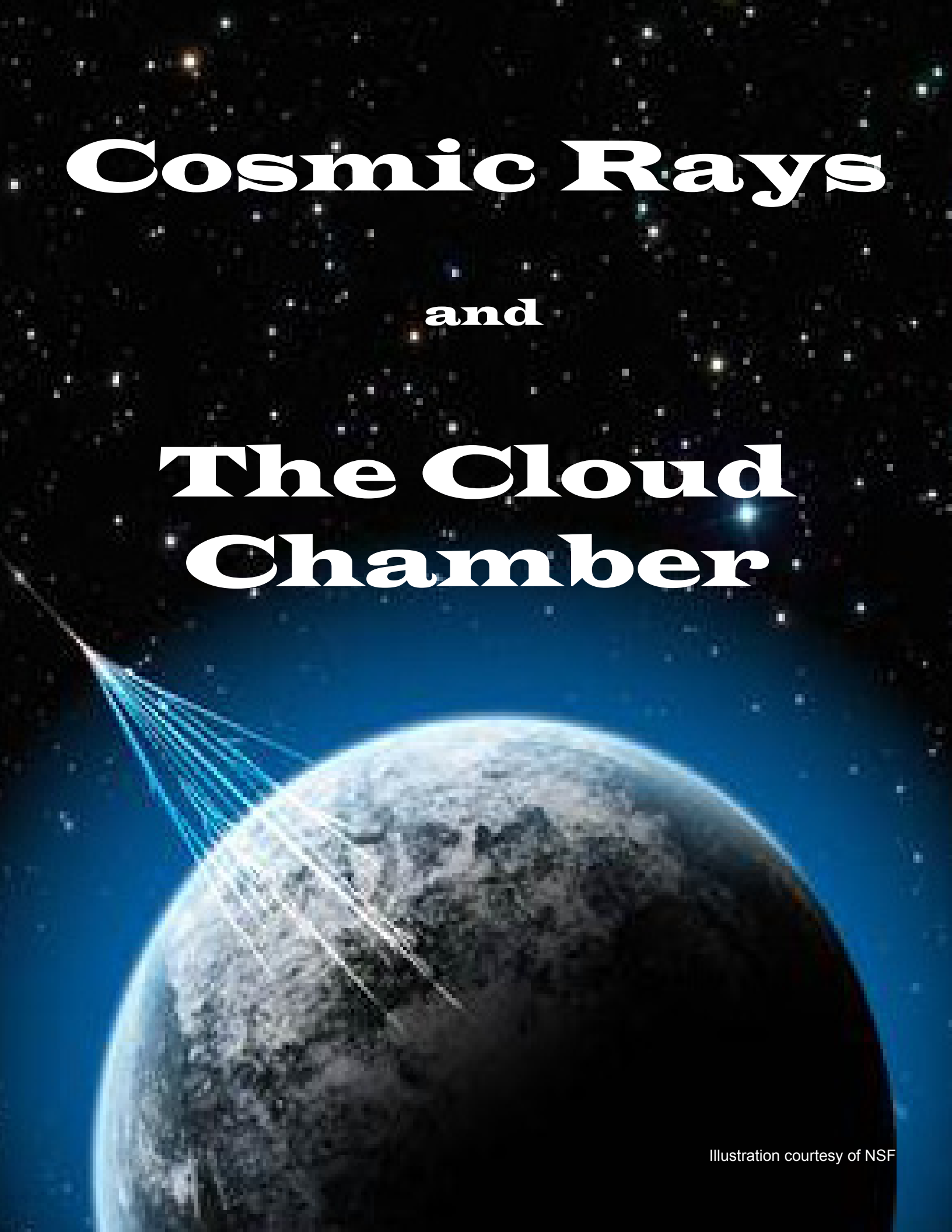


Illustration courtesy of NSF

By the CRaTER Team, Institute for the Study of Earth, Oceans, Space,
University of New Hampshire, Durham, NH
2012

Image courtesy of NASA

"Time to start your science projects," **announced our teacher. Some of the kids in class groaned, but I am really looking forward to doing mine.**

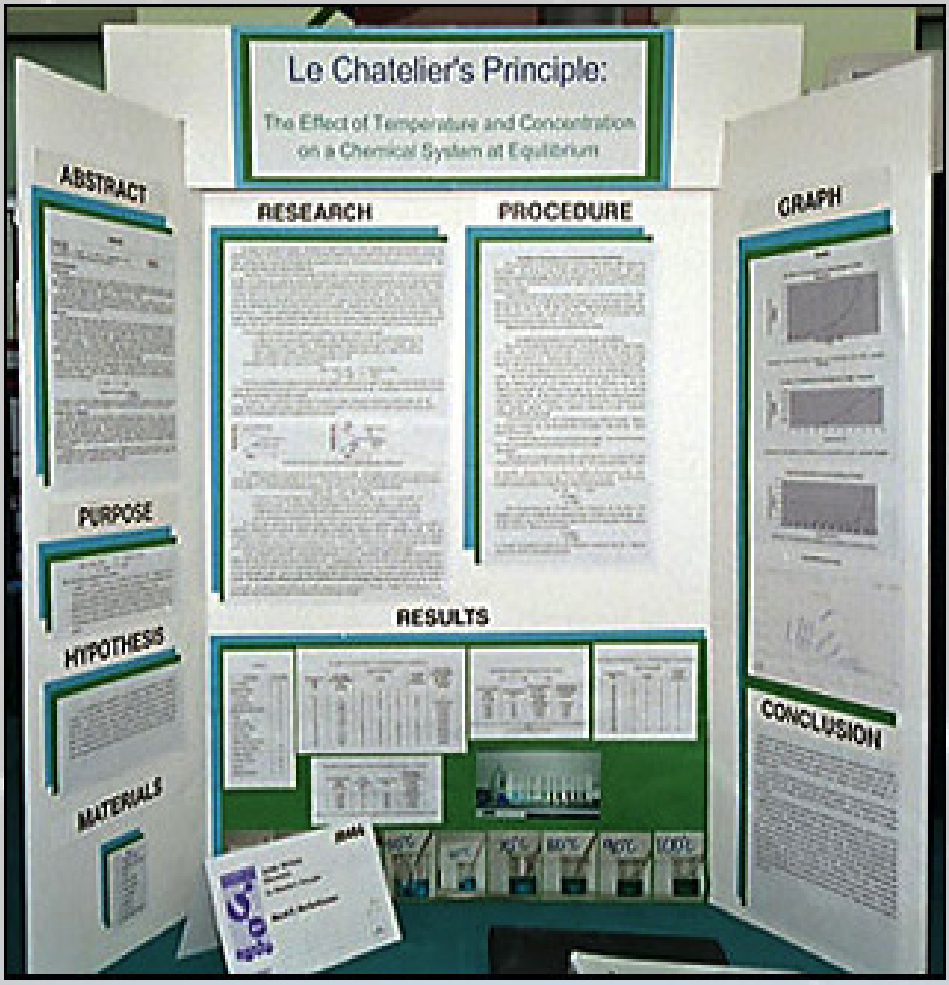


Image courtesy of Free Science Fair Project Ideas, Answers and Tools

I want to do a project that is really different. Something no one in my school has ever done.

One that would surprise even my teacher!

Image Courtesy of MSDC

I already have a great idea. The other day I was at the McAuliffe-Shepard Discovery Center and I saw a cloud chamber. When you look inside this black box you can see misty squiggly lines. These lines are made by the particles in cosmic rays. Normally we can't see these particles even though they are all around us. It was really cool!

I am going to design a cloud chamber for my science project. I'll start by researching all about cloud chambers and learning how they work. Once I know enough I will come up with my own design and test it out.

