The Aurora and the Arctic

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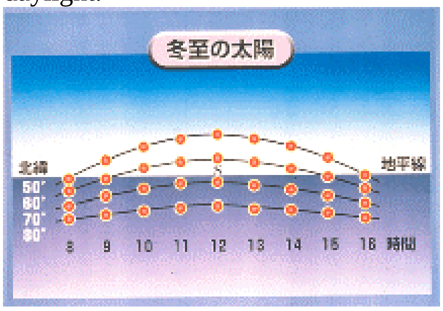
Good morning, my name is Syun Akasofu. I am the director of the International Arctic Research Center of the University of Alaska. President, Mrs. Michaud, and Mr. Suzuki the Japanese chairman of the organizing committee, distinguished guests and the people of Sapporo, Hokkaido, I am greatly honored to give this keynote talk to the 11th International Winter Road Congress, and today I would like to talk about the Arctic, which is a sort of the top of the world.

The top of the world of course, is the Arctic. The Arctic consists of two parts; the central part is what we call the Arctic Ocean. The Arctic Ocean is surrounded by lands and for this reason the Arctic Ocean is often called the Mediterranean Sea of the Arctic.

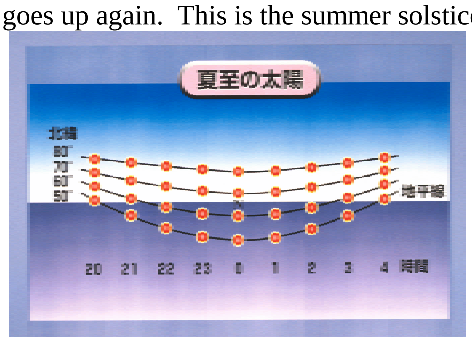
The Arctic has many, many interesting aspects, and among one of them is the movement of the sun. This photograph shows the movement of the sun at Fairbanks on the winter solstice day. The sun came up from the horizon at about 10 a.m. and set at about 2 p.m. We have about 4 hours of daylight.



This shows the movement of the sun at various latitudes. At 60 degrees, 50 degrees the sun rises as the figure shows and if you go to higher latitudes, of course the movement of the sun comes closer to the horizon. If you go to 70 degrees the sun does not show up above the horizon. And if you go to even higher latitudes, of course, you cannot see the sun on the winter solstice day. However, the sun isn't so far below the horizon so even at 80 degrees latitude we have a beautiful twilight sky around midday.

Sunlight doesn't come to the Arctic, so we have very cold winter days. Two days ago when I left Fairbanks it was about 40 below zero. And did you know that at -40 degrees, Fahrenheit and Centigrade are the same. So it's very cold.

But an entirely different thing happens in summer months. As you can see, this photograph was taken a little north of Fairbanks and the sun comes close to the horizon but does not set. And then it goes up again. This is the summer solstice photograph.



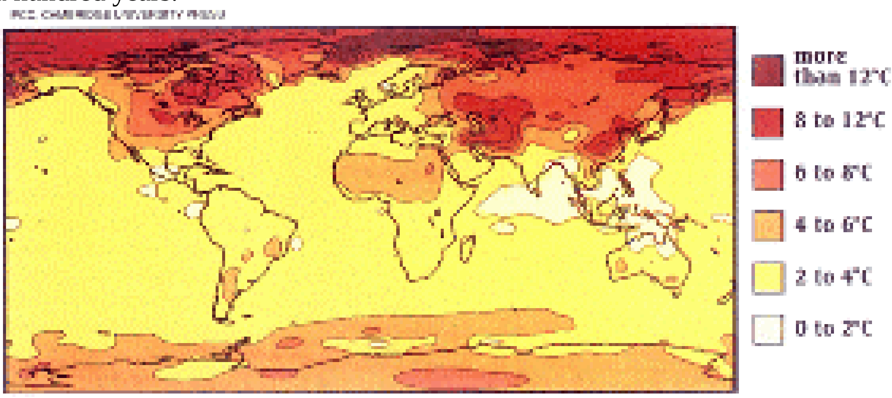
This shows how the sun moves near the horizon, at 50 degrees the sun sets for many hours. But if you go to 60 degrees the sun sets only for a few hours. And if you go to 70 degrees on the summer solstice day, the sun does not set. In Japanese this is called "byakuya". At 80 degrees you can see that the sun is way above the horizon at midnight. In Fairbanks, on the summer solstice day, we have many, many all night activities like golf, baseball without lighting. There is no problem there.

