Introduction to Atmospheric and Space Science

Prof. M. V. Sunil Krishna
Department of Physics
Indian Institute of Technology, Roorkee

Lecture – 60
Airglow and Aurora

Hello, dear students. So, after having discussed various aspects of ionosphere we will discuss today a subtopic of ionosphere let us say what is generally called as Airglow and Aurora. So, our objective will be to understand what are the processes which will result in the formation of aurora and a closely associated phenomena called as airglow.

So, these two are or the optical effects that you can see in the upper atmosphere. So; that means, that not much that happens in the ionosphere can be seen with the naked eye, but these two are the processes or the optical effects that we can see in the ionosphere.

So, to begin with let us say aurora is a magnificent pattern of light that you can see in the night sky generally from the polar latitude. So, not many of us has have seen aurora in real lives, but we have seen it in many instances of let us say in television or in science documentaries or documentaries about sun earth's atmosphere things like that.

So, today's class we will try to understand how aurora is formed, what is responsible and how is sun responsible for the aurora, how sun modulates the structure of ionosphere or how sun modulates the way we structure of aurora and how suns magnetic field in combination with the earth's magnetic field is responsible for the formation of aurora.

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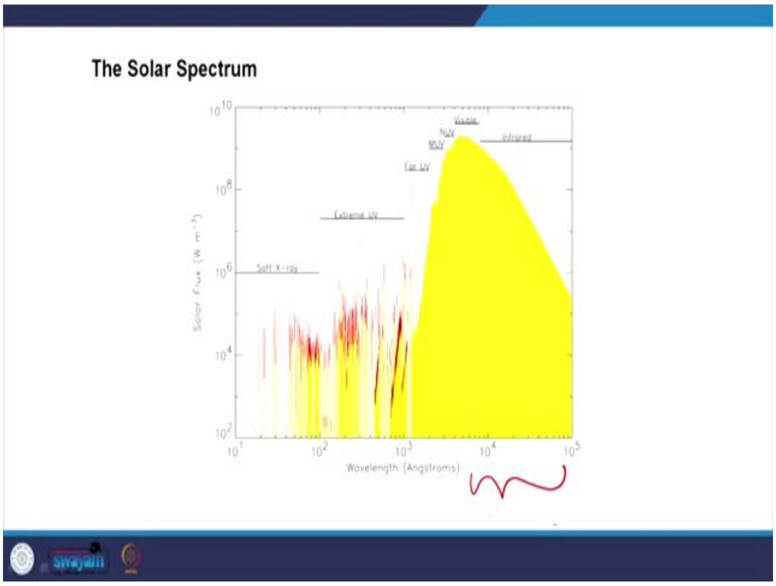

So, if you look at the familiar solar spectrum that you see it is categorized into many different parts.

So, soft X rays, extreme ultraviolet, X rays atrium extreme ultraviolet, far ultraviolet, middle ultraviolet, near ultraviolet visible and infrared. So,there is no such thing that this labels or this name should exist we have named them because of each of this part has very distinct effects on the ionosphere or for example, on the atmosphere.

So, for example, X rays, ultraviolet radiation let us say has more energy they have very less wavelength, they have more in energy in the sense that they have the ability to ionize or dissociate atoms and molecules respectively. But on the other hand visible radiation and infrared radiation is very weak in energy and they are very long wavelengths, they are very long range wavelengths so they do not have the ability to ionize atoms or dissociate molecules.

So, as a result what you can say is that the entire atmosphere is kind of transparent for the visible and infrared radiation, so nothing in this particular part we will get absorbed by the radiation. So, nothing in this let us say visible and infrared radiation, we will not be absorbed by the atmosphere so it will be, it will directly travel to the earth. So, we have seen this aspect in while discussing the structure of atmosphere and while discussing the structure of sun things like that.

So, but on the other hand this part which is the X rays, ultraviolet and far ultraviolet near ultraviolet radiation, have the ability to ionize atoms and dissociate molecules. Now, what we are trying to do is we are trying to understand how the radiation of the earth effects atmosphere or ionosphere in such a way that it results in the formation of aurora or airglow.

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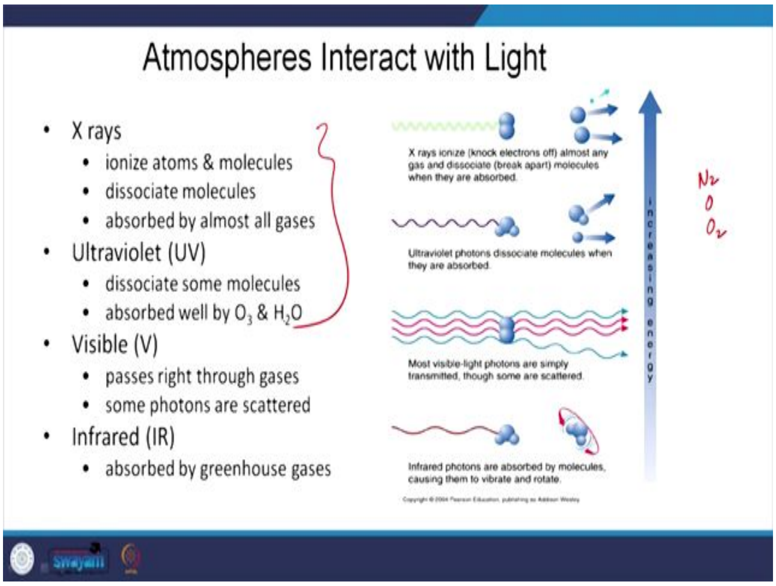

Now, if you see what I mean with each part has different effect so; that means, theatmosphere interacts with the incoming light that is coming from the sun. So, X rays are highly energetic in nature they can ionize atoms and molecules and ionize atoms and molecules, they can dissociate molecules into individual atoms and they are generally absorbed by almost all gases. So, whatever the gas so predominantly you have nitrogen, you have oxygen. So, predominantly these are the gases that you have and all these gasses the molecules or atoms have can absorbed the X rays.

So, X rays ionized let us say almost any gas and dissociate molecules when they are absorbed then comes the ultraviolet radiation, ultraviolet radiation dissociates some molecules not all molecules, but it can dissociate some molecules. Ultraviolet photons dissociate molecules when they are absorbed and ultra well it is very well absorbed by ozone and water vapor.

Visible radiation is least I mean is not that energetic. So, visible radiation passes right through the gases so visible. So, not any gas will absorb this visible radiation and some photons may get scattered in the process.

And infrared radiation is the least energetic of the entire electromagnetic spectrum infrared radiation is absorbed by the greenhouse gases and this is a more involved process anyway. So, what we have to understand is these two parts are the ones which will be absorbed by almost all gases in the atmosphere.

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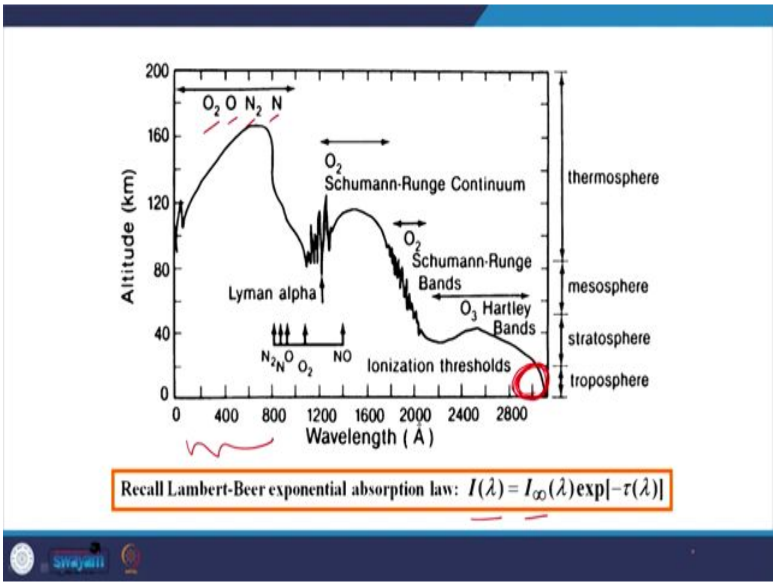

Now, if you put it lets say so now you have the solar radiation traveling from the upwards towards the ground. So, in the process it starts to encounter little amount of gas at the highest point in the atmosphere, as it travels down it starts to encounter more and more gas species and this rate at which it encounters the gas species increases exponentially as it travels towards the ground.

