Higher Surveying

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Module – 03
Time and Astronomy
Lecture – 08
Application of concepts of astronomy and time

Hello everyone. Welcome back on the course on Higher Surveying and we are in the last lecture of module 3, time and astronomy. In this module, we have already done 3 lectures. In the first lecture, we have find out what are the possible reference system for the astronomy. And we say that there are 4 possible systems. And then we find out that declination and right ascension are the independent coordinates with respect to the earth. Or since we are measuring these coordinates declination and right ascension using some fixed point and using some fixed plane that is equator or more specifically celestial equator and vernal equinox.

So, for that reason they are not dependent on the rotation motion of the earth. And hence they can be considered as global coordinates or they are basically coordinates which remains same for any users on the planet earth; that means, it is irrespective of the place can be used as a global coordinate of a star. Well, with this we then, we have talked about what are the possible applications there we can connect the 3 reference systems. And then in the last lecture we talked about time. In case of time we learned that there are 2 possibilities of measuring the time. First possibility is to measure the time with respect to sun that is what we call solar day.

And there is another possibility where we learned that how to measure the time with respect to far distance star. And we make the differentiation there that with respect to sun we call solar day or solar time, but with respect to far star the rotation of the earth is measured by the sidereal time. So, that was the idea. So, hence we said that for the far distance star suppose you are setting on a far distance star. In that case you will feel that earth is rotating with the sidereal time or earth is completing 360 degree in a sidereal day.

But, if you are sitting on the surface of earth, then you will feel that you are completing one day in one solar day or 24 hour so, that is a difference. So, whenever we are there on the surface of earth we will use solar day, but if you are away far away for example, satellites station or in the satellite or in some other star, we will use sidereal days.

The meaning here is if we are trying to study the motion of the stars which are far away as reduce sidereal days. And, if I trying to measure the motion of the sun or some other purpose with which is governly, which is mainly governed by the sun for example, our biological life or our civil time, then we should use the solar time or solar day. That was the idea.

Now, in this lecture we are going to do some applications of time and reference system for astronomy. So, let us delve in to this lecture. And that is the last lecture on this module, and that is application of concepts of astronomy and time.

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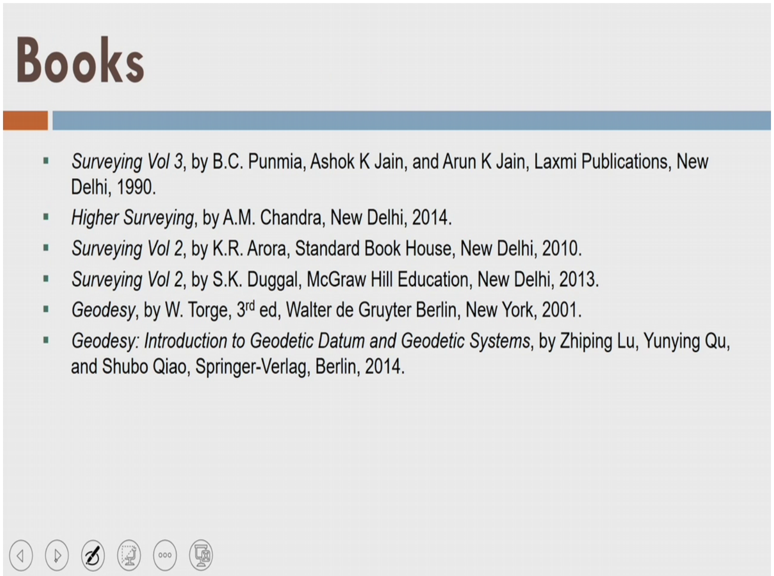

Now, again these are the books we have already recommended.

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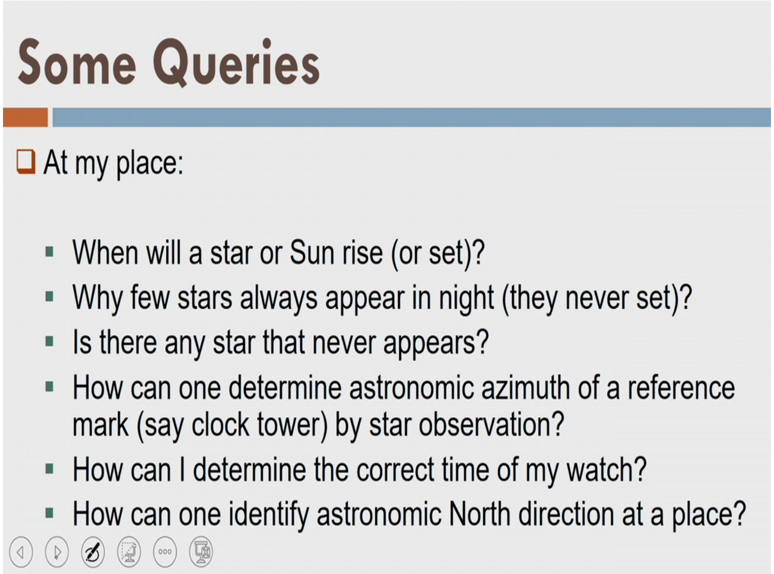

Now, before starting this lecture let us raise some queries. And the purpose of these queries are; we should first understand what are the basic problem that we are going to address by this lecture of by the knowledge that we are going to learn, or we are going to gained in this lecture.

So, once we have few queries beforehand, then you will try to respond to these queries in the process of responding to these queries in this lecture. You will also learned some other knowledge and you will develop knowledge based in order to response to other questions also if we have in future so, that is the idea here. So, the idea here is not to limit yourself to these queries also, but raise your further queries right, and try to respond to those queries that you have raised using the knowledge shared in this lecture, fine? Let us go ahead.

So, the first query is when will a star or sun will rise or sun will set that is my first question. Remember then you have already realized that what do you mean by sun set when sun is on 0-degree altitude with respect to given celestial horizon, we call it sun set or sun rise. So, sun if moving ascending up above the horizon we call it sun rise, and if it is descending down below the horizon we call it sun set. But most important is at what time so now, I can see that why few stars always appear in night they never set.

So, if you go to an open ground, and try to see the stars in night time you will find out at your place. Irrespective of your location; that means, even if you go anywhere in the ground, you will find out there are few stars they will always remain in the sky and every day you can observe them if we can identify those stars, ok.

Similarly, either in a stars which never come at your place or are there any star like sun rises above the horizon and again set below in the morning which rises themselves which rises like sun and they set like a sun, ok. Now, using astronomic observation for example, star or sun can be find out they astronomic north, also can I find out the error of my watch, why this is important question? Because, as we said that time and celestial reference systems or the reference system for astronomy are connected to each other. Basically when we said that we have defined some reference system for astronomy will ultimately came to the point that I want to determine the rotation of the earth. And by determining the rotation of earth is nothing but that determining the time.

So, are can we find out the current time of my watch using some star observation, ok. Then last question is how can I identify the north direction without any astronomic observation using sophisticated instrument like total station theodolite. Or any other instrument what is some kind of common knowledge we should have, ok. So, let us look into these questions today.

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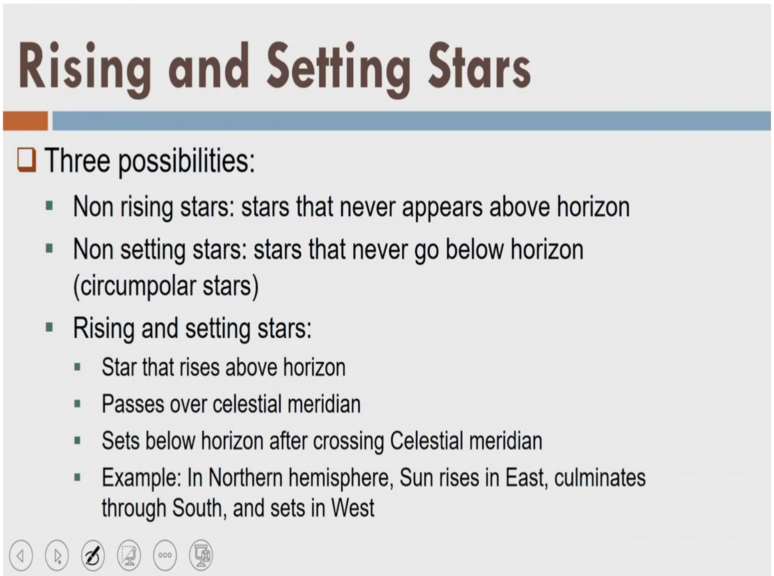

So, in case of rising and setting stars; that means, there are few stars which are rising there few stars which has setting. There are few stars which are which even never which never set and there are few stars which never rises above horizon. So, I can visualize 3 possibilities. Here, what are these 3 possibilities? First is a star that never set below horizon and we call it non-setting star and we also call them circumpolar star. There are few type of stars or there are some stars which never come above horizon and we call them the non-rising stars.

