Higher Surveying
Dr. Ajay Dashora
Department of Civil Engineering
Indian Institute of Technology, Guwahati

Module - 03
Time and Astronomy
Lecture – 07
Time

Welcome back and we are again in the course of Higher Surveying and we are in module 3. In this module, we have already done two lectures before and in these two lectures we talked about the reference system for astronomy, ok. Then, in the last lecture we saw the applications of these reference systems so that, we can locate the observers location as well as we can locate the position of a star with respect to observer. And then we also calculated various positions of the star in different, different situations like elongation and it could be like prime vertical and then we have also calculated about the sunrise and sunset or the star rise and star set.

Well with this now, in this two lectures, we have assumed that we know a quantity called time that at a given time we are measuring the position of the sun or may be some other star. Well, that is a good assumption to take but today, we will discuss about the time in this lecture. And if you recall the last lecture, we said that hour angle is somehow representing the time because hour angle is that angle which is measured in the plane of equator with respect to a celestial meridian. And, the celestial meridian is nothing but the location of an observer because according to location of observer, we are defining the celestial meridian, ok.

So, now we say that once we measure the hour angle of a star, we are measuring that how much duration it will a take to come to the celestial meridian and that is idea here that how hour angle helps us to measure the time. So, remember if star makes two transits, let us say two upper transit or two lower transits on these celestial meridian, what will happen? From upper transit 1 to upper transit 2, it will take complete 360 degree rotation of hour angle or I can measure the hour angle as completing the 360 degree rotation. Now, if I say that sun is passing over the meridian, two upper passes or two upper transits of the sun on my meridian, I can say the hour angle of sun will change by 360 degree or since I know that is the solar day that difference between two transits of sun over my celestial meridian. So, I can say that ok, that is 24 hours, that is a idea here that how to use hour angle.

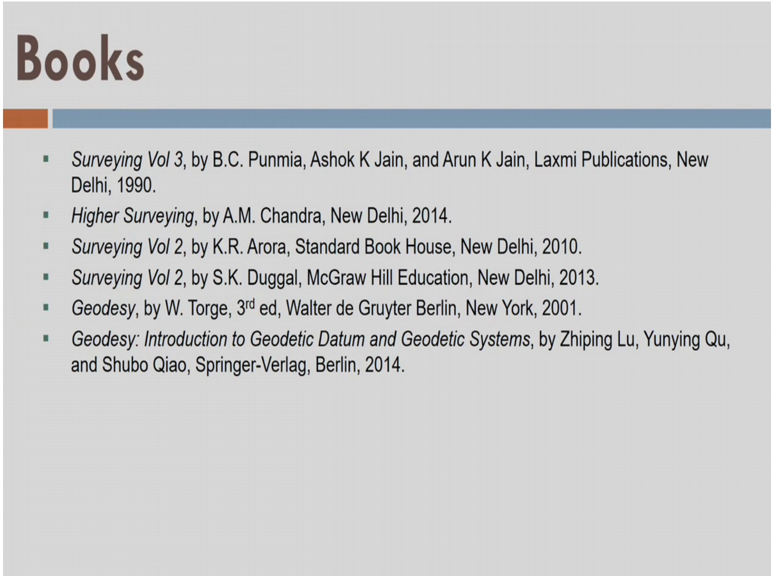
But before that let us take a global view on the time or let us tell little compliance view on the time. What is a time? If you remember we stared with the concept that earth is rotating, spinning and earth is orbiting the sun also. So, then we said that earth is making a complete one rotation or a spin around it is own access and that we call a day. Secondly, if earth completes one orbit around sun, we call it 1 year

Now, we can say one thing here that since I want to measure the time; that means, I want to measure a day time or I want to measure the daily rotation of the earth, right. So, the measurement of rotation well, we do in the mechanical engineering many a time during a many instruments. So, do we have an instrument that can measure the rotation of the earth? Since it is not possible because earth is very big body and we do not have any instrument like that.

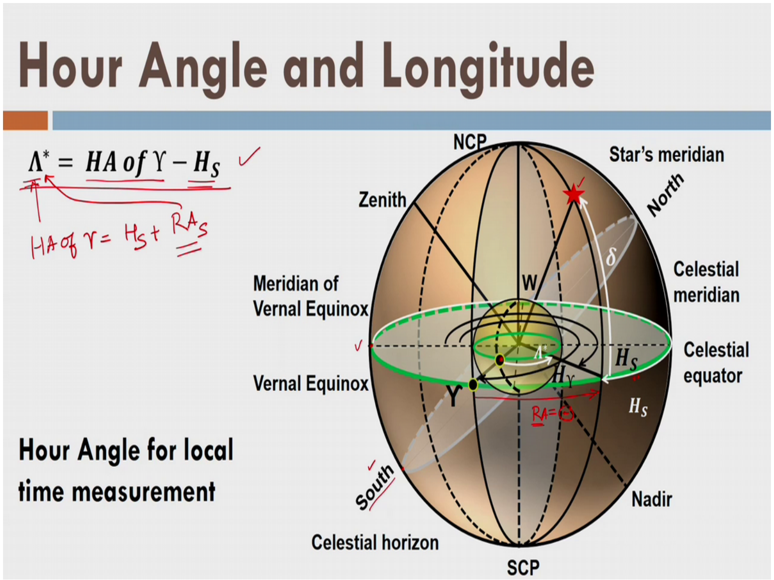
But human being is very very intelligent. So, human has devised a simple method and what is that method? Since earth is rotating and all the stars are appearing to me rotating apparently around the earth. So, what can we do here? Assume that earth is stationary and measure the motion of the star on a daily basis like sun or may be some other star. So, that will give me the idea of complete one rotation of one star at one place. So, that will be complete one day and that is a key here. So, the rotation of the earth is nothing but the time and we measure the time by measurement of the stars around the earth which are apparently moving.

So, let us look into the time and first the thing is hour angle. What it is hour angle and if we measure the hour angle of a star that is apparently moving, how can we measure the time ok. So, we are in the lecture 3 of this module; time, these are the books again.

(Refer Slide Time: 05:10)



(Refer Slide Time: 05:12)



And now, the concept here the hour angle and longitude what is the relationship. So, let us see this is my celestial sphere. So, this is the celestial equator, this is NCP, SCP. This is your celestial horizon then it is nadir and now this is celestial meridian. Well, we know that this is my east west and north south fine, let us say there is a star. So, this is my stars meridian and then this is the declination, now we want to measure the hour angle and this is the hour angle of the star, well. We have chosen this point on the equator as we have discuss earlier also, we will chose a point on equator which is above the celestial horizon. As a result, we say that this is the point because it is above this point of the celestial horizon. So, they are measure the hour angle of the star here. So, this is the another expression of hour angle. So, what is the connection between hour angle and other variables; for example, right ascension.

So, let us see there is an ecliptic and so, there is a Vernal Equinox as we know fine right. So, this is the meridian of Vernal Equinox like this. Now, I want to measure the hour angle of the Vernal Equinox; that means, how far is it from the celestial meridian of an observer. So, this is the angle which is equal to the hour angle of the Vernal Equinox.

Now, I can see here very clearly that this is the right ascension of the star right. We have written like this in the last lecture fine ok. You can also assume now that there is a connection what we write here is hour angle of the Vernal Equinox is the hour angle of the star plus right ascension of the star. So, what is the equivalent of right ascension? Let us look into that. If you remember we have said that we are measuring the longitude from the Greenwich meridian, remember. So, what is the Greenwich meridian? Ok, the meridian of Vernal Equinox is also passing through the terrestrial equator of the earth right because the celestial equator is an extension of the terrestrial equator.

So, definitely the meridian of Vernal Equinox will pass through the terrestrial equator of the earth and the intersection of the meridian plane of Vernal Equinox and terrestrial equator will give us the point where Greenwich meridian is passing. So, now, if I draw the earth here, that this point is my point where Greenwich meridian is passing. So, this is the Greenwich meridian shown by the dotted black line. Now, I want to measure the time using the star. Now what can I do? I can do one thing that when star comes on my meridian, let us say when star is here and that is the celestial meridian of a particular observer.

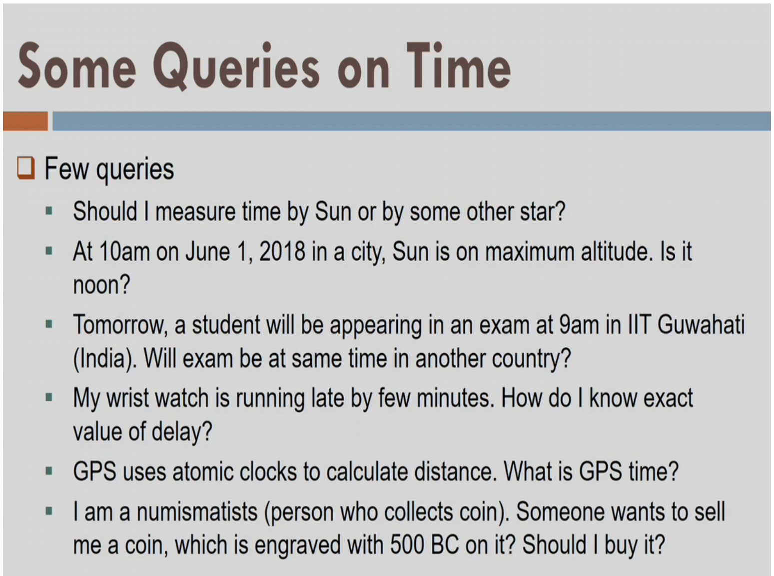
So, at this stage, if I measure the longitude of the observer, so this longitude is equal to this value right and it is nothing but the lambda star or reduced astronomical longitude. And as a result, you can see the relationship very clearly that right ascension is equivalent to the lambda star or the longitude of a place. So that means, if a star is on the celestial meridian of observer, I can write that the right ascension is equal to the longitude of the observer and as a result, we write this relationship here.