At the same time the density decreases exponentially as you go up and most importantly the rate at which solar radiation encounters the neutral species increases exponentially, as you go towards the ground and parallel to that the available photons to be able to ionize or to be able to dissociate will decrease as the radiation travels , towards the ground.

So, we know very well how the radiation attenuates as it travels through a particular distance by the simple Beer Lamberts law which says, I lambda is I infinity I infinity is this is the intensity of light at the beginning at a particular value of lambda times exponential minus tau of lambda. So, this absorption coefficient can be deduced from this equation.

So, what it says is that, as the radiation travels a particular distance its intensity drops exponentially and its intensity drops exponentially at the expense of the increasing density of the neutral species. So, these two things go parallel with each other, but just in opposite directions.

Now, so if you see this curve shows how or where exactly the radiation is absorbed and by which species is the radiation absorbed. For example, if you take the altitude on the y 1 axis and on the y 2 axis you have the respective layer of atmosphere for reference. So, what you can see is that the nearly at 120 to 160 kilometers the most intense radiation in terms of its energy is absorbed in this limit.

So, which is nearly 100 kilometers to, 180 kilometers the most intense energy in terms of wavelength is absorbed, by the species O 2 O N 2 and, the most dominant atmospheric constituent absorbs radiation at this height.

So, if you go towards the higher wavelengths or lower energies you will always see that the highest wavelength or the lowest energy does not get absorbed anywhere it almost travels to the lowest point in the atmosphere. So, it travels down to the earth almost.

So, the point is as the radiation travels towards the earth it gets attenuated, at the expense of ionization and dissociation of the molecules which happen to be in its track.

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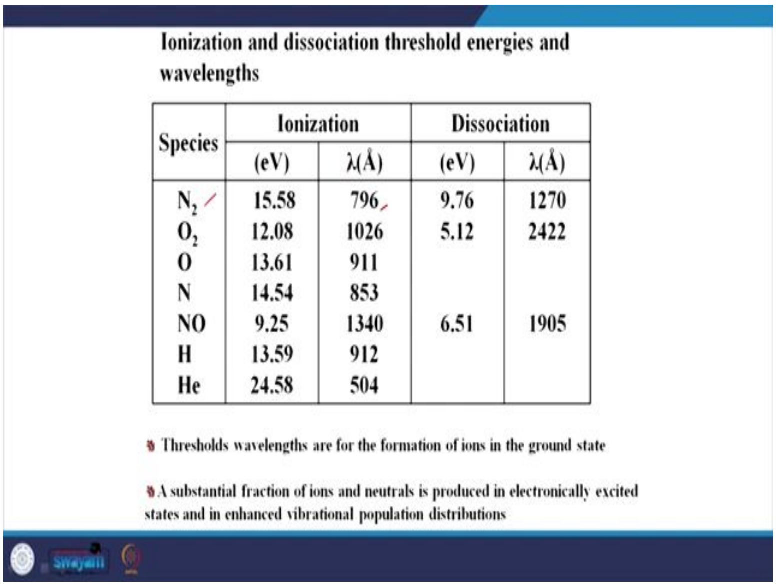

Ionization and dissociation threshold energies and wavelengths

Species	Ionization		Dissociation	
	(eV)	λ(Å)	(eV)	λ(Å)
N_2	15.58	796	9.76	1270
O_2	12.08	1026	5.12	2422
O	13.61	911		
N	14.54	853		
NO	9.25	1340	6.51	1905
H	13.59	912		
He	24.58	504		

- Thresholds wavelengths are for the formation of ions in the ground state
- A substantial fraction of ions and neutrals is produced in electronically excited states and in enhanced vibrational population distributions

Then, so it is very important that not all molecules can absorb ultraviolet not all molecules can absorb infrared.

So, every atom or molecule and its ability to absorb a certain amount of radiation can beunderstood by looking at its ionization potential. Let us say for example, so for ionization the value of energy that you require to ionize N 2 nitrogen molecule is typically of the order of 15.58 electron volts that is in the limit of 796 angstroms.

So, that means if you see all these energies, the extreme energies are lying below the visible spectrum so; that means, that the energy below the visible spectrum is capable of ionizing and dissociating atoms and molecules.

So, threshold wavelengths are for the formation of ions and in the ground state. So, again this depends I mean to which state they are excited or they are ionized. A substantial fraction of ions and neutral species is produced in electronically excited states and enhanced vibrational population distributions. So, the point is the solar radiation has a ability to produce electronically excited states vibrationally populated distributions because of the interaction with the highly energetic radiation .

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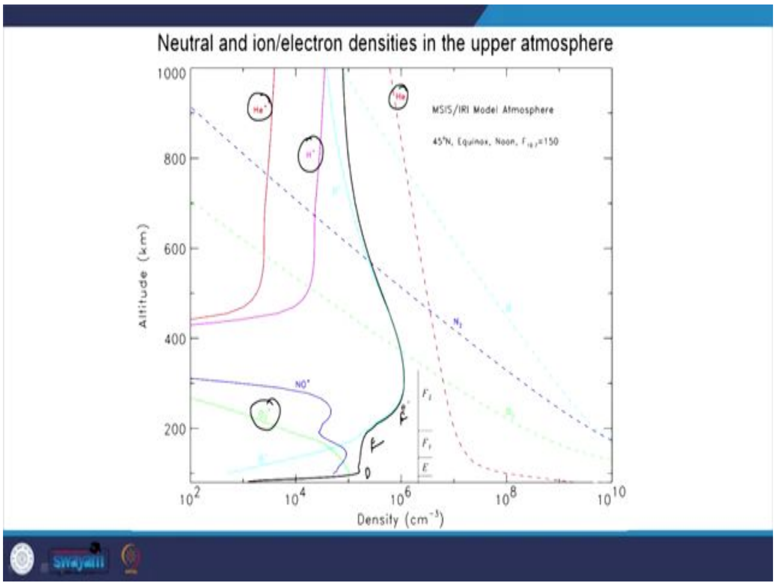

If, you look at a moral output of electron densities and neutral densities what you will be able to see the familiar distribution for us so far is the oxygen, nitrogen and oxygen molecule.

So, what you can simply see is that this is a kind of exponential decay in terms of its number density with respect to height. And you also see the electron density this is the D layer this is the E layer and this is the F layer so, you also see that the electron densities are varying in this way

Now, you have to put these two things in comparison. So, apart from this if you look at the ion species you will see that O 2 plus ion has a very different distribution and the lighter ions H plus He plus have the tendency to occupy the highest or topmost altitudes and the neutral species such as helium also has ability to, since being very very light it tends to be present at the highest altitudes.

So, now the point is the atmosphere offers different neutral species at different heights and in the ionosphere different ion species are present at different heights.

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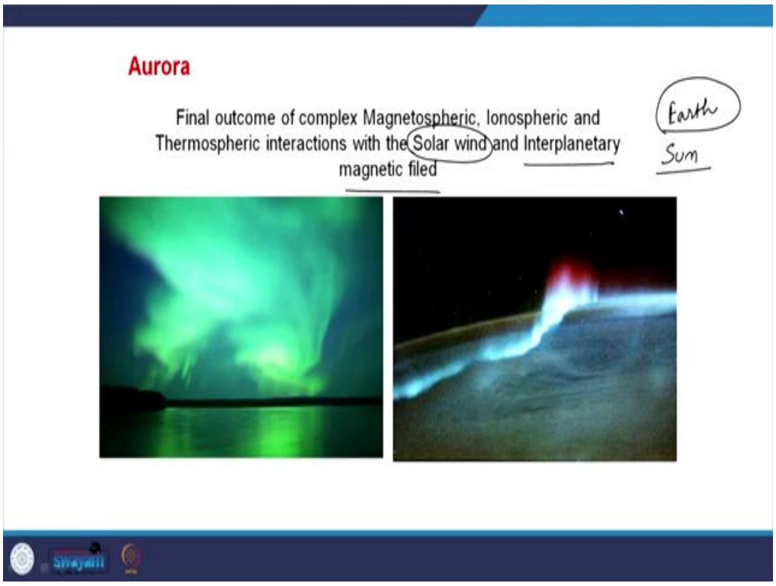

So, now it to be able to define aurora, aurora is simply the final outcome of a complex magnetospheric, ionospheric and thermospheric interaction with the solar wind and the interplanetary magnetic field. So, aurora is a physical phenomena that is an outcome of an interaction between the magnetosphere ionosphere and thermosphere with the solar wind.

