**Astrophysics & Cosmology**
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**Lecture - 01**
**Introduction**

Welcome to this first lecture on astrophysics and cosmology.

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The picture over here shows you the sky, a part of the sky during daytime as it is quite obvious the only astronomical objects that you typically see in the sky during daytime are the sun, and sometimes the moon and on rare occasions where there are very bright comets in the sky you can also possibly see them. So astronomy is essentially a nocturnal subject, something which is studied when normal people all go to sleep, the astronomers then get down to work like thieves and burglars you may say, okay.

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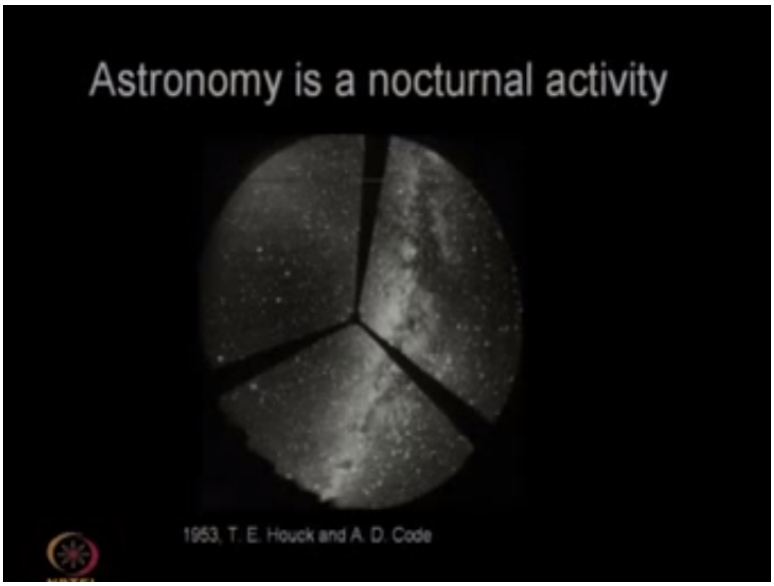


So this picture shows you a part of the sky at night, the part of the sky that is shown over here is particularly important because you can see our galaxy the Milky Way in this picture. We shall come back to the Milky Way in a later lecture. For the purposes of the current lecture of the present lecture it suffices to note that every bright object that you see in this picture, every bright object that you see in this picture nearly every brighter object that you see in this picture is a star.

So what we see is that the night sky is dominated by stars. If you look at the night sky which I am sure all of you have done, it is dominated by stars. Stars are predominantly what you will see and the stars in the night sky have fascinated the human mind. They have aroused the human curiosity for few 1000s of years, over few 1000 of years, this is particularly so before the advent of electricity.

With the advent of electricity, the night is largely illuminated in most of the inhabited areas and in some places it is so bad that you cannot even see the stars at night. But before the advent of electricity when it really became dark at night people naturally spent large part of or possibly a part of their time looking at the sky and the stars arouse the curiosity of many, many people, over 1000s of years.

It was noted long ago that the stars maintain fixed positions on the sky over periods of few years. Okay, so if you look at the skies say over the period of a year or 2 years you will see that the

relative positions of the star with respect to one another remain fixed, they do not change. So the position of the stars in the sky are fixed, this whole fixed position of stars, so if you look at the sky say tonight and if you happen to see this part of the sky, the part that is shown on the screen and then again if you look at the sky at the same time tomorrow night you will see exactly the same pattern, okay.

And the entire pattern that you see here, the entire pattern of fixed stars on the sky it revolves around us. If you look at the sky say continuously for 1 or 2 hours you will see that the entire pattern, the pattern remains fixed relative to one another, the stars remain fixed, but the entire pattern revolves around us, rotates and it completes 1 whole rotation in 24 hours. This diurnal rotation, it is now known arises because of the rotation of the earth.

Okay, so the earth is rotating, it has a period of 24 hours and the sky, the fixed pattern of stars appears to rotate because of the rotation of the earth okay and the stars we also know now that the stars are at great distances from us so even if the stars move their positions, the angular position in the sky will not change significantly over time scales of few years at least to the naked eye.

So the motions of the stars even if they are there will not be visible on the sky because the stars are very far away okay and it is a consequence of this that the stars remain fixed relative to one another and this fixed pattern of stars rotates, the pattern is fixed in the sky and the entire sky rotates seems to rotate around us okay now ancient people they looked at the pattern of stars in the sky and they identified certain distinct patterns in these.

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And these patterns that they identified are known as constellations. Before we go to that let me show you what the night sky will look like if you go out tonight at around 08:30 or 09:00 and look at the sky. Okay, so this picture, it is a sky chart, it shows you the sky as you expected if it is clear tonight if you go out at around 08:30 or 09:00 it shows you this picture shows you the position of all the bright stars that you expect to see.

Okay so this is a sky chart, it shows the upward directions is north, east is to the left and west is to the right. And if you go out around 08:30 or 09:00 you expect to see something that looks like this. If you go out earlier than you will not see these parts, they would have just risen, they would have not risen then and these parts would be shifted to the left that is the rotation of the sky around us.

Okay and if you go later, then these stars would have shifted to the centre and these would have shifted out. So I suggest that you go out tonight at around 08:30 or 09:00 after dinner and have a look at the sky and see if you can compare it with this picture okay and see if you can identify these stars on the sky.