That means, hour angle of the Vernal Equinox minus hour angle of the star which you can see here, it is equal to the reduced astronomic longitude of the place and that is the idea; that means, when star is on the celestial meridian, I can write this relationship where this lambda star is representing the right ascension of the star. Remember, the same relationship we have written in the last lecture where we say that hour angle of Vernal Equinox is equal to hour angle of the star plus right ascension of the star, right.

Now, I am replacing this right ascension by the lambda and lambda is nothing but the longitude or reduced astronomic longitude of the place. And it is valid when star is on the celestial meridian right. I hope you got the concept that what is the connection between right ascension and the longitude or reduced astronomic longitude of a place. It helps us to measure the hour angle of the Vernal Equinox using a star observation.

And as we said that time measured with respect to the Vernal Equinox or the hour angle of the Vernal Equinox can be taken as a universal time because Vernal Equinox is a fixed point right and now we can define some kind of local time using celestial meridian or we can also define a global time using the hour angle of Vernal Equinox. And that is the key here to defined global time or local time. So, local time is defined with respect to a celestial meridian and global time is defined with respect to the Vernal Equinox and in most cases, we measure the hour angle.

(Refer Slide Time: 11:33)



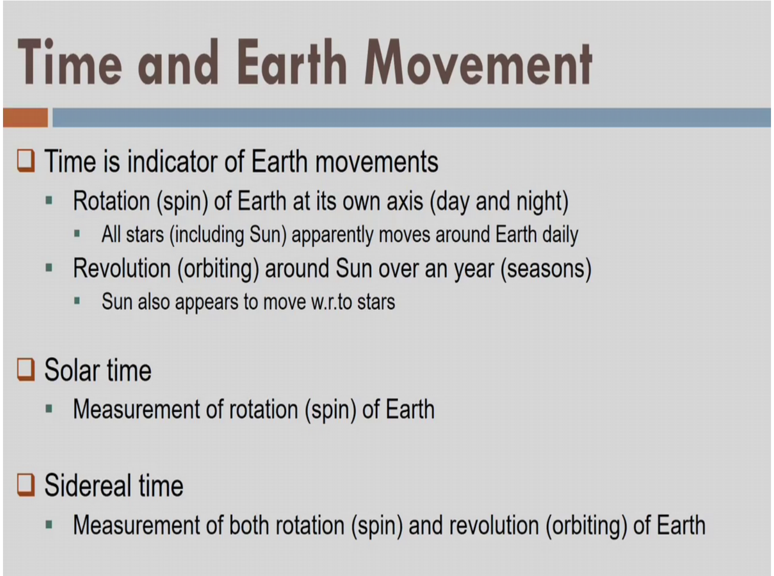
So, before we go into this lecture of time, let us put some queries and try to the responde to these quires by the end of the lecture. The first is, should I measure time by sun or by some other star. That is a good question; that means, there are many many stars in the sky, should I take sun or should I take some other star. Now, another question is on June first 2018 at tenth am in the morning, sun is on the maximum altitude at a place; for example, this place IIT Guwahati. So, should I say it is a noon for me or it is a noon or afternoon or it is a kind of mid noon. Can I say like that, I should say or should not let us look into this also into today's lecture.

Then we have student is going to appear tomorrow in exam. So, exam will be starting at 9 am, simple example is the gate examination that we conduct in all India as well as some other countries. So, the thing is that, exam should start at correct position of time or the correct epoch of time. Now since if exam is conducted in Singapur and Dubai as well, so, at what time we should conduct we will should start the question paper there. Is it not a little critical because we know that would wide this exam is conducted in few countries and the exam should start at one time. So, how can I coordinate between the three countries; that means, time should be same, the epoch should be same, but should be have same time?

Again, let us see my wrist watch or my mobile clock watch is little late let us say by few minutes 10 minutes, 12 minutes above one or two minutes. So, how can know the delay of my watch or how can know the reference time or the correct time? The moment I know the correct time, I can find the difference between the correct time and the my mobile time and that is the delay of my watch, ok. I want to find that also fine. You might have done some kind of work on GPS and you might be knowing from your mythic surveying that GPS uses the atomic clocks and it calculates the distance between GPS satellite and a receiver on the earth well. It uses the time difference of the two clocks; one is the receiver clock and atomic clock.

So, what is the GPS time? That is it a mobile time or is it some other time? So, and then finally, we have one more question and which is most interesting that suppose if I am a numismatist; that means, a person who has a hobby to collect the coins and few days back someone came to me and try to offer me a coin and rather he offered me purchase it and offer was that this coins is 500 BC old coin why because, something is written 500 BC on it, it is engraved on that coin. Should I purchase it. So, let us try to respond to these questions in this lecture.

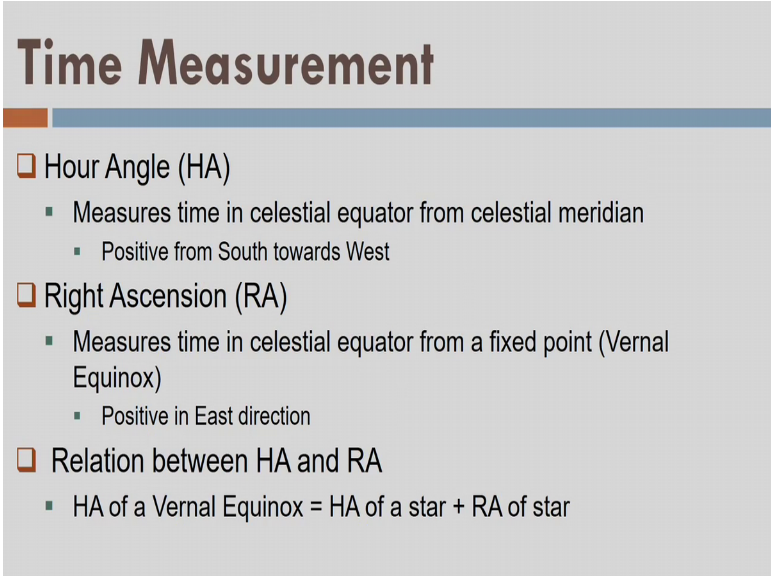
(Refer Slide Time: 14:35)



So, as I already told the time and the earth movement are synonym of each other; that means, as earth is rotating, time is passing. So, I can measure the time by measuring the rotation of earth and we have decided that since it is not possible to measure the rotation of earth, we have devised in another method; that means, I will assume that earth is stationary and the apparently moving stars around the earth you will measure those stars. By measuring the stars which are apparently moving, I can find out what was the time that is happening in the certain country or that is happening at certain place.

So, let us see how do I connect various countries across the planet by a single time. So, the idea is solar time. The solar time is nothing but the measurement of rotation or spin of earth around it is own access well, possible, ok. And there is another time we measure that is called Sidereal time. The Sidereal time considers not only the rotation, also considers the orbit of the earth around sun. So, in a day earth is slightly orbiting such that it will complete one cycle around the sun in one year right. So, there are two type of time we have define now. So, let us look one by one into that.

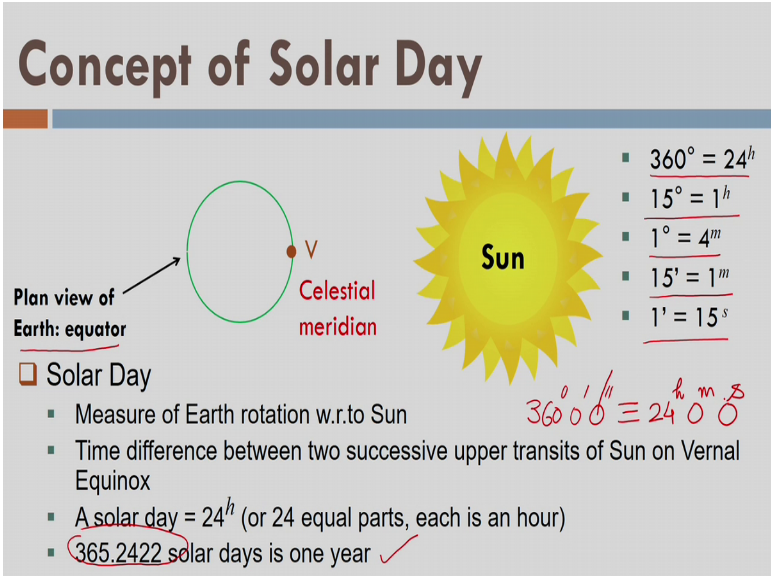
(Refer Slide Time: 15:58)



So, as we have also seen the time measurement is done by hour angle. Secondly, we have also saw in the last lecture what is the connection between right ascension and the hour angle and in this lecture, we have seen what is the connection between hour angle of two meridian; especially one is a reference meridian or the Greenwich meridian and one is the local meridian or celestial meridian of observer.

So, with this idea, we are proceeding now or let us look into the solar day, fine. Let us assume that there is a point on the equator and this point is represented here by V. V can be any point and it is shown by red dot. Now, let us say that earth is making one complete 360 degree rotation about it is own access. So, we are showing here the equator you see. So, plan view of a equator, in that equator there is a point.

