Introduction to Atmosphere and Space Science
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Lecture – 05
Atmosphere of other Planets in Solar System

Hello dear students. So, so far we have seen what is the mechanism by which the earth's atmosphere has evolved over the period of 4.5 billion years; we started with the premolar atmosphere which was there at the time of the formation of the earth, then we have seen various processes which has resulted the in the present day chemical composition of the atmosphere. So, today we will continue the discussion to some extent where we will understand how the atmospheres of the other planets in our solar system are different from the atmosphere of the earth ok.

So, in the last class, we have see that the evolution of Earth's atmosphere and the evolution of life who are hand in hand I mean one is totally dependent on the other both of them are coupled in a way that one cannot exist could not have existed without the other. So, today we will see major changes in the atmosphere of the other planets in comparison to the earth ok.

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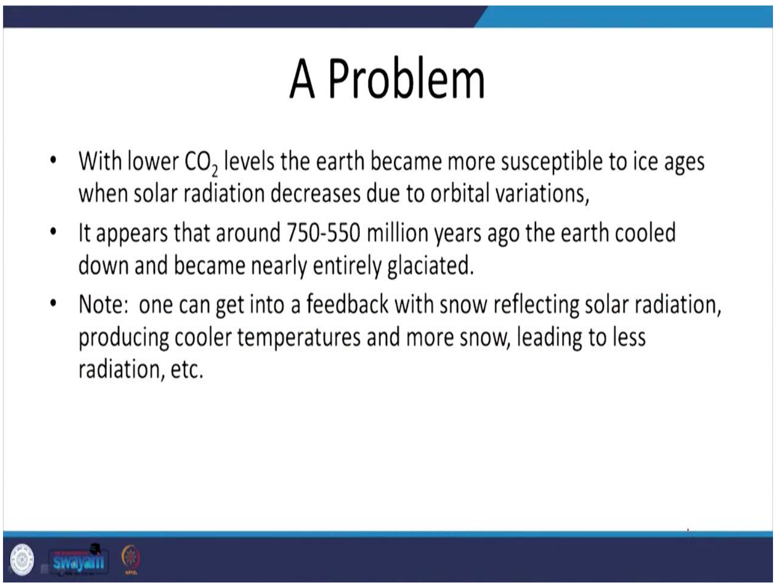

In our discussion there is there was a point where the CO2 levels were taken care by the photosynthesis reaction, that means, the CO2 was lost. We have seen that CO2 was the major constituent in the secondary atmosphere which was basically the volcanic eruptions, volcanic eruptions have created a lot of CO_2. We have seen how CO_2, how much CO_2 was there is system and how the CO_2 was lost in to the system into the earth itself, and right now we do not have much CO_2 in the earth's atmosphere ok.

So, with the decreasing levels of CO_2 on the earth, earth became more susceptible to ice ages, let us say CO_2 is a very important species because it has a tendency to be excited by the infrared radiation bands, that means, that it has the ability to trap the outgoing infrared radiation in the heat is generally given a term as infrared radiation, infrared radiation is heat. So, CO_2 has ability to keep a planet warm.

So, if you do not have CO_2 that means, that you will the planetary surface will be hot when it is exposed to sun when it is a day time, and when you when you have the night time the planetary surface will be very very cold, that means, the average temperatures between the day and night will fluctuate over all very large band. So, CO_2 is a very important species just because it can hold the hold the heat and it can maintain a average temperature which is not very different from day to night ok.

So, CO_2 levels were decreasing due to the photosynthesis reaction which was happening for at a very fast rate building up a lot of oxygen in the atmosphere right. So, with the with the lower levels of CO_2 with the with the decreasing levels of CO_2, the earth became more susceptible to ice ages because the temperatures were going down, when the solar radiation decreases due to the orbital variations ok.

Now, it appears that nearly 700 to 550 million years ago the earth cooled down and became nearly entirely glaciated. So, it happened once I mean the ice age was there for reason with the decreasing levels of CO_2 nearly 550 to 750 million years ago the earth has cooled enough, so that it was nearly an ice age, the entire earth became nearly glaciated.

So, it may be possible that how did we got out of this problem. So, here it is a very important point to we know that when the ice cover of on the on the planet increases what happens due to the high reflectance of the of the ice; that means, ice has ability to the reflect most of the incoming solar radiation that falls on it. So, snow reflecting snow can reflect larger amount of solar radiation, that means, once the ice formed there is even the solar radiation is reflected more, that means, you go into a negative feedback in which the more and more with time more and more amounts of ice is expected to form, more snow leading to less radiation. So, this is a kind of negative feedback which could have resulted.

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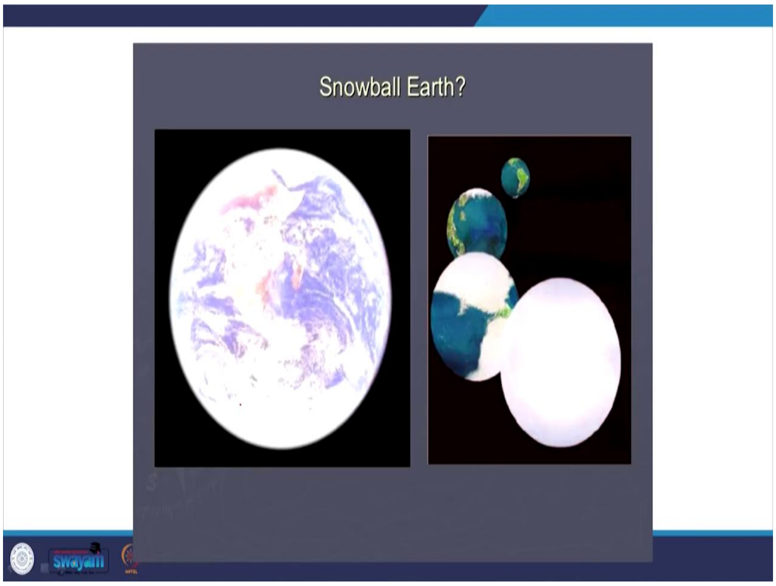