On summer days many beautiful flowers cover the Arctic. This is one kind of orchid. I was surprised when I found this. I thought that orchids were a kind of tropical flower, but it's not. There are many kinds of orchids in the Arctic too.

We also have many, many animals in the Arctic; in particular they enjoy the short summer days.

This is a moose. We are interested in road transportation safety with the moose. The moose does not care, they don't worry about cars and because of that, from time to time, we have very unfortunate accidents and cars collide with them. And if they collide usually both moose and humans cannot survive, that is a big problem in Alaska.

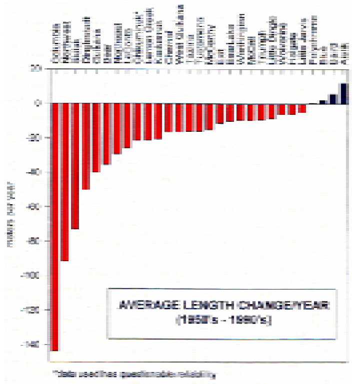
Now in the Arctic, there are many noticeable changes going on. One is what we call, climate change. Some people call this global warming; global warming is a part of the climate change. According to the IPCC, the international group that is predicting the Earth's temperature in 50 years, 100 years from now are using a super-computer and without exception all the groups predict that human activities will prominently heat up the Arctic. That is mainly caused by the release of carbon dioxide. This is an example of one prediction. You can see that the Arctic will become much warmer than other places on the Earth. From these computer predictions the IPCC reported that, if we continue the present human activities, Earth's average temperature would increase by about 6 degrees in a hundred years.



So, let's look at the Arctic region.

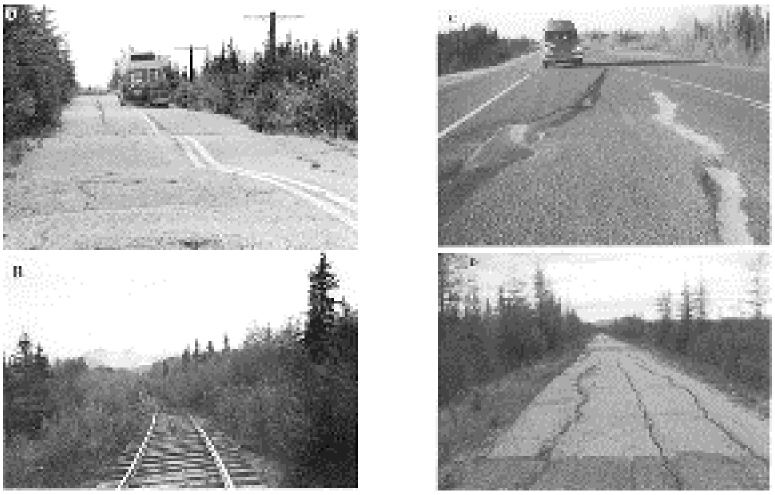
In the Arctic we have many glaciers, the river of ice. Even in Alaska alone we have ten thousand glaciers and Greenland also has many, but most glaciers are now receding.

This is the receding rate per year of many of the Alaskan glaciers. Some of them are receding at a rate of 100 meters per year. So, definitely some major climate changes are happening.



In the Arctic we have what we call permafrost, frozen ground year round. The definition of permafrost is that the frozen ground doesn't melt and is kept frozen year round.

Building roads on permafrost is a major issue, even without global warming. You can see the problems the Arctic nations have when you want to build a highway on permafrost (Niel Davis). Our major concern is that "If global warming really takes place, what's going to happen?" Road construction will become much more difficult on melting permafrost.

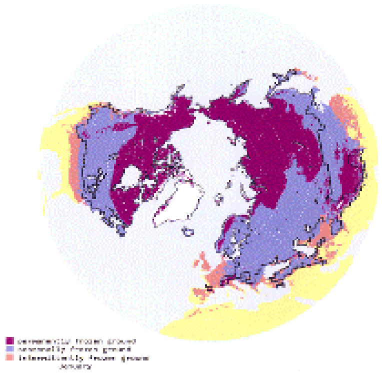


In fact, we have been measuring the temperature of the permafrost in many places, and noticed that the surface temperature is becoming very close to the melting point in certain areas now.