So, solar wind is the driver in this particular process, so, solar wind is the driver; that means, solar wind it drives the aurora. When magnetosphere or ionosphere, thermosphere interacts with the solar wind you get to see what is called as aurora, and this interaction is permitted or this interaction should be permitted by the interplanetary magnetic field.

So, this is solar wind and interplanetary magnetic field are some things which are related to the sun, and magnetosphere, ionosphere and thermosphere are the regions of the earth or earths atmosphere.

So, when earths atmospheric, regions such as these interact with the solar wind in the presence of the interplanetary magnetic field the process that the outcome of this interaction is generally called as aurora. What is distinct about aurora is? Aurora is an optical effect, optical phenomena that you can see with your naked eye, if you are present at that particular latitude where aurora is most likely to be seen.

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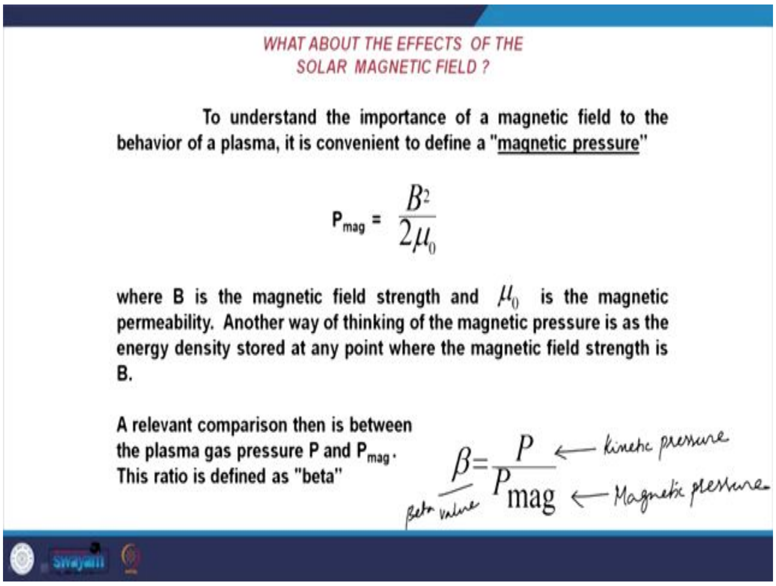

Then, now if you want to understand this interaction let us say, how solar wind interacts with the atmosphere. We have to understand few important aspects about the solar wind and few important aspects about this interplanetary magnetic field right. So, what is solar wind? Solar wind is defined as the plasma that travels away from the sun into the interplanetary space.

So, the solar wind constitutes mainly of electrons and ions and there is also a magnetic field which is inter coupled with or which is intermixed with this plasma. So, to be able to define solar wind or the strength of solar wind we introduce a parameter which is called as the magnetic pressure.

So, to understand the importance of magnetic field to the behavior of plasma, which is very convenient that we use or we define a parameter which is called as magnetic pressure.

So, if B is the magnetic field associated with a particular plasma in Tesla let us say for example, then the magnetic pressure associated with this magnetic field is given as B square by 2 mu naught, where B is the magnetic field strength and mu naught is the magnetic permeability of free space, or we can simply say that magnetic pressure is the energy density that is stored at any point in the where the magnetic field strength is B.

So, when the magnetic field strength is B in the energy that is stored at any point is B square by 2 mu naught. Now, that is just a parameter to quantize some, physical parameter in plasma, but how is it important for us is that.

If you put a comparison between the the kinetic pressure of this plasma assuming that it is a gas you calculate the kinetic pressure, the plasma also has some magnetic field associated with it some magnetic field intermixed with it, if you know the strength of that particular magnetic field the pressure that is exerted by this plasma is the magnetic pressure.

So, this is the P here is the gas pressure or the kinetic pressure and P mag is the magnetic pressure. The ratio of these two parameters is called as the beta value of a particular plasma. Now, we all know that plasma is just an ionized gas, it is already ionized gas and if you put some magnetic field into it will exert some pressure.

Now the every plasma is identified with a typical value of beta ,the beta value of plasma, now solar wind is a high beta plasma; that means, the beta value for solar wind will be high, that is just one way to label solar wind and its effects.

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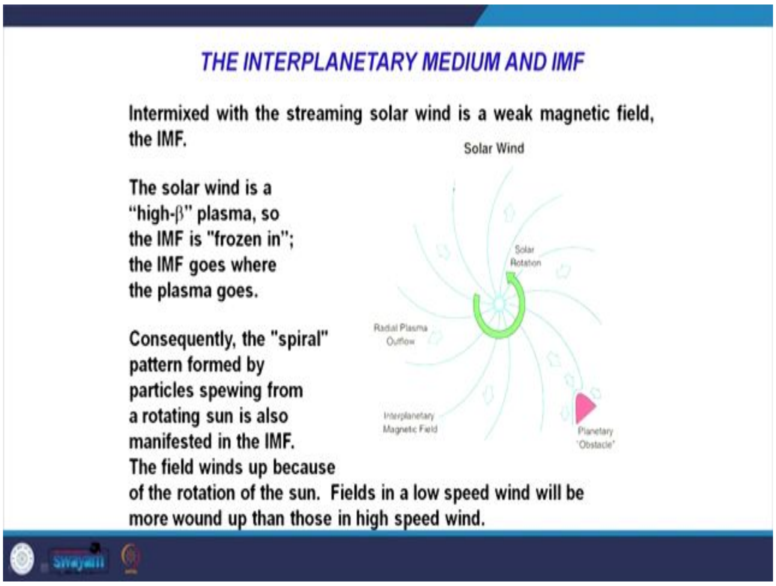

, now let us talk some details about the interplanetary magnetic field. So, solar wind has to interact with the earth's atmosphere magnetosphere or thermosphere or ionosphere and this interaction has to happen in the presence of interplanetary magnetic field, now we have seen some very small detail about the solar wind let us see some detail about the Interplanetary Magnetic Field which is also called as the IMF.

So, interplanetary magnetic field simply put is the magnetic field that is associated with the sun. If the suns magnetic field is something which pervades the entire solar system this magnetic field strength is called as the interplanetary magnetic field.

So, interplanetary magnetic field is intermixed with the streaming solar wind is a very weak magnetic field. So, interplanetary magnetic field is intermixed with the solar wind plasma. The solar wind is a high beta plasma so the IMF is frozen in with the solar wind plasma; that means, wherever the solar wind goes the interplanetary magnetic field goes with it actually.

Consequently, the spiral pattern formed by the particles spewing away or from a rotating sun is also manifested in the IMF. So, the field winds up because the rotation of the sun fields in a low speed wind will be more wound up than those in the high speed wind naturally.

So, sun rotates from west to east. So, sun is also rotating on itself. So, as the magnetic field that is emanating from the sun should also be rotating because of the rotation of the sun so does the plasma that is emitted from the sun.

So, now if you have a rotating object and if something some out flux is expected out of that rotating object; obviously, the out flux will also have a spiral pattern that is forced by the object which is in rotation. Now, so here this diagram simply shows the sun at the center and as it rotates as the sun rotates you see that it the out coming solar wind patterns or forms in the pattern of a spiral.

So, now the important thing is the magnetic field that is associated with the solar wind or the magnetic field emitted by the sun is intermixed with the solar wind so both of them will form a spiral pattern.

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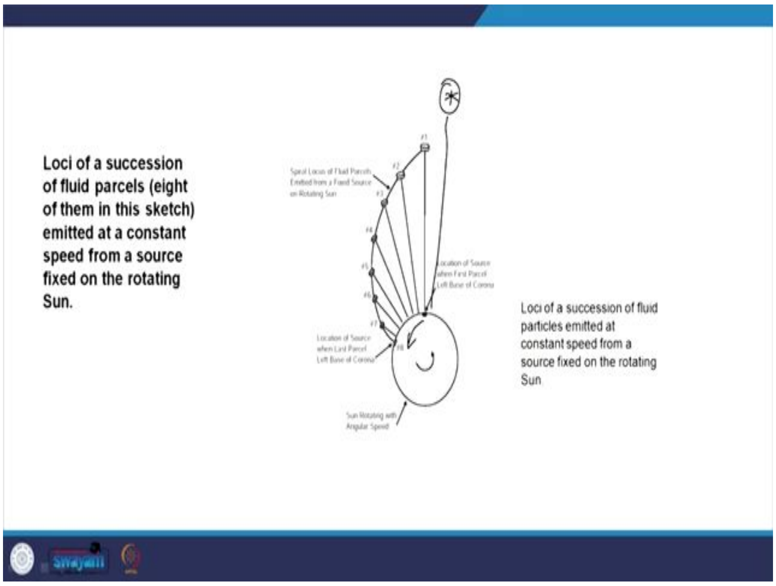

Now, how does it look like? Let us say if you consider consequent parcels of solar wind that are emitted by the same source. So, if you take sun's bay sun's surface to be the origin of the solar wind and if you take one particular point, which is emitting solar wind continuously let us say then, how does it look like, if the sun is rotating angularly in this way if you are looking from the top? .