But so this is I mean in artistic impression where the earth must have turned into a snowball or let us say glaciated earth with the deceasing levels of CO2 which is definitely a possibility

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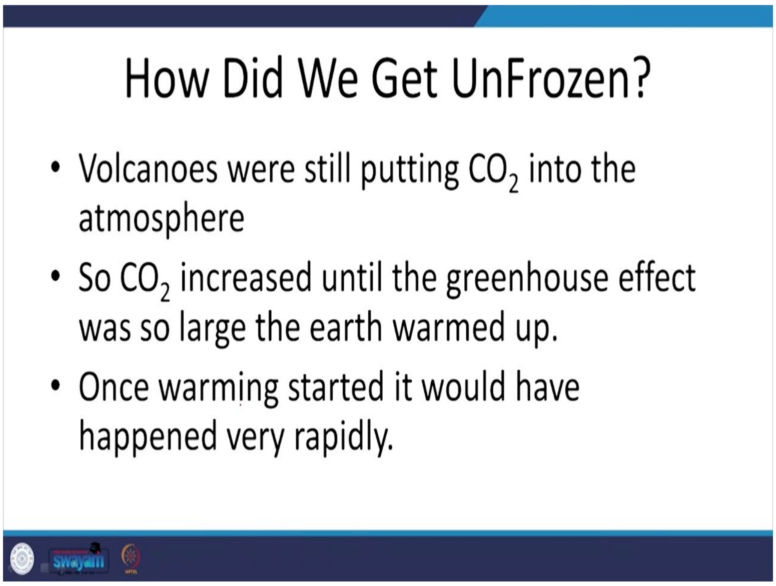

Now, but we did not we did not completely get an ice ball or let say snowball. What happened is there were still volcanic eruptions which were active that time there were still lot of volcanic eruptions was still throwing a lot of water vapour and a lot of carbon dioxide into the atmosphere. So, this CO2 was increasing at the same time with the time at the same time as it happened. So, CO2 increased until the greenhouse effect was so large that the earth warmed up and it got out of the ice age. So, once warming has started, it would have happened very rapidly, so that that must have gotten us out of the ice age.

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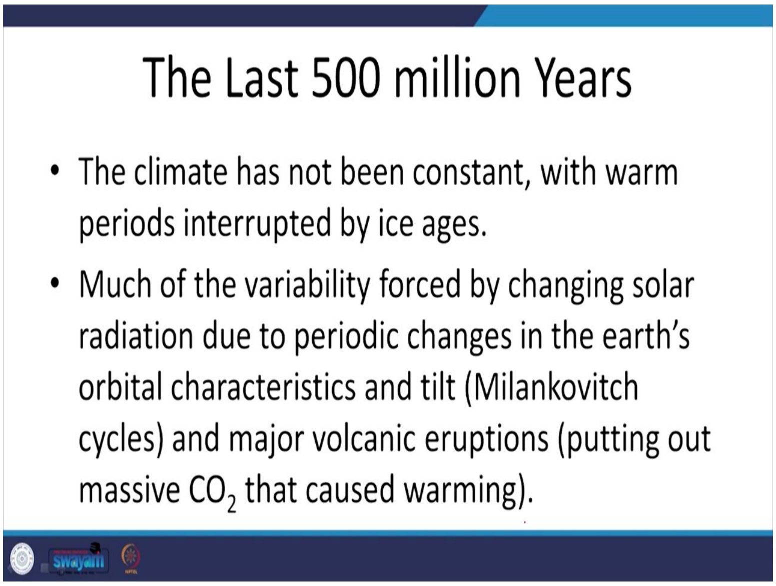

Now, in the last 500 million years, so the climate has not been constant with warm periods interrupted by ice ages, so that the average temperature is what I am talking about. So, warm period is some point of time where the average temperatures have gone up, and ice age is the period of time when the average temperatures have temperatures have gone below the limit.

So, much of the variability was forced by changing the solar radiation due to the periodic changes in the earth's orbital characteristics and tilt these cycles are called as Milankovitch cycles and major volcanic eruptions were trying to put as much as CO2 possible into the atmosphere just to just to make sure there are the temperature fall beyond the limit ok.

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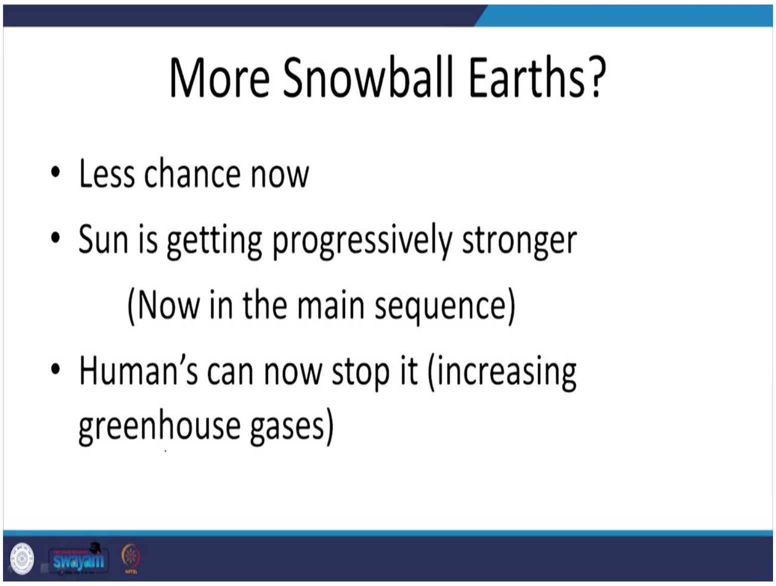

So, there is a chance I mean there are very little chances of course, so we can we can find ice ages in the in the coming future. And the main reason is that the sun is getting stronger, and now it is the main sequence star we know that right. So, now, even the anthropogenic effects such as increasing the levels of CO2 can avoid the formation of or the resulting of snowball earth.