And there are third category, which are rising and setting; that means, there like sun they will rise above the horizon, they will pass through they will culminate they will make a transit on the celestial meridian of an observer. And then again they go to the west, and they will set, ok. In case of sun we call morning and evening; that means, in morning sun rises and evening sun set. What about the other stars? Well, morning and evening terms are not used. Rather we say that star rises in east. Make a transit on the celestial meridian and then it sets in the west, fine. In the one of the lecture; that means, the in the second lecture of this module we also calculated whether sun is exactly coming in the west, or exactly rising in the east, or exactly setting in the west by calculating the azimuth value. So, you already learn from numerical process.

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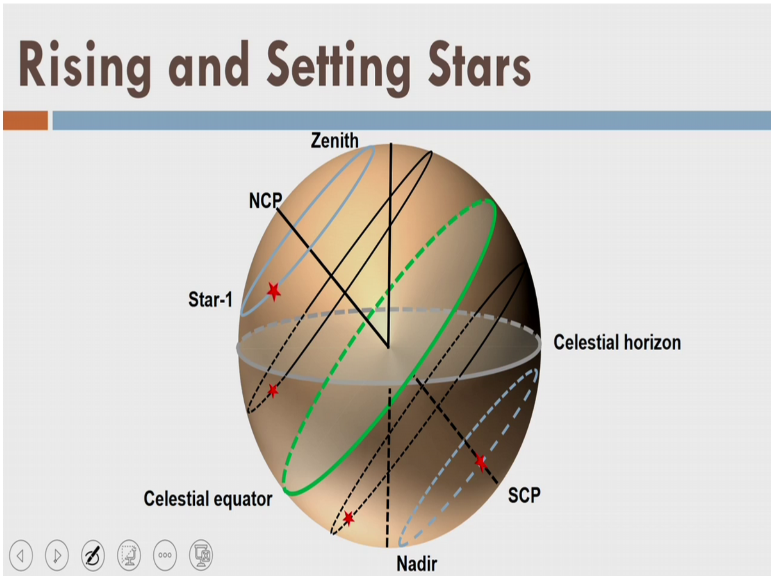

Now, let us come to the part what do you mean by rise rising and setting? So, let us come back to our original set up of celestial horizon and celestial equator. And this is my celestial sphere which is shown here. So, we have zenith and other in place, again the north celestial pole, NCP and SCP south celestial pole both are in place here, ok. So, let us go ahead. Let us say there are 4 star as shown in the figure now, ok and since we know that all the stars will appear apparently moving around the north celestial pole because of the rotation of the earth.

So, these are the path of the stars. Let us take the first star which is my star-1, and let us see it is motion. So, it is moving in a clockwise direction from east to west like this, well, it is shown in the animation. So, you can see that this star will always remain above the celestial horizon of an observer, ok. Let us take the next star, star-2 here if you see the star movement, now you can see the daily orbit of the star; where if I mark then I can say that this is the point here, and there are 2 points, one is this, I can uses see that these are the points where star touching the celestial horizon of observer.

So, let us see what is the motion here. So now, star is moving, now it is below the horizon. And now it is coming up, and now it is moving above the horizon going down coming up and so on. So, these are the movements of the star, and remember that star if it is not moving in the space, then because of the rotation of the earth it will appear moving in 24 hours by 1 circulation or 1 rotation around the earth. Apparently, it will appear like that, ok. The idea here is this is the star which is going below the horizon and above the horizon. So, this star will go as a sun and it will set down, and again it will rise in the next day night.

So, it will appear as it is setting below the horizon, and it is again rising next day evening. So, such stars are called rising and setting stars. Again, you look that for the third star like this star 3 here, and this star is again moving, and now we can see that it has a longer period below the horizon, compare to star-2. And as a result we can see that it will appear for very shorter time above the horizon. So, when a star is above the horizon and observer can see that.

Now, what about the day time, day time all the stars are there in the place, but because of the presence of the sun. Sun light is so intense that we cannot see the other stars. But yes stars are there in the place. And that is the best example is the solar eclipse; at the time of solar eclipse the complete eclipse we can see the stars around thus in the sky. Well, now again if we look at the star-2 and star 3, they are coming above the horizon. And they are rising and setting.

But, what about the star-4, like this, which is never coming above the horizon and because it is moving like this, as shown in the animation here. Now we can see that even it is rotating around a earth, it is not able to come over the above the horizon, because of it is own position in the celestial sphere. So, what is the idea here? How can I distinguish between a star who is rising or whose non-setting star, and there is another star which is non-rising star; that means, non-rising star will never come above horizon, and non-setting star will never go below horizon. So, non-setting star which is called circumpolar star will always appear in the sky with respect to the horizon, ok.

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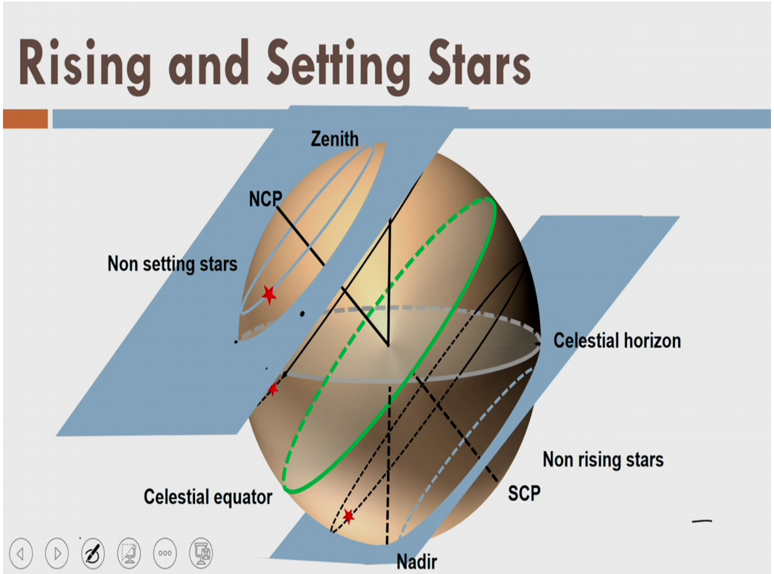

So, if I draw this kind of plane, parallel to the celestial equator passing through the celestial horizon; that means, this plane is touching the celestial horizon, at this point here, and it is parallel to the equator, I can see that this is the zone of non-setting stars. Similarly, if I draw a plane over this point and parallel to the equator, I can see that there is a plane like this and below this plane all the stars will never come above the horizon. So, the zone below this plane is called non-rising star zone. What about the zone below between the 2 planes? And, remember these 2 planes are parallel to the celestial equator, but they are passing through the these point, this point and this point.

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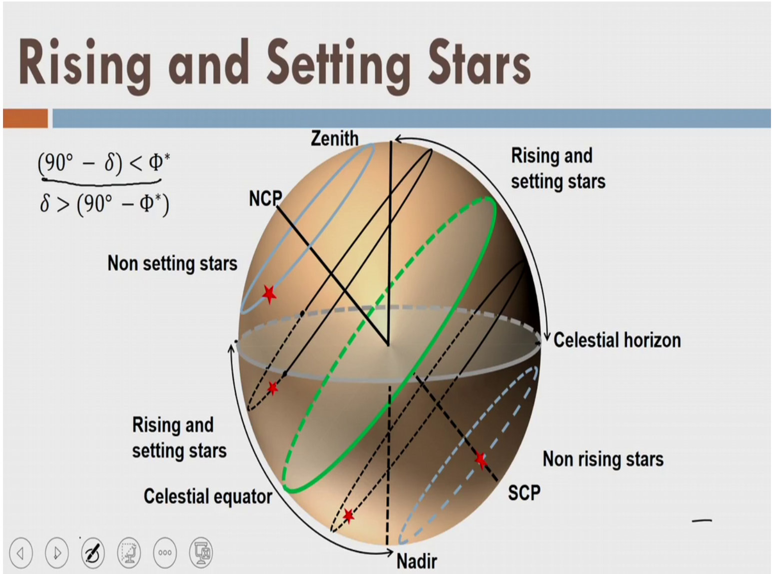

Now, the zone between these 2 planes is called the zone of rising and setting stars. Why because, between these 2 planes a starts which are appearing like that they will be rising above the horizon and they will be going below the horizon after making the transit over the celestial meridian. So, we can write this kind of relationship very easily. Now we have learned many times what is declination and what is the longitude and latitude of the plane. So, I am writing this relationship here, where I can see that latitude of the place if it is more than 90 minus delta that is codeclination. This star will be non-setting star or circumpolar star.

Similarly, you can find the other relation for the remaining stars. So now, I can write this (Refer Time: 15:12) chip; that means, the declination of the star is more than colatitude. Then that star will never set it will be always non-setting stars, ok. So now, we can just open the star catalog and find out which star is having delta more than colatitude of your place. And those stars will never set below your horizon or other they will circumpolar stars or they will always appear in the sky every day so that is a idea here.