This is the highway construction near the University of Alaska in Fairbanks. You can see the buildings in the back, those are buildings at University of Alaska and below you see the construction work, and what we had to do there was completely remove the permafrost. If the permafrost starts to melt there is no way you can build a highway. So, permafrost of a thickness of about 10 meters had to be entirely removed, and it became a major, major road construction project.

When you excavate for gold sometimes you find things from the past. I met the person who discovered this prehistoric animal, and he told me that he tried to move the eyelid of this animal and the eyelid moved while the animal was frozen.

Now, this shows the distribution of the permafrost in the entire Arctic region. Any roads or buildings in this area that is covered by permafrost will have major problems, if the permafrost melted.



Because global warming is a major worldwide issue, the government of the United States and the government of Japan have jointly established the International Arctic Research Center in 1999 to study this phenomenon called, global warming. The reason why we need to study global warming is because we do not know if all the changes I have shown earlier are really due to man-made effects by releasing large amount of carbon dioxide into the atmosphere or is it merely due to natural changes. Some scientists believe that 80% maybe due to man-made cause, on the other hand many scientists believe that 90% of global warming is a natural cycle. In order to actually see, what carbon dioxide released from human activity is doing, we have to remove the effect of natural changes. Only then can we tell how much of the problem is being caused by human activity. This is the purpose for the establishment of the International Arctic Research Center. At this time our findings suggests that perhaps 60 or 70% are due to natural changes, and not a result of human effects. But we still have to confirm that to be certain.

This is a cartoon that we may be, all of us may be in a pot and some people are saying we need more time to study. Well, do we have time to study? We don't know but this is something we have to do.

The Arctic has many unique natural phenomena. I have showed you just a few of those like permafrost, the glaciers and so on, but perhaps one of the most spectacular one is the aurora borealis. So, I'd like to spend the rest of my time on that.

First I will show you a few snapshots of the aurora. Then later on I will show you a video clip. But let's see several photos first.

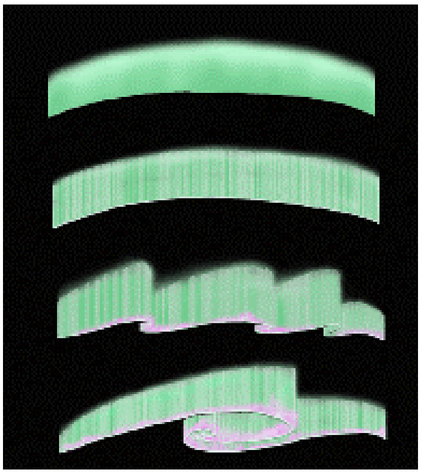
Of course, the aurora phenomenon is quite familiar to the native people living in the Arctic and to the Eskimo people. Usually they have many legends and most of them associate the aurora with the spirits of dead people. Some legends say that the spirits of dead people are playing a soccer game in Heaven. There are all kinds of stories like this in the Arctic.

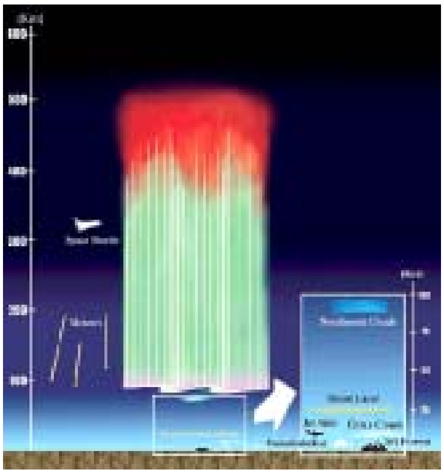
One Finnish legend says that there is a very special type of fox that has a beautiful tail and its name Ra, and when it throws snow into the air, it causes the aurora. That is one of the Finnish legends.

The American Indian people also have very interesting legends also, and they usually associate the aurora with the eagle. I will show you in the next slide how the aurora looks like a big eagle in the sky spreading its wings. So all the legends have some interesting things to think about.