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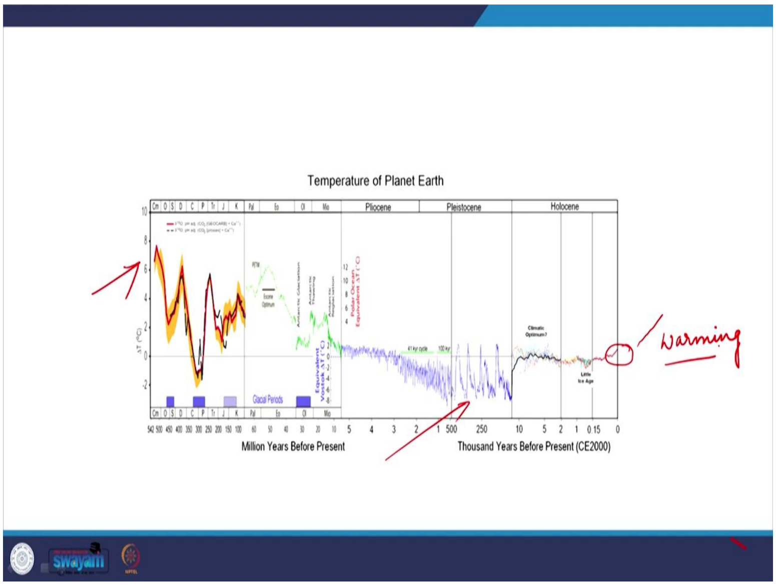

So, this is the average temperature variation over very long moment of time, larger amount of time. So, what you see is there have been severe warmings and they have been severe cooling's let us say. So, now, this is this average temperature is what you see here. And if this average temperature goes beyond a limit, you call this as warming. There are several reasons for this I mean this is a very elaborate discussion in itself.

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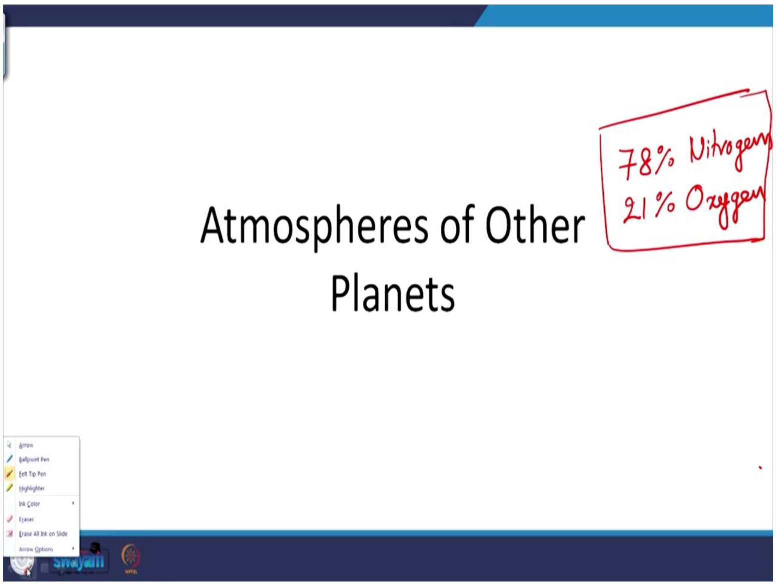

So, here what you can see is, so this is what happened which in its entirety has resulted in the formation of the earth's atmosphere to the composition that we know today. So, just before we go ahead, we will make a recap. So, the recap is that the earth's atmosphere was resulted mainly from the volcanic eruptions; volcanic eruptions gave away a lot of water vapor into the atmosphere. This water vapor was broken or disassociated by the ultraviolet radiation giving you the initial hints of oxygen, and later the certain other reaction which is called as the photosynthesis reaction took over. And this reaction being fast gave away or created a lot of oxygen in the atmosphere right.

The nitrogen levels were almost the same since the beginning, and this is the nitrogen this nitrogen is inert chemically inert, it would not participate much in the chemical reactions with the other species in the atmosphere. So, it remained as it is. And today in today's chemical composition of the earth's atmosphere is always to be remembered as 78 percent nitrogen and 21 percent oxygen right. So, this is a chemical composition which we know is very much suitable for the existence of life on this planet. So, this is a very important thing. So, this is what makes the earth livable or habitable right.

The beginning we know that the planet earth has formed by the agglomeration of large sized objects which are called as planetoids. They came together. There was a volatile substance which was trapped in between these rocks and as a gravity grow stronger, these species came together. And there was a lot of compression between these species and there was huge temperature increase in this; in this system. And all the heavier elements sank to the deep or they occupy what is called as the core and all the lighter elements were raised to the top right. So, this is what happened I mean right.

Now, there is a very strong reason for us to believe that since the entire system the solar system itself resulted out of the out of the nebula of gases and dust. So, every planet that has formed, must have formed at the same time as the earth and must have gone through the same physical or chemical processes which have resulted in to the formation of earth or the earth's atmosphere right.

Now, we know it now very well that earth's atmosphere is the only place which supports the existence of life. Apart from life earth's atmosphere is also very different or has a very clear contrast with respect to the earth's atmospheres, atmospheres of the other planets. We will see how it is different right. Now, it may be interesting to find out what were the processes which went different in other planets, so that now you have a different chemical composition on those planets right, but that is the discussion itself right.

So, today what we will do is we will not go into the details as such how or why this composition has resulted in on this planets, but rather what we will do is we will see what is the what are the salient features of atmospheres of other planets in our solar system.