(Refer Slide Time: 16:29)



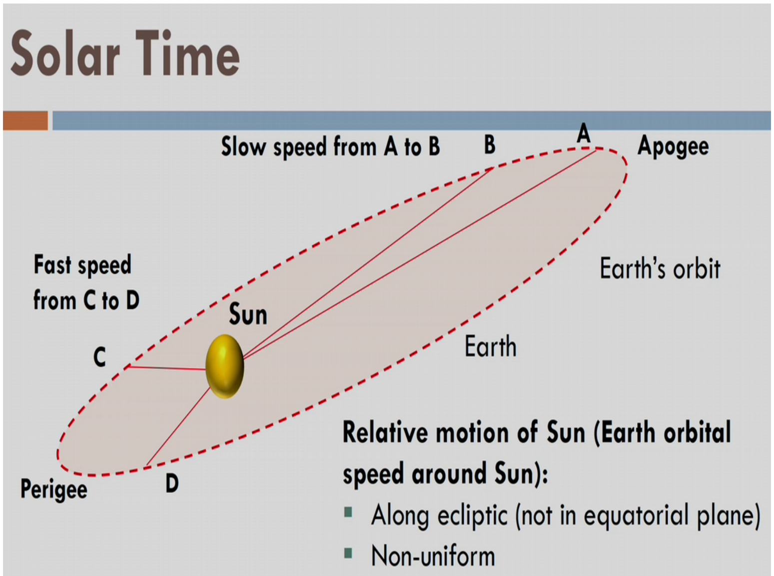
So, let us do this rotation like this. So, this rotation is 360 rotation and as a result of that now point has come backs to it is position V again. So, that is a 360 degree rotation or I call it 24 hour in the day. So, in this 24 hours, how can I make it or how can I measure it well as I told the movement of the star fine. Now, if I take sun as a star, I can easily do it and I will define that 360 degree rotation as 24 hours or a solar day. Now, I will divide the solar day into 24 equal parts and each part will contains 60 minutes.

Further, if I take one minute, each minute will take 60 equal parts each of the equal part of one minute is one second and now I can further divide it in nanosecond and so on. If I say that I measuring the hour angle and to represent the time so if I; measure the hour angle of the sun that is nothing but hour angle of the sun at a given celestial meridian. So, that will represent the time. But apart from that, we should also know some of the information here that the difference between two successive upper transits of sun on Vernal Equinox because the Vernal Equinox is also 6 point.

So, with respect to that 6 point, if I consider the transits at that meridian, I can also find some time and that time will be same as if I am finding out the time by the two successive transits of sun at celestial meridian or even it is applicable to you wherever you are staining right now. So, solar days has 24 equal parts and so, in one year we have so many solar days that is 365.24 22 solar days, but that has been measured by someone or by some instrument with this information if I divide the 360 degree in 24 hours, I will have 15 degree equal to 1 hour; 1 degree equal to 4 minute; 15 second equal to 1 minute and 1 second of rotation equal to 15 seconds of time.

Now, here you see there is a convention. When we equate the time that is in hour, minute in second to the degree minute and second of rotation, we have a custom to write hour, minute and second as a superscript; for example, I will write here let us say 360 degree 0 minute, 0 second is equivalent to 24 hours 0 minute and 0 second. So, I am writing this h, m and s as a superscript not as a ordinary text, be careful on this notation.

(Refer Slide Time: 19:50)

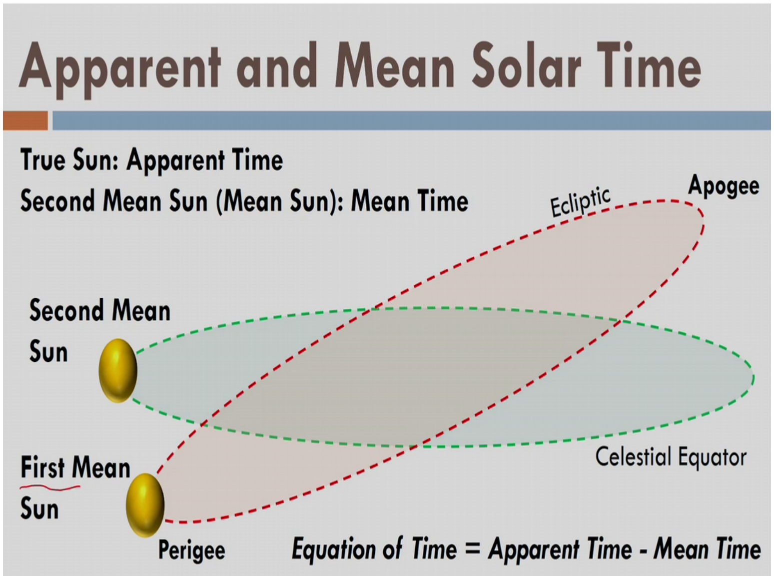


Now, what about the solar time as we talked that one complete 360 degree rotation of a point of the earth is there, but what about one year because every year is consist of 365 days and similar to that number. So, let us see what is the problem or what is the solar time in a year. So, it is earth orbit what we call as ecliptic or we already said ecliptic is a relative motion of the sun with respect to earth. So in fact, earth orbit itself is a elliptical part or it is a ecliptic around the sun.

So, now that is apogee and perigee. So, if you can see that these two point A and B. So, earth will be moving very slow from A to B as per the Kepler's law. So, this is point C and D since earth is very close to sun here. So, it will be moving very fast and so, the relative motion of sun with respect to earth is along the ecliptic and not in the equatorial plane. Remember, we call that hour angle we are measuring the equatorial plane. So, now, that is the problem here. Sun is moving relative to earth in ecliptic, also it is non uniform. Non uniform means let us say this is the earth and earth is moving with this is speed from this point to let us say A, from A to B you see it is moving very very slow as shown in the animation like this.

Now, earth is not going to stop here it will further move and it is now moving little slight faster ok. Let us say it comes to point C and from C to D, it would be much faster like this and then again on the same path, on the same speed what is it is started this in the animation. So, that is the idea here that the speed of the earth in the ecliptic is non uniform; because of this non uniformity, if I want to measure the solar day or the solar year, what should I do. Let us develop some kind of concept here.

(Refer Slide Time: 22:11)



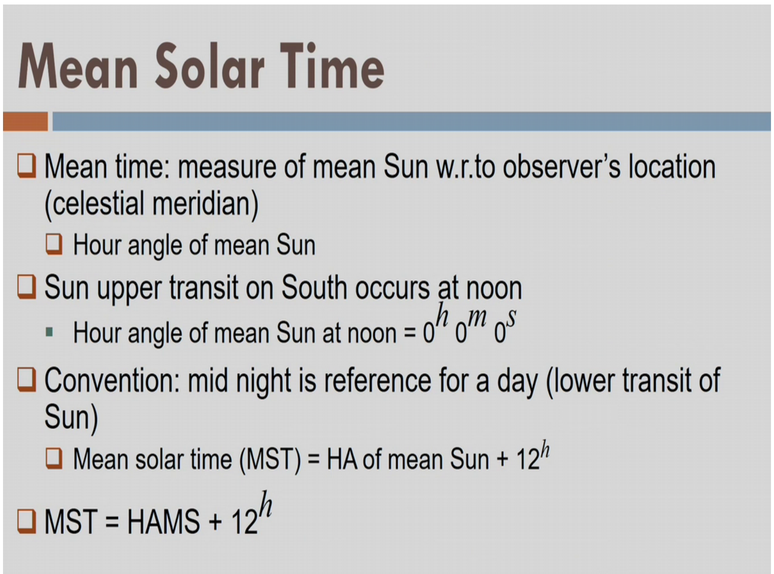
Let us see this is the ecliptic shown here, the path of the sun and we know that now sun is relatively moving with respect to earth in a non uniform fashion. And so, let us see if I assume mean sun that is called a first mean sun and which is a fictitious sun frictional body, this fictitious sun is moving at a uniform speed in ecliptic ok. So, what is deal here? I want to make this fictitious sun or first mean sun as if it is moving a uniform rate, but it is going to come at the same time or after one orbit; that means, if is start from this position after one year it will come back in the same position. So, it is coming with the true sun at the same time why because it is moving in the uniform rate or uniform speed, but still it is moving in a such a uniform speed that it is coming back with the sun the true sun at the same time after one year.

Now, we have resolve half of the problem; that means, we have assume that there is a mean sun, but still it is moving in the ecliptic. So, now, move consider another mean sun that is called second mean sun and which is moving again at the uniform rate and it is also matching with the true sun, but it is moving in celestial equator and now I can use the second mean sun in order to measure the time because now it is moving in the plane of celestial equator right. So, that is a simple concept for the solar time.

Now, I am dividing this complete movement of second mean sun in the celestial equator in 365.2422 days. Now, making the uniform days making the uniform time and now I am measuring the solar time or solar day or solar year. So, we are very sure that the second mean sun will also come with the true sun after one year at the same place in the celestial orbit and that is nothing but the celestial equator.

So, now I defines two terms; one is true sun and I measure the apparent time. If I measure the true sun that is the hour angle of true sun is apparent time and hour angle of the second mean sun is mean time because second mean sun is moving on the celestial equator with the mean speed or uniform speed. So, I have a mean time. Then we have equation of time that is the difference between movement of true sun and movement of mean sun. So, when I want to measure the apparent time or the true time, I will use the equation of time and I will apply to the mean time, I will calculate the apparent time. That is the idea here.

(Refer Slide Time: 25:03)



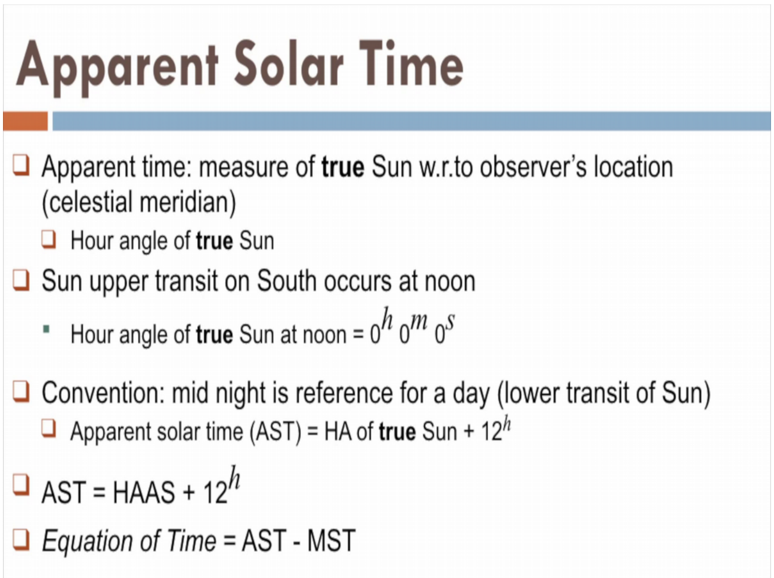
Now, what is a mean time? So, it is a measure of mean sun that is second mean sun remember with respect to observers location seen we are measuring the hour angle with respect to celestial meridian which is observers location. Now, I am measuring the hour angle of mean sun or we second mean sun in the plane of equator is it not very simple.