Similarly, we can develop other definitions for non-rising star and rising and setting a stars so, let us go ahead. So, what about the sun? Sun is a star which appears above the horizon and below the horizon daily. So, it is a rising and setting star. So, I have drawn the ecliptic which is the annual path of the sun; that means, what do you mean by annual path of the sun? Annual path of the sun is similar to a noting down a position of a star every day at same time. For example, let us said 11 am morning, you go to your rooftop, and measure the declination and right ascension. You cannot measure them directly, but let us say your determining it every day 11 am at your place. So, the declination and right ascension if you plot, you will get the everyday. Let us say, you plot these right ascension and declination every day you will get ecliptic path. So, that is a idea of annual path.

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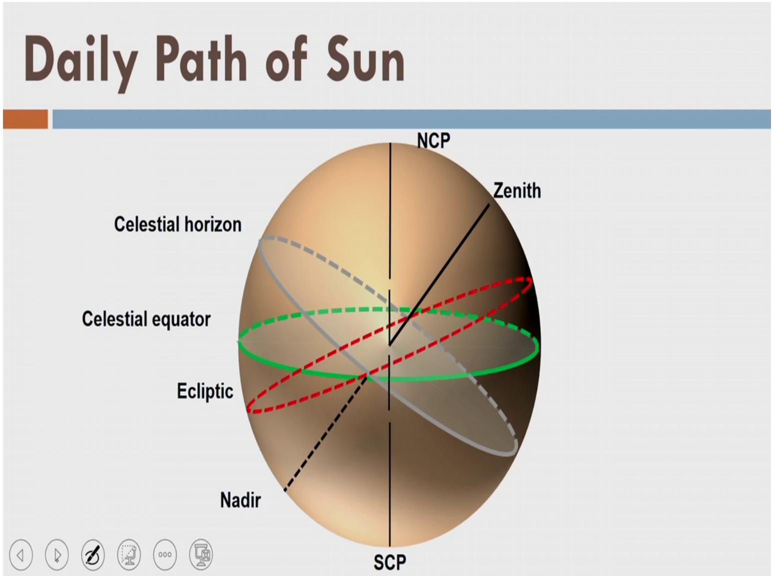

So, your marking those 355 positions along the equator of the earth and you are getting this kind of path, which is shown here in red color call ecliptic. Now, it happens that let us remove this zenith nadir and let us say sun is here.

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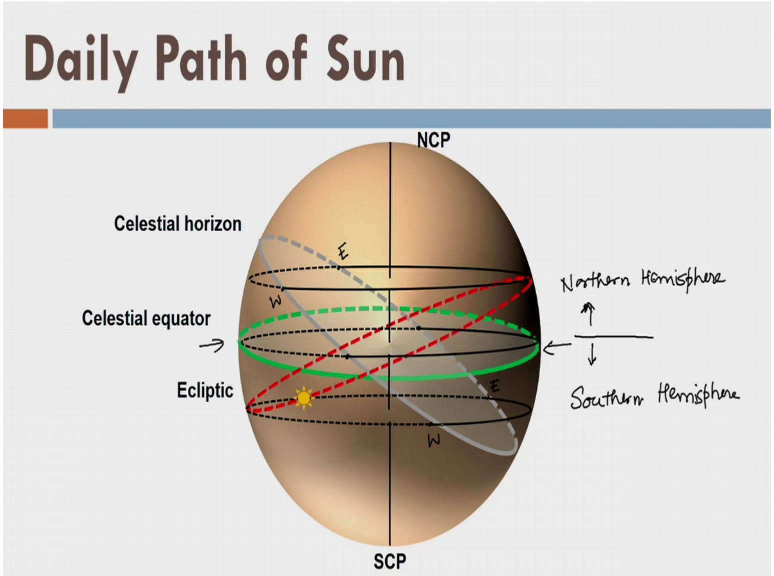

So, what about the daily path of the sun? We have marked one position on a one day on this ecliptic. So, daily path is parallel to the celestial equator almost close to the parallel it so, like this. Now sun will move in this way and it will first set here and it will rise here. So, this is a rising point I can say is around east, and that is the west here, fine let us look the motion by animation.

So, this is the moving sun is moving here, right? And it will go below the horizon. Now it is night time it is again morning and sun has come up above the east above the horizon and now is there. So, we have learned at this given position, what is the motion of the sun in a daily path. You can see the difference between east and west quite longer compare to the length of the some path below the horizon. And as the result we can say the days are longer when sun is on there northern hemisphere. You can see with respect to this equator here. This is my northern hemisphere, and this portion is my southern hemisphere, right?

So, this is and this is northern hemisphere above this equator plane well. So now, the sun is in the northern hemisphere and as a result I have longer day in the northern hemisphere, or for a position of observer which is in the northern hemisphere. Now let us look in the other position of the; let us say sun is in the equator; that means, this position on the ecliptic path which is very close to the equatorial path? Now, what is the daily path of the sun this is the daily path of the sun. Now you can see that it is coming above the horizon here on this particular day and here it is setting down right. So, this is the motion of the sun shown by the now it has just come above the horizon and now it is the day time at that observers location. And now it is going to set it set here in the evening and again it is the night time when it is travelling it is transacting to north. And it has done complete one cycle, ok.

So, I can see here the length of the day and length of the night. That is the length shown here by the dotted line and the length shown by a firm line. So, the length shown in the firm line is the day time. And length shown in the dotted line on a daily path of sun is the night time. So, there almost equal let us take the position of the sun on the, it is ecliptic that is a angle path on a certain day in a southern hemisphere let us say around in month of November December.

As a result, you can see that is a daily path and in the daily path we can see that for observer northern hemisphere, the length of the days quite small. Although it is an animated figure, it is not it is highly accelerated figure, but still it is conveying the message here. That the path from this point here east here and to west right that is much smaller than path below the horizon further. Let me specify more. So, length of the day for an observer in the northern hemisphere is much smaller if sun is in the southern hemisphere. And that is idea we have explicit every year because of the winters and summers and so on.

So, in the northern hemisphere when summer is there days are longer. That is the idea here. Now, what about the daily path of the sun? In the last figure it was quite little complicated to understand, but here in the books we will find this kind of figure. So, we are also showing in a rotated form now, ok. So, this is the path sun here. So, sun is now rising above the horizon.

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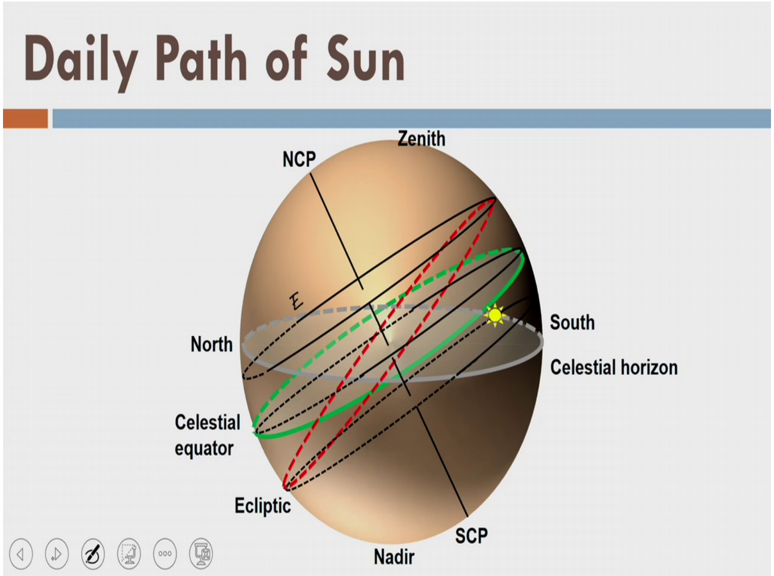

And now it is travelling in the day, ok. So, that is the now it is and the south going down. So, there is soon it will go below the horizon and now, it is sunset here, right. So, it was a east point here, and it was a west point here, opposite point is west. So now, it will go sun will the below the horizon sun has set. So now, it is in the night time. So, evening to morning is coming in the. Next day morning sun will again come in the direction of east, but not exactly it east, it could be slightly north part or south (Refer Time: 22:11).

So, in the season of summers, it comes slightly north way or southly north. Then it passes through the south, and that is why from north to south it will take long time and again south to again north; that means, it will settle down further east sun is here. So, this is the point we are sun will rise and let us see this is the sun is moving above the celestial horizon. So, your facing the day time and this is the transit of the sun on the celestial meridian of an observer and sun has now going to set; it is the point where sun will set, ok. So, let us sun is now below the horizon. And you are feeling evening or night time, right. So, it is a north transit here lower transit what we call. So, after lower transit sun will again rise, and it will come to the horizon of an observer, ok. The third position again we are explaining here.