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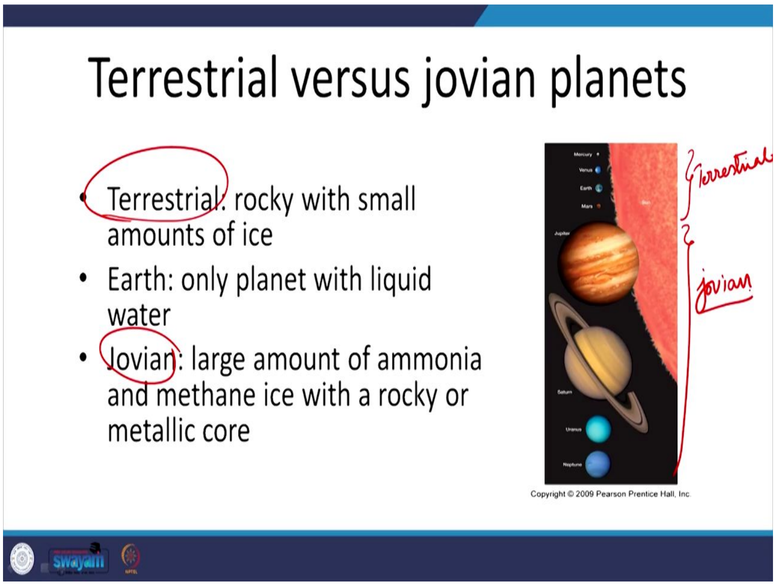

Now, to begin with let us say the planets in our solar system are mainly categorized into two different types. One terrestrial planets and the other Jovian planets. Jovian planets are the ones which have which have no rocky surface which are basically gas giants. And terrestrial planets are the ones which have rocky surfaces let us say that means, a surface where you can put your feet on or the surface where you can land ok. So, the terrestrial planets are the ones which have rocky surfaces and Jovian planets are the ones which does not have a rocky surface ok.

So, terrestrial planets generally have some small amounts of ice of course. And the earth is the only planet with liquid water as of now that we know today. There are other planets or there are other moons where water is has proven to be present, but that is a discussion away right. And Jovian planets are mainly characterized by large amounts of ammonia and methane ice with rocky or metallic core. Generally, the first four planets – Mercury, Venus, Earth and Mars are terrestrial, and the rest are Jovian.

Now, these planets let us say for example, some of them have not rocky surfaces, but they have ice sheets, I mean they are frozen. So, the entire planet itself is a is an ice of not liquid or not water rather it is an ice of gas that is a different thing right. Now, let us see one by one.

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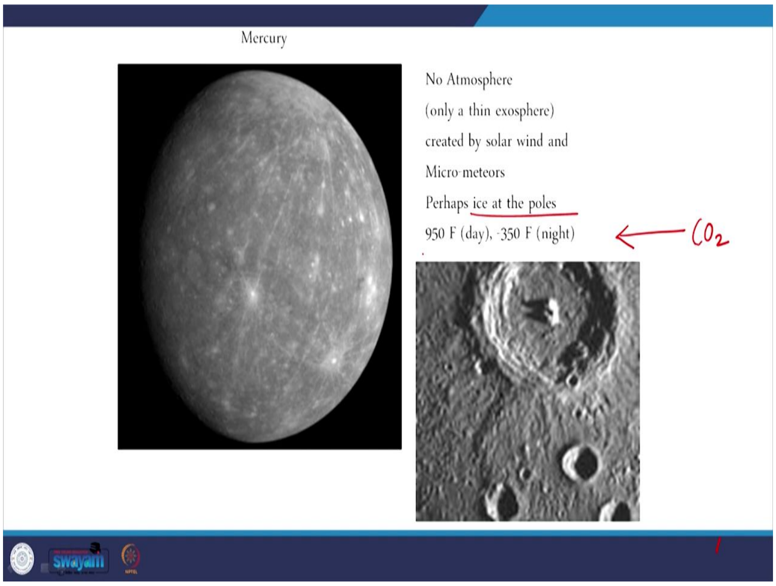

Now, let us start with mercury. Mercury practically has no atmosphere only it has it exist only it exist it has only a thin exosphere which is mainly created by solar wind and micro-meteors ok. Now, there were some reports which predicted the formation or existence of ice at the poles not confirmed anyway. The important feature about mercury is that mercury's average temperature fluctuates a lot because of the lack of atmosphere that is why.

So, we have already seen because if you do not have an atmosphere or if you do not have CO2, then your atmosphere, your the planet will lose heat easily and will gain heat easily, that means, that that is why the temperatures on Mercury vary a lot. So, Mercury is the closest planet to earth, so sorry closest planet to the sun of course, it receives immense amount of energy in terms of radiation over a particle flux from the sun. So, Sun basically cooks up the entire planet when it is the day, and when it is the night there is since there is no source of energy. So, sun, the Mercury immediately loses the heat, and the night time temperatures reach a very low value of nearly minus 350 Fahrenheit ok.

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Now, then you have the Venus. Venus is to our neighbor. So, which has 96 percent of CO2, so this is mainly CO2 dominated atmosphere I mean it is mainly nothing else actually. So, if Venus also have sulfuric acid clouds; Venus has very, very important phenomena which are not totally understood.

It has sulfuric acid clouds suspended in the atmosphere has its surface temperature goes nearly as high as 900 in Fahrenheit. And it has a very high surface pressure, so this is an interesting phenomenon in which happens in the Venus. Venus surface pressure is immensely high which is nearly 90 times more than that of the earth ok, so which is a very very big number in itself ok.

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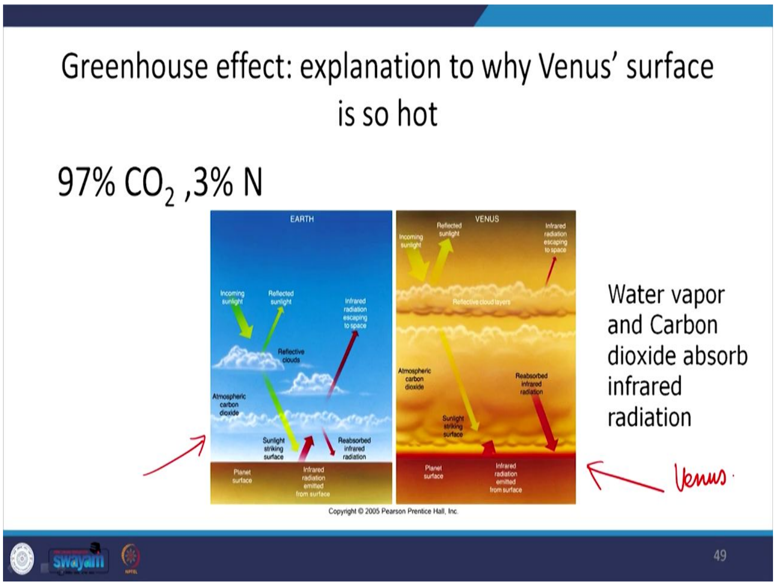

Now, why is it that Venus surface temperatures are very high is mainly because of the large amounts of CO2. CO2 you know you have seen that CO2 tends to trap heat and it would not allow heat to be given away from the planet right we have seen that. So, because; so this is basically the an example of greenhouse effect where you see this, this the figure on your left is the earth, and this is Venus.