So, now let us think that sun is transiting or sun is doing calumniation 2 times a day; the upper transit and the lower transit. Now, upper transit as you know that it is near to zenith of an observer. So, that is occurring at the in the afternoon; that means, when it is exactly at the astronomic south of a observers meridian or of the celestial meridian of observer, I will say that is my 0 0 hours that because I can see the sun. Now, we call the time as afternoon or local afternoon. Traditionally, we believe that the day starts in the night. So, what do we in order to measure the time locally, we add 12 after that because we are our day starting in the midnight.

So, I can write that the mean solar time MST is nothing but hour angle of mean sun plus 12 hour and in short, in the formula basis I write like this ok. So, we understand what is the mean time or the mean solar time. Now, I can attach this mean solar time to different different locations and I can find out the time for India, the mean solar time for India, for America, for Greenwich and so on.

Similarly, if I attach the apparent time with India, then it will apparent time in India or apparent time in Guwahati or apparent time in London and so on or apparent time at Greenwich meridian; that means, I measuring hour angle of the mean sun or apparent sun from the celestial meridian. So, the way I fix the celestial meridian according to the place, I can find out the local time at that place and that is simple key ok. So, now what is the apparent solar time, again as I told I already given you lot of hints.

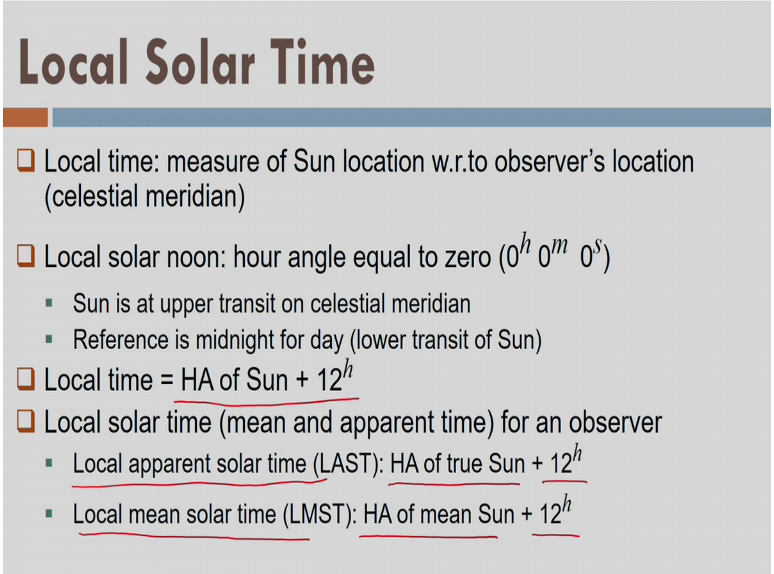
(Refer Slide Time: 27:14)



You can make it out. So, the mean time or the measure of true sun with respect to observers location or celestial meridian. So, that will be a local apparent time ok. We will see: what is the local and what is global time in coming slides, wait for few minutes ok. Now, similarly, the sun upper transit on south that is a astronomic south of celestial meridian occurs at afternoon. So, the hour angle of true sun at noon will be equal to 0 hours this time.

Now, again we have the convention, I am repeating the same thing that let us add 12 hours to the apparent time. So, I will have apparent time or apparent solar time with respect to a celestial meridian of a observer. So, I hope that is things are clear. So, we have this formula now, apparent solar time is hour angle of apparent sun plus 12 hours and then, as we told that equation of time is connecting apparent solar time and mean solar time.

(Refer Slide Time: 28:15)

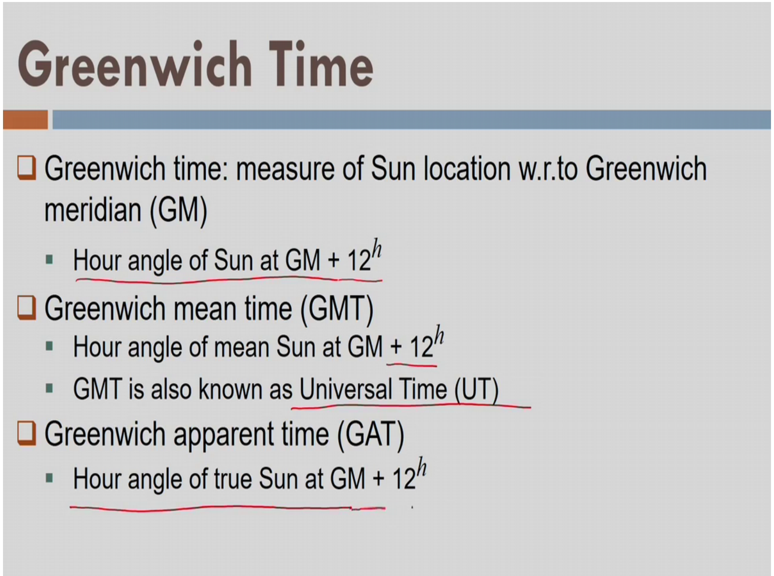


Now, I am defining the time according to a local location or local observer. Let us call that local solar time. So, what is the local solar time? What is the local time here at now or what is the local solar time at your meridian or at your celestial meridian or at your observer's location. Let us make the things very very crystal clear and simple ok. So, local time is the measure of sun location again as we are talking about. Sun it could be mean sun, it could be apparent sun. So, depends which sun we take. So, we can define mean time or local mean time, local mean solar time, local apparent solar time something like that

So, now we have the measure of sun location with respect to observer's location ok. So, local solar noon again at 0 hours 0 minute and 0 seconds when sun is on the south or astronomic south or it is doing the upper transit because that upper transit is near to the zenith and we know that on the horizon with respect to celestial horizon that upper transit occurs at the south ok. So, again we take the 0 hours at midnight or the lower transit of the sun which is which occurs bellow the horizon because we have tradition of midnight, the day started midnight 12 am or 00 am in midnight ok.

So, now we have the local solar time has HA of the sun and plus 12 hours. So, local solar time is I can define as a mean and apparent time. So, I can define two terms; local apparent solar time like this which is hour angle of true sun plus 12 hours and local mean solar time as hour angle of mean sun plus 12 hour idea is very very simple one way we are going for apparent time and the mean time and another way we are going for local time and global time and we are making two combinations or other two combination of the two options each.

(Refer Slide Time: 30:23)

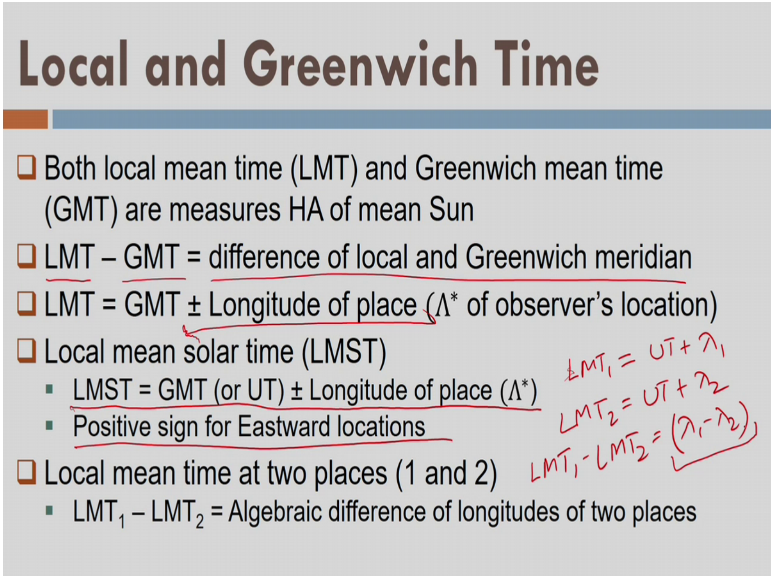


So, now what is Greenwich time? So far, we have defined the time with respect to the local meridian or the celestial meridian of observer. Now, we have Greenwich time, ok. Let us fix the Greenwich meridian somewhere on the planet earth and if I measure the hour angle of sun could be mean sun or apparent sun, then I will say that that is the Greenwich time; that means, the hour angle of sun with respect to Greenwich meridian. So, measure of the sun location with respect to Greenwich meridian is right, then hour angle sun at Greenwich is nothing but will add again 12 hours because to start day and midnight, ok.

One thing I would like to say here; we have two concepts also, one is called civil time and one is called astronomic time. So, civil time or the civil day starts at midnight, but astronomic day starts in the noon. The mid noon, so the moment I am add 12 hours and we are talking about the civil time, if I do not add 12 hours to the hour angle of sun and sun is on the transit, then it will be a as you noon, it is a mid noon or the astronomic noon also, we call it astronomic noon also or other the start of the astronomic day. So, if you remember the this is the civil time and there is a astronomic time. So, if you reduce 12 hours from the civil time, you will get the astronomic time.

So, again come back. So, Greenwich mean time what we call is hour angel of mean sun right and then add 12 hours that. So, GMT or the Greenwich mean time is also known as universal time or UT. We will see into that also, what is exactly meant by UT or universal time. Now, I can also define the Greenwich apparent time GAT and I can write hour angle of the upper true sun at Greenwich meridian plus 12 hours.

(Refer Slide Time: 32:32)



So, what is the difference between a local and Greenwich time? The Greenwich time is measured with respect to a certain meridian call Greenwich meridian and the local time is measured as hour angle of sun with respect to a local meridian or a celestial meridian of an observer. Since observer's location is changing on the earth, local time is keep on changing according to the location of observer or according to the change in the celestial meridian according to observer well, that is key here ok. We have already talked about this thing before in the first slide of this lecture. The relationship between the hour angle of the Vernal Equinox and the hour angle of the star and we said that it is nothing but equal to the longitude of the observer. We have shown it also.