Now, we can feel that sun is above the horizon is very, very low time, because sun is in the southern hemisphere, across the year, ok. So, this is the path of the sun, when very slow now this is the path of the sun. So, we can feel that yes sun rise to sun set time is very, very small. Because the length of the path of sun in is completely short, at the given celestial horizon of an observer. So now, this is the time we have in the night after the evening where sun is moving through the lower transit. What you call mid night and now sun has come to again at horizon. So, that was the idea above of the rising and setting star. So, sun is very special for the earth because it is governing the daily life as well as all the biological life most our activities are governed by this sun or the sun light.

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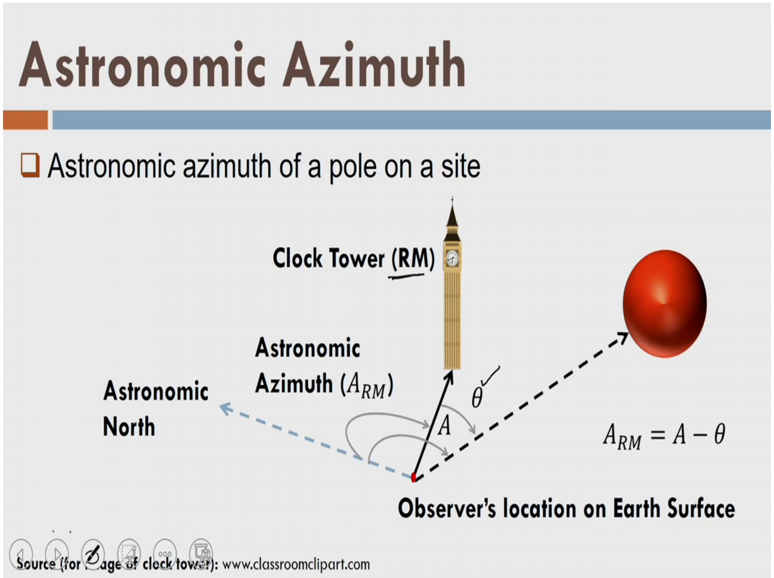

Now, let us look into the application of these time and the reference system on the astronomy, ok. The first idea here is I want to find out what is the astronomic azimuth of a pole on a site. Basically, I want to find out what is the value of astronomic north, or what is the direction where my astronomic north is located at my place. So, what will I do? What can I do? Not what will I do, what can I do?

Here idea is very simple what will I do I will make some star observation or sun observation and try to find out the direction of north. But, here where to start where to measure some angles of the sun also? I do not have any reference. So, let us make the reference mark as RM here as my clock tower it is my reference mark as shown here.

Now, I will measure the angles with respect to the reference mark of a star or a sun so, like this. Let us see there is a sun like this, and we are measuring the sun, so I am measuring this angle or I want to find out this direction that is nothing but the astronomic north, and this is the astronomic bearing of a sun at a given movement. So, if I can find out this value, I can also find out the azimuth of the clock tower. So, then what will I do? I am measuring the angles, that is my A azimuth of the sun, and this is the angle theta that I am going to measure.

So, theta I am going to measure for the sun because I know the position of clock tower, with respect to that I will measure the value of theta for the sun at a given movement. And then I will find out the astronomic north or astronomic bearing of the sun for that movement, and then I can find out I can reduce that if I go back like this. So, this is the astronomic north, and from that north I can say this is the azimuth of my tower. This is sun here at this point; this is the angle I am measuring finding out the by calculation what we have learn last time.

So, let us say this is my sun direction here, shown by this pen this is my clock tower direction here. So, I am measuring this angle here, at a given movement, and by using some calculation and finding out what is the angle that sun is making right now from the north like this, ok. So, this way if I go back in this direction I can find out this is my north direction. And now I can say what is the azimuth of this reference mark that is clock tower.

So, let us see what is the process here, but remember that in our basic fundamental concepts of astronomy, we have assumed that we have done some calculations on the center of the earth; that means, my observer is located on the center of the earth; more specifically, is eyes are located on the center of earth. So, I am performing all the calculations on the center of earth for example, declination (Refer Time: 27:44) hour angle and so on. And, as a result, the there is a some contradiction because we are observing the sun on the surface of the earth, right which is above some MSL mean sea level or above at some place.

So now, we need to make some corrections so that we bring our coordinates that is we are measuring on the altitude of sun. So, I will bring the altitude of the sun with respect to the center of earth, and not with respect to the surface of earth. Let us look what are the corrections are needed here. So, before we go this is my formula here. So, first correction we make for reflection, what is that?

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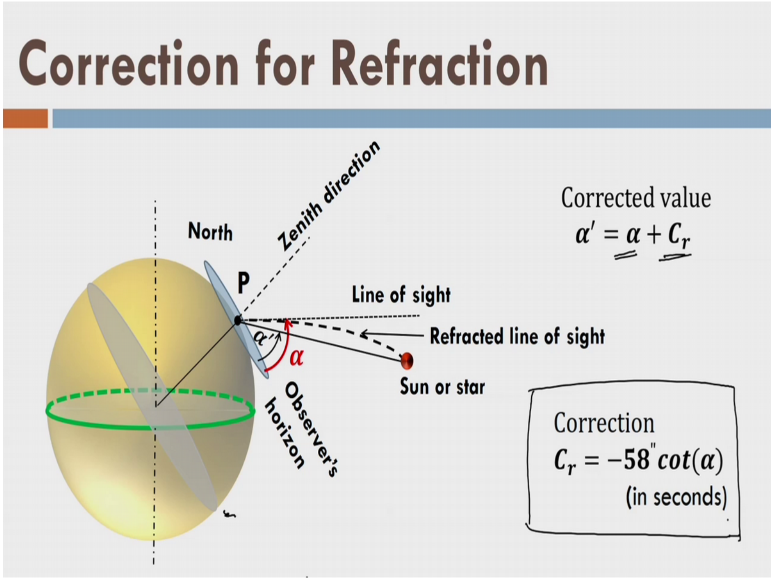

Let us see there is a point P on the surface of earth. And I am showing the horizon at the equator. There is this is celestial equator I am showing. So, this is the not the celestial spear it is the earth and I am assuming that the earth is spherical here where radius r.

So, this is my observers horizon at surface of earth. And this is my observers horizon here, shown here at the equator of the earth. So, since I am measuring the angle altitude angle of the sun with respect to center of earth. So, I need not to show the celestial equator even celestial equator of the earth terrestrial equator of the earth will also work here. So, let us see there is a north here on the observers horizon and so, this is the zenith direction or the line showing here is vertical line.

Now, let us see sun is there right now. So, what will happen here this is the sun and I am going to measure this angle and let us call this angle as alpha dash. Because this is the correct angle I want to measure, but now what happens this because of the refraction in that atmosphere, the rays which are coming from the sun they travel some other path, they travel some curve path. And because of that I measure little more angle or little higher angle. Let us see will this is my line of sight why because the line which are passing through my eyes. That is line of sight will curve and it will curve down and will restore some. And that is why I measure little higher angle. So, this is the line of sight right.

So, as a result at a point where I am observing the sun my line of sight is tiltrate up. And so, I measure this angle. Show in the red color called alpha, now the alpha dash. And I need to put some corrections for that in order to find out the alpha dash and that is the correct angle. So, the correction is let us see I put C r is my correction for the refraction. And alpha is my measured value here. That I measure, now this correction is given by this value in seconds remember, you should put your alpha value is here. Let us you measure 23-degree alpha for example, put this value here and you multiply with 58 and that corrections you will get in seconds and that will be the negative, because we know alpha dash is smaller.

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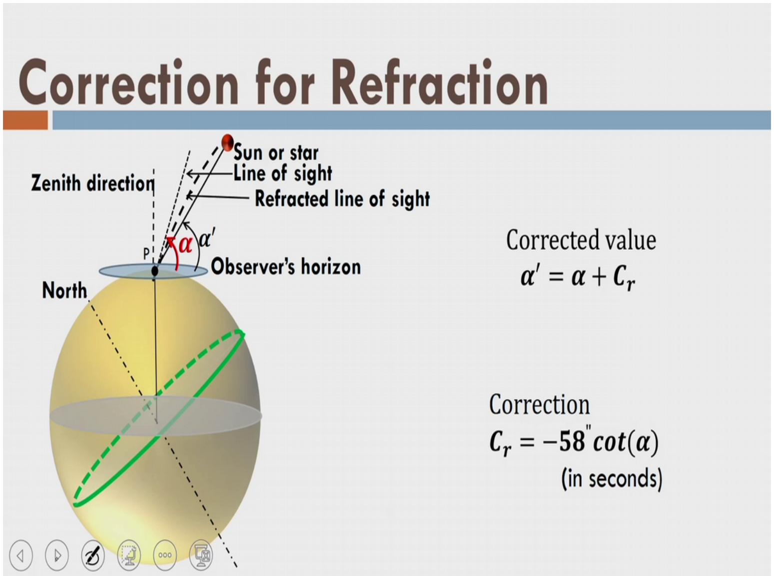

So, let us look into the next correction, ok. Before that so, in the book this figures are shown like this, right. So, we have shown the tilted figure the actual position in the books you will see this kind of figure, where the alpha dash and alpha R marked in the same fashion. Now let us look for the correction of parallax, ok. What is a parallax here? The parallax is generally termed as the change in the angle, because of the successive exposure, well what is that here.