So, what you see due to the enhanced availability of CO2 to a very large extent, the greenhouse effect is enhanced I mean it is an enhanced greenhouse effect which basically traps the outgoing radiation, and it would not allow the outgoing radiation to escape into the space, and it will heat the planet to a very large temperature. So, the point is the Venus is not at a particular distance where this surface temperature is where its surface temperatures should be 900 Kelvin, but it is it is because of the large availability of carbon dioxide which is which has the ability to trap the heat.

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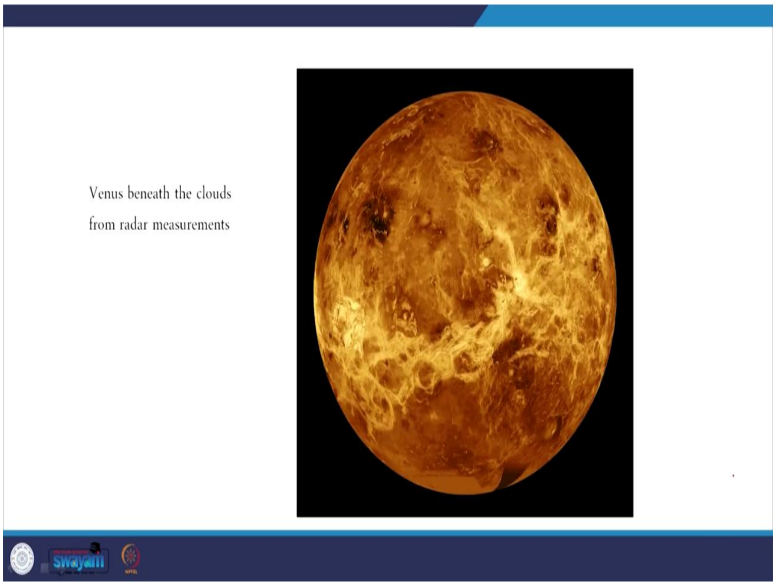

This is just a figure with shows Venus beneath the clouds from the radar measurements. So, you see several patterns on this on this planet right.

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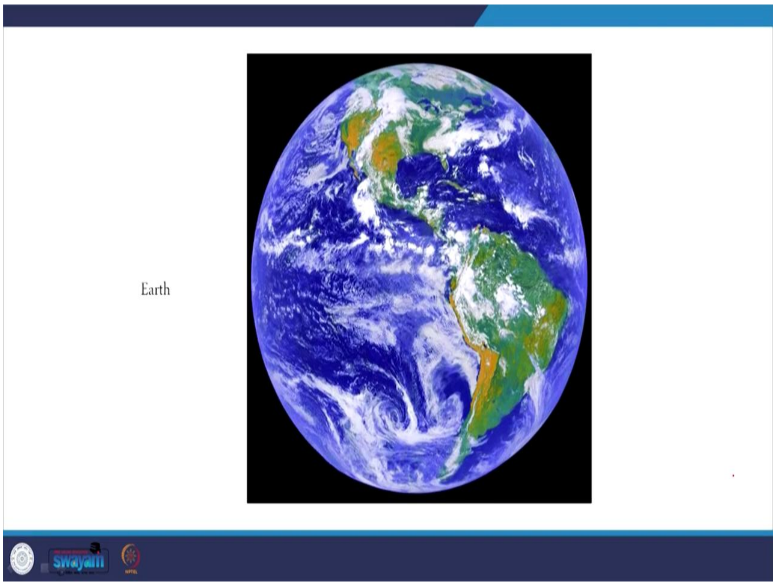

Then the then you have the earth of course, we know the chemical composition of earth, and how it has evolved how it has come to existence today the way it is. We know several other features about the earth's atmosphere itself right.

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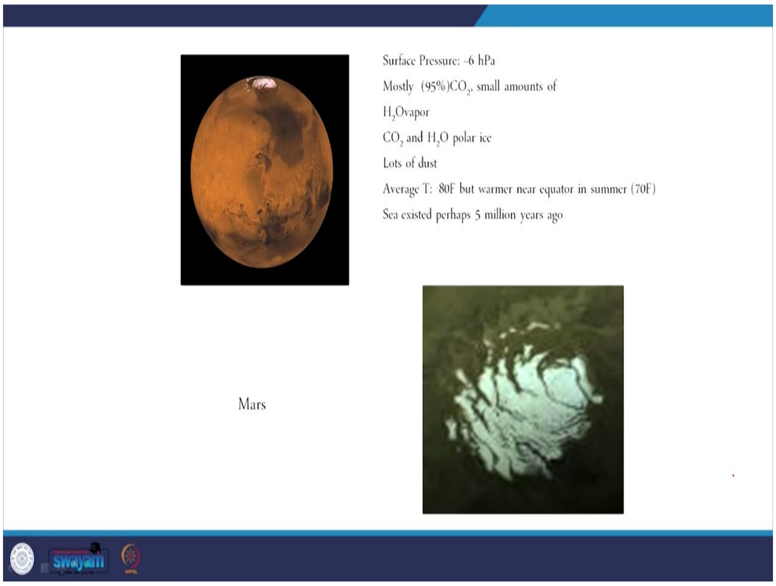

Then you have on the right the nearest neighbour is Mars, which is which has the surface pressure of mass is nearly 6 hectopascal, and the atmosphere is 95 percent is CO2 and small amounts of water vapor. And there also been seen that in the poles Mars has the ice formation ice crystals made up of carbon dioxide and water vapor.