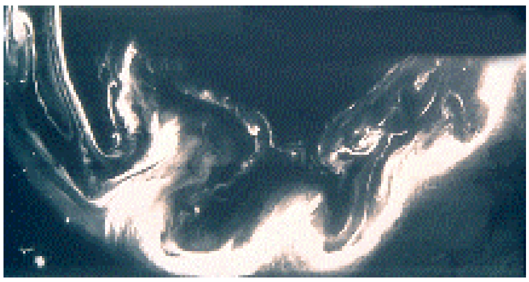
The aurora is an atmospheric phenomenon; so the first thing we would like to know is where in the atmosphere does this phenomenon take place. This view-graph shows that the aurora has a curtain like form. The very basic form of the aurora is like a curtain hanging in the air. The aurora is sort of a curtain of light hanging from the sky. So the question is, where is it in the sky? We now know that the bottom height of this curtain is about 100km or 60 miles from the ground. Of course that means that it is considerably higher than the cruising altitude of jet planes. When you fly on jet planes, usually the cruising altitude is about 10 km. The reason that jet planes fly at that altitude is because most of the meteorological phenomena, cloud formation, all these things occur below the cruising altitude of a jet aircraft. Of course pilots try to give the passengers the maximum comfort by trying to fly above the clouds, since meteorological phenomena usually takes place below 10 km. The bottom height of the aurora is about 100 km, this means that the aurora has nothing to do with meteorological phenomena.





As soon as I say that some people ask “Why can I see the aurora on cold nights but not so much on warm nights? There is a simple answer to this. Because, when the sky is clear its usually cold and you can see the aurora. On the other hand, warm nights tend to be cloudy. Since the aurora appears above the clouds it is only visible when the sky is clear. The aurora is not a meteorological phenomenon. The space shuttle actually flies through the aurora. The first Japanese astronaut, Mr. Mori from Hokkaido told me that he flew through the aurora on his mission aboard the Space Shuttle. He said it was one of the most spectacular experiences he’s had. So in other words, you can think of the aurora’s altitude to be where the space shuttle flies. This is an example of the aurora taken from the space shuttle; here you can see the tail fin.

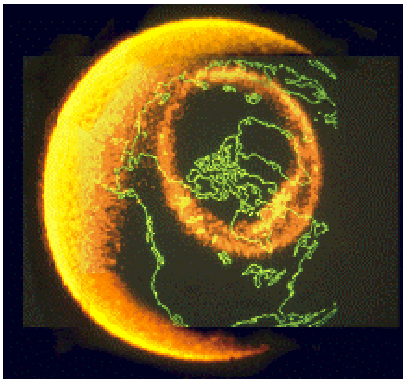
Now we go a little higher up, how high, just several hundred kilometers and from that particular satellite you can see the United States in the evening. You can see all the cities, Chicago, New York or Los Angeles. From that kind of altitude how does the aurora look?

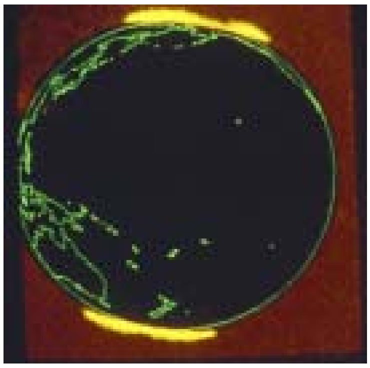


The aurora looks like this. If this pointer works I can show you where the Murmansk is. But the Murmansk is near the upper left and then the upper right is Alaska. So this aurora was located above Siberia. O.k. now let’s go even higher up.

Now we are up about 3 or 4 time the radius of the Earth and you can see that the Earth looks like the moon now. Can you see the bright ring? That is the aurora borealis seen from space. By overlapping the geography onto this image using a computer, and this is the way the aurora looks from space. It's a ring of light but from the ground you can only see a very small portion of the ring (about 1/30), so you cannot see the entire ring from the ground. Only from a satellite way up in space can you see this feature. So let's call this the aurora ring.

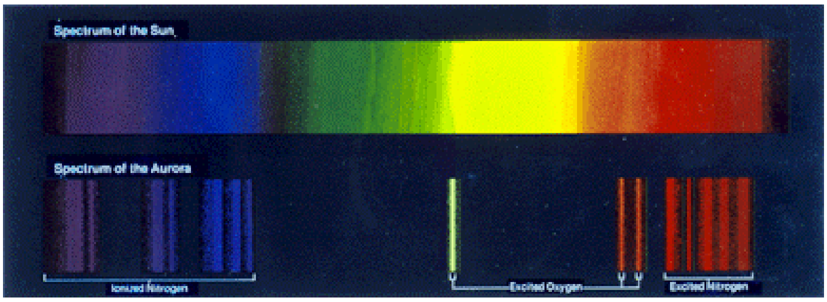
The Antarctic or the southern hemisphere also has its own aurora ring, and this is a satellite image taken from above Antarctica. So the Earth has two beautiful rings of light, the northern one is called aurora borealis or northern light and the southern one is called aurora australis or southern light.