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Okay now the ancient people they looked at the sky and they identified fix patterns and these patterns which they identified, these patterns are called constellations so I have already discussed the first 2 points the relative positions of stars are fixed and the whole pattern rotates around us. So we are now discussing this third point that the ancient people they identified these patterns in the distribution of stars in the sky and these are called constellations.

And the constellations that were identified defer from place to place, culture to culture essentially and these constellations that were identified are closely related to the mythology of the people, so the constellations that were identified in say India and by the Red Indians in America by the original inhabitants of the American continent and by the Europeans or the Egyptians they would be different, they could possibly be different, some of them may be same.

And many of these constellations the patterns, they are quite obvious but not all of them, some of them they require someone to show you okay so somebody really imaginative must have identified that this looks like this okay so the definition of the constellations also change with time in the sense that what say people 1000 years ago defined as constellations, possibly 500 years ago people redefined them.

And in 1929 the International Astronomical Union, the IAU fixed the 88 official constellations, so all the stars in the sky were divided into 88 official constellations, so these are now officially

accepted as defined by the International Astronomical Union so they have identified 88 constellations, the boundaries have been fixed and every star now belongs to some constellation or the other, so it covers the entire sky.

Okay and there are 88 of them, so if you wish you can look up the names of the these constellations, they are available.

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So this picture shows you the Orion constellation and the Orion constellation, let me go back to this picture the Orion constellations is visible over here, you expect to see, it is very prominent in the sky so if you go out tonight you cannot miss the Orion constellation. Let me explain to you what this Orion constellation, why it is called Orion, what it looks like.

So it essentially is a warrior, a hunter okay and this is the belt of the hunter, these 3 stars is the belt of the hunter. These are the legs, so this is 1 leg, you can imagine the belt.

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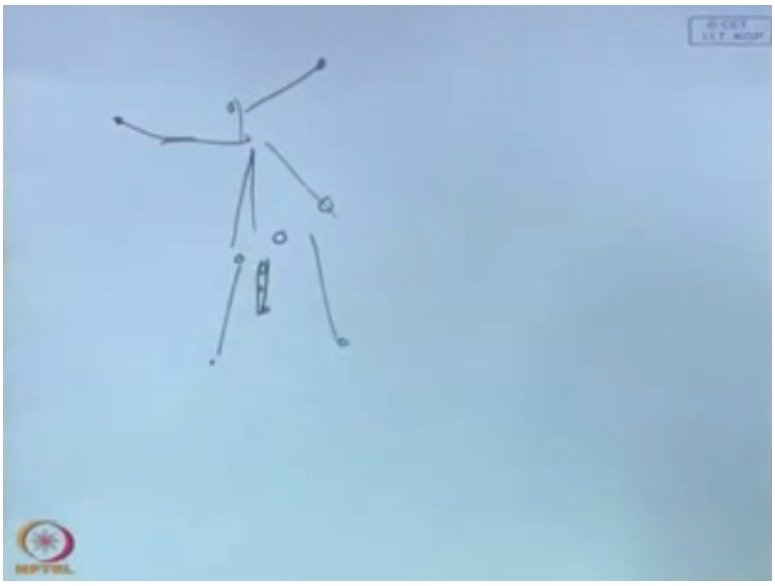

So it looks like this somewhat and there are 3 stars which make the belt and then there is 1 star here and 1 star here and then there are 3 stars here, which may be can think of something like this and there is a sword which has 3 stars over here, so this is the sword of the hunter, the hunter sword.

This is the belt, you can join this here, 1 leg and this is the other leg and this is his 1 hand and this is the other hand and the head. Okay, so this is a hunter, Orion the hunter, he is followed by a dog, we will not go into that. So Orion is a very prominent constellation on the sky and if you just go out tonight you can see Orion around 08:30 or 09:00, it will be little to the east at that time. And you can easily identify this.

The Orion constellation is a very interesting constellation and the belt, the sword, 1 of the stars in the sword has a nebula, there is a gaseous cloud around it, the Orion nebula, where star formation is taking place, but these are details which we shall not go into right now. I suggest that you go outside tonight and have a look at the Orion constellation.

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This is another constellation, the Ursa Major or the big bear, okay, now the bear is not so obvious, but it is referred to as the big bear. In India, this is referred to as Saptarishi Mandal, okay so this is the Ursa Major and there is also the Ursa Minor and this appears let me again go back to the picture of the sky, this appears over here in these regions to the north, Ursa Major and Ursa Minor and what is interesting is that this constellation essentially points to the Pole star.

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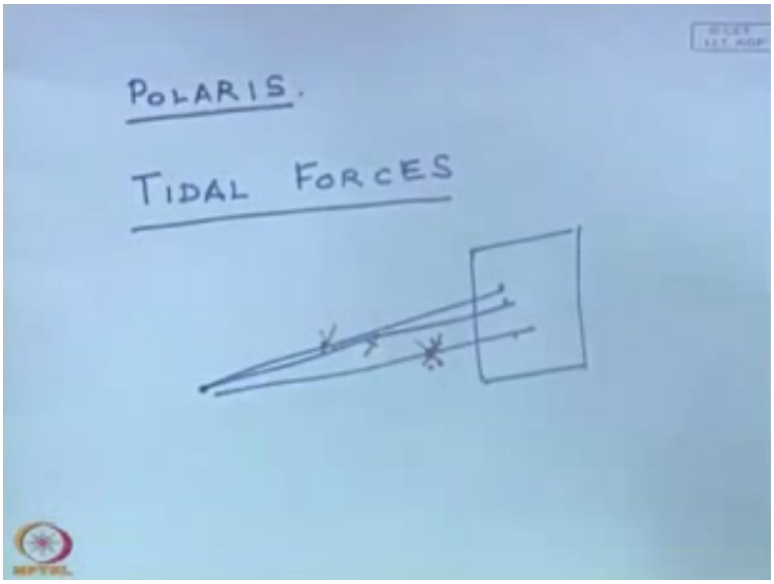


So this is the Pole star, Polaris, okay so we have the Pole star, Polaris and the Pole star, Polaris, is very interesting because the rotation axis of the earth points towards the Pole star okay so the Pole star again is somewhere over here that the Pole star, Polaris.