Mars of course, has a lot of dust I mean it has a rocky surface. The average temperatures minus 80 Fahrenheit, but it is generally warmer in the near equator in the summer, so that means, the temperature at the poles at the equator is not as high as low as minus 80 degree Fahrenheit. And it is believed that there water bodies must have existed on the surface of Mars nearly 5 million years ago, so this is still unverified ok.

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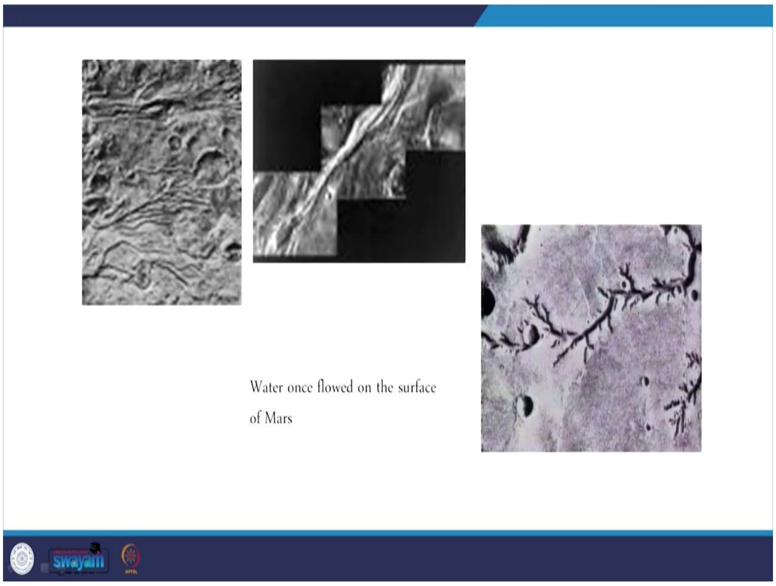

So, what you a very important or very prominent feature that you see on the on the Mars if you if you open any image of Mars, you will always be able to see that there were a lot of; there are lot of patterns in which indicate that the water must of flowed are there was water flow on the surface of the planet, the several millions years millions years ago.

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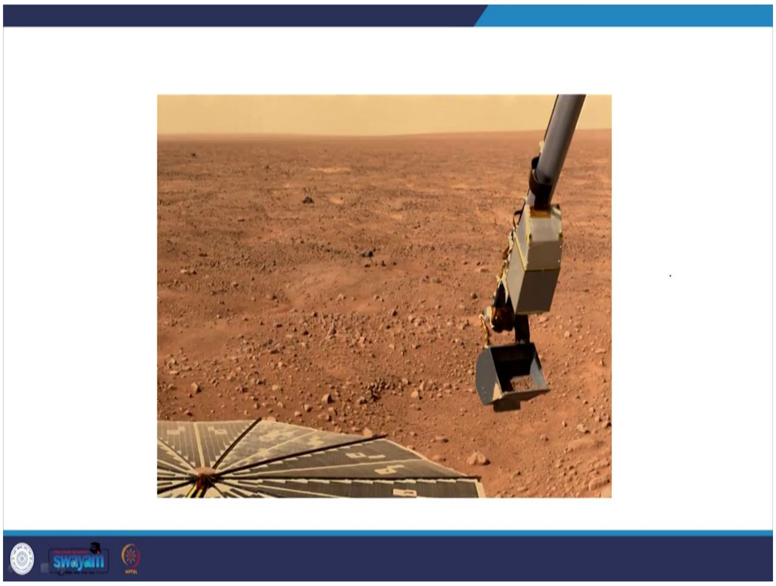

So, this is how it looks like the Martian surface looks like - the red planet right.

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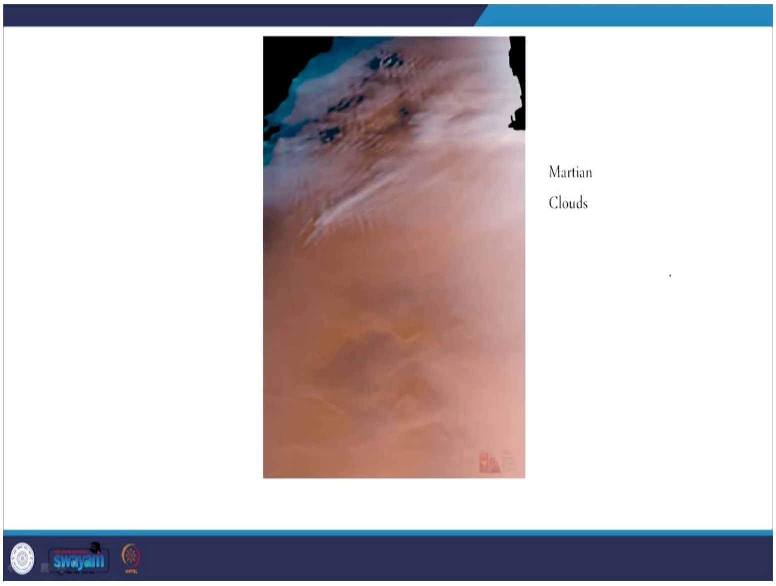

So, and the Martian clouds are also been seen by several spacecrafts right.