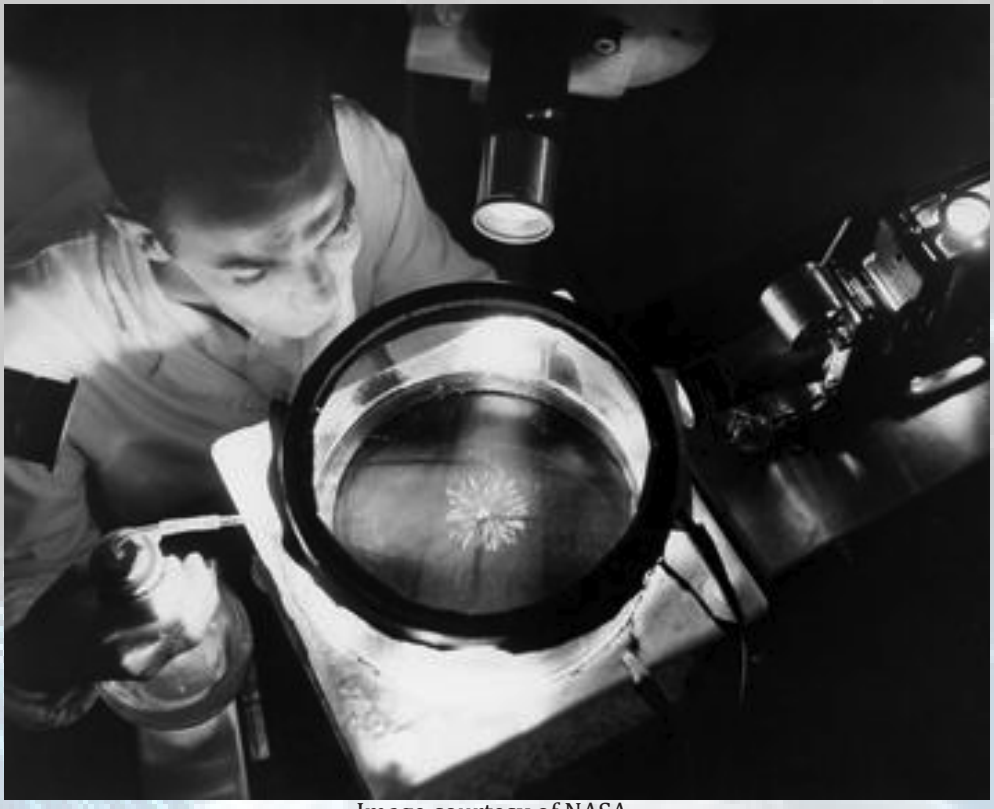


Image courtesy of NASA

I will also learn more about cosmic rays. Where do they come from and why do we want to detect them? I already learned that the person who invented the cloud chamber won a Nobel Prize. So the detection of cosmic rays must be important.

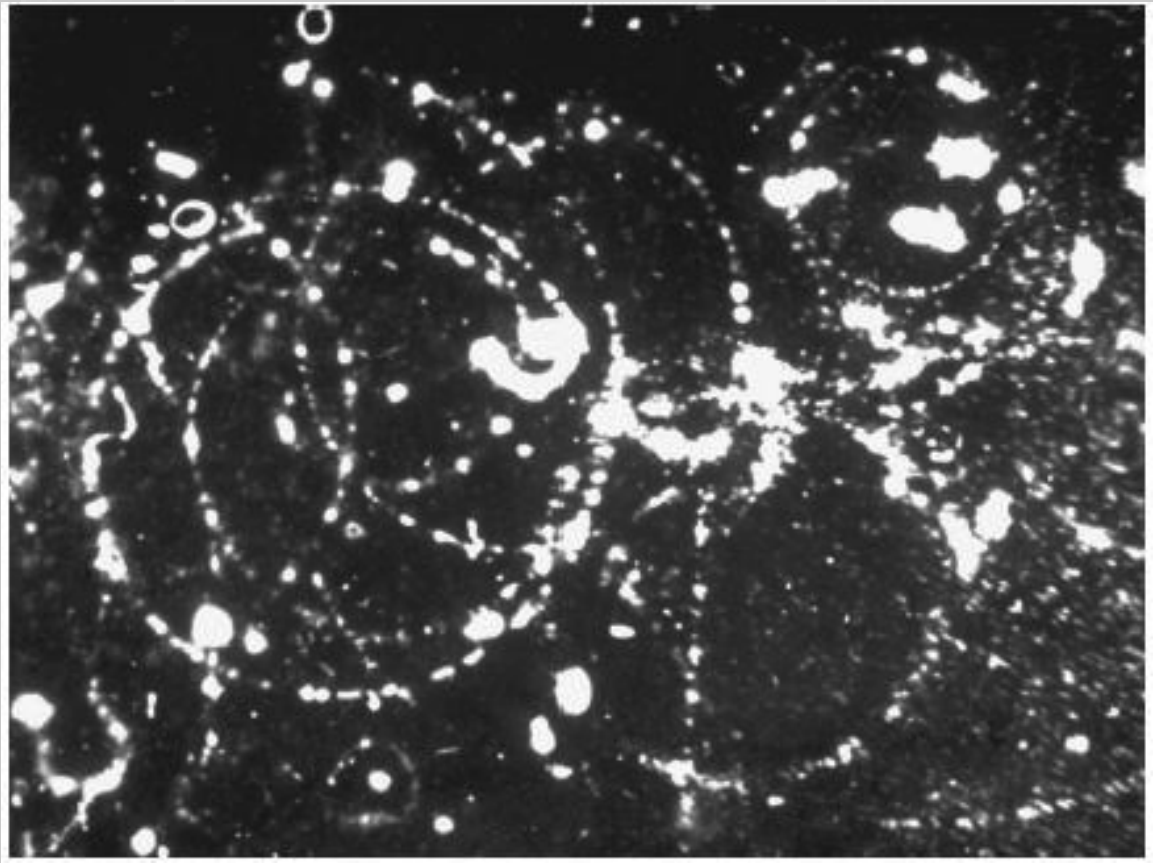


Image courtesy of Science Clarified

Why can't we see cosmic ray particles? Well, that's because they are high-energy particles. They move almost as fast as light. Plus, they are really small. They are subatomic particles. That's smaller than an atom.

Image courtesy of NASA

Where do these fast moving particles come from? Most cosmic rays come from outer space. They come from the sun, other stars and events like supernova explosions. Can you believe that!

Did you know we are hit by cosmic rays every day? A few enter our planet's atmosphere. They pass through the roof of our house and bounce around our classroom. Keep in mind cosmic rays are not really rays; they are particles with very high energies.

Image courtesy of The Resilient Earth

Source unknown

Fortunately, not enough cosmic rays make it to Earth to cause serious damage to us. Our atmosphere absorbs and prevents most of the cosmic rays from reaching us. We can tolerate the few cosmic rays that do make it through the Earth's atmosphere.

Image courtesy of Wikipedia.org

Once my friend's Dad showed me his Geiger counter. It detects high-energy particles like cosmic rays. Each time a cosmic ray hits the sensor it makes a clicking sound. You can see a Geiger counter in the Mars exhibit at the McAulliffe-Shepard Discovery Center.

Image courtesy of School of Ocean and Earth Science and Technology, University of Hawaii

Even if you put your hand around the Geiger counter's sensor it still clicks. That's because the cosmic rays pass right through your hand.

I've learned that scientists at the University of New Hampshire study cosmic rays. In fact, scientists at UNH started studying cosmic rays back in the 1950's.

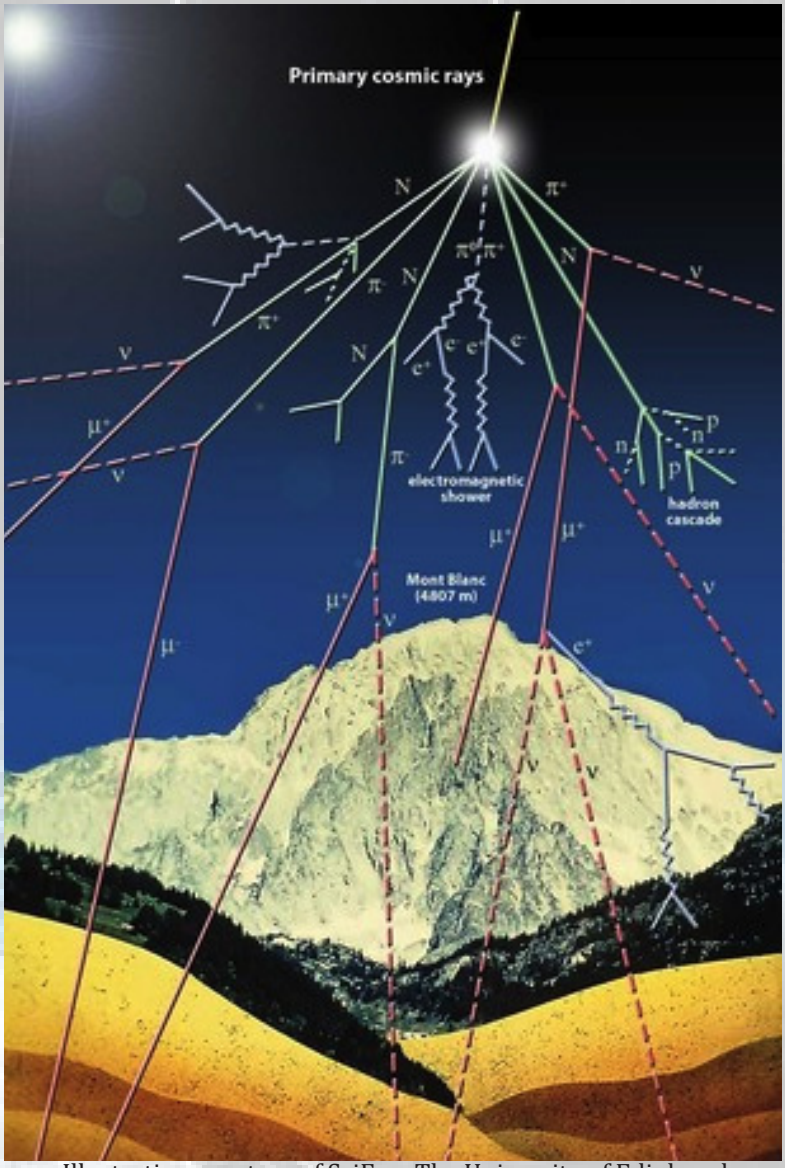


Illustration courtesy of SciFun, The University of Edinburgh

They studied them with detectors called neutron monitors. A neutron monitor counts the number of cosmic ray particles that hit its detectors.