So, this is the point where the first parcel is emitted let us say this point.

Then as the time travels. And as it rotates like this the consequently at equally separated intervals of time if you imagine the parcels to be emitted the loci of these points these parcels position with respect to time will look something like this.

Now the first parcel of solar wind that is emitted from the sun if you trace the location and if you think that the location of this parcel is this point you will not be correct; that means, this location of the point where the parcel was emitted have has traveled away to a different point and the loci of the parcel will look something like this.

So, that means, that the solar wind. Now, if you put earth anywhere the by the time the solar wind parcel reaches the earth the apparent location of its origin will not be seen from the earth, it may be in a different point. So, it is not correct if you just trace it back directly to the sun, that is the point.

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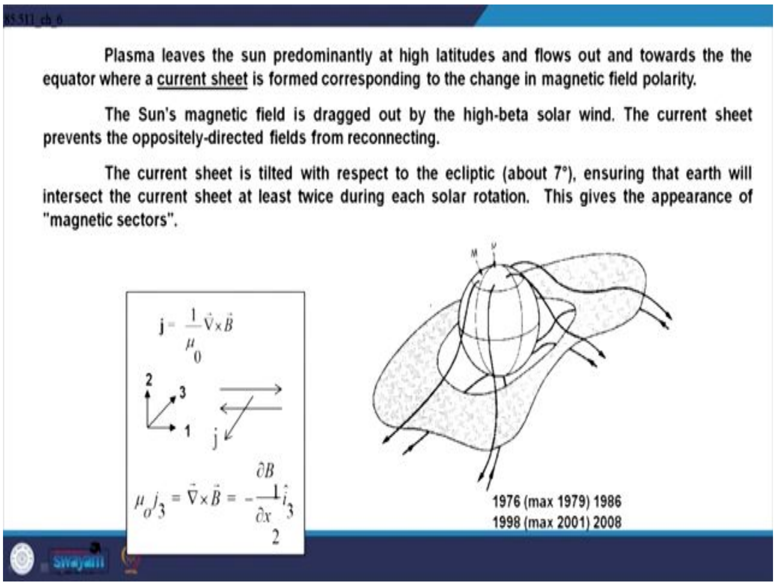

Now, now plasma generally leaves the sun predominantly at high latitudes and flows out and towards the equator where a current sheet is formed, correspondent to the change of magnetic field polarity so you have a magnetic field change polarity change.

So, you imagine a current sheet that the formation of current sheet at the equator the sun's magnetic field is dragged out by the high beta solar wind we have already known what is high beta solar wind, the current sheet prevents the oppositely directed magnetic field lines to be reconnecting.

So, the current sheet is tilted with respect to the ecliptic plane by about 7 degrees ensuring that the earth intersects the current sheet at least twice during each solar rotation. This gives the appearance ofwhat are called as the magnetic sectors.

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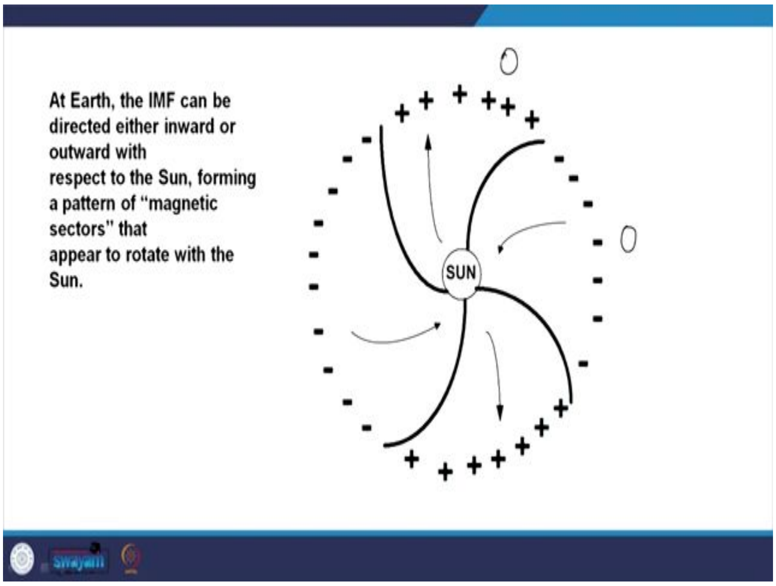

So, what are magnetic sector? So, you see that the magnetic sectors are those regions in which magnetic field is oppositely aligned, let us say this is the positive magnetic field sector we will say that the field lines are directed away from the sun and opposite in the case of a negative sector.

So, at the earth let us say the IMF can be either directed inwards or outwards with respect to the sun, forming a pattern of magnetic sectors. Nowthe earth can be anywhere I mean if the earth is here it will see the magnetic field lines away from the earth or towards the sun and if the earth is here it will see a magnetic field line towards the earth.

So, depending on that position which is decided by the time, a particular time of the year or whatever it is. So, earth can be in a positive sector or it can be in a negative sector it is just a matter of time.

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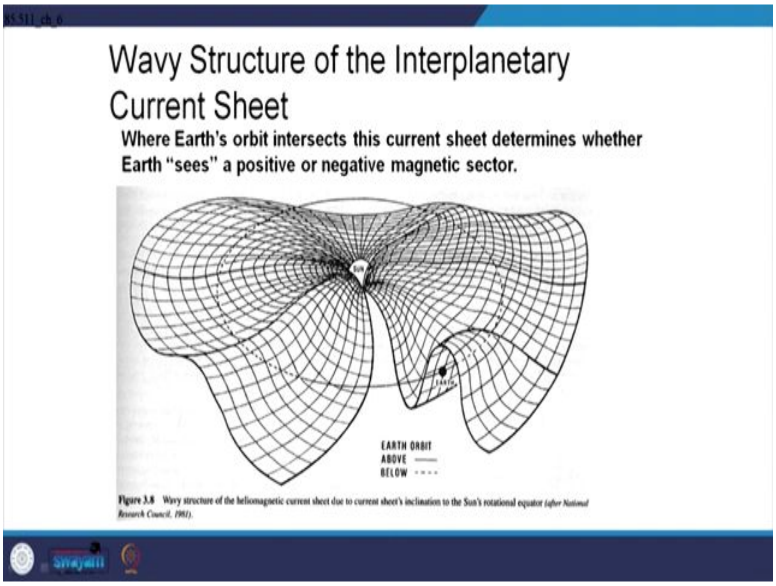

Now, if you look at this plasma sheet what you will realize is that, it will look like a wavy structure of the interplanetary current sheet the spheres of the earth. So, with time this current sheet will become very complex any other times of solar maximum, but what can happen is at any given time the earth can be on the top of this sheet or near the bottom side of this I mean either above or below this current sheet, sometimes above sometimes below.

Thisstructure shows the interplanetary current sheet so depending on the time earth can be imagined to be existing on the top of the current sheet or in the below the current sheet.

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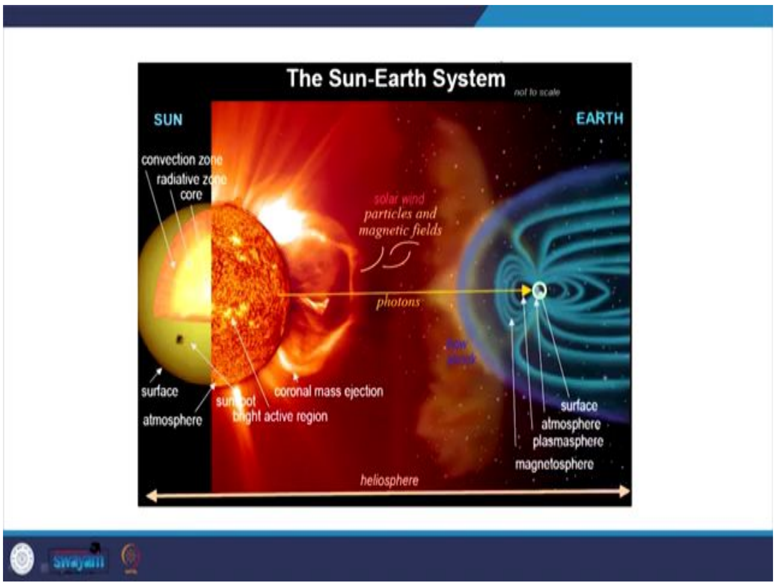

So, as a result what happens is, the polarity of the interplanetary magnetic field will be different at different times that is experienced at the earth.