So, if I want to do local mean time and Greenwich time are measure of the hour angle of means sun ok. So, local time is measured with respect to celestial meridian of observer, but Greenwich mean time is the hour angle of mean sun with respect to the Greenwich meridian, that is the only difference and the difference between the two meridian the Greenwich meridian and the local meridian or the observer's meridian is nothing but the difference of longitude. Remember, we stared measuring the longitude with respect to Greenwich meridian and hence that is a difference between the two meridian that is GMT, 0 degree longitude and some observer's location is lambda star. So, this is the difference.

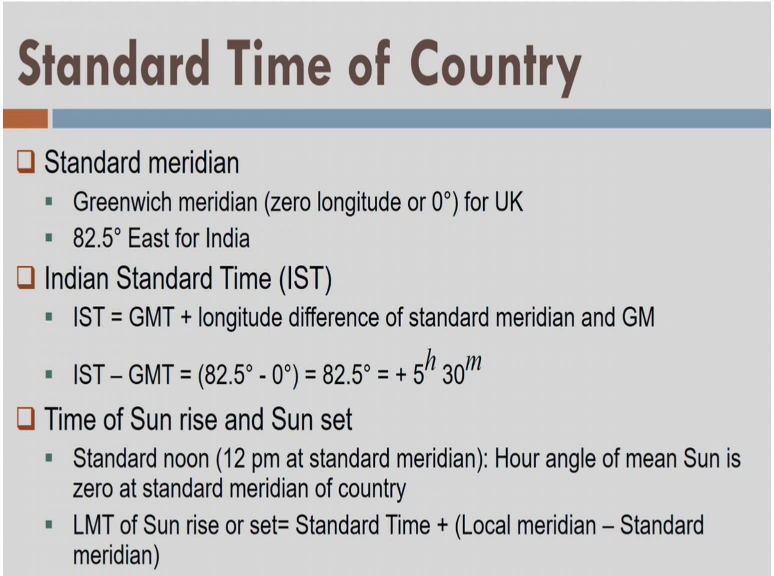
So, now I can connect the time with lambda or the longitude of the place and that is the key here ok. So, I can write that LMT minus GMT is nothing but difference of the local and Greenwich meridian and what is nothing but the difference of longitude. So, I am writing plus and minus longitude of the place remember the positive longitude are taken eastward and negative look longitudes are taken westward of the Greenwich meridian that is means for India which is in the eastern side of the Greenwich meridian will have positive time correction with respect to Greenwich mean time and similarly the America country will have a negative type correction.

So, what is the meaning here? Suppose, this is 11 o' clock on the Greenwich mean time. So, the time in America or any other western country with respect to Greenwich meridian will be lagging and the countries like Japan, India which are on the eastern side of Greenwich meridian will be ahead of time ok, not in terms of technology, but in terms of solar motion. So, that is the idea here. So, if you read it now that ok, we will talk about this correction later, but there is a correction of time of 5 hours and 30 minutes for India, why do we do it? Let us talk in the coming slides ok.

So, now we have the local mean solar time is nothing but the GMT or UT plus minus longitude of the place. So, since we are taking positive longitude on the eastern side, I will have positive sign for my local mean time or the local mean solar time. Now, I want to do the difference of two local meridian and I want to find out what is the difference of two local solar time at different different meridians.

So, what can I do? If you write this equation for example, like this LMT 1 equal to UT plus let us say lambda 1 and LMT 2 equals to UT plus lambda 2 and now, if I make it LMT 1 minus LMT 1 minus LMT 2 it is nothing but lambda 1 minus lambda 2. So, it is nothing but the difference of longitude of two places is equal to the difference of local mean time or local mean solar time of two places. That is written here like this.

(Refer Slide Time: 36:48)



Let us go ahead, what is the standard time of country? Now, as we talked about the local mean time or local mean solar time at my meridian or at my longitude, I will have different local time ok. Now, at your place you have the meridian passing through your place and longitude also you know the value. So, you will have a different time. So, how can I coordinate because there are many many events in a country that are very very coordinated.

For example, the examinations GATE examinations, J examination or any exam of UPSC or any public service commission in country. They start at exactly some time for example, 9 am in the morning and they will finished exactly at 12 pm after 3 hours. So, I need a standard time for a country and hence we define a particular longitude as a standard meridian for the whole country and for our country, it is 82.5 degrees longitude is what and this meridian pass through place called Dehradun which is the capital of Uttaranchal state in India.

Now, when sun is at that meridian of 82.5 degrees exactly overhead at the south, we call it the noon or the standard noon for the whole country. So, now, we are responding to the one simple. Why in Guwahati which is on the eastern side of the Dehradun, I have the maximum altitude or the sun comes in the south direction at 10 o' clock not a 12 o' clock because it is time m when sun comes in Guwahati in the south or the upper transit. So, that is the time when it is at the 10 am Dehradun right. So, similarly, when there is a 12 pm in the day time, so it will be exactly the 12 pm at that meridian, but still because we need a standard time and that is why we use the standard meridian or the time with respect to that meridian, we call it Indian standard time or for any country this is true. So, each and every country fix their meridian the standard meridian and then they find their own standard time; for example, America has it is own standard time, United Kingdom has it is own standard time, Japan has it is own standard time according to the longitude passing through certain place in their country and which meridian they declare as a standard meridian well. So, that is the idea here.

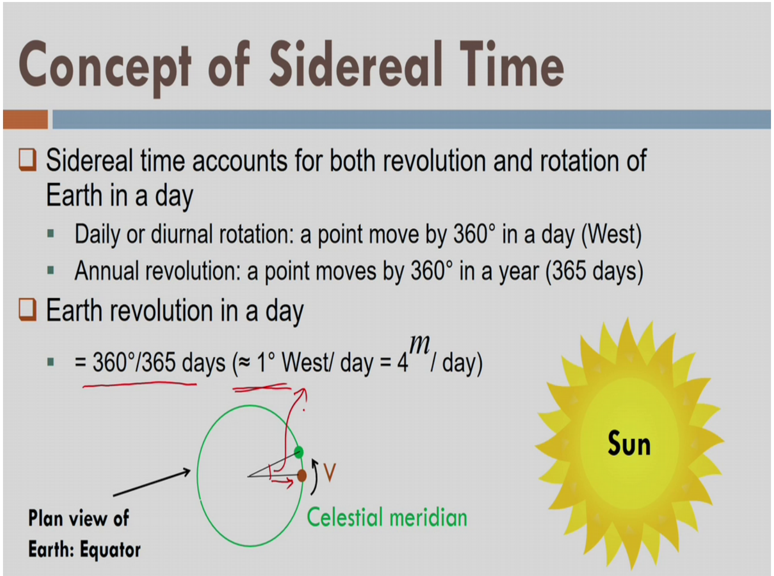
Now, if I take the 82.5 degrees as my standard meridian then, you can find out what is the difference between in Indian standard time and GMT and if you convert this 82.5 degrees in hour minute and second, you will get a correction of positive 5 hours and 30 minutes and perhaps that is written in your mobile when you stole your mobile for the first time. So, at the time, you will feel there is a time that is called New Delhi, Chennai, Kolkata and Mumbai and in bracket plus 5 hour 30 minutes and that is nothing but you know setting up your time with respect to the Greenwich mean time because mobile device or any device which is manufacturing by a company like Apple or may be Nokia or may be some other company for name sake.

So, with respect to GMT, you will put a correction of certain country. So, even the same device can be used in any of the country. The movement I fix the time or the fixed time zone of that country, it will start giving the time of that country. So, that is a very simple idea and in this process I have been responding to your questions. I hope you are getting the correct answers or try to revisit that particular slide of queries which we raised at the start of this lecture and try to rethink on those whether I am responding to you or not properly and if you feel try to develop your own questions or own queries and try to respond. So, you may raise any queries and it could be similar query it could be completely different query, but with this lecture the knowledge we are sharing, you can respond to each and every question

Now, time of sun rise and sun set as I told that at 12 pm of the country time for India, there is a sun at the upper transit at place Dehradun, not all the places ok. So, at 82.5 degree, sun is on the upper transit fine and that is what we call this standard noon of the country. Similarly, at 82.5 degrees celestial meridian if sun is on lower transit, we call it the midnight at 12 am or the 00 am.

Now, if I want to find out the local mean time with respect to the standard time of country not with respect to GMT, then I will use this simple logic that the standard time plus this longitude difference of the local meridian and standard meridian. If I take that delta lambda here within the country, I can find out the local mean time; that means, at 10 am in morning if I want to find out what is a local mean time, I should take a difference of the longitude of this place where I am standing and the 82.5 degrees, convert that difference to equivalent time and add to the or subtract to the standard time and I will get the correct local time at this place. That is the idea here ok.

(Refer Slide Time: 42:30)



Now, coming to the concept of Sidereal time ok, this time is also called sidereal time sidereal time, but I would like to call it side real time because it is combination of two words side and real. So, call it is my personal preference to call it sidereal time. What is the concept of sidereal time? The idea is very simple. If you see during one complete rotation of a point by 360 degrees on the equator earth also orbits slightly since it is moving in one year by complete one rotation.