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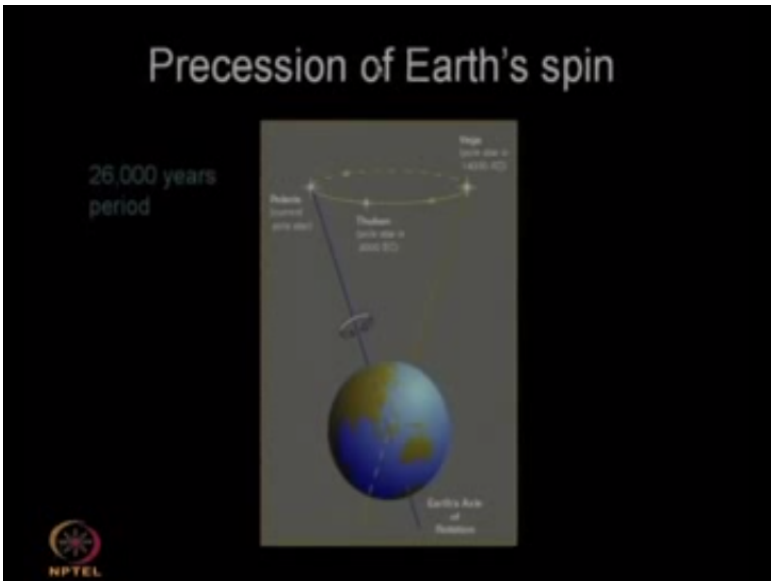


And the rotation axis of the earth shown over here points towards the Pole star, so as the earth rotates all the starts they move on the sky but the Pole star it remains fixed. The Pole star does not rotate as the earth rotates because the earth's axis is lying towards the Pole star. Now it is now known that the earth's axis of rotation is not fixed, that is a very interesting fact. So the direction of the North Pole is not fixed and the rotation axis of the earth precesses.

It precesses because of the tidal forces. So we shall discuss tidal forces later. So the rotation axis of the earth, earth's rotation axis precesses, it goes, it does not remain in the fixed direction but it goes around like this and it does 1 revolution in 26,000 years, the period is 26,000 year and it does not remain fixed because of the tidal forces due to the sun and the moon. So the sun and moon exert tidal forces on the earth and this causes the rotational axis of the earth to precess with the period of 26,000 years.

So at present the rotation axis of the earth points towards the Pole star, Polaris, but in the past it pointed in a different direction and in the future again it is going to point towards some other star. Okay so it is something that is changing very slowly in time, over our lifetimes the change is really very small, it is there but it is very small.

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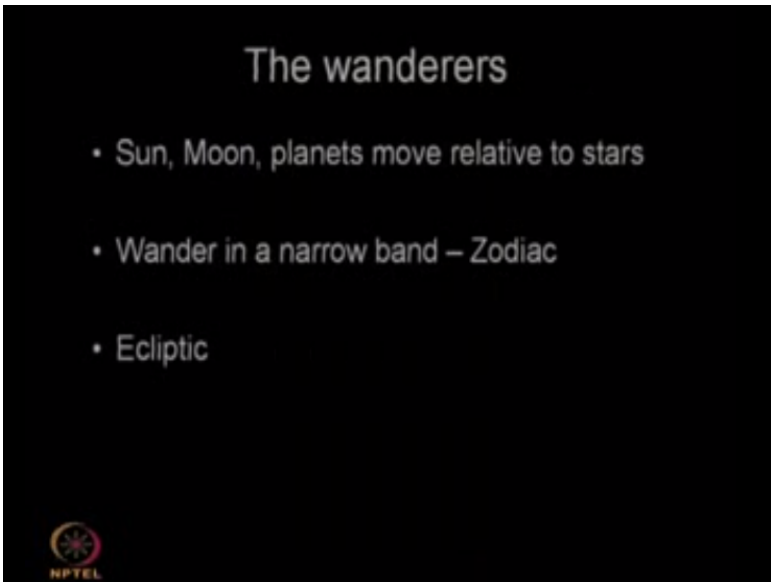


Sp we have discussed very briefly the fix objects in the sky, the stars and people have visually identified certain patterns called constellations. There is another point which I should mention before we go ahead, the point is that the constellations are not real. What do I mean by this, what I mean is that the stars that we see in a constellation, for example the stars that we see in the Orion nebula, all of these stars, the stars in the belt or the stars in the sword, they are not physically associated.

So the stars in the belt and all of this pattern of stars that you see that you make out, these stars are not physically associated with one another, they are not located in the same place, they are actually located at different distances from us okay so it is like this that I am an observer sitting here on earth and there could be what we see is the projection of everything onto the sky and there could be 1 star over here and another star over here.