A neutron monitor called Cosmo was placed on the top of Mount Washington. Another one called Climax was put inside a building in Durham, NH. The monitor in Durham is close to sea level. The one on top of Mount Washington is 6,263 feet above sea level.

Scientists have learned that there are fewer cosmic rays in Durham than on top of the mountain. This is because there is less atmosphere between the top of Mount Washington and outer space. So there's less protection from cosmic rays on top of the mountain.

Image courtesy of the University of New Hampshire

Image courtesy of NASA

Scientists and engineers at UNH built an instrument called CRaTER (Cosmic Ray Telescope for the Effects of Radiation). It is on the LRO (Lunar Reconnaissance Orbiter) satellite circling the Moon.

Image courtesy of NASA

Image courtesy of NASA

Engineers and scientists often work together on projects at UNH. The scientists decide what information needs to be collected. The engineers design and build the instruments for collecting that information, and then the scientists analyze the data.

For CRaTER, the scientists found a plastic that behaves like human tissue when cosmic rays pass through it. The engineers designed detectors to measure the cosmic rays. The detectors take measurements before and after the cosmic rays pass through the plastic.

Above is a drawing of the instrument. It shows the two pieces of plastic (dark grey) between detectors (light grey). The detectors are connected by cable (brown) to the computer processing board (green). All of this had to be compact, lightweight and durable to be on the satellite.

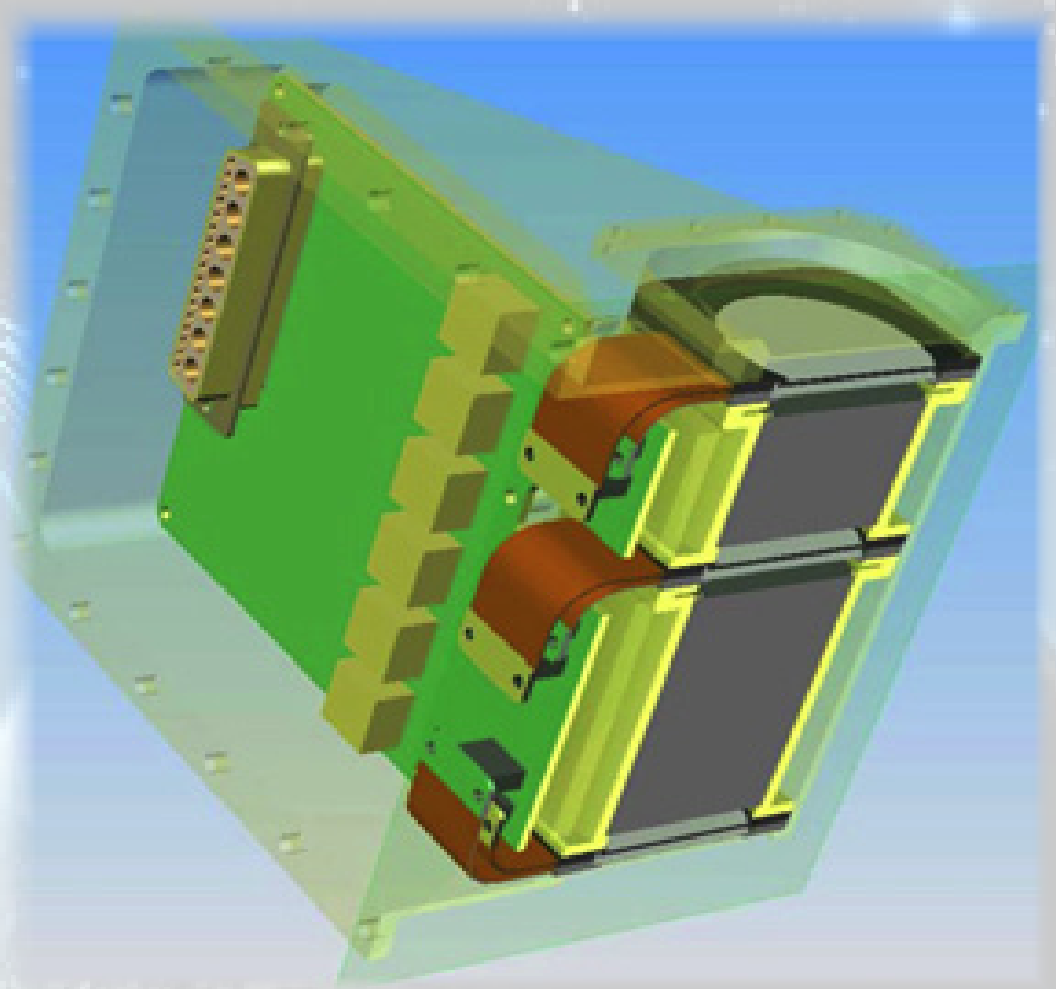


Illustration courtesy of NASA

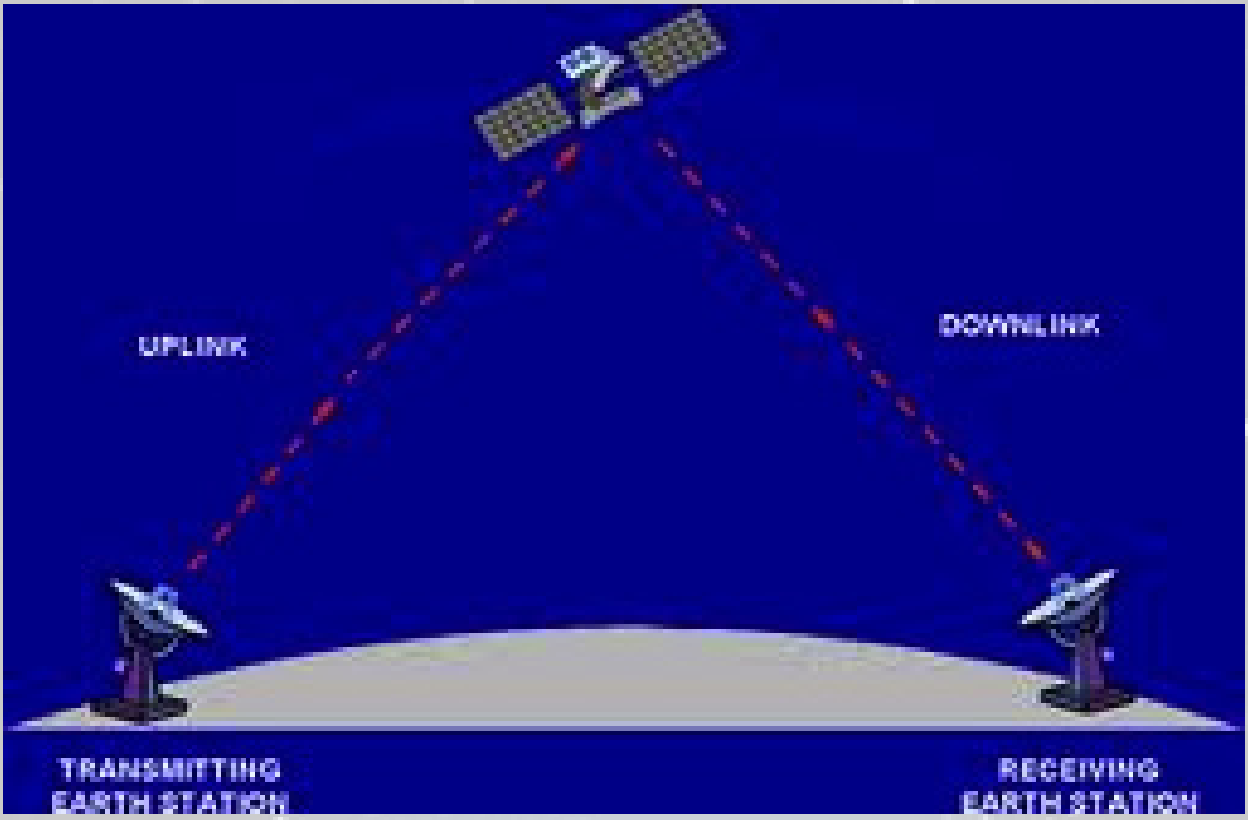


Illustration courtesy of FCC.gov

The information collected by CRaTER is sent to computers at UNH. The scientists study the data to learn how cosmic rays affect the plastic. This will help us understand how cosmic rays will affect humans traveling in space.