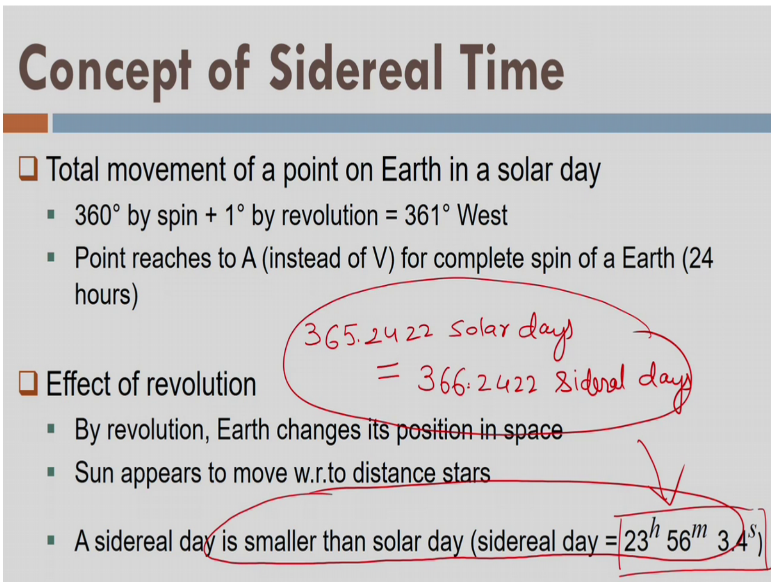
So, it is moving slightly in one day and if I consider that orbit time or the orbit rotation in one day, then I will see that sidereal time is little ahead or other a point which should come after 360 degree rotation it is coming little early because during that 24 hours that point is further pushed by the orbiting of the earth in one day. So, that is the idea here.

So, let us look into animation. So, this is the point green point is moving, but now instead of reaching to red point, it is reaching to little ahead because during that 24 hours earth has also orbited a bit such that it will be during it is complete orbit around sun in one year. So, I can see that since earth is completing 360 degree rotation one more additional rotation in 365 days around the sun. So, I can say it is approximately 1 degree, additional rotation happening within 24 hours of solar hours or solar day.

So, in one solar day, I can see this slight additional movement of the rotation of earth because of the orbiting and that is the concept of sidereal time that we say that sidereal time is the time which is from same point to the same point considering both rotation as well as the revolution or the orbiting of earth in 1 day, not in 1 year. So, I am considering the complete rotation within one day as well as the orbiting of one day of earth. So, that addition of these two things will give me a time which is little earlier or rather I say that point which is started here will come little earlier than solar day and that is sidereal days ok.

So, let us go ahead. So, that is a movement here and now this is the additional movement I should subtract from the solar day to calculate sidereal day and this angle is approximately as I wrote here, it is almost 1 degree per day. So, it is nothing, but the time of 4 minutes per day fine ok.

(Refer Slide Time: 45:17)

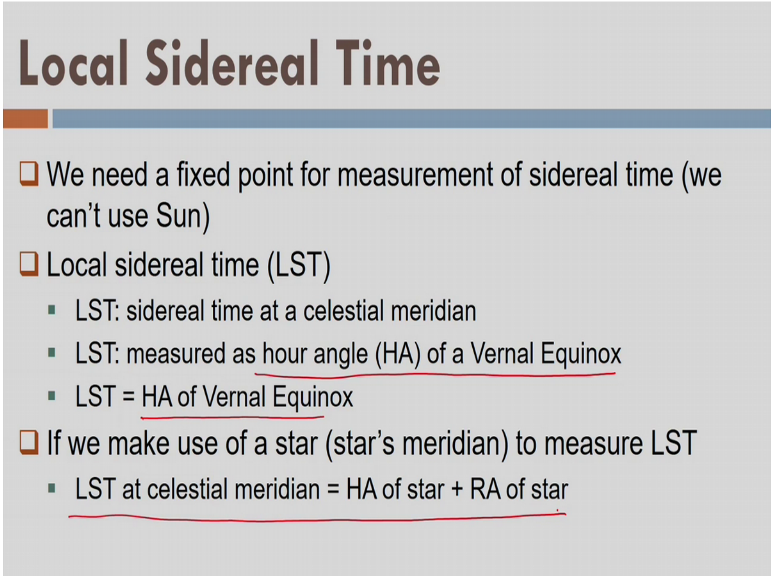


Now, the sidereal time is the total movement of point of earth in a solar day considering both orbiting as well as rotation that what is the importance of sidereal time. So, if you are sitting at a star which are far away from the earth and that star is appearing fix because it is far away. So, now, if you see from that star to sun and the earth together what will happen? There is a sun and there is a earth here, now there is a rotation no problem, but the movement earth orbiting in a year, you will see that it vector between the earth and sun is changing and that is visible from that star if you are setting on that star and that is a concept here.

Now, if I assume that earth is stationary or if you are setting at that star and assume that earth is stationary, what will happen; sun will start appearing to you as a moving. And hence, this concept of sidereal times comes into picture or not only that suppose if you are on a satellite station in the space, you will feel the same thing. Why? Because, at the time it is more important to understand complete one rotation of earth rather than rotation of the one point around the sun or around this own access.

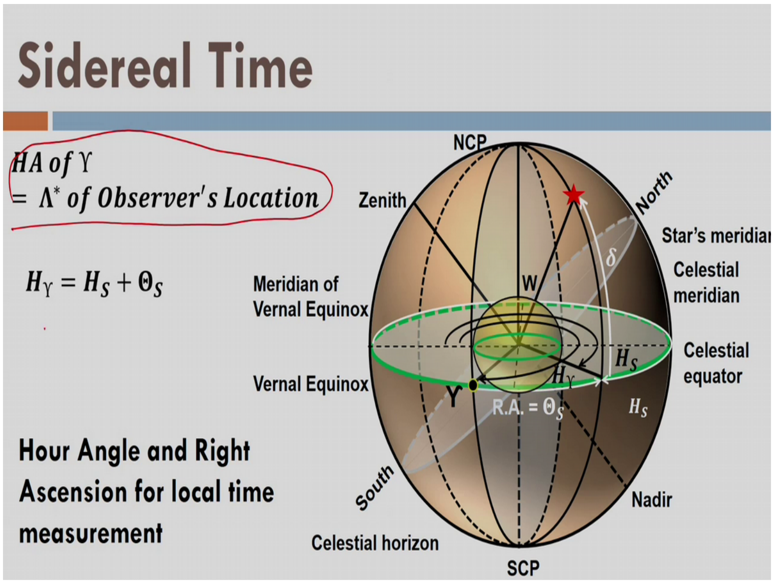
A sidereal time as a result is small than the solar day as I told by almost 4 minutes time. So, exact time is this much 23 hours 56 minutes and 3.4 seconds. The simple calculation I will tell you here let us see the 365.2422 solar days equal to 366 and that is because one additional rotation by the orbiting; that means, a point which is here after one rotation, it is coming everyday, but after one orbiting around the sun, again it will come at the same place facing the sun. So, I can add one more day here or one more rotation here. So, I can write this equation and from this equation, you can find this figure. So, one solar day that is 24 hour is equal to how many sidereal days; that is the idea here ok.

(Refer Slide Time: 47:30)



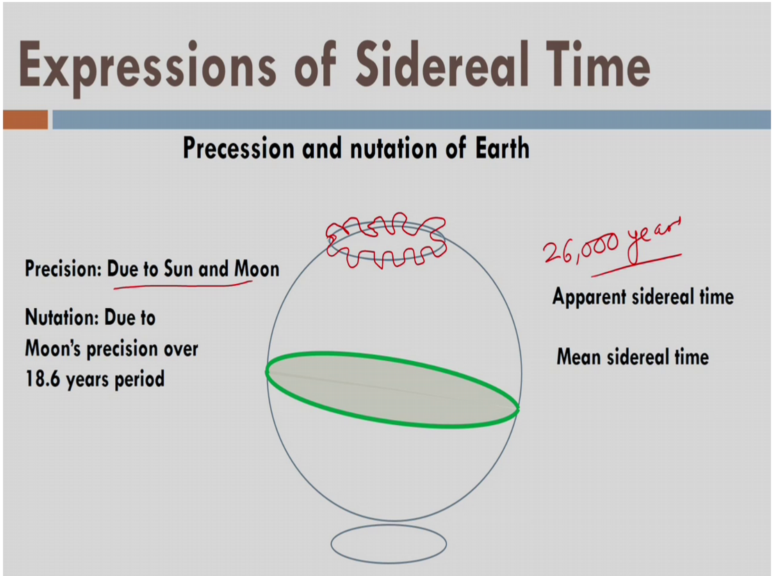
So, now we have local time, Greenwich time, I can define local sidereal time and that is we need a fixed point for measurement local sidereal time is LST and sidereal time at a celestial meridian is nothing but hour angle of a Vernal Equinox. You remember the Vernal Equinox is a point we said it is stationary, but in fact, because of the orbiting of the earth around sun that will be moving slightly and we will see in the coming slides why. Now, we have the LST as hour angle of the Vernal Equinox if we make use stars meridian, than in the last lecture we say that hour angle of star and RA of star will give me the local sidereal time at celestial meridian, ok.

(Refer Slide Time: 48:19)



So, what is hour angel and right ascension? Let us look into this thing again. Now, I am defining the Vernal Equinox here and that is the stars meridian and now these are declination ok. So, this is the right ascension here and this is the hour angle of star and that is hour angel of the star and that is the hour angle of Vernal Equinox. So, idea here is that right ascension is equivalent of longitude for the star, not for the place, right. So, we wrote this equation here before and now if I connect the RA of the star and hour angle of the star, I can wrote another equation that I shown in the last slide. So, that was the idea here fine.

(Refer Slide Time: 49:11)



Now, in order to consider the sidereal time, we have to understand precession and nutation of the earth. So, what is the precession? Sun and moon put gravitational or attraction force on the earth and as a result, the access or the rotational access of earth it moves in certain fashion. As I told initially also and that is called the wobbling fact and wobbling consist of two facts precession and nutation. So, let us see this is the access and it is making rotation in a elliptical path right and that elliptical path takes almost 26 thousand years of time and it is because of the gravitation forces excited by moon and sun together.