And I will see them projected and they may appear nearby. Okay, so this is let us say 1 star, another star and maybe another star here. They actually are quite different distances but when I look at them on the sky, they may appear very close okay so the stars that make up the constellations are not physically associated, they are typically at different distances, it may happen that 1 or 2 of them may be physically close.

But typically they are at different distances and they are in no way physically connected with one another, they just appeared to be together and the pattern just appears on the sky, that is all, so if I go to some other star and see some other say I if live in some another plant elsewhere in the universe, in our own galaxy, I will see some totally different set of constellations. Okay so there are just things that we see on the earth, but still they have their utility.

And they have the utility because they help you identify different parts of the sky, identify objects of the sky, etc. okay which is why IAU International Astronomical Union has taken the pain of identifying 88 constellations okay and we still refer to objects by the constellation in which they like for example there is the Andromeda Galaxy which is the nearest full-fledged spiral galaxy okay, it is called that Andromeda galaxy because it lies in the Andromeda constellation.

Okay now in addition to these fixed stars whose relative position remains fixed in the sky, there are other astronomical objects which do not maintain fixed positions, these are the Wanderers okay and the name planet comes from there. So these objects that move around wander on the sky, the sun, the moon and the planets they are all seen to move on the sky relative to the fixed stars okay they do not have fixed positions on the sky.

So this is one very distinctive feature that distinguishes between planets and stars, the stars maintain fixed relative positions. Over a period of a year you will see it in the same relative configuration whereas the planet over a period of a year would have moved. The sun and the moon they all move on the sky okay in addition to the rotation of sky. Another very distinguishing feature is that the bright planets they do not twinkle, whereas the stars they twinkle.

Okay, the stars they twinkle whereas the bright planets do not twinkle. Okay there is a third point which is mentioned just over here so these objects that wander, their wandering is not over the entire sky, their wandering is restricted to a narrow band on the sky called the Zodiac. Okay, so the wandering of these planets of the star and the moon is restricted to a very narrow band which is called the Zodiac.

And the sun goes around in a very definite orbit in the Zodiac that has a very definite path on the sky, it is called the Ecliptic. And the zodiac is a region around the ecliptic. So you will find the planets only in this region mainly, okay only in this region whereas the stars are distributed all over the sky, so you will not find planets very far away from the Ecliptic.

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So let me explain this now a little bit more but before going into that there are these constellations that lie in the Zodiac. So there are 12 constellations that lie in the zodiac and these 12 constellations play a very important role in another subject called astrology okay. So astrology is based on these 12 Zodiacs. So these again are constellations, they have been shown over here, these again are constellations, the Zodiac, the signs of the Zodiac.

These are all different constellations, just like the 88 constellations that we have discussed, they are part of that. But these are the constellations that lie along the Zodiac so the stars, the planets, the moon and sun, the planets, moon and the sun, the move only among these constellations. They never go into the other constellations okay and astrology is based on the position of the sun, the moon and planets at the time of your birth, etc. etc.

Okay so that is why astrologers are interested in the Zodiac so these are the 12 constellations that lie along the Zodiac, these are the Zodiac symbols.

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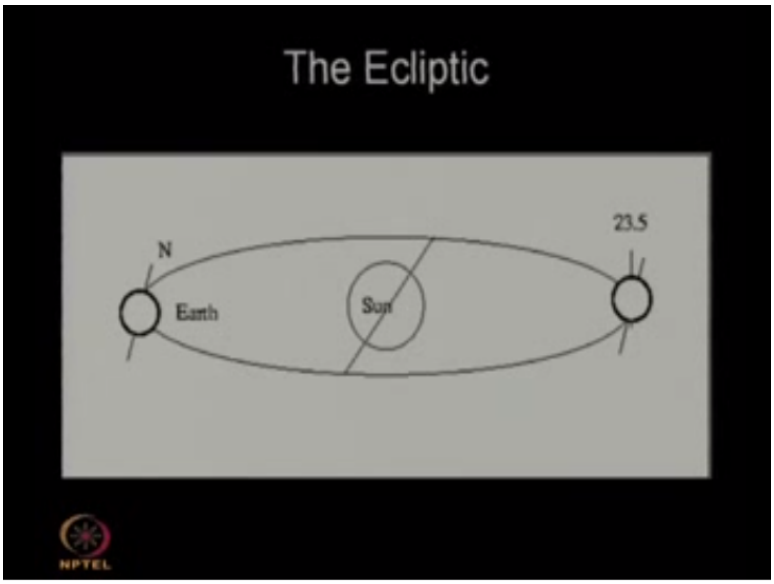


Okay so let us now understand this whole thing to try to get some picture of what is going on. The earth we know revolves around the sun so it goes around the sun in an orbit like this, with the sun at the centre and the earth we also know rotates around an axis. Now the rotation axis of the earth which I just old you points at present towards Polaris is not perpendicular to the plane of the orbit, but it makes an angle, the angle being 23.5 degrees.

So the rotation axis of the earth makes an angle of 23.5 degrees shown over here with respect to the normal to this orbit of the earth, so the rotation axis makes an angle 23.5 degrees with respect to the normal to the plane of the orbit. This plane of the orbit is called Ecliptic plane. Okay now when the North Pole points towards the sun, we have summer in the northern hemisphere and winter in the southern hemisphere.