All of us who plan on traveling in space will benefit from their research. In space there is no atmosphere for protection. And it's difficult to shield from cosmic rays since the particles travel through shields. So, we have to figure out how to prevent damage to our bodies and our spacecraft

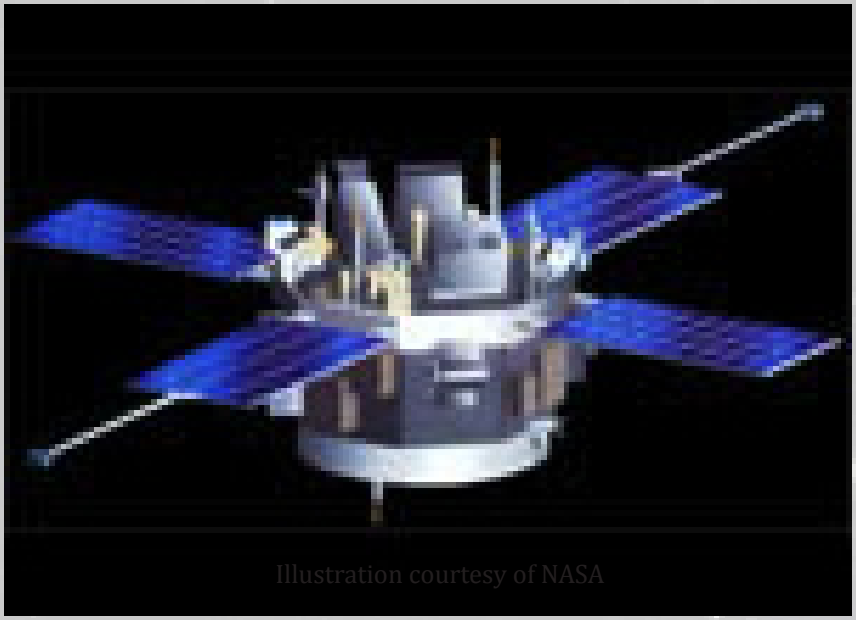


Illustration courtesy of NASA

CRaTER is similar to detectors made for other NASA spacecraft. A similar instrument flew on ACE, the Advanced Composition Explorer. And before that, one flew on WIND, the Comprehensive Solar Wind Laboratory. UNH was involved in both of these earlier missions. I never realized how much space research UNH does.

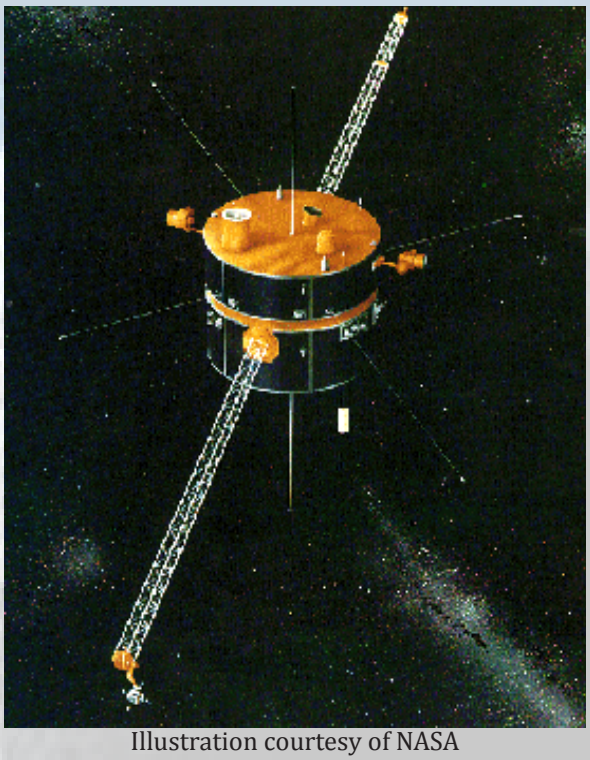


Illustration courtesy of NASA

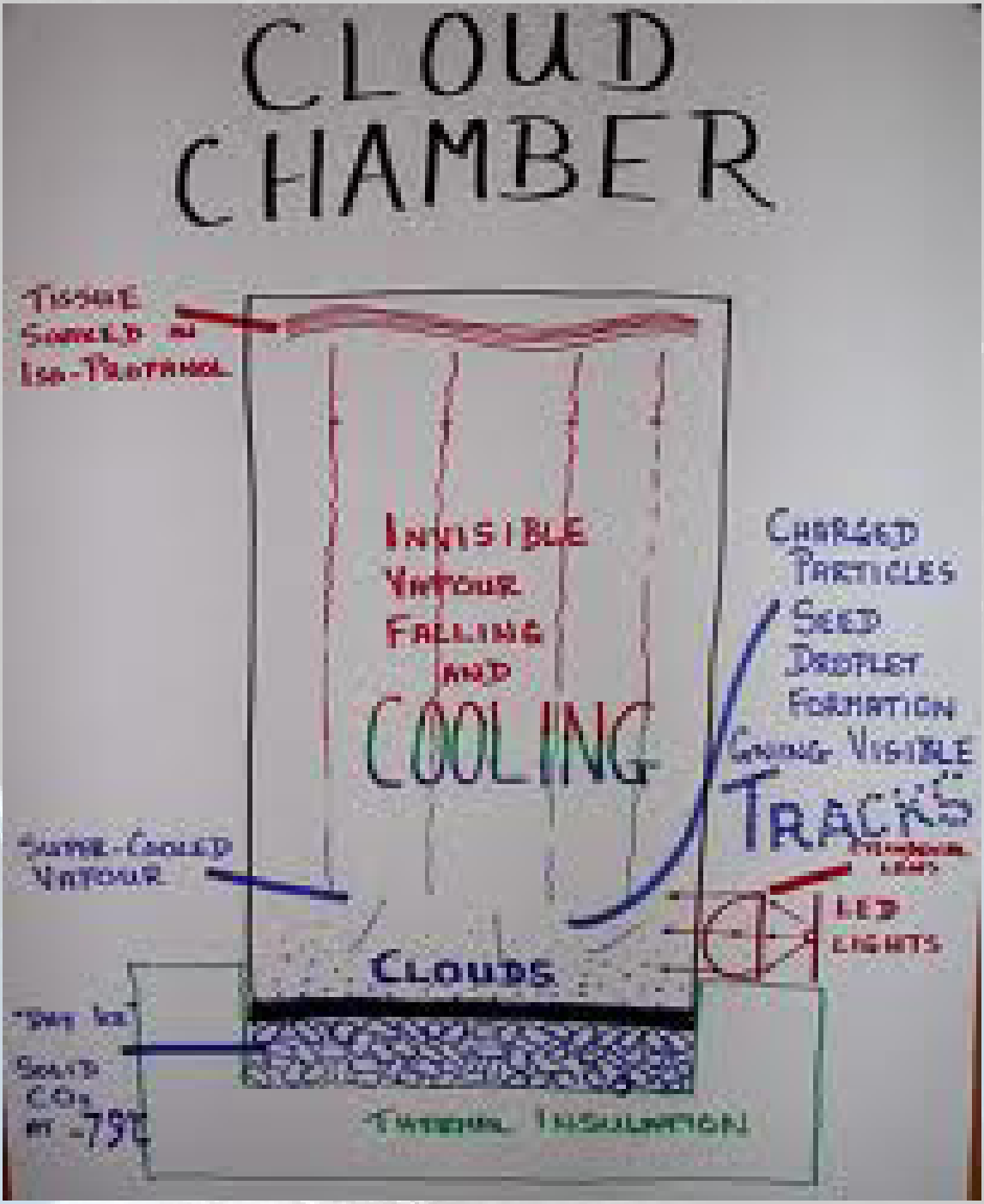


Image courtesy of Department of Physics, University of Cambridge

Now that I know about cosmic rays I need to get back to my cloud chamber. I keep thinking about how cool it will be to show everyone!

Image courtesy of the United States Naval Academy Summer STEM

This is great! I'm both the engineer designing the chamber AND the scientist explaining the particles.