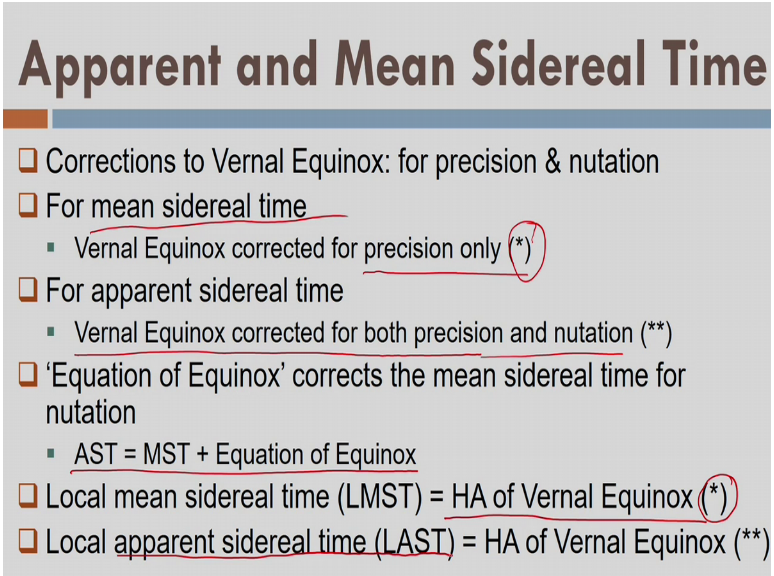
Now, so this is the path here elliptical path of the rotation of access of earth ok. If I consider the motion of the moon or other the moon also exert force on that and because the precession created by the moon itself has a shorter period of 19 years. So, that creates an additional force and as a result if I look at the real motion is the I call it nutation or precession now, the precession is combinedly by sun and moon and again the additional effect created by the moon because it is closer to the earth as well as it itself precise and as a result, it create some kind of different effect and that is called nutation.

So, if I take the combined effect of precession and nutation that will be the real part of the earth will be list around like this over the period of 26 thousand years like this. This is sinusoidal motion and that is that takes period of 26 thousand years. So, because of this the location of the Vernal Equinox also changes. You see that rotation access of the earth is like that and as a result, equator itself is changing.

So, the intersection of equator the celestial equator and the ecliptic is also changing slight here and there, every year or every movement, every second, but we should consider that also to define the Vernal Equinox. The movement we consider these and we take some kind of mean we say that mean Vernal Equinox and then we define the Greenwich meridian passing through that mean location of Vernal Equinox and that is why we see that we should take Greenwich meridian to measure the time.

Now, one more information that now the says this 0 degree longitude which is an average location of the Vernal Equinox, it is no more passing through the Greenwich place in England. So, still we are using the same term Greenwich meridian again and again, but you should consider this thing ok. So, now we have apparent sidereal time and we have mean sidereal time.

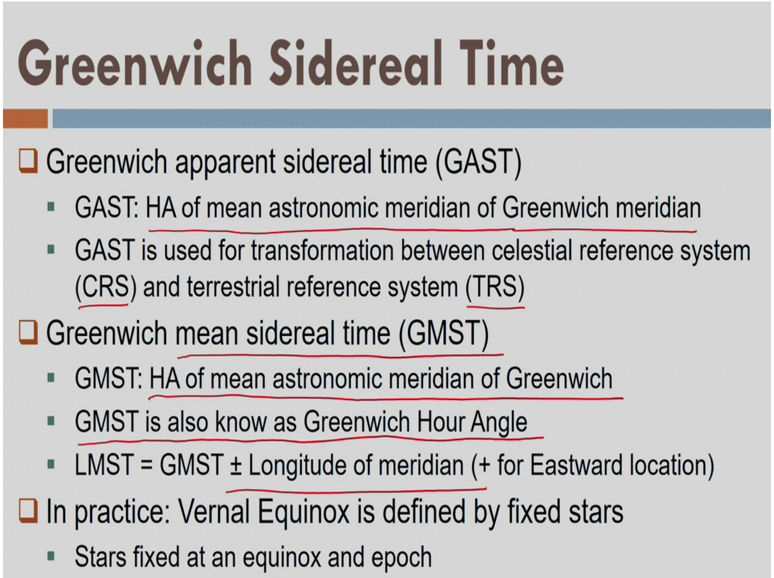
(Refer Slide Time: 52:07)



So, apparent and mean sidereal time is if I put corrections to Vernal Equinox for precession and nutation both, then I call it the apparent time and now we have mean sidereal time; that means, if I correct the time only for precessions and putting the star here you see ok. So, apparent sidereal time, I correct the Vernal Equinox for both precession and nutation; that means, the hour angle of Vernal Equinox with respect to celestial of meridian. So, I am putting both correction precession and nutation, then I call it apparent sidereal time. So, again I connect the apparent sidereal time and mean solar time with equation of equinox by this, right.

Now, I have local mean sidereal time which is hour angle of Vernal Equinox that is considering only precession and I have local apparent sidereal time; that means, I am correcting the hour angel of Vernal Equinox for both precession and nutation. Now, you can understand the difference between apparent sidereal time and mean sidereal time ok. So, now define the Greenwich sidereal time. It is the hour angle Vernal Equinox with respect to the Greenwich meridian, is it? That is it.

(Refer Slide Time: 53:24)

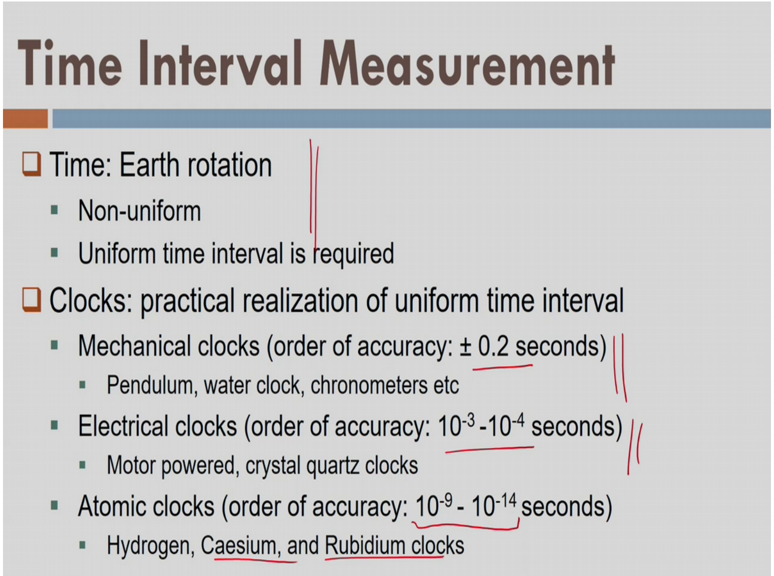


So, what is the GAST? Greenwich apparent sidereal time, it is hour angle of the mean astronomic meridian of Greenwich meridian right. Again, as I told it is a mean, so, I am correcting that hour angle by only precession and not nutation and if I correct it for the both precession and nutation, then it is called apparent time and if I correct it only for precession, it is called mean time. So, for apparent time GAST and correcting the hour angle by both precession and nutation. Similarly, I use this GAST for the developing the correction between CRS and CRS. I will explain in the next lecture, what is that.

Now, Greenwich mean sidereal time; that means, I am correcting the hour angle of mean astronomic meridian only by precession. Further we call the Greenwich mean sidereal time as a Greenwich hour angle ok. So, what is the local mean sidereal time if you going to find out at your local celestial meridian. Just put correction of longitude, same way we did for the solar time. Idea is same.

In practice, now coming question is that what about the Vernal Equinox. We decide the location of Vernal Equinox with respect to some fixed stars because we say that from the fixed stars I can fix the location of Vernal Equinox right because earth itself is moving there by precession and nutation and the Vernal Equinox is moving. So, better to fix the Vernal Equinox with respect to the far star which are not moving with respect to the earth. That is the idea here.

(Refer Slide Time: 55:07)

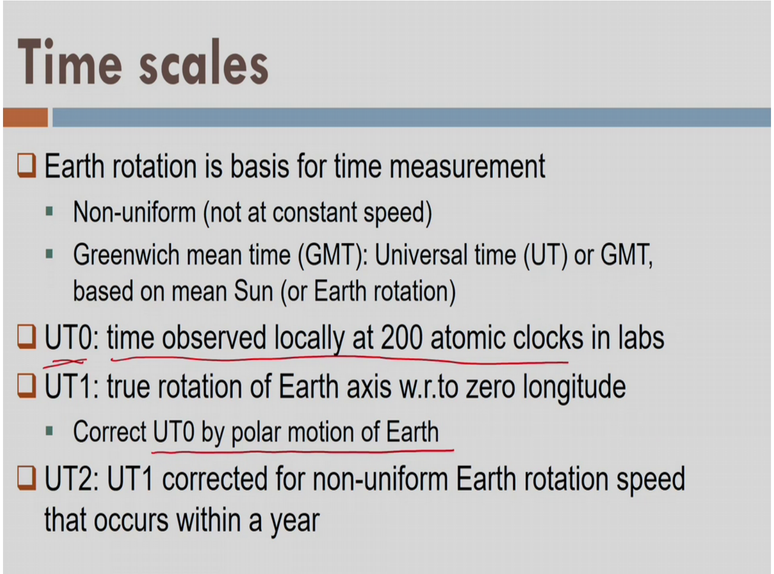


So, then we fix and that is why the astronomic comes into picture, when we fix the location of Vernal Equinox on the celestial equator. Now, coming to the time interval measurement; we has seen already time measurement by the earth rotation, but we know that it is non uniform, but we need a uniform time interval and as a result, we have clocks now in the picture. So, clocks create some time interval at regular fashion, one second, one second, one second or one hour, one hour, one hour or one minute, one minute, one minute and so on right.

So, they tick or they click on at consistence intervals and that is why we use clocks right because earth rotation cannot be used unless we put lot many corrections. So, let us some other device called clock. So, we have some kind of mechanical clocks, they were used in past back, then we have electrical clocks they have different accuracies you can see here. And then, today we have atomic clocks also which you are invented almost 1955 or 1960's and 19 we can 1950's, it where they were invented and once never invented.