Then the earth goes into this position where both the North Pole and the South Pole are equally illuminated by the sun and so we have summer then we have autumn and then here we have winter when the North Pole points away from the sun and the northern hemisphere is winter like at present and the southern hemisphere points towards the sun and then it comes here again we have spring where both are equally illuminated and then it comes back over here.

So these 4 positions which are particularly important, so this is the winter, this is spring, this is summer and this autumn.

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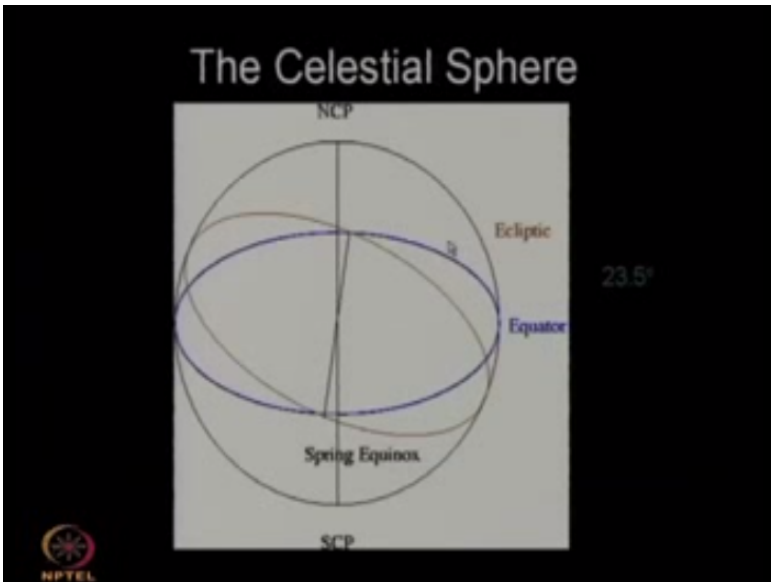


Now we are interested in what this appears from the earth, sitting on the earth what does it appear like okay that is what is of interest to us. Now when we sit on the earth and look at the sky it is convenient to define something called the celestial sphere okay this is a sphere of infinite radius and all the objects that we see on the sky we think of as being on this sphere called the celestial sphere okay.

And the rotation axis of the earth we extrapolate that, so this is the rotation axis of the earth, we extrapolate that and the place where it intersects the celestial sphere, this is the north celestial pole and this is the south celestial pole okay just like the North Pole of the earth and the South Pole of the earth. We also have the north celestial pole and the south celestial pole and if you take the equator of the earth which is the plane perpendicular to the rotation axis and extend that it will intersect the celestial sphere at the equatorial place, so that is a celestial equator.

So the blue curve over here is the celestial equator, it is the equator of the earth essentially, perpendicular to the rotation axis, if you extend that to infinity the place where it intersects the celestial sphere that is the equatorial and the celestial equator okay so we have the celestial

equator and we have the north celestial pole and the south celestial pole and the whole sky rotates around this but we are not interested in that.

The positions of the stars remain fixed on the celestial pole in the celestial sphere. So we are not interested in the rotation of the sky so the position of all the stars this is a sphere that is fixed to the stars, the stars maintain fixed relative positions so this sphere, the celestial sphere is fixed to that. Now when I look at the sun sitting over here, sitting on the earth, what will the position of the sun look like.

To understand that let us go back to the previous picture. During summer the sun is going to be appeared to the north. So this corresponds to summer, during summer the sun you can see here this is summer, the equator is perpendicular to the rotation axis so the equator actually points downwards now and the sun appears to the north, it is fixed okay, so in this picture the sun during summer the furthest position from the equator is the peak of summer okay.

The peak of summer is the furthest position from the equator, it is called the summer solstice okay so that is the summer solstice. And then after summer we have autumn, in autumn the sun is exactly perpendicular to the rotation axis so it is in the equatorial plane so the sun has moved down towards the equator and at autumn exactly in the middle of autumn, it exactly intersects the equatorial plane and then in winter the sun has moved to the southern hemisphere on the sky.

Okay so now the South Pole points toward the sun, the equator points upwards so the sun is now in the southern hemisphere. So the sun has moved to the south and this is the extreme, the furthest below the equator that the sun gets, this is the extreme of winter around 22nd December and then the sun again moves up, so the earth moved from here to here and the sun appears to move towards the equator.

Then we have the spring equinox in the middle of March so this is spring equinox where the sun again cuts the equator and then the whole thing repeats. So the sun appears to move in an orbit like this and the orbit of the sun on the sky, the parent orbit of the sun on the sky makes an angle

of 23.5 degrees okay so in 1 year over a period of 1 year the sun completes that great circle which makes an angle of 23.5 degrees with the equator okay.

And this great circle that along which the sun moves, this great circle is called the ecliptic okay that is the motion of the sun on the sky, so the sun does not maintain a fixed position, its position changes, it changes over the period of 1 year, it goes along the great circle so it does effect motion on the sky and that is inclined at an angle of 23.5 degrees to the equator, the celestial equator and this curve is called the ecliptic.

Okay and the plane through this is the ecliptic plane and this position where the ecliptic cuts the equatorial plane is the spring equinox around 22nd of March okay and the day and the night are exactly equal on that day. After that we have summer and then again we have the autumn equinox and then we have the winter, so summer and winter we have solstices, the sun keeps on moving further up, and then it comes to a stop solstices and then again it goes down.