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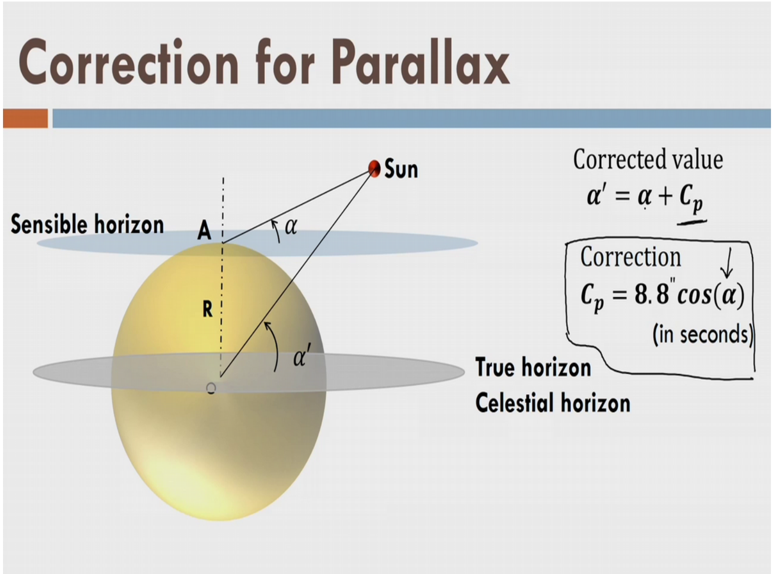

Let us look let us see this is the earth and your at point A at equator your at point A at on surface of earth. So now, it is your sensible horizon, where you feel as if there a horizon like this at a given place, but now let us say this is the sun. And so, measure this angle which is called alpha here, like this, fine that is very normal idea here, ok.

Now, but we have measured or we have assumed that the observers should be located at the center of the earth and as a result remember the concept of celestial horizon and celestial equator. So, we have defined celestial horizon as well as celestial equator passing through the center of earth. So now, we should measure the angle of sun with respect to the true horizon or the celestial horizon which is containing the center of earth. So, this is the correct angle. So, I should measure alpha dash, not the alpha, and as a result I need to apply some correction and this correction is for the parallax is given by C p for the measured value of alpha, and this correction is given by this value in the again seconds, ok.

So, you put the value of alpha here that you measure. And then you find out the C p again it will you positive correction as visible from the image that angle alpha dash is more than alpha. So, will put a positive correction here. So, let us take the third correction that is correction for dip of horizon, what is the dip of horizon? Remember that we have assumed that observer is located on the center of the earth. But we said we know that observer is on the surface of the earth moreover. It is not exactly at this spherical shape of the earth; it is above that and what we call the elevation of the surface above the MSL.

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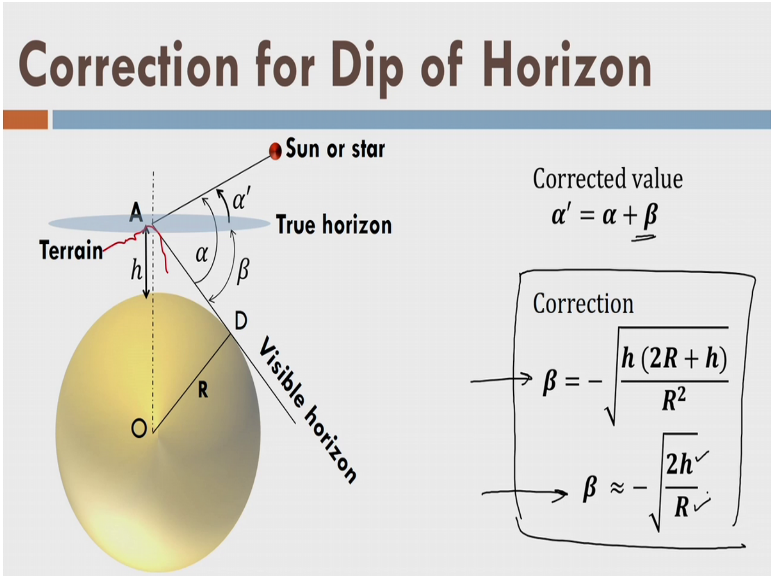

So, it is like that let us say it is earth and it is horizon. And let us say it is radius R. And let us say this is a terrain and this is the point A which is above the mean sea level at and elevation of small h.

And this is the sensible horizon or what we call is observers horizon and what we call let us say true horizon now. And let us say this is the sun here. So, and measuring this angle; however, we have term the 2 horizon at point A. Remember, I should draw it parallel to the equator or parallel to the sensible horizon, but it should pass through the center of earth, then I should call it true horizon. But here we are still calling it true horizon, because we have already made correction for the parallax.

So now, assumed that I have already made a correction for parallax and I am getting alpha dash value not the alpha. But on top of that alpha dash, I need to understand that or the location of observer is situated on the height h above MSL, then he has a different horizon, right and you see that he will look towards point D as a visible horizon. That is call the visible horizon because it is our tendency to look around the earth and; obviously, from the point A we have finding a point which is lying at the horizon you can feel it, but that is the lower point than be point A.

And if I extend the line of sight you will find out there is a point on the visible horizon, and this is the point D. Now as a result I will measure this angle, right. And let us call this angle is alpha. This is the angle I measure, and this is the angle I should measure. So, this is the alpha dash here, ok. So, the correction here is beta angle. And this correction I am writing here like this and adding always and putting the sign. So, know I know that beta is positive or beta is negative beta is definitely negative because alpha dash is smaller than alpha.

So, this correction is given by this. So, this is the lower one is approximate value here, this is an approximate value and this is the exact value. Well, the height of the observer above MSL is much lower compare to the right R radius. So, radius is in order of 60 from 400 kilometer, and MSL height could be in general around maximum 500 600 comma with 1000 meter. Remember the MSL height of Nainital is 2000 meter and if you compare 2000 meter with 6400 kilometers is in negligible.

For example, for Guwahati it is almost I can say 50 to 100 meters. If you go to some places in hilly station; like, Missouri Nainital they could be around 2000 meter, but if you go to the Himalaya or higher altitudes it will be higher. So, anyhow this is an appropriate correction this approximation is a very appropriate here, ok.

So now, we have put 3 corrections, ok. Let us looking to the 4th correction and that is correction for semi diameter of sun. What is that correction? Let us say this is my earth and that is the horizon and drawing at the center of earth.

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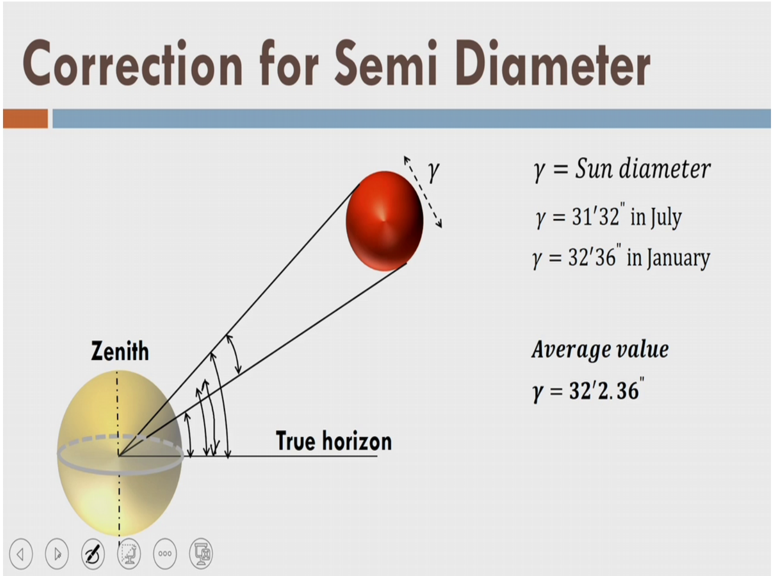

So, this is my zenith here, remember the zenith I am calling because it is a direction of zenith. Now this is the true horizon, because it is passing through the center of earth and this is the angle we measure. Because, we have already calculated the value of the angle by parallax correction.

Now, so, I either I measure this angle; that means, one h of this sun or may be lower h of this sun. But, ideally I should measure the center up of this sun, but I do not know the exactly center lies. So, what will I do? I will make some corrections. So, I am this is the sun diameter, here shown by this angle. So, I should measure this angle, which is shown right now this angle here right ok, but I measure either this angle or I measure this angle, ok.