So, now as a result that leaves as a possibility of magnetic reconnection near the extreme of the magnetosphere and which allows some plasma to be flowing into the atmosphere.

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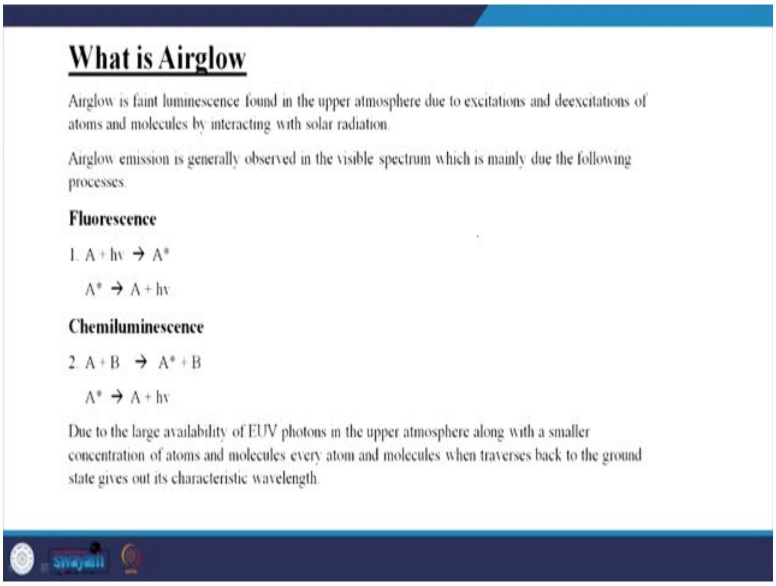

So, with this plasma when it interacts with the earth's atmosphere this plasma has the ability to ionizeor dissociate atoms and molecules, as a result whatever the optical effects, optical emission that are given out using this interaction are generally called as aurora.

So, what is the airglow? Airglow is the faint luminescence that you find in the upper atmosphere due to the excitations and de-excitations of atoms and molecules by interacting with the solar radiation. So, airglow is a very faint luminescence that you find in the upper atmosphere due to the excitation so simply when you excite an atom it will take up the energy and when you de-exite an atom it will give out the energy and if this energy is in the visible spectrum it can be seen by you. So, this faint luminescence that is originating from these excitations and de-excitations is generally referred to as airglow.

So airglow emission is generally observed in the visible spectrum which mainly, which is mainly due to the following processes. The processes are fluorescence and chemiluminescence, fluorescence is when an atom absorbs a photon gets into an excited state subsequently it cannot stay in the excited state for a longer amount of time it has to come down, it will give out the energy.

And come back to its ground state this process is called as fluorescence. Chemiluminescence is a process in which a chemical reaction may lead to getting a particular atom in the excited state and when this excited atom comes back to the ground state releases a photon and if this photon is in the visible spectrum you will see you will be able to see that.

So, due to the large availability of extreme ultraviolet radiation photons in the upper atmosphere along with the smaller concentration of atoms, each atom or molecule when travels is when travels back to the ground state gives out its characteristic wavelength. So, this wavelength is a characteristic of the electronic excited states that are available for that particular atom.

So, each atom depending on the amount of depending on the energy that it has taken will release its characteristic wavelength so; that means, that looking at the characteristic wavelength that is emitted at a particular height or we can be able to see we can be able to guess what is the species that has emitted that particular radiation.

So, salient features of airglow are; airglow was discovered in 1868 by Anders Angstrom in the form of green light in the upper atmosphere when aurora was absent. So, aurora is also an optical phenomena and airglow is also an optical phenomena, but the aurora intensity aurora is a very intense light and airglow is a very faint luminescence so there is a clear difference.

So, airglow was discovered in 1868 by Anders Angstrom in the form of green light in the upper atmosphere when aurora was absent. Solar radiation is only responsible for, directly and indirectly for the formation of airglow and half of the luminosity of the sky during the night time is attributed to the airglow.

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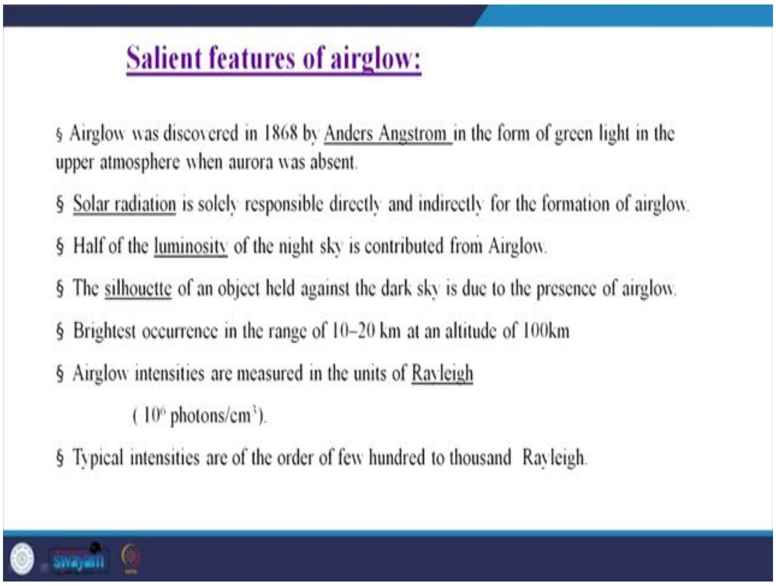

the boundary of the object that you see let us say when you keep something against the sky is basically due to the presence of airglow. And brightest occurrence of airglow is in the range of 10 to 20 kilometers at an altitude of nearly 100 kilometers.

So, at an altitude of 100 kilometers within a strip of let us say 10 to 20 kilometers you will find the brightest occurrence of airglow. Airglow intensities are measured in the units of Rayleigh generally 10 to the power of 6 photons per centimeter cube is considered as 1 Rayleigh.

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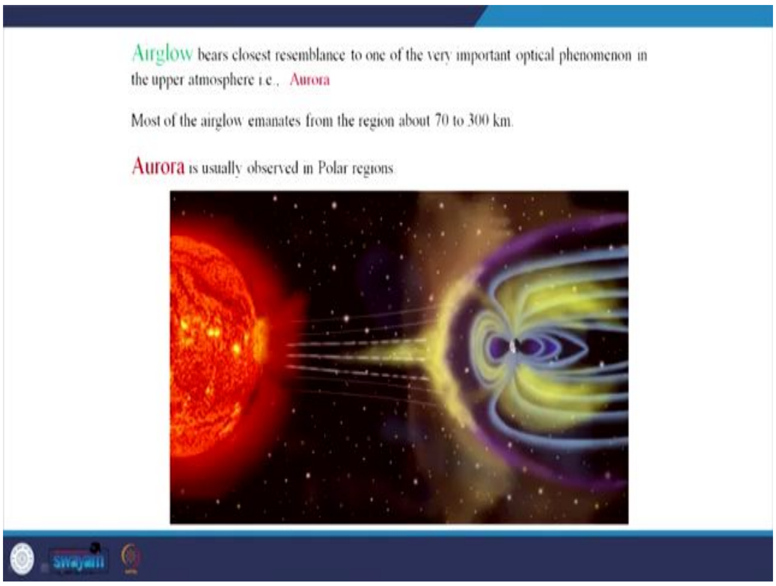

So, typically the intensities are few 100 to few 1000 Rayleigh the intensity of airglow is typically of the order of few 100 to few 1000 Rayleigh. So, now, most importantly airglow bears a very close resemblance with the other optical phenomena that we have seen is which is called as the aurora.

So, most of the airglow generally emanates from a region of 70 to 300 kilometers and aurora is seen only in the polar region.