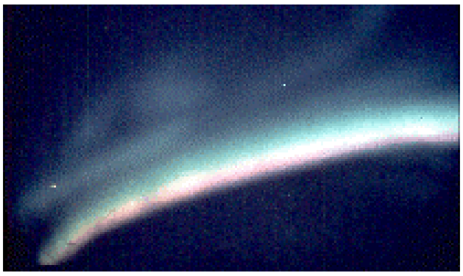
Now the next question, I told you how high the aurora is from the surface of Earth, and the next question is "what kind of light is that?" Until about 1850 most scientists thought that the aurora might be something similar to a rainbow. Now days, it is clear that a rainbow is caused by water droplets in the air refracting sunlight and you can see the seven colors from red, yellow, orange to violet. In those days people thought that there was no water droplets in the Arctic atmosphere because the air is too cold, so maybe ice crystals have something to do with it. People thought that that aurora was caused by the reflection/refraction of sunlight caused by ice crystals. The best way to examine this idea was to split sunlight using a prism.

As you know sunlight, if you use a prism, you can see seven continuous color spectrums from red, orange, yellow, green all the way to violet (This is sunlight). But physicists, who examined the light from the aurora, in about 1850, was surprised to find that the aurora was an entirely different type of light than the sunlight. In the aurora spectrum, there are bands of line with dark spaces in between. This is not how the light spectrum will appear if the aurora was caused by sunlight, so there needs to be something else that creates these lights. By then the physicist knew what kind of process would produce this kind of light.



If you have a thin vacuumed glass tube and put a little bit of neon gas in and connect both ends to a high voltage supply, of about 10,000 volts, then this glass tube glows, just like that very beautiful red light. This phenomenon is called the high vacuum electrical discharge process. Similarly this high vacuum electrical discharge process causes auroras. Therefore, the aurora is not created by reflection/refraction of sunlight; rather it's an electrical discharge phenomenon. In this case we put neon gas in but if we use other gases you see a different light. If you use nitrogen gas in the tube, you see this bluish light or violet light. This light is visible in lightning, so this is from nitrogen. Different atmospheric molecules produce different specific light. In fact by using this knowledge, we don't have to go up 100 km to sample the air and then bring it down to analyze it. Just by examining and studying the light from the aurora on the ground we know what kind of molecules are in the upper atmosphere.

This is a neon sign, and if you don't know what pachinko means and I'm sure your colleagues will tell you and I hope you have a chance to play this game when you are in Sapporo. You see in the red, it says Aurora. This pachinko shop has the name aurora so I took a picture. And you can see the different color of lights, the Aurora pachinko sign uses neon gas and the bluish gas is caused by mercury vapor inside the tube. In order to produce different colors, they use different gases. As you can see, this is a good example of an early day technology transfer from physics to commercial use.



The aurora's most common light is a greenish white light, or a whitish green either way it comes from atomic oxygen. At the ground level we breath molecular oxygen, but if you go to the 100 km level all the oxygen molecules split into two atoms from various processes, so there are plenty of atomic oxygen in the upper atmosphere. And that produces the most common light of the aurora.

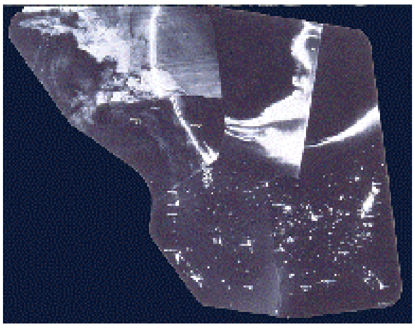
Why do we have oxygen molecules? It is because we have plants on the ground, and photosynthesis produces oxygen. It is for this reason we have a greenish white aurora. Now we are proposing to use this technique to explore life on other planets in other solar systems. And when we see an aurora on other stars and if we can identify the lights from atomic oxygen, there is a good possibility that that particular planet will have plant life on it. I think this is far better than using binoculars to try to find dinosaurs on other planets.