And these have been identified few 1000s of years ago so 1000s of years ago people identified the motion of the sun on the sky and in India we have Makar Sankranti or Poush Sankranti. In the Assam, it is called Bihu, in Tamil Nadu they celebrate Pongal, in Punjab they have Lohri, all over India it is celebrated it is well-known okay so all of these things have been known for over 1000s of years by people all over the world, it is not something new.

Okay but the reason now we believe we know is because of the fact that the earth's rotation access is tilted at an angle of 23.5 degrees okay now let us take up the other so why do the other, the moon and planets all appear to move around the ecliptic okay now it is now known that the moon revolves around the earth and the orbit of the moon is nearly coplanar with the earth's sun orbit, okay so the orbit of the moon is nearly coplanar which is also why you have eclipses.

If the orbit of the moon were perpendicular then you would not have so many eclipses, okay so the orbit of the moon is nearly coplanar with the orbit of the earth and the sun and as a consequence the moon also appears to move around very close to this ecliptic. Okay the moon

also does not deviate very far away from the ecliptic. Similarly, except for Mercury all the other planets also have orbits which are nearly coplanar within a few degrees.

So all the planets they move in orbits which are coplanar with this orbit of the earth around the sun okay so all the orbits of the all the planets are nearly coplanar with the earth's sun orbit and they move little bit off this plane so as the sun moves along this ecliptic, the inner planets they move very close to the sun, the move along with the sun nearly and the outer planets they all move, not deviate very far away from this plane okay.

And they cover the region called the Zodiac, a band on the sky called the Zodiac. So all of these wanderers, they move around only in a small band around the ecliptic. Now this spring equinox is extremely important and at present the spring equinox points along Aries, along the constellation Aries.

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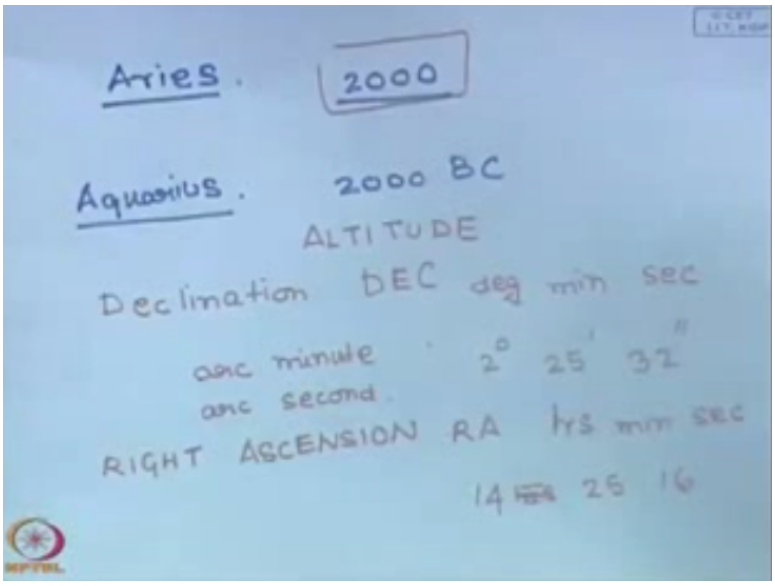


So at present the spring equinox points along Aries. To be precise in the year 2000 it has pointed along the constellation Aries okay. "Professor - student conversation starts" right, right that is the point which I did not mention very explicitly. "Professor - student conversation ends" Where is the observer, the observer, the celestial sphere is a sphere centered on the centre of the earth okay and since it is of infinite radius the fact that we are not at the centre of the earth.

But at some distance from the centre does not make matter okay so you can think of the celestial sphere as being centered around us. Okay so when you look at the sky you are basically at the centre of the celestial sphere. And the rotation does not, we are not bothered with the rotation of this sphere, it rotates every 24 hours, the whole thing goes around, we are not interested in that okay so all the stars maintain fixed positions in the sky.

And the sphere is relative to one another and this celestial sphere is fixed to that. So the position of the fixed stars do not change on the celestial sphere. The position relative that we see what we see is going to change because it rotates every 24 hours. “Professor - student conversation starts” right, they will see different parts of the celestial sphere. but the same, they are still at the centre. “Professor - student conversation ends”

So the part of the celestial sphere that you can see will depend on which hemisphere you are located in okay. So if you are located in the northern hemisphere you will only see things above, okay so if you are located in the northern hemisphere your view will be restricted to the northern parts near the northern celestial pole. If you are in the southern hemisphere obviously you will not be able to see the North Pole or things near the north celestial sphere.

So people in the southern hemisphere will be seeing things near the southern celestial pole. People in the equator are privileged because they will see nearly the very large part of the celestial sphere. So India for example, we are quite privileged in that way we are close to the equator and we can see a large part of the celestial sphere. Okay now we cannot see the whole of southern celestial sphere.

But we can still access a large part of it, okay which is one advantage of having your observatory located near the equator. Okay so what I was telling you was that at present in the year 2000 the location of the spring equinox was in the Aries constellation but I also told you that the rotation axis of the earth precesses and it precesses very slowly, but it does precesses. So as a consequence of this the location of the spinning equinox also changes with time okay and in the year 2000 BC, the spring equinox was located in the Aquarius constellation okay.

So the location of the spring equinox with respect to the other fixed stars has changed gradually over time and this is something that has to be appreciated because we use the location of the spring equinox so people have over in different cultures okay people have used the location of the spring equinox to set their timescale. So the timescale is decided by the event that we have the spring equinox so say we start our calendar from the day.