So, whichever angle I measure I need to put either positive correction or negative correction. Let us see this is the diameter of the sun as gamma, and it has some value, given by 31 minute 32 seconds in July. It appears to be dilating in January as 32 minute 36 seconds, but in general average value it take as 32 minute and 2.36 second for our calculation purpose.

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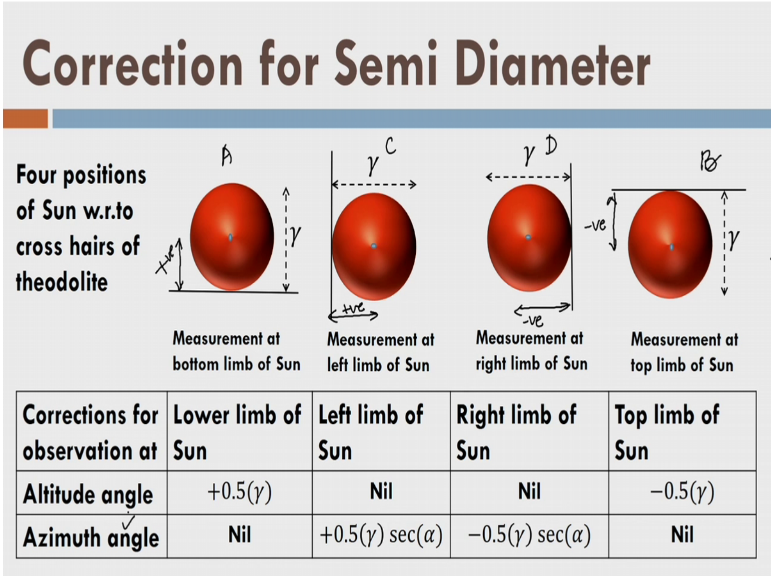

Now, these are the 4 possible combinations, where I can observe the sun. So, this is the position when if I measure the sun I need to measure put this kind of correction and that will be positive here, right. If I measure this correction, then I should put this kind of correction here, positive and if I make this kind of observation, then I should put this correction as negative. Similarly, if I make this kind of observation, I should put this correction negative.

You can see in the first position, I should make correction for the altitude, as well in the 4th position this position let say B and A here. I will be putting corrections to the altitude value for the C and D here and there. I will put corrections to the azimuth value or the horizontal angle value, right. And as a result I can draw this table for the corrections.

So now we can read this table. So, if I measuring making azimuth angle or horizontal angle, then I should make this correction, for this situation, c and d this or this positive and negative. But if I measuring the altitude angle, then I should make corrections in this position and in this position again this is your negative, and this is your positive correction, ok. Now we have made corrections for semi diameter also. So, we have made total 4 corrections to the measurement of the sun.

So now we understood that if I measure the altitude of the sun what kind of corrections I should met ok. So, let us go ahead.

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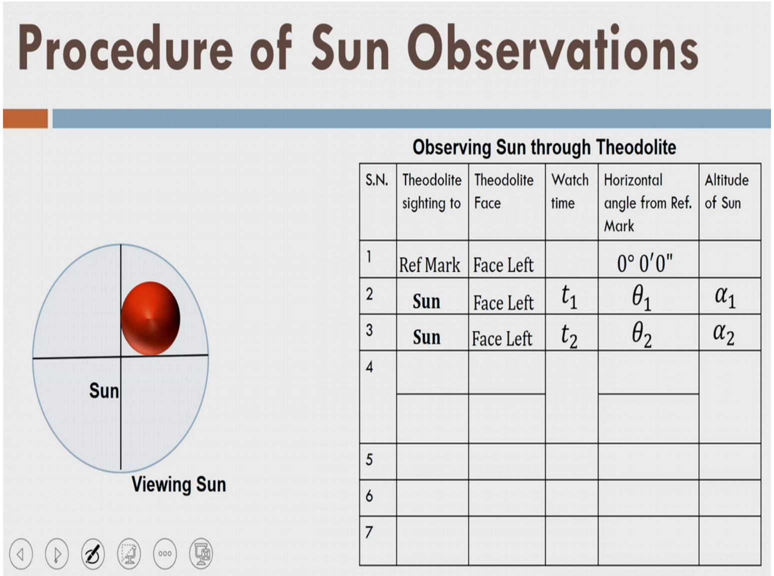

And now try to learn what is a procedure to observer the sun in order to make the calculation of the azimuth of the reference mark or finding out the 2 astronomic north, fine? So, first of all we will make our theodolite or angle measuring instrument it could be total fission also. Or it could be electronic theodolite also or it could be an analog or mechanical theodolite no problem.

So, let us see this is my theodolite eye site and I can look like this or I am looking at any object with this cross hairs, and object sight or eye sight whatever you say right. So, these are my cross hair. So, I am putting my object somewhere in this cross hair. So, the first reading is I will target my reference mark and with face left and so, this is my 0 degree because I have make level than center my theodolite well, ok. So, there is no need to measure any altitude now, ok. Let us see this is the sun, and now I will bring the sun like this.

And I will make with the face left observation to the sun in this position. Now, sun will come in this position. So, what will I do? I will measure 3 things, first is the time, second is the theta angle, that is the horizontal angle from reference mark. And third is altitude angle above the horizon. Look this, this and this.

Then now again I will bring the sun in the face left only in the this quadrant cross. So now, we were earlier I was in the third quadrant of my quadrant geometry. Now I come into the first quadrant of my quadrant geometry. So, I brought the sun from third quadrant to the first quadrant and now I will measure time theta and alpha, ok. Now what will I do? Ok, I have to change the face.

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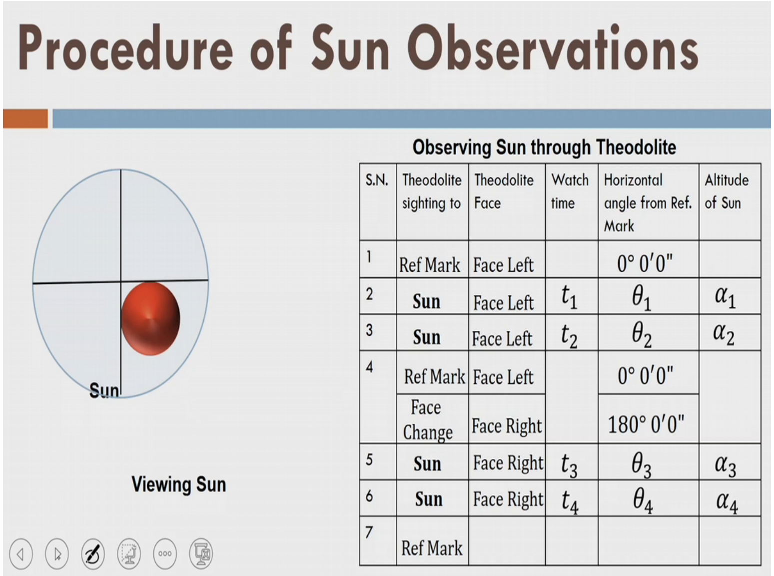

S.N.	Theodolite sighting to	Theodolite Face	Watch time	Horizontal angle from Ref. Mark	Altitude of Sun
1	Ref Mark	Face Left		0° 0′0"	
2	Sun	Face Left	t_1	θ_1	α_1
3	Sun	Face Left	t_2	θ_2	α_2
4	Ref Mark	Face Left		0° 0′0"	
	Face Change	Face Right		180° 0′0"	
5	Sun	Face Right	t_3	θ_3	α_3
6	Sun	Face Right	t_4	θ_4	α_4
7	Ref Mark				

So, what will I do? I will go back to the reference mark. And I will change the face well. So, I have change my face left here. So, I should get 0 degree answer again. Now will change the face, I will bring the face right change the face of theodolite, and then I should have 180 degree here, very obvious, if there is no error in the theodolite then I will again measure the sun with face right.

So, let us see I am bringing the sun, but this time I will bringing to the second quadrant like this, and I will measure this way. So, I will bring the sun in my cross hair arrangement in such a way that it is touching this way here. So, I have measure t theta and alpha again third time, ok. Finally, with the face right I will measure the sun in this 4th quadrant now. You see your measure the sun in the 4th quadrants. And I note that term and theta and alpha values. Again now my observations are completed, I can check my results by bringing back that theodolite to a reference mark like this.