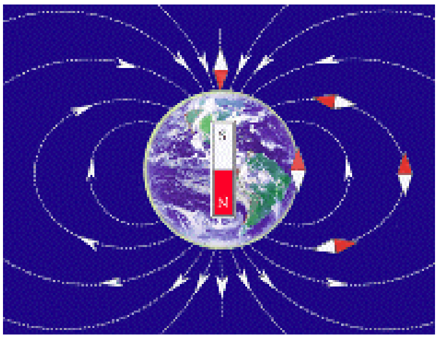
Sometimes you see a very beautiful pinkish light. That color comes from molecular nitrogen. As you can see, aurora physicists can learn a great deal about the upper atmospheric composition by just looking at the light from the aurora.

I told you about the light and I also mentioned earlier that the aurora is an electrical discharge phenomenon. Perhaps you will forget all that I told you today, but one thing I'd like you to remember is that the aurora is like a giant natural neon sign. Many visitors come to see me and say "Don't tell me any complicated stuff, just tell me in one word what the aurora is." and I say, "The aurora is a natural neon sign." It is a very accurate description because it's a high vacuum, high voltage, electrical discharge process and furthermore the degree of vacuum in the neon sign tube is about the same degree of vacuum at about the 100 km level. To say that the aurora is a natural neon sign is not completely true, because it's not neon gas in the upper atmosphere, but this explanation is a sort of an easy way to remember that the aurora is a giant natural neon sign.

Now that I told you that the aurora is an electrical discharge phenomenon, we know it requires large amount of electricity to work. This means that there needs to be a generator for the aurora somewhere. So, during the last thirty years or so aurora scientists have been using many satellites trying to find where the generators are in the sky. Some of you may know that a generator is one of the simplest machines. If you go to a power plant it sounds very complicated, but a generator is one of the simplest machines there is. All you need is a magnet and copper wire and if you rotate the coil, made out of copper wire, in the magnetic field you can generate electricity. So the question becomes, “what are the things that are equivalent to a magnet and a copper wire?” “Where are they in the sky?” Over the years, aurora scientists were able to come up with an answer that I’d like to share with you today.

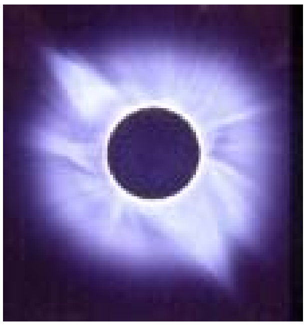
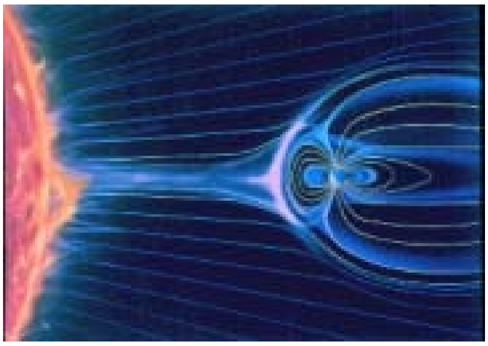
First of all about its total energy, and in order to demonstrate that, I’d like to show you the nighttime picture of the United States. You can identify major cities such as New York, Miami and Los Angeles from the city lights. This next image shows a very bright light hovering over Canada, that’s the aurora. The aurora is much, much brighter than the city lights on the ground. And we estimated that the total electrical power required for the aurora is about a million mega-watts. Perhaps that may be very difficult for anyone to comprehend, the largest power plant in the world generates about 1,000 mega-watts. In other words, the aurora electrical power is about 1,000 times more powerful than the largest generator in the world. That means that if we could harness the aurora power we could supply the world’s total electric consumption needs. So, when people ask us why we don’t do that to prevent global warming problems. We say, “No. We don’t want to do that because then we cannot see the aurora if we do”.





Now I told you that a generator needs a magnet and a coil. It’s very easy to find a magnet because Earth itself is a magnet, a gigantic magnet. That’s why when you have a compass the northern end of the needle points north. The pole in the northern hemisphere is actually the south pole of the magnet and the opposite is similarly true on the southern hemisphere. So the northern end of your compass is attracted to the south pole of the Earth magnet, which is actually the North Pole. In any case, the Earth itself is a magnet so we have no problem with finding a magnet. The question is, “what is something equivalent to a copper coil?” A copper coil is an electrical conductor so we have to find a moving conductor.