We have the spring equinox okay which is roughly what we do now also right, our calendar the Bengali calendar particularly starts from the day roughly is decided by the day of the spring equinox okay but the spring equinox itself has changed over time okay because of the precession of the earth's axis of rotation. So this is an important point to note in 2000 BC it was in the Aquarius constellation, so it was when the sun entered the Aquarius constellation and now it is when the sun enters the Aries constellations so this keeps on changing with time.

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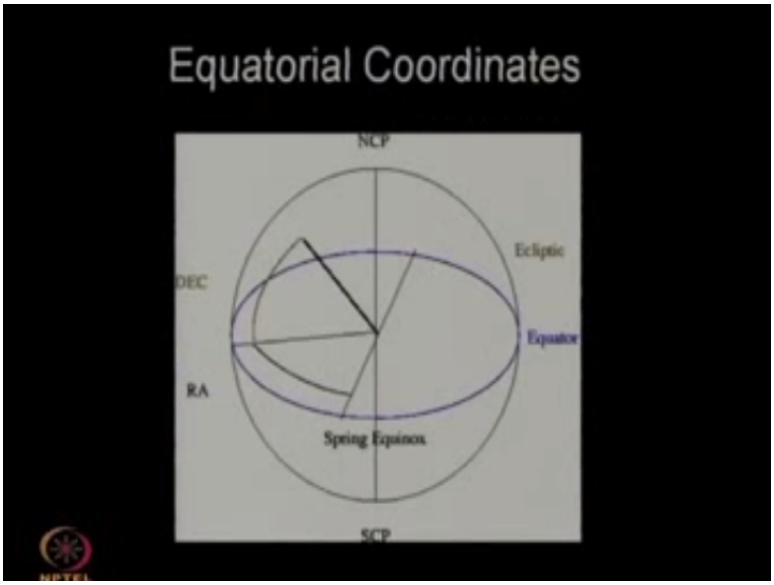


Okay so finally let me tell you about the celestial, the equatorial, the coordinate system that we use on the sky this coordinate system is called the one that is most commonly used is the equatorial coordinate system so this is a celestial coordinate system which is a coordinate system that is fixed to the celestial sphere okay and this coordinate system is very similar to the latitude and longitude that we use on the earth, it is very similar to that.

It is also very similar to the spherical polar coordinates that we use in 3-dimensional geometry. Okay so this is a celestial sphere and the aim of the coordinate system of this equatorial coordinates is to label every point on the celestial sphere, the whole sky is on the celestial sphere so the aim of this coordinate system is to label every point on the celestial sphere and the observer that is us, we are located at the centre.

Now so let us see how we label this point on the sky, this particular point on the sky, so there is a point which is shown over here by this black line, so we are looking in this direction there is a star in this direction let us say and we want to give coordinates to this okay so what we do is, we project one coordinate, there are 2 coordinates that are used, we all know that it requires 2 coordinates to define the point on a sphere, it is a 2-dimensional surface.

So there are 2 coordinates needed and one of these coordinates is the angle that this point makes with the equatorial plane. So if you measures this angle that it makes to the equatorial plane you get one coordinate, this is very much like the latitude that we use on the earth's surface okay, so it is very similar to the latitude that we use on the earth's surface, the equatorial plane corresponds to 0.

And if you are looking at a star which is in the northern hemisphere then you give it a positive angle, if it is below the equator you give it a negative this angle, this angle is called the declination okay, declination DEC. So the angle is called the declination DEC and it is the angle that say a star or a position on the sky it makes with the equatorial plane okay and this is measured in degrees and if you want smaller units each degree is divided into 60 minutes and every minute is divided into second, so these are arc seconds, arc minute and arc seconds.

Okay so let me write it here, arc minute and we have arc second. So degrees arc minute and arc second. So if I give you a declination 2 degrees 25 arc minutes 32 arc seconds. This is position on the sky, it will be in the northern hemisphere above the equator 32 degrees above the equator, quite close to the equator actually. Okay this is one of the coordinates and this is essentially the altitude, this is an altitude alt-azimuth coordinate system, so this is the altitude.

Now we need a second coordinate to specify the position of a point on the sky on the sphere, so the second coordinate is as follows: you take this point over here which you wish to label and you project this point down to the equatorial plane. So you project point down to the equatorial plane and then you measure the angle that it makes, the projection makes with respect to the spring equinox.

So essentially what you do is you put the equatorial plane, you divided up into angles and you see where the 0 corresponds to the spring equinox, the spring equinox corresponds to 0 and then you see what degree what angle the point that you wish to make when you project it on the equator what angle it makes with the line joining here to the spring equinox, centre to the spring equinox.

So this is like the longitude okay, it is angle on the equatorial plane that this projection makes, I hope it is clear and this is called the right ascension RA. Okay so the declaration here is this angle and the RA is this angle in the equatorial plane. So if you give the RA and DEC, you have identified this point okay and the right ascension is measured in a slightly different unit, it is measured in hours, so the whole equatorial plane is divided into 24 hours.

Okay it is somewhat convenient because if you stand on the earth surface and look at the sky, the whole sky will go around in 24 hours so the whole thing goes around you in 24 hours which is why it has been divided into hours and these hours have been divided into minutes and seconds again okay and 0 corresponds to the position of the spring equinox, so if you have RA and declination coordinate system say specified in the year 2000, then it will be the spring equinox of the year 2000.