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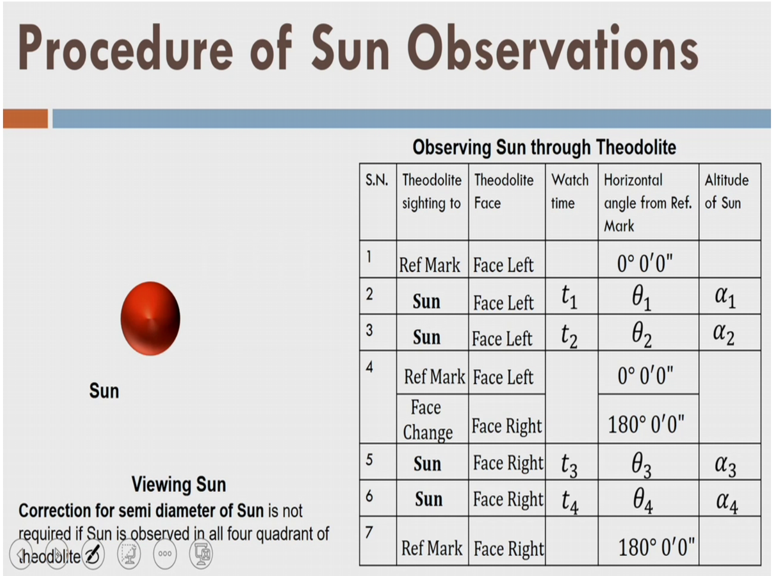

S.N.	Theodolite sighting to	Theodolite Face	Watch time	Horizontal angle from Ref. Mark	Altitude of Sun
1	Ref Mark	Face Left		0° 0′0"	
2	**Sun**	Face Left	t_1	θ_1	α_1
3	**Sun**	Face Left	t_2	θ_2	α_2
4	Ref Mark	Face Left		0° 0′0"	
	Face Change	Face Right		180° 0′0"	
5	**Sun**	Face Right	t_3	θ_3	α_3
6	**Sun**	Face Right	t_4	θ_4	α_4
7	Ref Mark	Face Right		180° 0′0"	

With the face right and I should have the 180-degree angle again right that is. So, idea here I should measure, the sun I should observer, a sun this way, the 4 quadrants, ok.

Now, the what is a advantage of this by measuring the sun in 4 quadrants, I can remove I or I need not to apply the corrections for the semi diameter. Because I have measure the sun 4 times. So, I need to apply 4 corrections, these 4 corrections will be compensating each other from the left to right and top to bottom. So, positive correction, negative correction, right correction, left correction. They will compensating each other and they will be cancel out, ok that is the idea here. What is you measure only one line of the sun; that means, if you take only one observation in either of the quadrant, then you should make correction for semi diameter. And then you will take only one observation, that is t 1 theta 1 and alpha 1.

So, let us go ahead let us see whether you have measured 1 measurement of sun. Or you have measured, 4 measurement for the sun; that means, 4 times stamp and 4 values of theta alpha, theta alpha, theta alpha and theta alpha. So, let us go bit any arrangement. So, what are the calculation process? So, these are the steps here. First you will calculate the average time from this average time it is your countries standard time. That is for India it is Indian standard time. And now you will reduce this time to the GMT Greenwich meridian time by making a correction of 5 hours 30 minutes, right.

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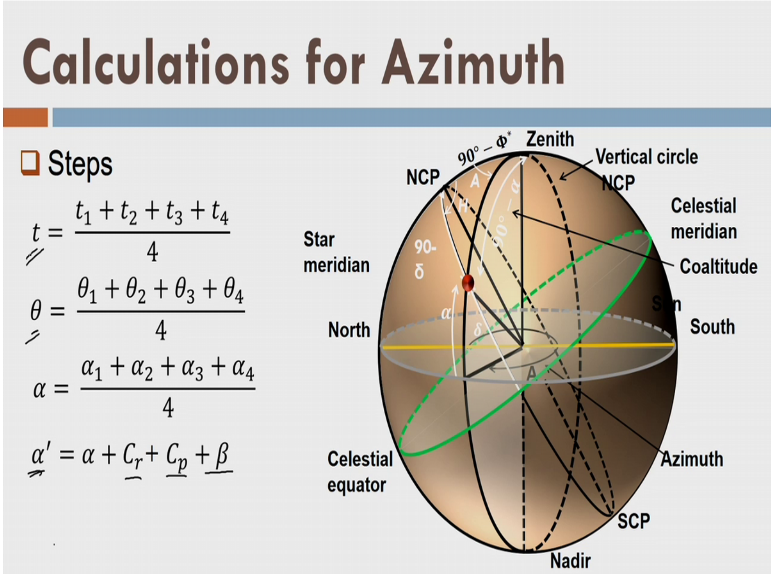

So, now you will measure the theta angle, the average value of theta, then you will measure the average value of alpha, ok. Now we will put the corrections to the alpha. So, all these corrections are given here C r C p and beta, fine. So now, this is my celestial triangle. That is being formed at this location or at this movement when I measure the sun at this value of alpha dash at this value of theta and at this time value. According to the time, I will refer my star catalog and find out what is the value of declination for given time. And remember that we have already find out the GMT, for that GMT what are the value of declination.

Well, so now that is my declination, ok. So, I can say that yes this is my spherical triangle, where I know the declination value delta, I know the alpha dash here from observation, and I know the latitude of the place of observer. Well, now let us calculate this zenith angle, this colatitude, codeclination and calculate this value of s here which is the summation of the 3 values and divided by 2.

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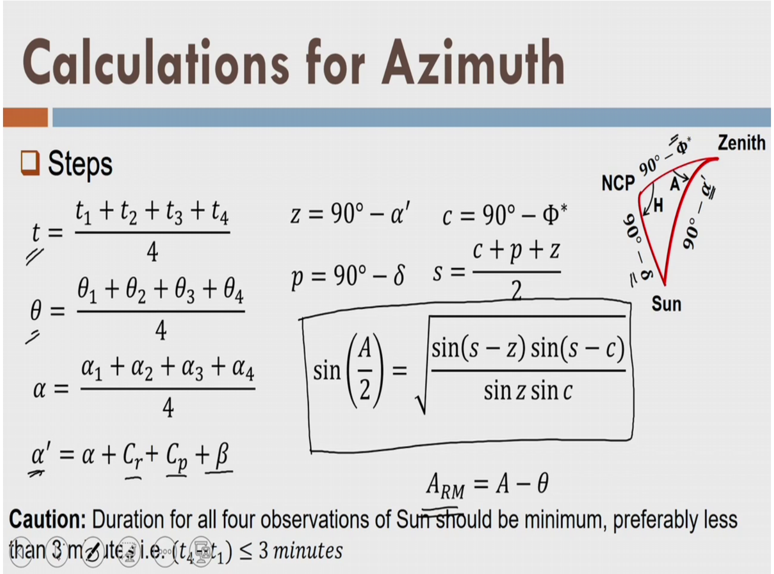

Then so, put this formula now, this sin A by 2 here. And find out the value of A, and that is nothing but the azimuth of the sun at a given movement t and a given altitude alpha.

So, basically it is at given movement t or given time t, the azimuth of the sun with respect to true north at your place. Now we can find out what is angle of reference mark with respect to true north and that is the azimuth of the place. What about the time? Can you find out the correct time of your watch? Remember, few things here. The duration of all 4 observations should be within 3 minutes; that means t 1 to t 4 should be taken within 3 months.

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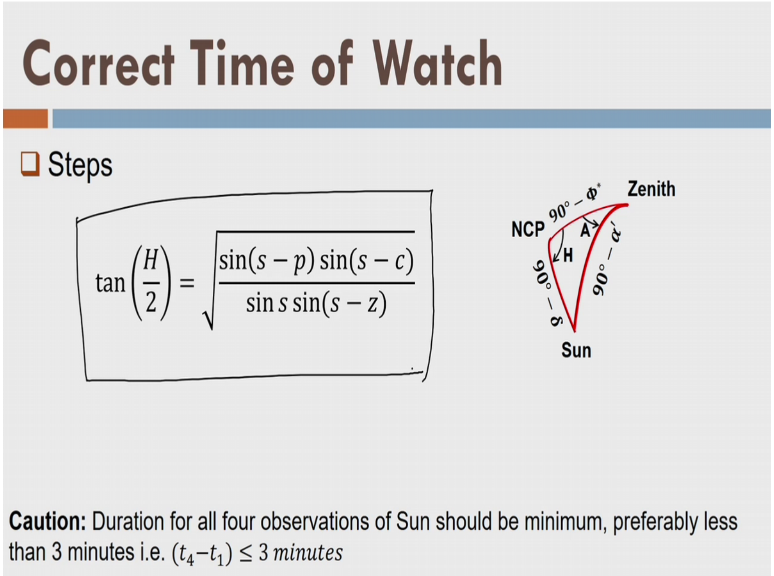

So, what about the correction time of watch. Remember, with the same spherical triangle we can also find out with a same set of measurement. The hour angle hour angle will be measured at your place at celestial meridian.

So now you have to bring that hour angle in terms of hour, minutes and second to the GMT and again put the corrections for your Indian standard time. I hope you got the message now. First, bring the hour angle to the GMT by putting the correction of 5 hours 30 minutes, may be positive or negative. Here it will be a negative correction for eastern side, right? Now from that time of GMT you put the correction of your country standard time, ok.