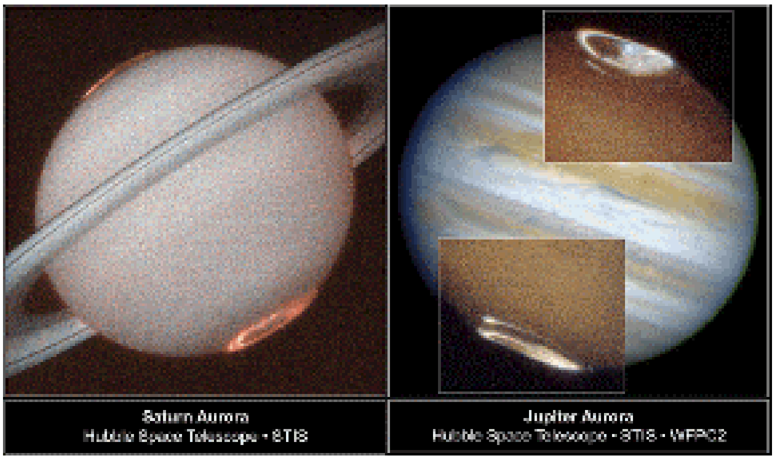
This is a photograph of a solar eclipse. During a solar eclipse the moon covers the very bright photosphere (sun) so that you can only see the outer part of the solar atmosphere and what you see is what we call the corona. Coronal gases have very high temperature, about a million degrees. Temperature is so high that all the particles, all the molecules, are split into electrically charged particles. Furthermore, the corona is so hot that it cannot stay on the sun. It is continuously blowing out with a speed of about 300 or 400 km/sec, very high speeds all the way to edge of the solar system. This is a very strong wind and is an electrical conductor. The solar wind also blows by Earth.

This is a photograph of a comet but if you can imagine something like that around the Earth, an invisible structure around Earth. This is just an artistic way of showing this. Eventually we found the generator at the boundary of this comet like structure, which generates a million mega-watts. There are invisible wires coming from this generator to the polar region and an electrical discharge takes place. So the upper polar atmosphere is like a neon sign too.

The aurora is moving. This was taken using a very highly sensitive camera, with the ASA equivalent of about a million. So this movement of the aurora, I'm not speeding it up, is the way you see it in the sky. The aurora usually does everything the camera doesn't like. First of all the light is very faint, it moves very rapidly and it covers the whole sky. It's very difficult for any camera to take a picture under these conditions, but fortunately ultra sensitive video cameras have been developed and we can actually record the aurora. So, this is how the aurora looks when you come to Fairbanks, or it doesn't have to be Fairbanks, another favorite place that people go to is Yellowknife in Canada or northern Scandinavia. Wherever you go you can see the aurora. (I wish that we could turn all the lights off and then it really looks good, with so many lights perhaps it's not so easy to see.) You can see the color changes because this shot is taking place at a different height in the atmosphere, here you see pink has come to a lower height.

This is a satellite image. What I have told you so far could be completely wrong. What I'm telling you today is the latest advancements in aurora science, which means that we could be wrong. But we are getting very confident about what I've told you so far, because over time we could test our ideas and our theories. We study the aurora only on Earth and as I told you the solar winds blow all the way through to the edge of the solar system. So all the planets are exposed to the wind from the sun, the corona flow we call the solar wind. What I just explained to you is that the Earth has a magnetic field and that generates power so that electrical discharge phenomenon can take place. It so happens that Jupiter and Saturn have very strong magnetic fields, we know that so we're hoping that someday there will be a satellite to take an image of Jupiter and Saturn to see their auroras. If the satellite cannot see an aurora, what I told you would be completely wrong. Fortunately, as you can see both Jupiter and Saturn have their own beautiful auroras. On the other hand, like Venus and Mars, for some reason they don't have a magnetic field and we have sent many spacecrafts to examine both Mars and Venus but we could not find an aurora. It turns out that, planets with magnetic fields will have an aurora and those without magnetic fields will not. So, luckily thus far we are o.k, but of course we may still be wrong. And this is the way it is with science.