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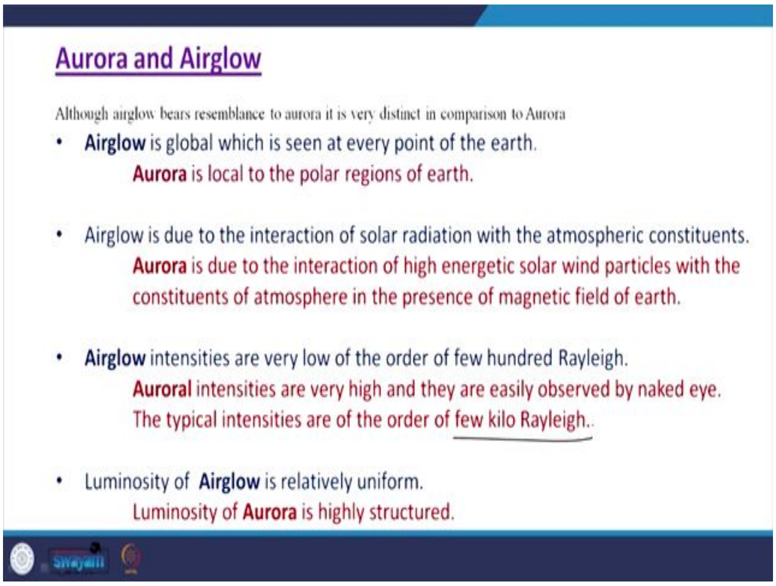

I mean although it is very similar they are they are distinct differences all airglow bears resemblance with aurora, it is distinct in comparison to aurora in many different ways.

So, airglow is a global phenomena that is to be seen at every point on the earth, aurora is not global I mean its not to be seen everywhere rather it is local to the only to the polar regions only the higher latitudes, let us say 60 to 90 latitude regions have the chance to see the aurora.

Airglow is due to the interaction of solar radiation with the atmospheric constituents of course, aurora is also the similar thing, but there is a distinct difference. Aurora is due to the interaction of highly energetic solar wind particles with the constituents of the atmosphere in the presence of the magnetic field of the earth.

So, airglow is when solar radiation, the electromagnetic radiation is absorbed by the atoms or molecules and when it when they give it out you see airglow, but aurora the source of radiation is not the electromagnetic spectrum rather it is the energy that is carried with the energetic particles of the solar wind.

So, the nature of energy itself is different here, and this interaction has to happen in the presence of the magnetic field of the earth. So, if you take away the magnetic field of the earth you will not be able to see the aurora, but airglow is not like that airglow you can see at any point and at any given time.

Airflow intensities are very very low and they are typically of the order of few 100 Rayleigh, aurora's intensities are very high and they are easily absorbed by naked eye, I mean you can see aurora with your naked eye. And the typical intensities are few kilo Rayleigh the interests are very high.

And more importantly the luminosity of airglow is relatively uniform, what I mean the luminosity or the intensity spread across the space is relatively uniform. But the aurora intensities are highly structured I mean you see various different structured intensity patterns in your in the night sky when aurora is occurring.

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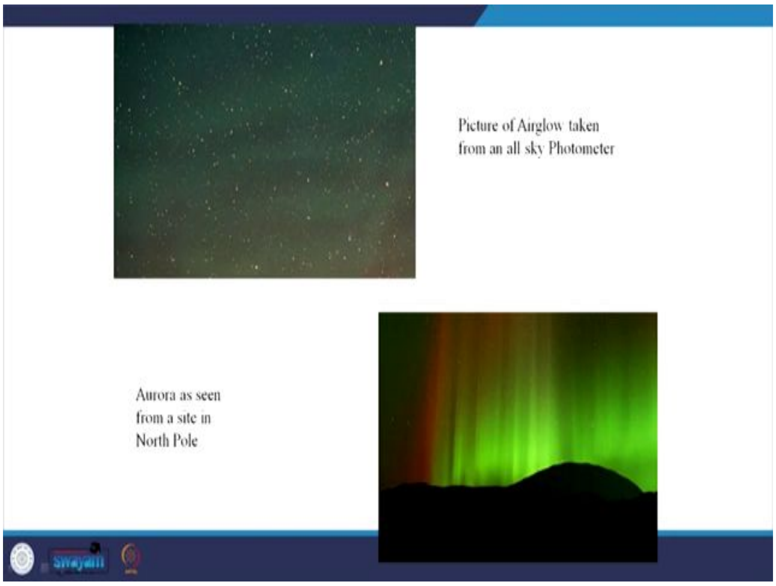

So, let us say for example, a picture of airglow looks something like this where you see faint strips of light that you see in the sky it is not very prominent, but it is there, I mean the night sky would have been much darker if airglow is not present, you understand. So, the night sky is bright because it is not completely black because of the star light and because of the airglow as well.

But at the same time aurora is a totally different phenomena totally different level that means, the auroral intensities you can see within a with a naked eye which are very prominent not to be ignored and not to be searched for. So, this is just a typically means that shows how intense aurora can be when you are present in the high latitudes.

And, aurora is structured you see way we structure of aurora basically auroral structure resemblance the travel of the solar wind and how the wind is traveling how the plasma is interacting with the atmosphere or with the neutral species based on this the structure of aurora will be formed.

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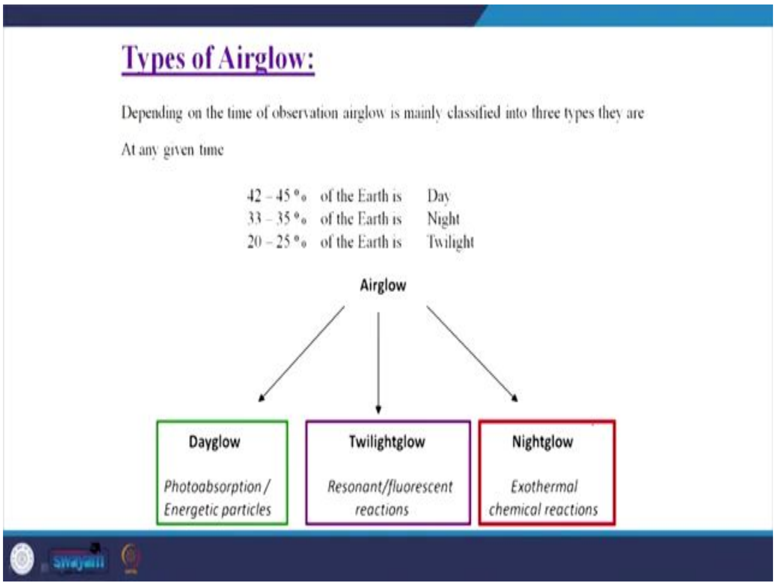

So, now the types of airglow, I mean air glow is basically defined or basically classified into three different types depending on the time of observation airglow can be classified into three types they are basically the day glow, night glow and twilight glow.

So, generally at any given point at any given time the total earth the complete earth of the earth 42 to 45 percent of the earth is in the daytime and 33 to 35 percent of the earth is in the night time and 20 to 25 percent of the earth is in the twilight.

So, it the airglow that is seen in these three conditions is known as the day glow, night glow and twilight glow, and the chemical processes that are responsible for these different types of airglow are kind of different. Different, in the sense day glow forms mainly due to the photo absorption and the energetic particles as well, twilight glow due to the resonant and fluorescent reactions and night glow is due to the exothermal chemical reactions.

Now, most importantly day glow is. So we have made a remark saying that airglow is simply the absorption of solar radiation and remittance of the same radiation by an atom or molecule. So, invariably airglow requires the presence of direct sunlight and it is not that only during the sunlight period you see air glow you also see airglow during the night time also.

So; obviously, these are the processes involved in the nighttime are in the absence of sun so they are different. So, this is the basic introductory aspects about the fundamental definitions of airglow and aurora.

So, we have seen how these processes are different and how the formation mechanism of these two processes are different.