Here I would like to say something that when you measure the hour angle at your location. So, it is the hour angle with respect to the celestial meridian not with respect to in the standard meridian of the country. So, what will we do now? You should make some corrections in order to find out the correct time in Indian standard time at your place. So, what will we do you will first take the difference of your meridian and the Greenwich meridian and you will put the corrections there so, that you will bring the hour angle to the Greenwich meridian time. From the Greenwich meridian time, if you add the time of 5 hour 30 minutes, you will get the correct time of your watch by astronomic measurement at your place, but in the Indian standard time.

So now you can compare the 2 times. That time which you have observed before taking the observation or for taking the some observation and the time that you calculated by the astronomic calculations and you can compare. But remember we have made an assumption here that I am performing all the observations within 3 minutes all 4 observations within 3 minutes, because during these 3 minutes the variation of the declination of the sun is minimum or it is as per the requirement of our accuracy of time calculation. So, it should be very careful about that. Well now, you have find out the correct time of your watch. I think we have responded almost all the queries.

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So, for let us look further, the precautions when should take while making the sun observation. First of all, you should use the sun objective filter. If you are using theodolite or total station or electronic theodolite. So, on the eye site, you should put the objective sun filter that will save your eyes from the intense light of the sun.

Secondly if the altitude of the sun is much higher then you will need the diagonal eye piece because let us say altitudes more than 20 degree it is very difficult to measure like this. So, better to use diagonal eye piece or perform the your experiment in the morning time because in the morning time sun is at lower altitude below 20 degrees. So, you should prefer; so, go to the open ground may be a hockey ground cricket ground of your institute, perform this kind of experiment in the morning, ok.

Further there is a warning that if you are using an electronic instrument like total station or electronic theodolite, first taken idea or first taken kind of recommendation from your manufacture. Suppose you are using like car trimble top con Pentax or Nikon any instrument. But you should first consultesting with your manufacturer of the total station that your using, and on their recommendation only you should use for these some observation. Because, sometimes electronic circuitry is not recommended to make measurement for the sun. So, be careful on this part also, ok.

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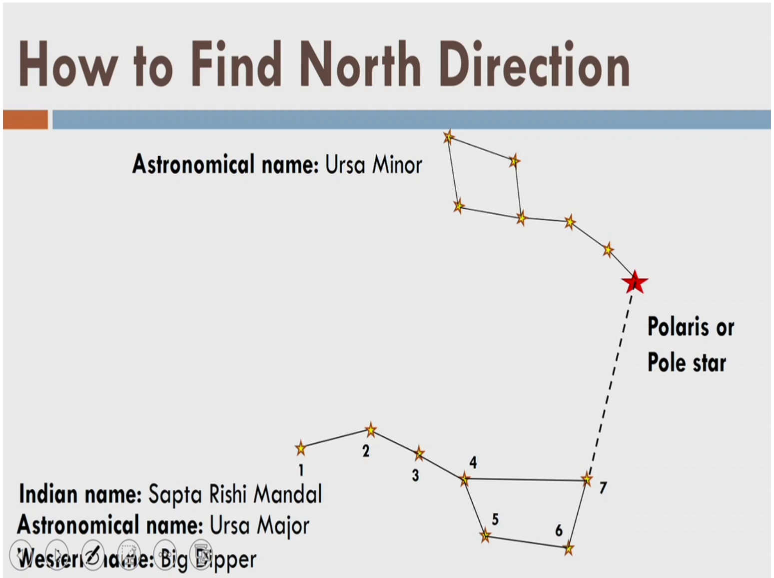

Now, the last question how to find out the north direction if you do not have any idea at a given place you do not have any astronomic observation, you do not have any star catalog with you, you do not have any idea about astronomy, but simple idea telling you; perhaps it is given in the early classes or early standards of classes 7th or 8h in the book so, I am repeating that. So, thanks to those knowledge and thanks to those books. Here you will find out there is some set of stars which are called Sapta Rishi Mandal and there 7 stars.

So, in Hindi or in Indian system, these stars are given the name of some saints like Vasishta or some other names I do not remember exactly. But now if you see that if I connect is stars by this line, it will create spoon (Refer Time: 51:29) where it is kind of spoon, where you was using in order to take something from a bowl and to serve someone. So now, we can see that star-4 5 6 and 7 are creating some kind of bowl shape, right. And a star 1, 2, 3, 4 are creating the handle of the bowl. So, creating kind of spoon all some stars. Now if you connect the star 6 7 and extend the line, this line will go to a star and this is the pole star, what we call polarized or north star.

Moreover this 7-star constellation is called would some major in astronomic term. And in the western name it is called big dipper, ok. What about the pole star? How can you further confirm your pole star location? The pole star itself is a member of a constellation, and that is called Ursa Minor, which is just inverted form of the Ursa Major like this. So, it is another kind of one more spoon, and where it has having a bowl and it has having a handle.

So, the pole star itself is one of the member of the Ursa Minor. So now, we can confirm this kind of star constellation in the sky and you can confirm where is the pole star. And remember the pole star is exactly or very close to located above the north celestial pole, or it is located above the north pole of the earth, ok. Further we are given you some more information about that. Now we have find out the pole star. So, there is a zenith for you, this is a pole star on this site in the sky for example.

Then you connect this line that is your meridian. And when this meridian, if you make this meridian, it will from the zenith to north star or the pole star and then on the horizon. This will connect you to the north direction at your celestial horizon. Well, that is a idea how to find out the north and opposite to this north direction there will south, ok. What about east and west? Fine, you can find out. So, if we are facing the east on your left hand side there should be north. Now you can find out the east location.

So, without measuring the sun you have find out the location of east, west, north and south. So, that is a simple knowledge one should have and while at least you can now go to any open place in the night time, and you can do your study above the north star. And you can find out the correct direction or at least approximate direction of north, the astronomic north at your place. Well, with this idea we are trying to conclude our module 3 here on astronomy, but before concluding I would like to give you some information about the celestial reference system.

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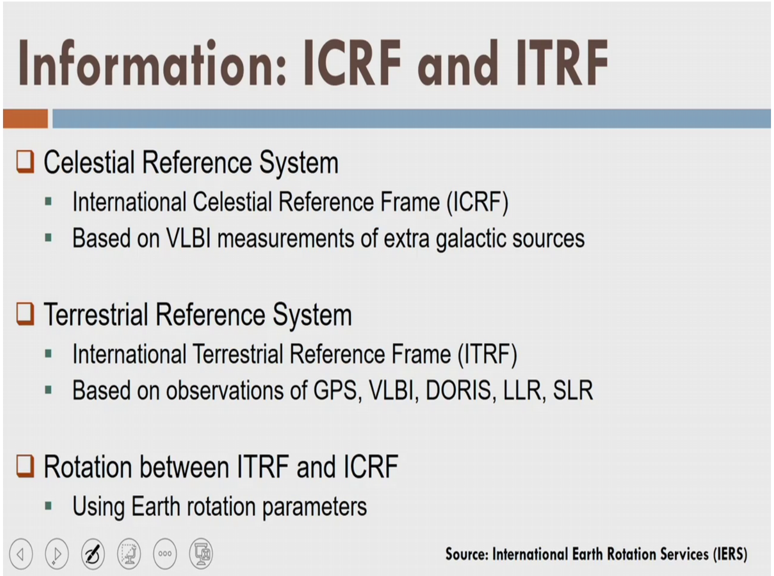

So, the celestial reference system is there and we are measuring the extra galactic sources which are far away stars and there called quasars. So, meting those quasars we are signing out the celestial reference frame for the earth and that frame is called international celestial reference frame. So, similarly we are using here the VLBI very large base interferometric technique in order to receive the signal from extragalactic radio source is which are the radio signals coming from the faraway stars.

Secondly we also have terrestrial reference system that we have discuss in module 2, ok. And this is the realization of TRS is international terrestrial reference frame ITRF, ok. And ITRF is established by various satellites programs and VLBI. So, GPS is one of the satellite program then we have DORIS. We have lunar laser ranging, then we have satellite laser ranging. So, using these type techniques we are finding out the surface of the earth and over all adjusted value of the earth. And then we are deciding what is the rotation excesses of the earth and rotation value of the earth and so on.

So, with this establish, we find out the center of the earth with very high precision. And now using those things we establish our ITRF, ok. And the relation between ICRF and ITRF is establish by the rotation and using the earth rotation parameters, ok. All these information is available with the international earth rotation services, who is responsible for measuring or taking all this information from various sources, various stations of GPS, VLBI and so on, ok.

So, with this we are going to conclude our module 3 here. We will see you in the next module on adjustment computation error and accuracy. Till then wait and watch and try to solve some problems on astronomy, is very interesting subject perhaps. It has been avoided because of the small complicacies or small complexities. So, try to enjoy the astronomy, ok. So, till then wait and watch.

Thank you very much.