Image courtesy of Taylor's University-Lakeside

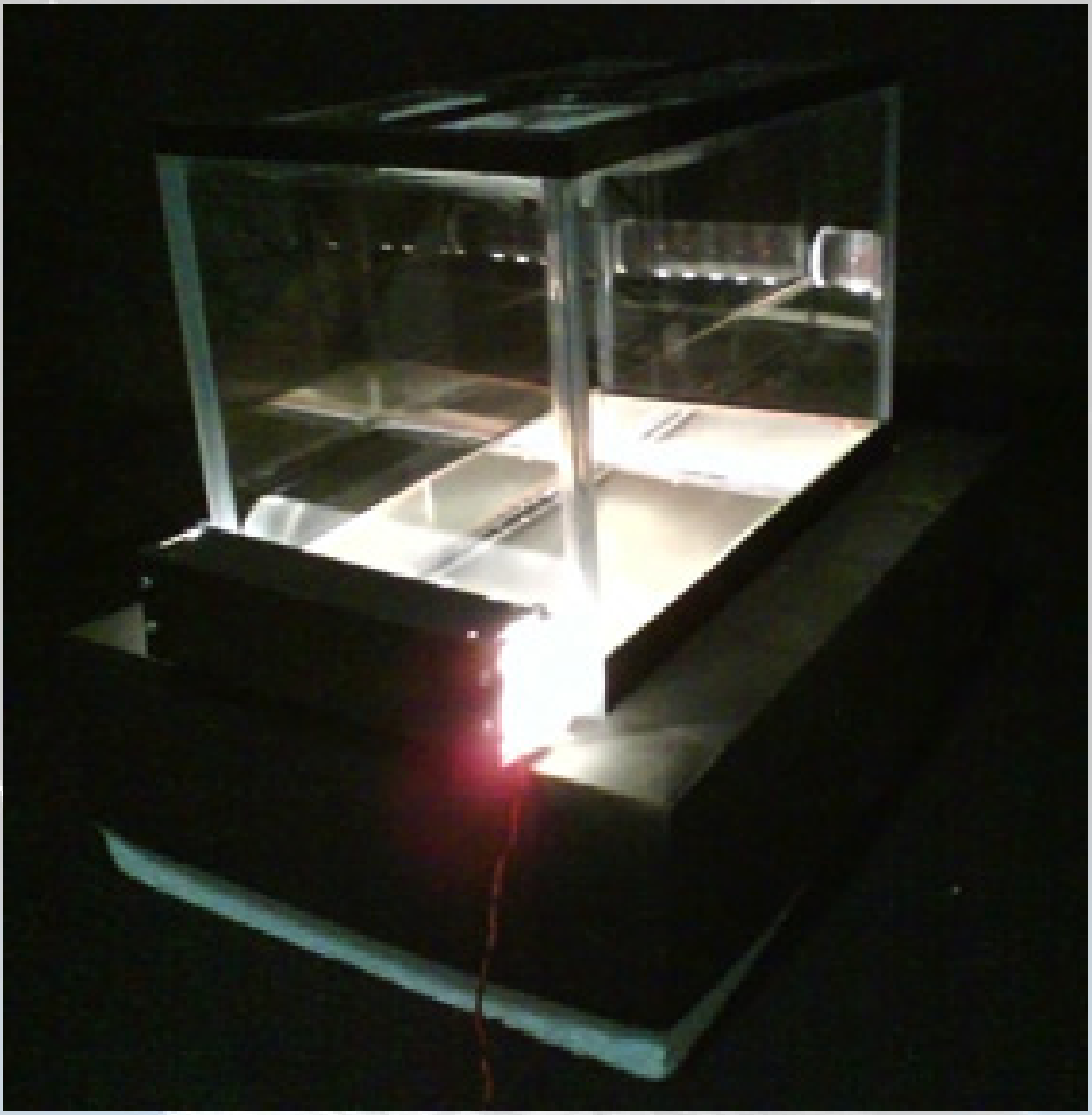


Image courtesy of the Department of Physics, University of Cambridge

What else do I need to know about cloud chambers? I know from the Discovery Center that a cloud forms inside the chamber. I also learned that the cloud droplets enable us to see the cosmic rays.

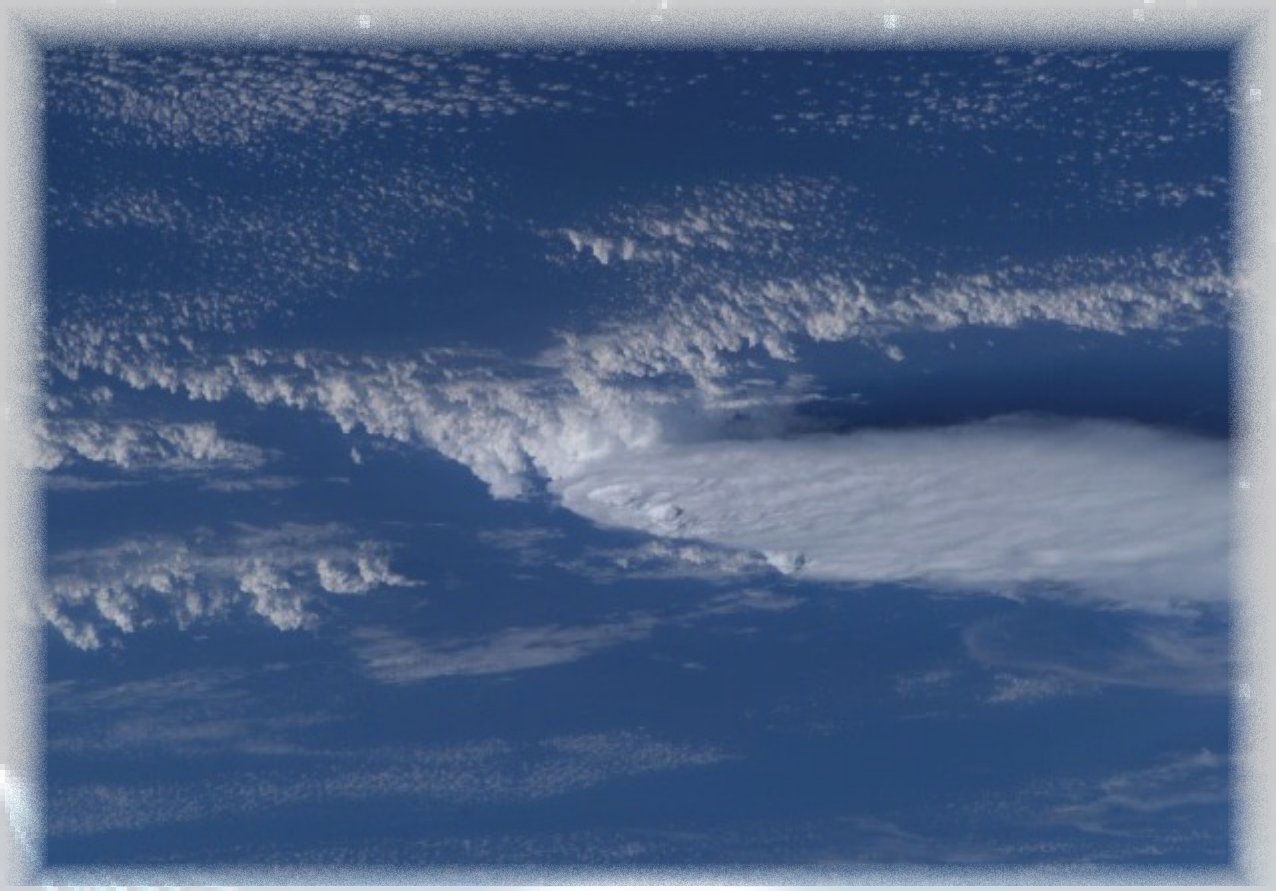


Image courtesy of Public Domain Pictures.net

So what do I know about forming clouds? Well, the ones I see in the sky are made from water vapor. The water vapor is a gas suspended in the air. When the gas cools enough it condenses around a particle of dust or salt. It then transforms into liquid or ice. So, lots of small drops of water or ice make up a cloud.

Image courtesy of Wikipedia.org

The teacher at the Discovery Center told me cloud chambers do not use water vapor. Most chambers use alcohol because the gas needs to be different so the high-energy particles will interact with the gas. It is this interaction that causes what we see.

It's important to know that isopropyl alcohol is easily set on fire. It is also dangerous if breathed in or it touches our eyes. So I found safety instructions for how to use it safely from Science Lab.com at http://education.jlab.org/frost/msds/isopropanol.pdf

Why 99% alcohol? Well, first it evaporates easily to form a saturated vapor inside the chamber. And when it is cooled it forms a super-saturated vapor.

Secondly, the cosmic ray removes an electron from the molecules in the saturated air (O_2 and N_2). This creates a charged particle called an ion. Lots of ions are made as the cosmic ray moves through the alcohol vapor. Mist forms around these ions. We see this trail of mist when we look into the cloud chamber.

Image courtesy of Department of Teacher Education, University of Nebraska-Lincoln

I will need to create a difference in temperature between the top and the bottom of my container. This will cause the alcohol vapor to condense more easily. And I need condensed vapor to create the visible mist.

I think the easiest way to do this will be to set my chamber on something really cold. Then the vapor in the bottom will become colder.