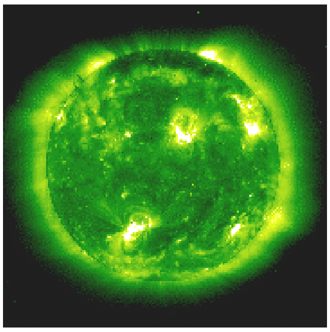


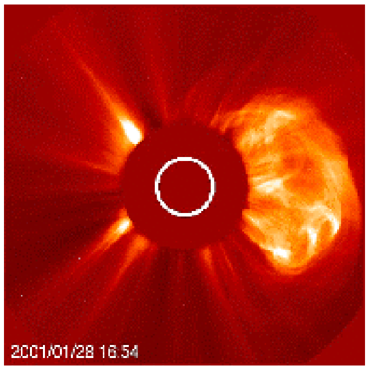
As I mentioned earlier on Earth we have atomic oxygen producing our aurora light. But both Jupiter and Saturn's atmosphere consists of hydrogen gas, which is why Jupiter and Saturn's auroras are pinkish. Hydrogen produces a pinkish light.

Talking about the corona blowing out all the way to the edge of the solar system, this is called the solar wind. And of course this wind is not steady. By looking at the sun visually, you don't see much structurally except sunspots. But, if you use different instruments aboard a satellite, you will see what is really happening on the surface. This is an x-ray image of the sun and you can see many, many interesting features on the sun, which you cannot see from the ground.

This is also a solar image. There are spectacular structures on the sun that is all magnetic fields. So the sun has many, many interesting activities that you cannot see by the naked eye or from the ground.

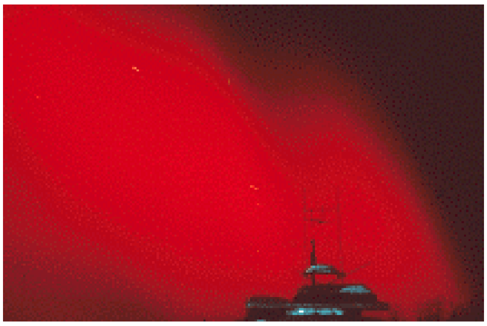
This is a major eruption on the sun. The white circle is the size of the sun. We can make an artificial eclipse, you can see the disk covering the sun then you can see the outer part of the sun, on the right hand the huge gas coming out is a major eruption. Let me show you a videotape of that.





The sun is continuously erupting and the eruption causes what we call gusty winds. And gusty winds are much stronger than the usual wind and then that makes the Earth's generators power go up by 10 or 100 times, then you see a brighter aurora. The situation is like rotating the coil a little faster in the magnetic field. Under these circumstances the ring of light becomes larger and descends down to lower latitudes. Sometimes on the North American continent we see the aurora coming down to the latitude of the U.S./Canada border or lower. In such a situation the aurora becomes very reddish.

This is also from atomic oxygen and is produced by a different mechanism and is very spectacular phenomenon. In the early days when that red glow appeared in the sky there were many, many pictures like this because people were so afraid of red lights saying "It's an ill omen!" or "The end of the world is coming soon!" So you can see how fearful they were when red lights appeared in the sky. Many paintings that depicted such fear in people by aurora of this kind remain today. This was perhaps done around 1500.



It is in such a situation that even in Japan, particularly in the Okhotsk seaside you can see the aurora. But this doesn't mean that the aurora comes down to Hokkaido, rather you are looking at the upper edge of the aurora, located still quite a bit far north. Perhaps, it is somewhere in Kamchatka, the aurora just can't come down to Hokkaido.

I would like to conclude my talk by saying that the aurora is the cosmic phenomenon closest to Earth. It is very fortunate that we can study a cosmic phenomenon on the ground. Many similar phenomena are taking place in the galaxy or nebula on many other stars. So the aurora scientists are trying to learn about this so that we can better understand many astrophysical processes. You may know that the one of the ultimate source of energy is the energy generated by nuclear fusion reaction, not nuclear fission. Nuclear fusion is to combine two hydrogen atoms to create helium; in this way you can generate tremendous power. In fact the sun itself is powered by this nuclear fusion and the way we study the same material hydrogen gas, ionized hydrogen gas so aurora scientists work very closely with fusion people and try to learn about it and hopefully in the next 40 or 50 years we will achieve nuclear fusion. There is no other major power supply source for human activity. Wind power and all this can perhaps support small villages but no way can it supply power for Tokyo or New York so we have to achieve this nuclear fusion. So we are working on it and that's about all I have to say.

Thank you very much for your attention.