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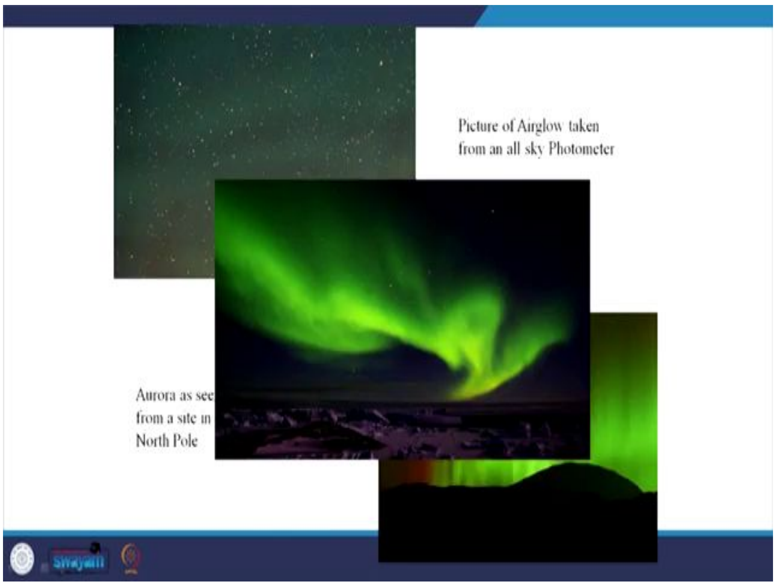

Let you have seen this picture you see that this picture is in the air aurora is generally seen in green or red color, I mean why is this seen only in green color not in any other color predominantly in green color not any other let us say blue or not any other yellow or orange or any other color.

So, the airglow or aurora appears distinct in terms of its color, and the main reason for airglow to be appearing or aurora to appear in various colors is the participating species the oxygen or nitrogen which is actually getting excited into the higher levels and getting de-excited subsequently releasing the photon at a particular wavelength is the main reason for airglow or aurora to appear in a particular color.

Now, what we will do these are the images of airglow and aurora from these images we can clearly understand that aurora is highly structured and the luminosity of aurora is several times larger than the luminosity of airglow. We cannot see airglow with a naked eye, but we can clearly see the aurora with a naked eye, but the most important thing is that aurora is a phenomena which occurs in the high latitudes or airglow is a phenomena which is persistent throughout the globe.

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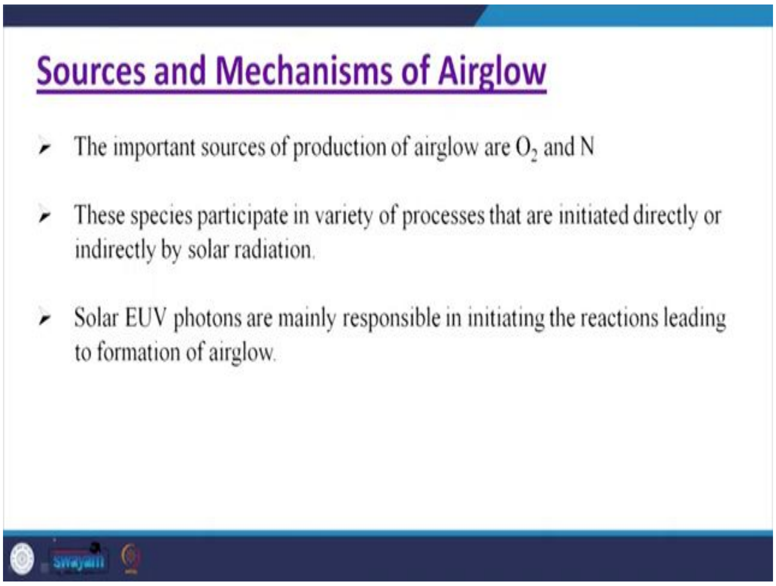

So, coming back to the main mechanism of airglow the important sources of production of airglow are oxygen and nitrogen, these species participate in a variety of chemical processes that are initiated directly or indirectly by solar radiation. Many processes are indeed directly initiated by the solar radiation and many are indirect.

So, the main mechanism is that solar ultraviolet, extreme ultraviolet photons, which have energy to dissociate a molecule or ionize a molecule or ionize an atom and subsequently exciting it will cause this airglow emission to occur. So, EUV photons are the mainly responsible in initiating these reactions leading to the formation of airglow.

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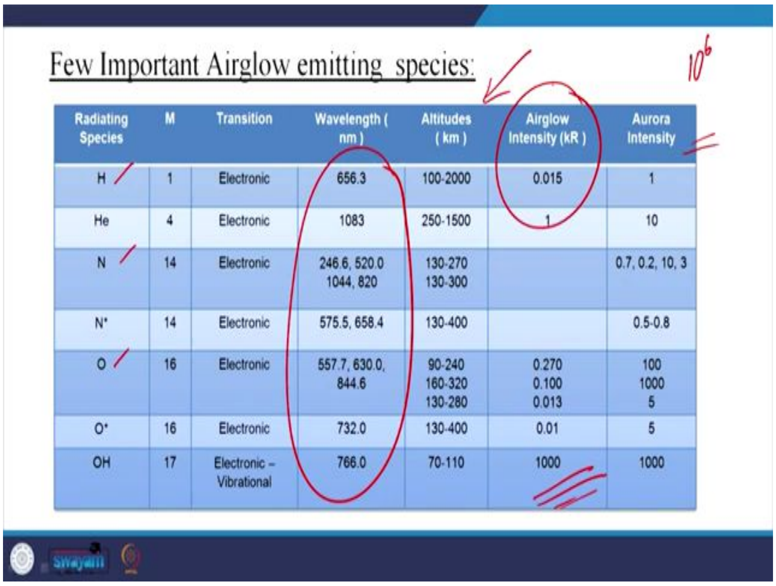

Radiating Species	M	Transition	Wavelength (nm)	Altitudes (km)	Airglow Intensity (kR)	Aurora Intensity
H	1	Electronic	656.3	100-2000	0.015	1
He	4	Electronic	1083	250-1500	1	10
N	14	Electronic	246.6, 520.0 1044, 820	130-270 130-300		0.7, 0.2, 10, 3
N^+	14	Electronic	575.5, 658.4	130-400		0.5-0.8
O	16	Electronic	557.7, 630.0, 844.6	90-240 160-320 130-280	0.270 0.100 0.013	100 1000 5
O^+	16	Electronic	732.0	130-400	0.01	5
OH	17	Electronic – Vibrational	766.0	70-110	1000	1000

Now, if you look at the various species we have seen that hydrogen is present oxygen is present in its atomic and molecular forms nitrogen is also present so and several other molecular species are present in a very limited proportion, at the high altitudes due to the large availability of extreme ultraviolet radiation, each atom will emit its characteristic wavelength when it is excited to a higher state. And that is why airglow emission can be a very important tracer in understanding the structure and the dynamics of atmosphere at any given height.

So, if you can get hold of the photons which are emitted they will tell a lot of things about what is happening at a particular height in the atmosphere. So, this table summarizes various species in the atmosphere, all of which can be excited to a excited state and when they are brought back to the ground state they will release this characteristic wavelengths of radiation.

So, what you realize is that you have the typical altitudes at which these airglow emissions are observed or the altitudes at which this airglow emission intensity is the maximum and the intensity is also given in the units of kilo Rayleigh.

So, 1 Rayleigh is nearly equal to 10 to the power of 6 photons per unit volume. So, we can see that all the important species hydrogen, nitrogen, oxygen are emitting air various airglow emissions we can also see that the airglow intensities are very very small in comparison to the auroral intensity; that means, the species depending on its availability in the polar region subject to the forcing of the sun in terms of its magnetic field and the particle flux will emit aurora.

If the same species is present at any other latitude due to the availability of only extreme ultraviolet radiation in the absence of the magnetic field from the sun, coupling from the magnetic field from the sun will emit airglow.

So, the most important thing that you should understand is that airglow and aurora are the participating species will decide the color that you see in the sky of the aurora, and airglow intensities are very very small in comparison to the intensities of the aurora.

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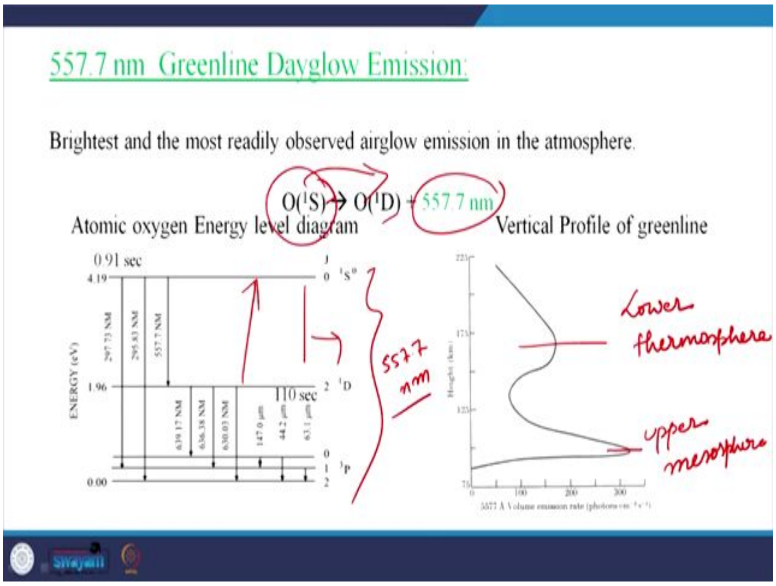

Now, let us look at two important airglow emissions which are most widely used in atmospheric physics or atmospheric research by the space physics community. So, the first important emission is the 557.7 nanometer green line emission. So, this green line emission is a result of the spectral transition from O singlet S to singlet D.