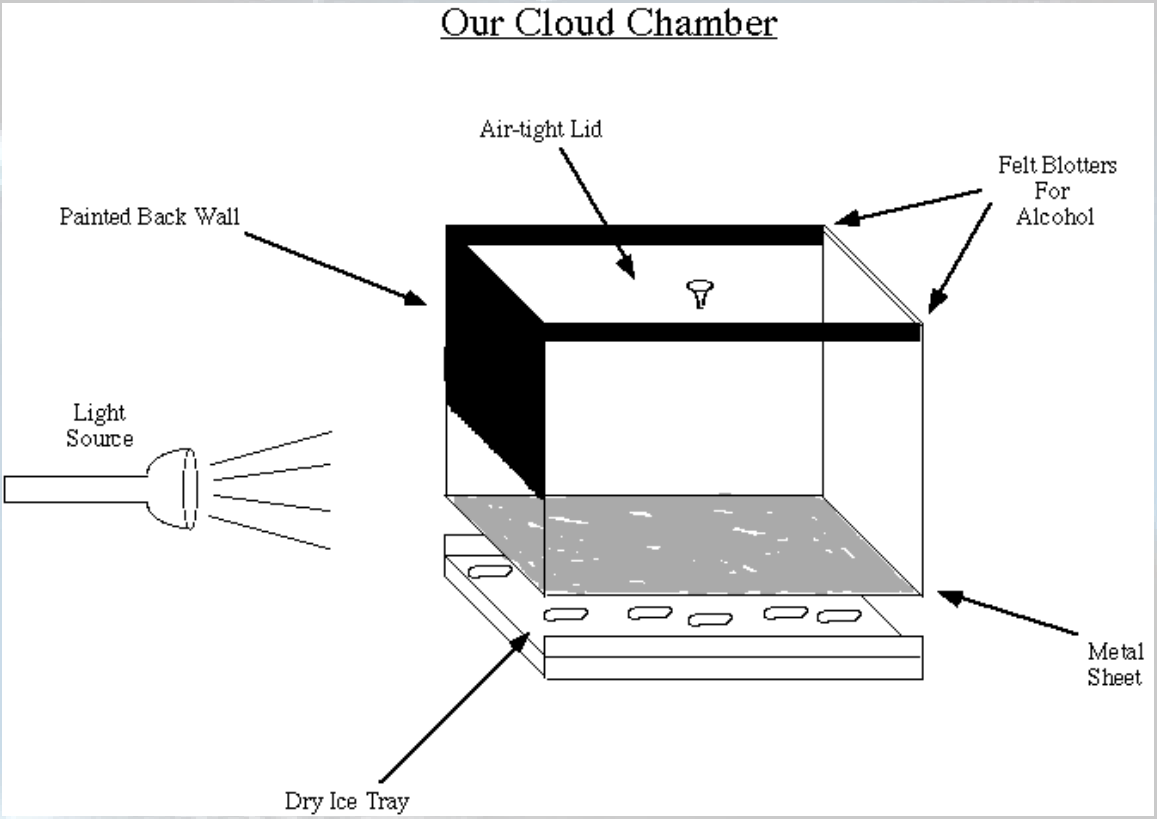


Image courtesy of Teacher Education, University of Nebraska-Lincoln

Image courtesy Jefferson Lab, Science Education

Dry ice under my Petri dish will make the bottom colder. It is important to use gloves when handling dry ice. It is so cold it can damage skin. For safety instructions for the dry ice I went to the Jefferson Lab: http://education.jlab.org/frost/msds/dry_ice.pdf

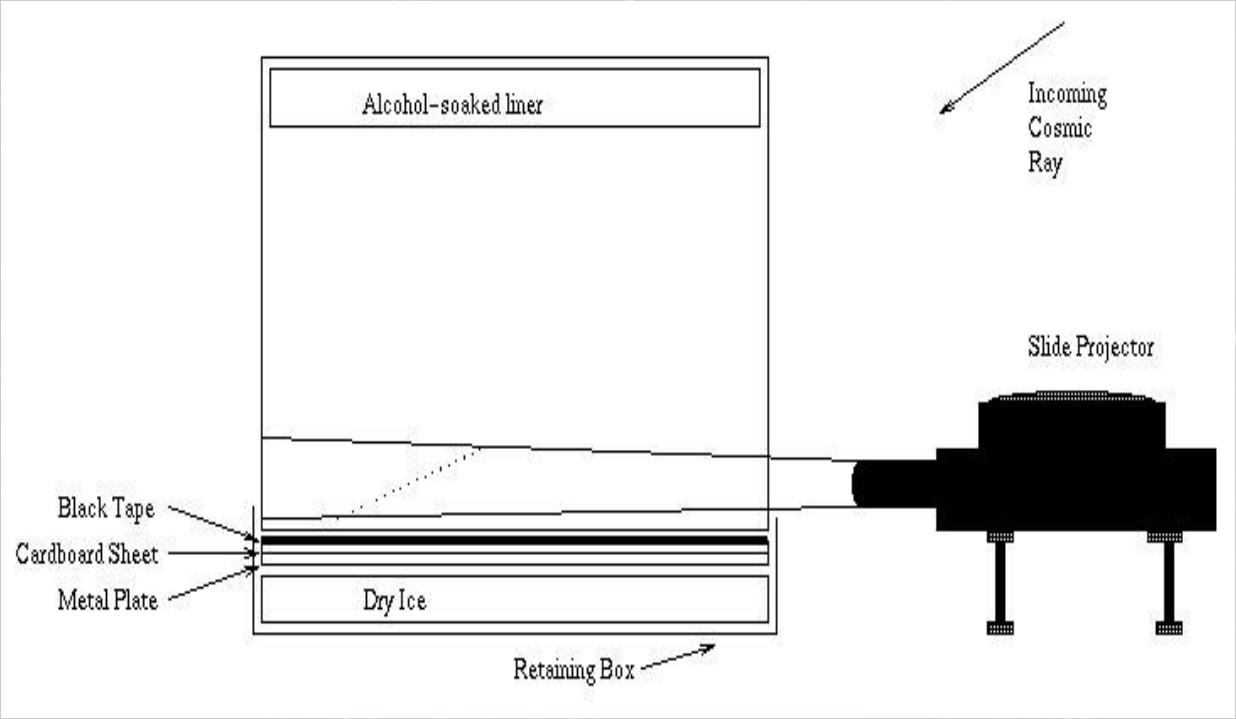


Image courtesy of Wilson Lab, Cornell University

My chamber will also need to be sealed. This way the evaporated alcohol stays inside. I'm hoping a Petri dish with a cover on top will work.

The droplets should show up better if I use a dark background. I'll put black construction paper on the bottom of the Petri dish.

And I think shining a light from the side will make the droplets show even more. I'll test this idea using a flashlight.

Finally I need a source of high-energy particles. The particles need to be similar to cosmic rays. Most cloud chambers use a radioactive source.

Obviously I need to be really careful if I use something radioactive. It's a good thing I have an adult to help me with this part of my project.

I am going to use a radioactive pin. I can buy one from a scientific supply company. It will be important to follow the safety instructions that come with the pin. I already know I have to wear eye protection and gloves.

Image courtesy of American Nuclear Society

Some cloud chambers do not use a radioactive source. I will try this too. Or I can try one of the other radioactive sources listed on the American Nuclear Society website. http://www2.ans.org/pi/teachers/reactions/2001-06-02.html








Images courtesy of public domain images and clip art

I think that's everything. Time to assemble the parts of my cloud chamber and see what happens!

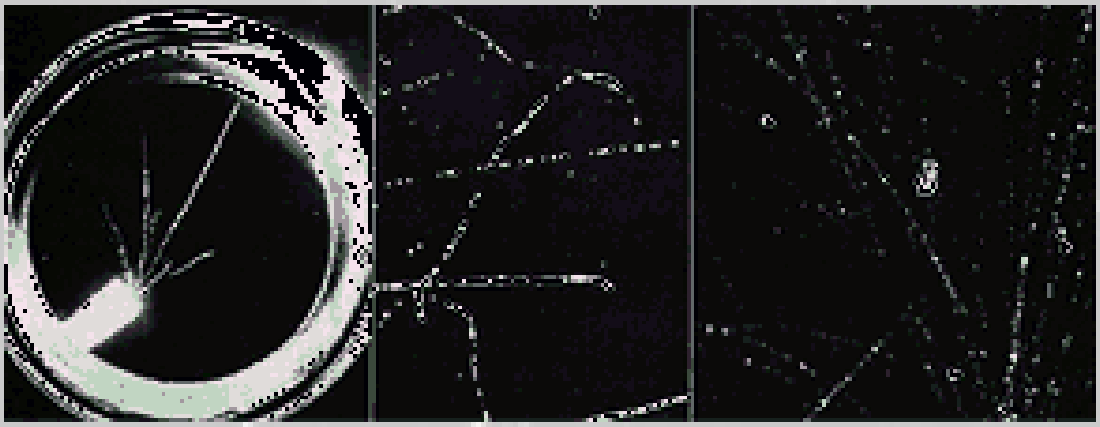
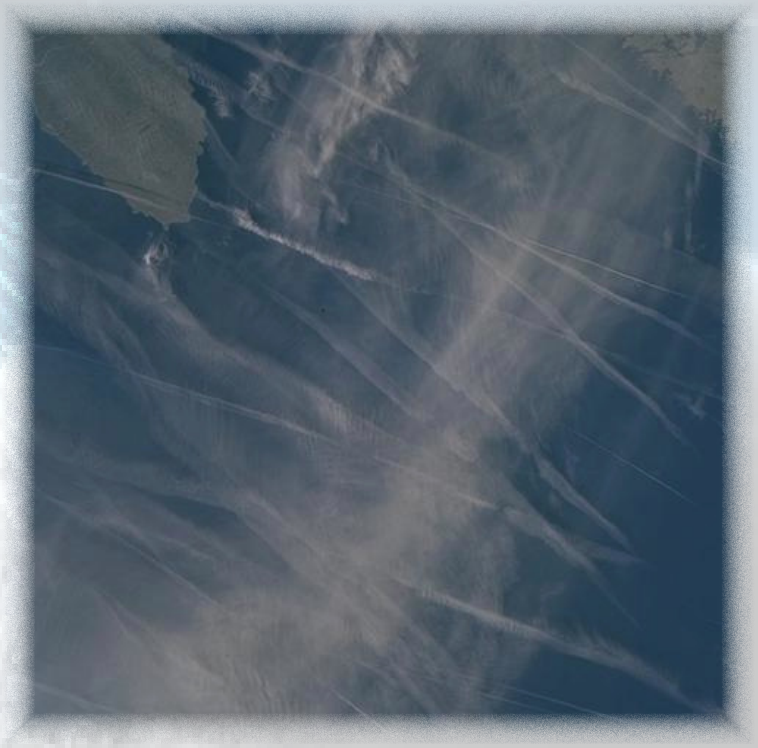