Now, we have achieved an accuracy of 10 raised to power minus 14 seconds and they were made up of Hydrogen, Caesium and Rubidium and now we have 200 such clocks on the planet earth, they are measuring the time consistently very regularly not only that, they can be used to measure the rotation of the earth also and that is the idea we need a higher accuracy clocks to measure the rotation of the earth. So, we have different different time scales now.

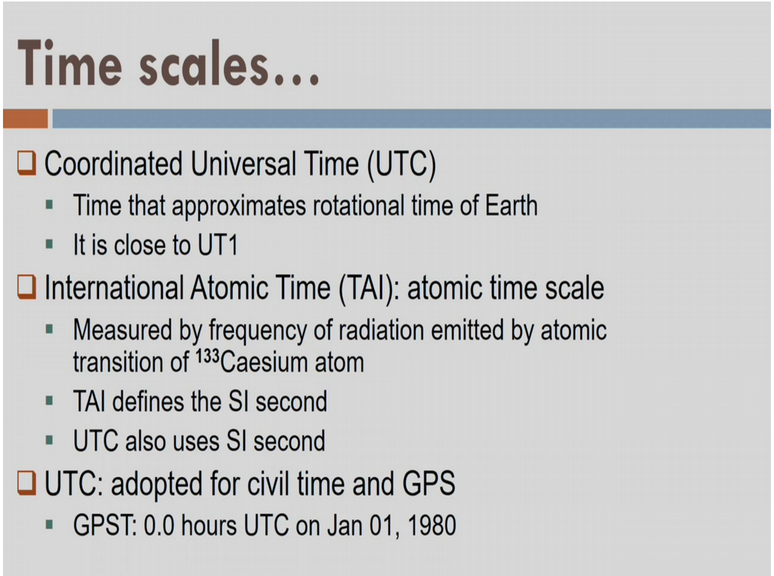
(Refer Slide Time: 56:43)



So, we have first time scale is the earth rotation right, but we see that it is non uniform also, then we defined Greenwich mean time for that universal time GMT based on the mean sun. Now, they something called universal time that is we called GMT ok. So, if I observe the time with this 200 clocks, it is called UT 0 and then, if I consider the two rotation of earth with respect to 0 longitude and if I correct the UT 0 by polar motion of earth, what is polar motion, that is a different and that motion is the rotation access of the earth itself move with respect to crust of the earth in almost 435 degrees in a year and that is called the polar wondering or polar motion of the earth.

So, if I correct UT 0 by polar motion of the rotation access, I call it UT 1. Further, then if I correct UT 1 by the non uniform earth rotation speed, then it is called UT 2 coming to the UTC what is called

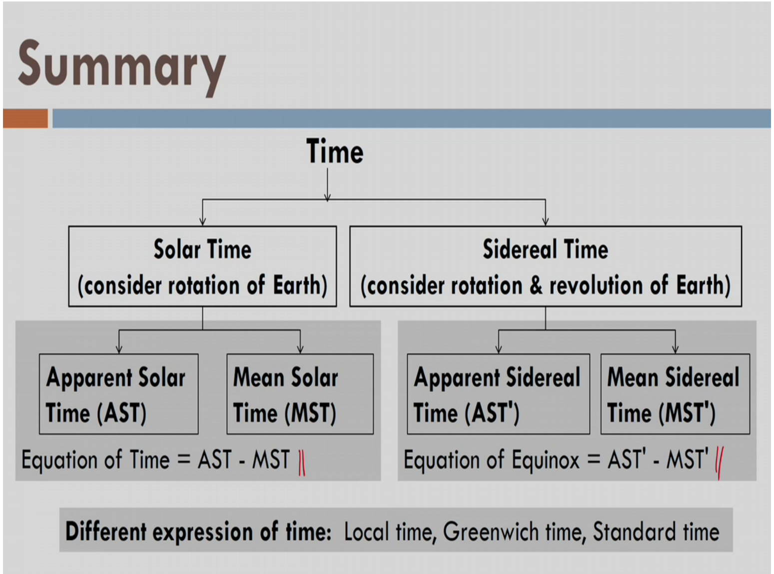
(Refer Slide Time: 57:43)



Coordinated universal time and this UTC, it is very close to the UT 1 and then, it is basically approximating the rotational speed or rotational time of the earth exactly it is trying to match and that is why it is very close to UT 1. Now, we have international atomic time which is the atomic time scale and there we use the frequency of radiation of atomic transition of 133 Caesium atom and we define one second with respect to that, not with respect to the earth rotation. Earlier it was done like that, but now we have more precise time scale like atomic time. So, we define that second with that and UTC itself though we have divide form UT UT 0 UT 1 UT 2 UTC, but UTC also using the SI second.

So, UTC is today adopted by the civil time as well as GPS I think I have respond it to your query like what happens to GPS time which time is GPS time. So, GPS time is nothing but the UPC. And on January 1980, 0 hours of UTC has taken as the reference time of the GPS. So, now I am summarizing the whole lecture.

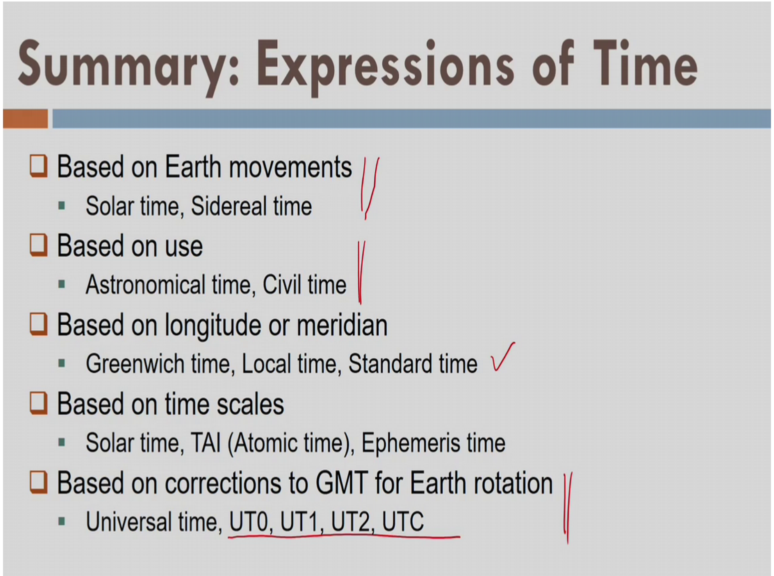
(Refer Slide Time: 59:05)



Time is represented by two ways; solar time and sidereal time. In solar time, we consider only the rotation motion of the earth while in case of sidereal time; we consider both orbiting as well as rotation of earth. And then, we define 2 days; sidereal days and solar days like that. Further, we have devise the time into apparent solar time and mean solar time with respect to the reference or with respect to the corrections. Apparent is for real, mean is for the mean or the average location of sun or average location of Vernal Equinox.

So, we have apparent sidereal time for two location of Vernal Equinox and we have mean sidereal time for the average location of Vernal Equinox. Similarly, we have apparent solar time for the true location of sun and we have mean solar time for the mean location of the sun or the second mean sun. Then, we have equation of time that connects solar time and means apparent solar time and mean solar time. We have equation of equinox that connects apparent sidereal time and mean sidereal time. Finally, we have different expression of time like local time, Greenwich time and standard time of a country.

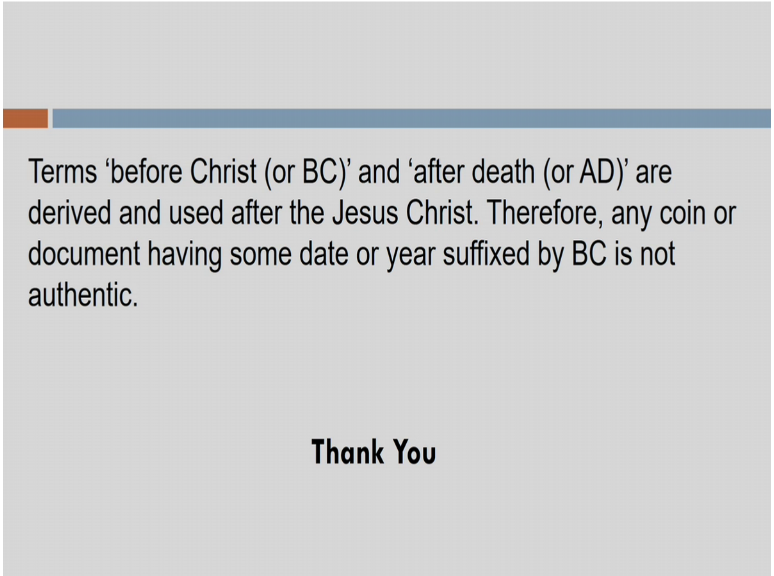
(Refer Slide Time: 60:18)



Further, we have expressions of time like based on the earth movement, solar time sidereal time; based on the use civil time, astronomic time; based on longitude or meridian, we have local time, Greenwich time and standard time based on time scale, we have solar time that is rotation of the earth and we have atomic time and we have also astronomic time, this is related to the rotation earth, but now it is no more used fine.

Then, we have based on corrections to GMT for earth rotation we have different different correction and then we define different different times like this and finally, we excepted that UTC is the time that we use as a intentional time and different countries make their standard time with respect to UTC. Moreover, UTC is not civil time. Furthermore, UTC is also used for the GPS. So, the or the some standard references and bibliography. If you want to read more about time and see, we can refer these and then I have not responded you.

(Refer Slide Time: 61:20)



The last question; so, if you have not laughed at yourself from so many days in this course right, if you know the answer of that question already you have laughed at yourself and if you do not know the answer of the last question. That means, if I am a numismatists and someone offered me coin having 500 BC engraved on it; should I purchase it or not? So, you did the answer on this slide and try to laugh at you again. So, in the next lecture, we will talk about the applications of time as well as reference system for astronomy together.

So, we will meet in next lecture. Thank you. Thanks for having patience.

Thank you very much.