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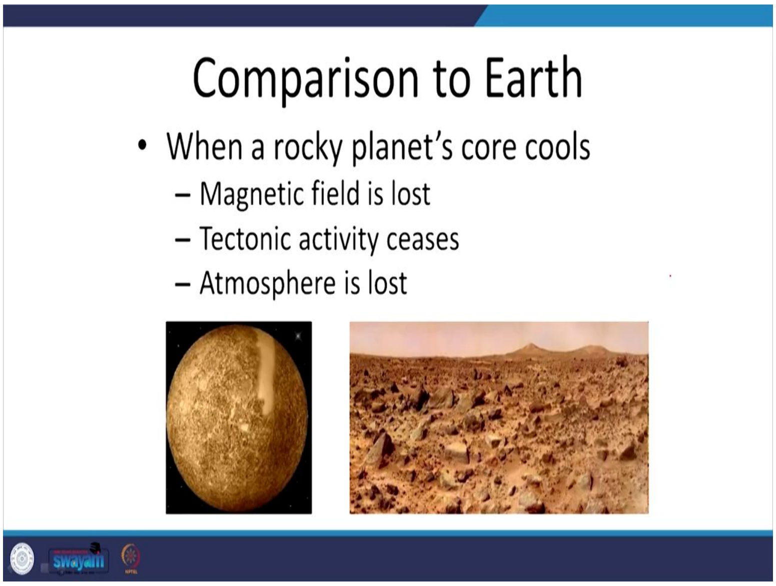

Now, when you compare the Martian surface or atmosphere what generally happens is when a rocky planets core cools, I mean now we know that the earth's core is the molten iron core that we have the centre of the planet is a very hot its molten. So, it indicates is very hot, it is rotating right. Now, when this core loses its heat, the core can lose heat due to a lot of reasons, due to a many reason. What, immediately happens is if you if the core loses heat, the magnetic field that it generates is mainly lost. So, you lose the dynamo right.

And the tectonic activity which moves the surface in and out basically the earth surface actually turns around we know that I mean it happens over several millions of years, it takes several millions of years, but earth's surface eventually turns out. So, the tectonic activity lose ceases to exist and then you have the atmosphere is lost that is what must have happened to these planets right.

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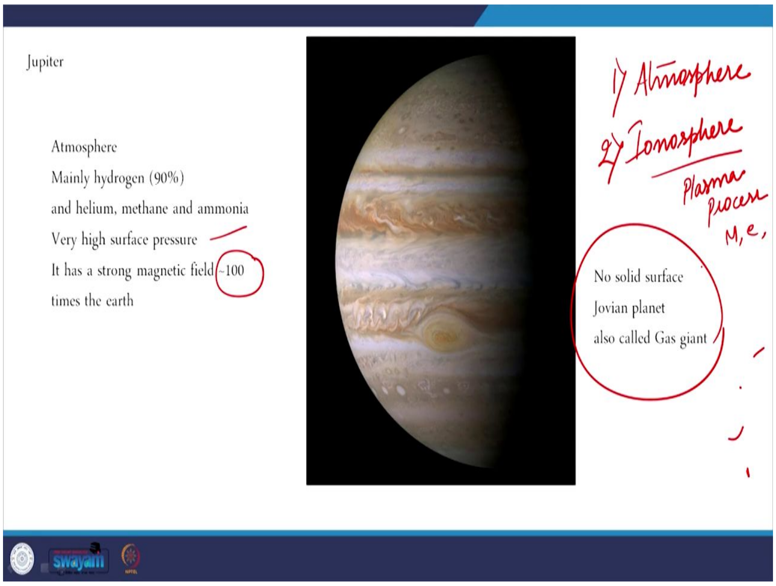

And then you have Jupiter, Jupiter is the gas giant I mean; that means, there is no surface there is no solid surface to land or to stand let us say and which is the Jovian planet by our definition right. And is there is also called as a gas giant, so Jupiter is a very large planet. So, atmosphere of Jupiter is mainly 90 percent hydrogen, and the remaining is helium, methane and ammonia. So, this presented in a very large number. So, this also has a very high surface pressure, it has strong magnetic field. The Jupiter has a very strong magnetic field which is nearly around 100 times the earth.

Now, in our discussions, in our in the entire course, two things really matter to us, what, what are the one, we will be interested to understand processes about atmosphere. When, when we say atmosphere we generally are referring to the processes which are mainly dealing with neutral constituents. Then you have another processes another set of processes which are different which we generally call as ionosphere right.

So, in this the in the second topic, we will mainly discuss about the plasma processes how, so this is these are the processes in which you talk about magnetic fields, you talk about charges, you talk about electrons, you talk about you talk about plasma right. So, for those discussions probably the strength of magnetic field or the origin of magnetic field or the shape of magnetic field, these things will be relevant ok.

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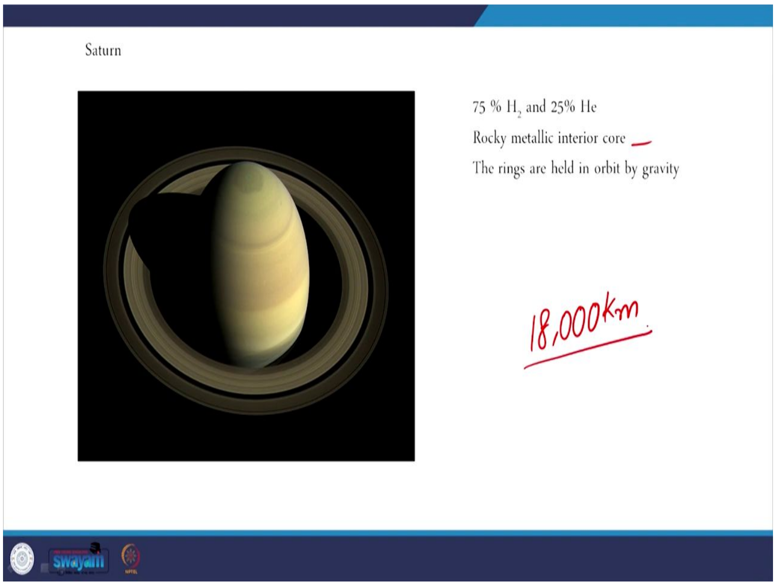

So, then the next planet is Saturn. Saturn is mainly 75 percent hydrogen and 25 percent helium. So, Saturn is also hydrogen and helium, this composition is not so different from the composition of sun itself. We already seen that. So that the sun is also a similar chemical composition, but the only difference is that Sun has as a reactor which fuses hydrogen to form helium right, where the other planets do not have it.

If this planet is believed to have a rocky metallic interior core, it is the core not the surface I am talking about. And the rings that you see which nearly span over nearly 180000 kilometres are basically held to the planet to Saturn by its gravity.