The spring equinox as I have told you the position changes with time so you have to specify the year in which who spring equinox you are referring to okay and so for example 14 hours, so if I say 14, 25, 16, it essentially means 14 hours 25 minutes and 16 seconds of RA okay so these are in hours, minutes and seconds. So these are the coordinates that we use on the celestial sphere or on the sky okay.

So now let us see for example let me ask you a question. “Professor - student conversation starts” yeah I will finish in the few minutes. “Professor - student conversation ends”. So let me ask you just one question, on 22nd or 23rd March what will be the RA and declination of the sun, it will be 0 why because on that day that is the spring equinox and on that day the sun cuts the equator that is also 0 of the RA.

So on that day the sun is at RA at declination of 0 approximately, okay in the year 2000 it would have been exactly 0. Now let me ask you another question, what is the RA of the sun, let us say 3 months after that or 10 days after that, right. So the sun goes around this whole thing in 365 days or even say it does 360 degrees in 365 days, so it does approximately 1 degree in a day okay so from there you can calculate after whatever 10 days or 20 days what the RA of the sun is going to be okay and so that is going to be the RA which you will have at transit.

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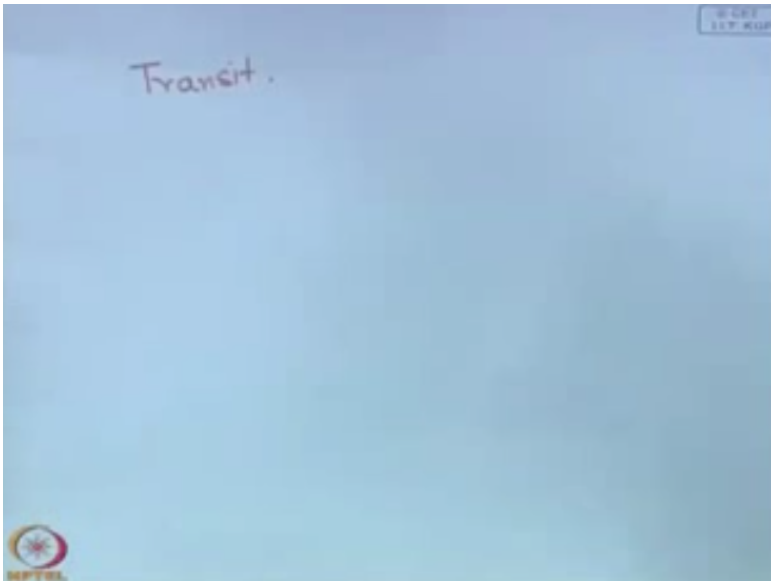


So there is a concept of transit. So at any time the RA that is exactly overhead, that by transit we refer to the RA and declination of the RA in particular of the point that is exactly overhead. Okay, so at 12 noon the sun is exactly overhead approximately so on the spring equinox, the 0, 0, 0 RA, 0 DEC transits at 12 noon and after some time it will transit at some other RA and DEC will transit at 12 noon, the position of the sun.

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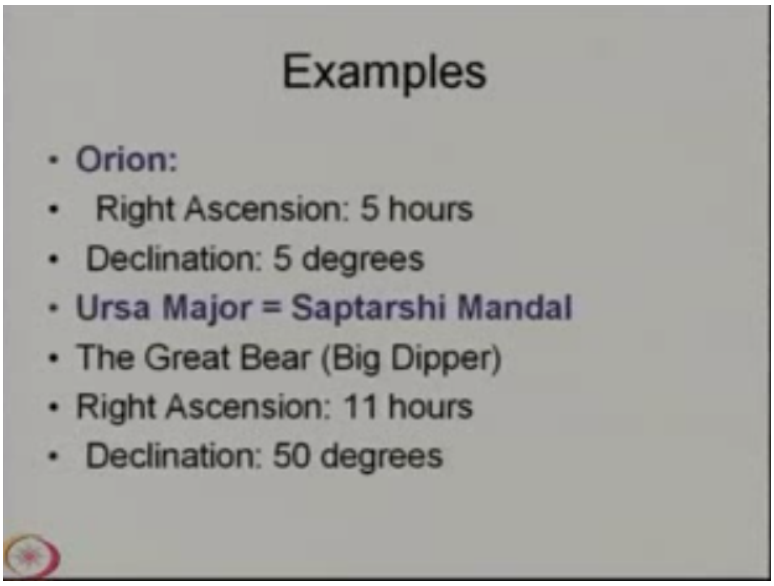


So these are things which one has to actually do to get a feeling for, so I will give you a brief exercise, this tells you the RA and declination of 2 of the constellations that we have discussed. These are the Orion constellation and the Ursa Major or great bear or the Saptarshi Mandal constellation okay and the Orion has a right ascension of 5 hours and declination of 5 degrees, it is quite close to the equatorial plane whereas the Ursa Major has a right ascension of 11 hours and a declination of 50 degrees.

Okay, so you have to locate these on the sky, it is not very difficult so you can if you know the time that you are looking at from the fact that 0, 0 transits, that the RA 0 transits on 22nd March, you know the date now, so you can calculate what will transit at noon and then you can calculate what you expect to transit for the time of your observation, so I suggest that you go out tonight and identify these and then relate them to the RA and declination values given over here. Okay. So let us stop here for today and we shall continue tomorrow.