So, this transition will release a photon at a particular wavelength 557.7 nanometers. Now this wavelength is in the green part of the visible spectrum so, that is why you see this emission to be green in color. So, why does such an emission happen, what happens?

I mean if you look at the energy level diagram you will realize that when the oxygen atom is given sufficient amount of energy it will get excited to this particular state, subsequently upon de-excitation it will release this emission at 557.7 nanometers.

Now, this is a global emission; that means, you can find this emission anywhere on the globe and this emission has two regions where the intensity is maximum. The intensity is maximum at a height of nearly 150 or 170 kilometers, which is in the lower thermosphere region. So, this is the lower thermosphere, and the most prominent intensity region is the upper mesosphere region, upper. So, the airglow is a final outcome of complex interactions between solar electromagnetic energy and the neutral species.

So, now the most important question that you should ask yourself is that, why should the atom get excited into this particular state why not into any other state.

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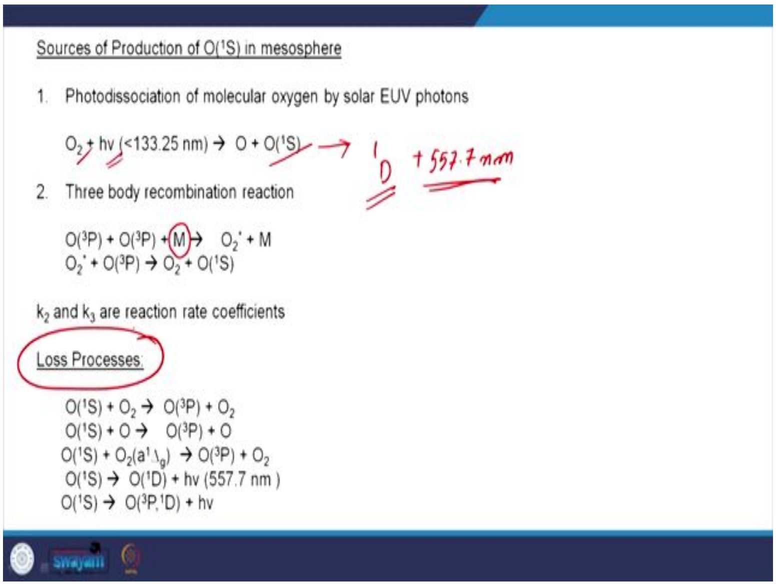

There are some processes which will populate the oxygen atom in the singlet S state, the processes are let us say, photodissociation of molecular oxygen where energy above a threshold will dissociate this molecule and populate 1 atom in the excited state. This atom as we have seen subsequently upon its de-excitation to this state will release this particular wavelength.

So, now the point is if you see this particular wavelength in the sky; that means, that this spectral transition is occurring at that particular altitude. Another important process by which 1 S is populated is by 3 body recombination where capital M is the third body which acts as a platform for this chemical reaction to happen.

And, once this oxygen is populated in 1 S it is not necessary that this should always participate in getting the excited to only this particular spectral state. Any other spectral transition which does not result in the formation of the green line are generally known as are categorized into loss processes.

So, the loss processes are these if these processes are capturing the oxygen in singlet S, then even though the excited oxygen atom is available you will not see the green line aurora or airglow.

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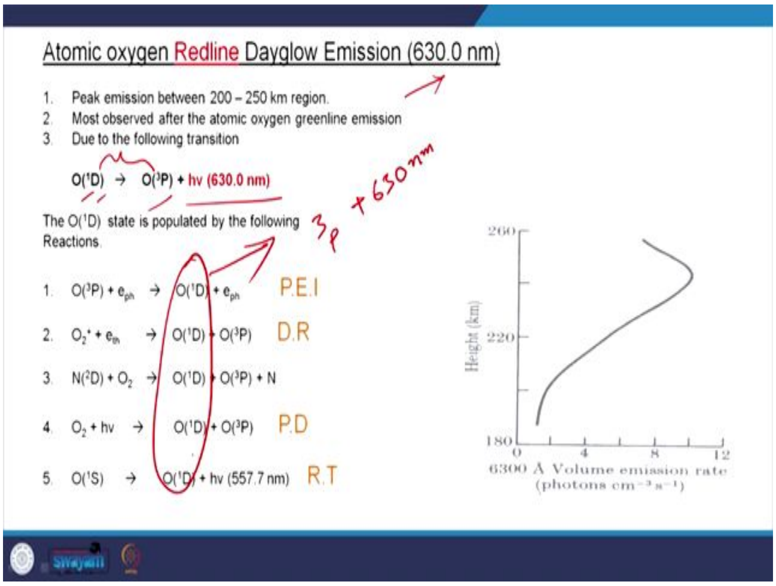

And, similarly another very important airglow emission that is most readily observed is the atomic oxygen red line emission, which occurs at a particular wavelength of 630 nanometers.

So, this emission has a single peak; that means, a single range of altitude at which the emission intensity is maximum. So, it generally peaks at 200 to 250 kilometers altitude region, and it is most observed after the atomic oxygen green line emission. So, redline emission is the most observed emission. So, this serves as a tracer to understand the atmospheric chemistry or the dynamics. And this transition occurs due to a spectral transition of oxygen in a singlet D to triplet P.

So, the difference of this energy is what is being emitted at wavelength of 630 nanometers. So, similarly just like we have seen for the case of oxygen green line emission, oxygen also gets populated in 1 D by these various processes, these processes photo electron impact dissociative recombination photo dissociation radioactive transfer.

So, these processes are just the ones which will populate oxygen in this particular state. Now once this D excites to triplet P you will see the 630 nanometers, any other process which will not allow this can be considered as a loss mechanism.

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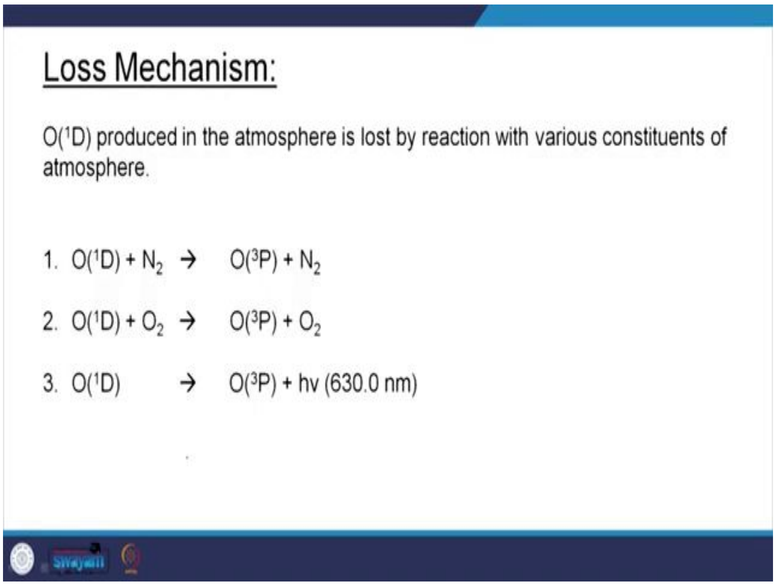

So, O singlet D produced in the atmosphere is lost by the reaction with various other constituents, because many other species are present. So, these processes will actually decrease the intensity of 630 nanometer emission. So, this was some details about the airglow and auroral emissions. So, this is where we end the course. I hope you have understood many contents that I have been covered in the course if you have any doubts you can contact me by various channels which the NPTEL provides.

So, this course was about an introduction to atmospheric and space sciences where we have covered a wide range of topics related to atmospheric physics, space physics, plasma physics. How each layer of the atmosphere is different and how each process in atmosphere at a particular height is unique to that particular height. So, I hope you will find this course useful for your career development, I wish you all the best.

Thank you.