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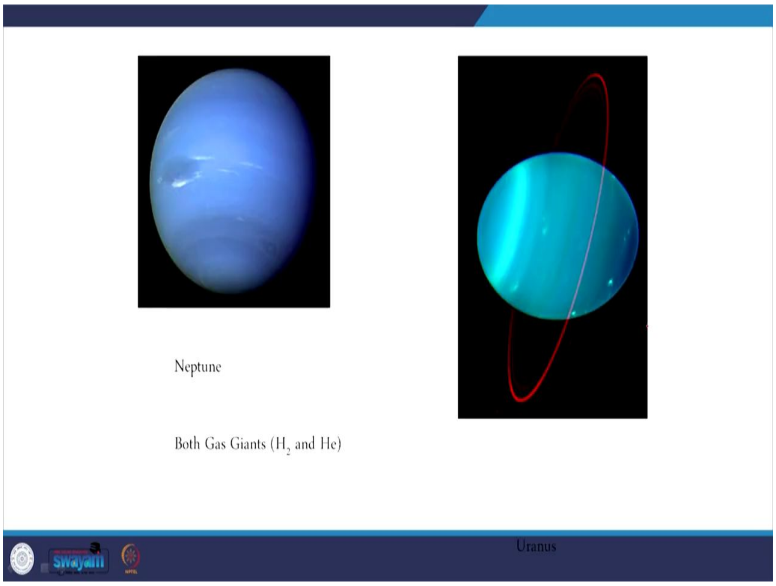

And you have another two gas giant which are Neptune and sorry Uranus and Neptune; both of these are gas giants let us say.

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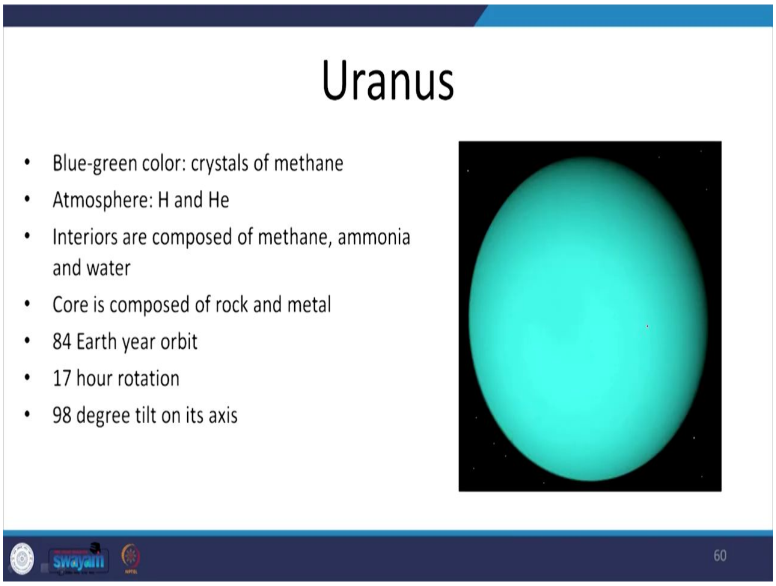

Uranus let us say which appears in blue-green color, blueish-green color is due to the crystals of methane that exist on the planet. And the atmosphere is mainly hydrogen and helium again. So, and the interior is composed of methane and ammonia and water. So, we do not know what exist inside the inside the ice or I mean ice surface and the core is composed of rock and metal. It is say I mean these two are the rotational characteristics of the planet that means, it takes a very large amount of time to rotate around the earth, and it has a huge tilt of nearly 98 degrees on its axis.

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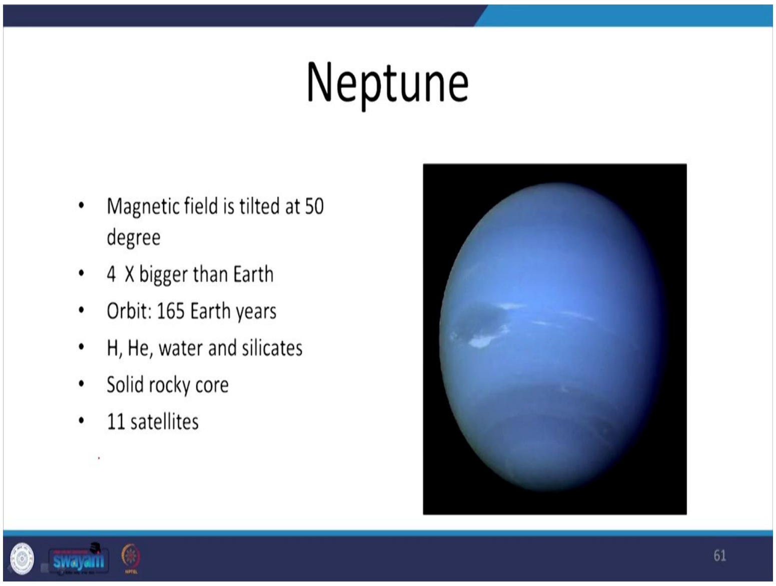

And Neptune, the farthest planet in our solar system is has a magnetic field is tilted at fifty degrees and the atmosphere is mainly hydrogen and helium. So, it is more or less similar to their the remaining Jovian planets. It has a solid rocky core and it has eleven satellites, it has many satellites.

So, this was something about comparison with the earth's atmosphere. So, one thing is that terrestrial planet's atmosphere apart from Earth is mainly dominator with CO2 for example, Venus and Martian atmosphere is mainly dominated by CO2, and the Jovian planet's atmosphere to very large extent is dominated by hydrogen and helium right. So, we can see that the terrestrial planets; among the terrestrial planet Earth is a unique example, where you have the oxygen and water and so many other things right.

So, this is the end of a module where we have discussed the evolution of Earth's atmosphere, how atmosphere has formed, how is atmosphere of the earth different from the other planets. So, in the next lecture, we will try to understand the structure of atmosphere of the earth, how is how many different layers of atmosphere exist in the according to the temperature, how does the pressure and density vary with respect to height, and things like that ok.

Thank you.