Image courtesy of Department of Teacher Education, University of Nebraska-Lincoln

Amazing! It works. Check out the trail left along the particle's path. It looks a lot like contrails left by an airplane in the sky. That makes sense since the word contrails is short for condensation trails. So contrails are also vapor trails.



NASA image Public Domain Pictures.net

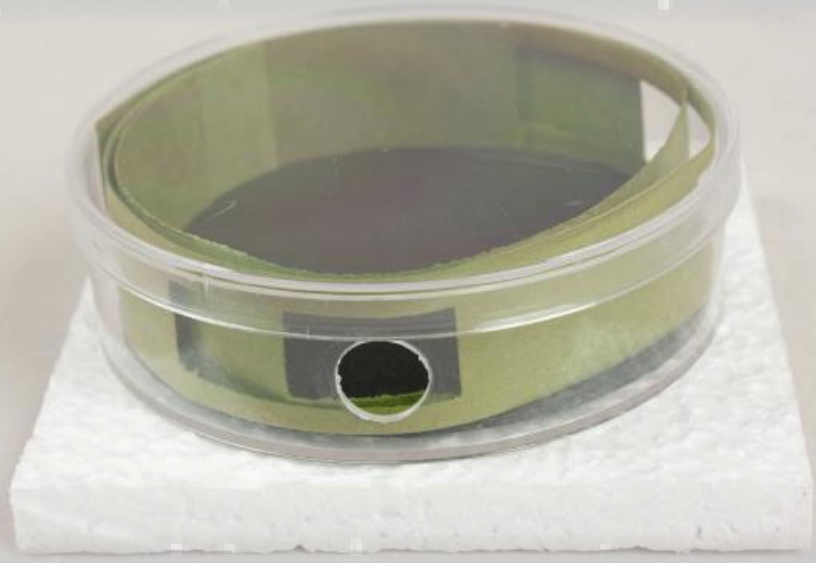


Image courtesy of the American Nuclear Society

It's fun building a scientific instrument. And it's exciting to see something that is all around us but is not visible.

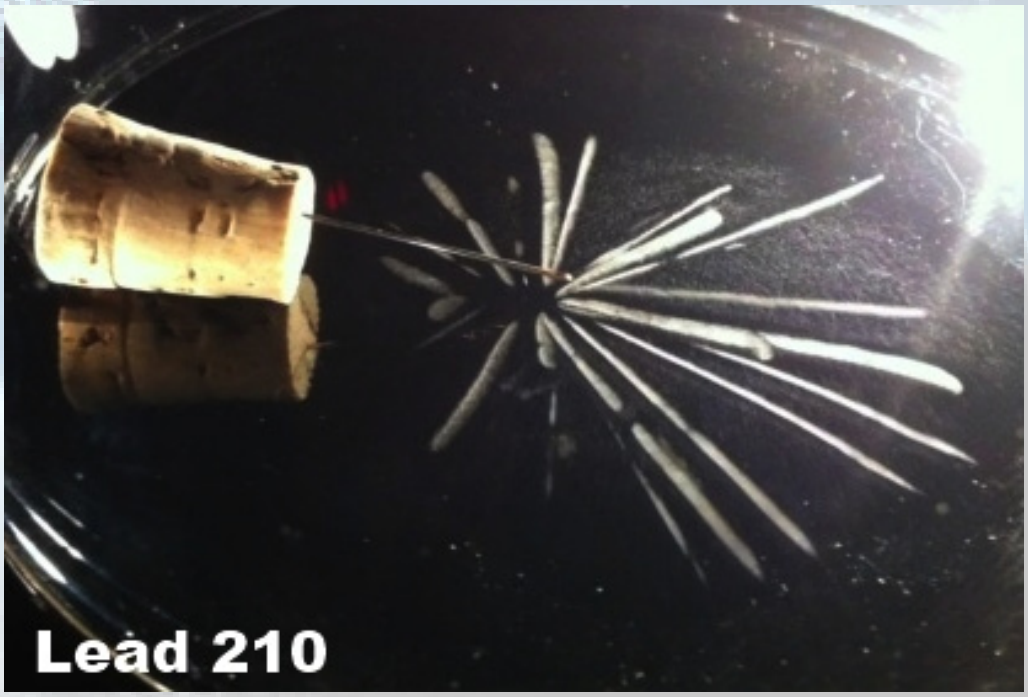


Image courtesy of the American Nuclear Society

I'm ready to put together my exhibit for the science fair. By the way, what are you doing for your science project?

Source: freemars.org
Other posters pictured at: blog/ctnews.com; scifun.edu.ac.uk
http://www.britishscienceassociation.org/web/news/BritishScienceAssociationNews/_IntelISEF07.htm
http://www.nbto.org/pages/article/name/NBHS_Seniors_Win_Science_Awards

Resources:

The Cosmic Ray Telescope for the Effects of Radiation Educational Kit (includes directions for building a cloud chamber without a radioactive source): http://www.nasa.gov/pdf/582876main_CRaTER_Edu_Kit.pdf

How To Make a Cloud Chamber!
http://education.jlab.org/frost/cloud_chamber.html

Cloud Chamber "How-To" Tips:
http://www2.ans.org/pi/teachers/reactions/2001-06-02.html

Building a Cloud Chamber (Cosmic Ray Detector): http://www.amnh.org/education/resources/rfl/web/einsteinguide/activities/cloud.html

The Exploration of the Earth's Magnetosphere – Cosmic Rays: http://www-spof.gsfc.nasa.gov/Education/wcosray.html

NASA's Imagine the Universe – Cosmic Rays
http://imagine.gsfc.nasa.gov/docs/science/know_l1/cosmic_rays.html

NASA Science News
http://science.nasa.gov/science-news/science-at-nasa/2008/19nov_cosmicrays/

Cosmicopia – Cosmic Rays
http://helios.gsfc.nasa.gov/cosmic.html
http://helios.gsfc.nasa.gov/qa_cr.html

Can People Go To Mars? http://science.nasa.gov/science-news/science-at-nasa/2004/17feb_radiation/

Image Artifacts – Cosmic Rays (STEREO)
http://stereo.gsfc.nasa.gov/artifacts/artifacts_cosmic_rays.shtml

Cloud Chamber/Cosmic Ray Detector
http://bizarrelabs.com/cloud.htm

How Cosmic Rays are Transforming the Surface of the Moon
http://www.mnn.com/earth-matters/space/stories/how-cosmic-rays-are-transforming-the-surface-of-the-moon

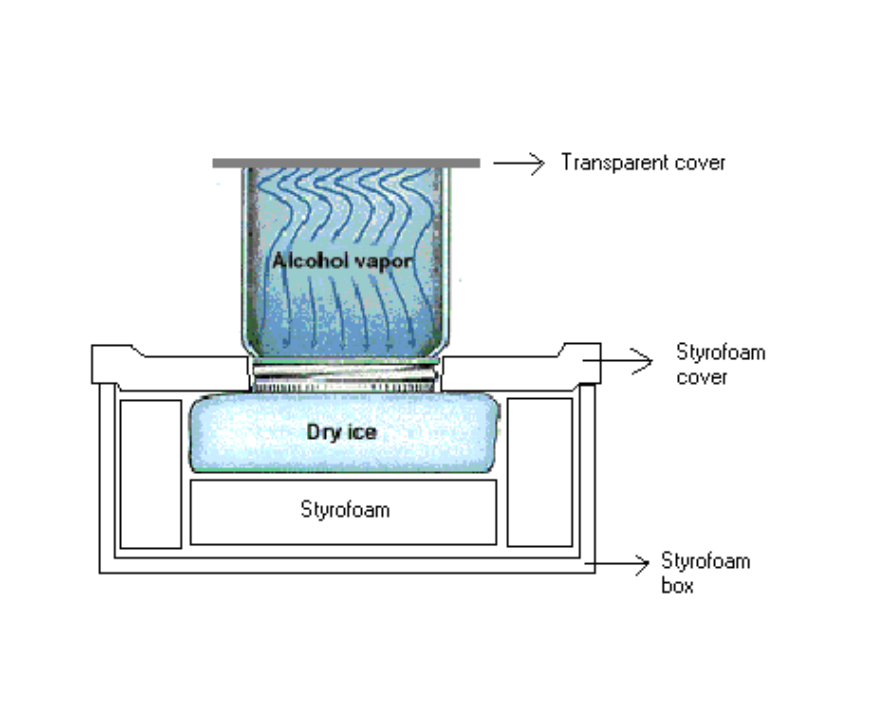
What are some of the dangers while flying in a spacecraft or on the moon? Dr. Harlan Spence, CRaTER Principal Investigator
http://www.youtube.com/watch?v=P8dYkVI4x0I

The Radiation Challenge, Middle School, grades 6-8

What is radiation and where does it come from? Act 1
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/SF_Radiation_Challenge_MS_video1.html

Space Radiation and Human Health. Act 2
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/SF_Radiation_Challenge_MS_video2.html

Protection from Space Radiation, Act 3
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/SF_Radiation_Challenge_MS_video3.html



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Page 18: hep.phy.cam.ac.uk

Page 19: www.usna.edu/admission/stem_reasons.htm and www.taylors.edu.my

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Page 25: education.jlab.org/

Page 26: w4.lns.cornell.edu/~adf4/cloud.html

Page 27: www2.ans.org/pi/teachers/reactions/2001-06-02.html

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Page 31: freemars.org

Vocabulary:

Atmosphere: the air or gas surrounding the earth

Atom: the smallest particle of an element that has the properties of the element and can exist either alone or in combination

Charged particle: a basic amount or simplest piece, such as a proton or electron, with a positive or negative electric charge

Cloud: visible water or ice suspended in the air; can also be smoke or dust suspended in the air

Cloud Chamber: a container of air saturated with vapor whose sudden cooling reveals the path of a particle such as an electron by a trail of visible droplets

Condense: to change from a gas to a liquid or solid

Condensation: the state of being changed from a gas to liquid

Contrail: a stream of visible water or ice particles created in the air by an airplane or rocket

Cosmic: relating to the universe; vast

Cosmic Ray: a stream of particles, usually from outer space, that moves at speeds approaching the speed of light

Detection: to discover the nature, existence, or presence of

Dry ice: solid carbon dioxide

Electron: a negatively charged particle, often occurring as part of an atom

Engineer: someone trained in the use or design of materials, machines, engines, systems, structures or other technologies

Flammable: easily set on fire

Gas: a fluid such as hydrogen or air that has no fixed shape and tends to expand without limit

Geiger counter: an instrument for detecting the presence of cosmic rays or radioactive substances

High-Energy: relating to elementary particles with energies exceeding hundreds of thousands of electron volts

Ion: an electrically charged atom or group of atoms formed by the loss or gain of electrons

Isopropyl alcohol: a colorless, flammable liquid that dissolves in other liquids

Liquid: a substance that flows; not a gas or a solid

Neutron: a particle in the nucleus of an atom that has no charge

Neutron Monitor: a detector that counts the number of cosmic ray particles that hit or passes through it

Nobel Prize: awards presented annually for achievement in physics, chemistry, medicine, literature, and the promotion of peace

Nucleus: the central part of an atom, composed of neutrons and protons.

Particle: one of the very small parts of matter

Petri dish: a small shallow dish of thin glass or plastic with a cover usually round

Plastic: a man-made or natural material that is hardened after shaping

Primary cosmic ray: cosmic ray originating outside Earth's atmosphere.

Processing board: a small computer that receives data from devices and performs some initial processing tasks before passing the data to another computer for more processing

Proton: a positively charged particle that is part of the nucleus of an atom; cosmic rays are primarily made up of single protons

Radiation: energy in the form of waves or particles

Radioactive: releasing radiation or energy in the form of waves or particles; the radiation can be alpha, beta or gamma radiation

Scientist: a person skilled in science; a scientific investigator

Secondary cosmic ray: cosmic ray originating within Earth's atmosphere as a result of a collision between a primary cosmic ray and another particle or molecule

Sensor: a device that detects a physical action or quantity, such as a movement or a beam of light, and responds by transmitting a signal

Shower: a chain reaction of collisions between cosmic rays and other particles, producing more cosmic rays

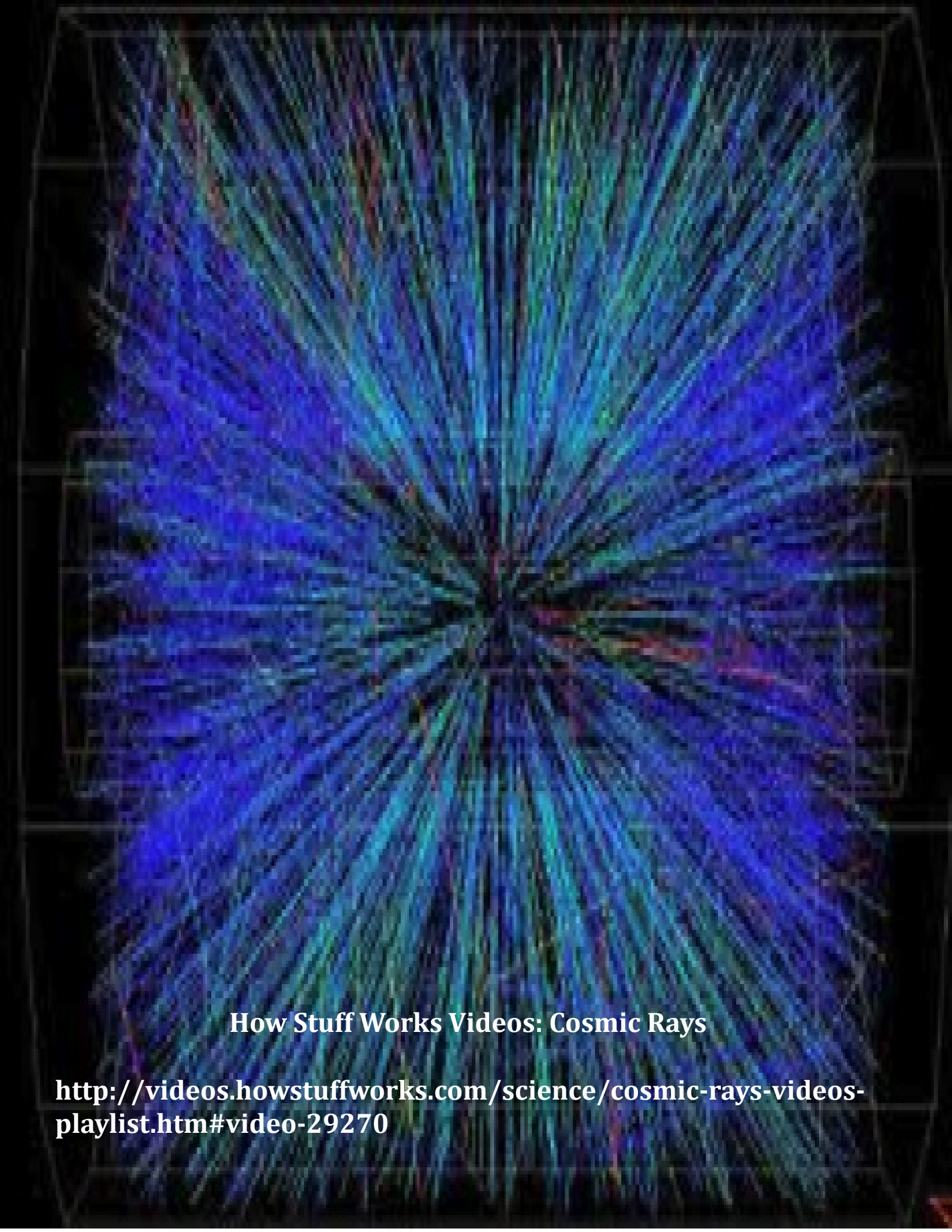
Subatomic particle: a basic unit of matter and energy smaller than an atom

Supernova: the explosion of a very large star in which the star temporarily gives off up to one billion times more energy than the sun

Super-saturated: to be more concentrated than is normally possible given the temperature and pressure

Vapor: a gas that is suspended in air; a substance that can expand indefinitely

Water vapor: water in a gas form; water that is not liquid or solid



How Stuff Works Videos: Cosmic Rays

http://videos.howstuffworks.com/science/cosmic-rays-videos-playlist.htm#video-29270