Astronomy in Ancient, Medieval and Early Telescope Era of India
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Session 01
Introduction

Professor 1: Good evening. On behalf of the physics department I welcome you all here. I would like to point out that physics society is a society run by the students of the physics department. But members of course, all the people who are members of the physics department automatically become members of physics society. So students have an executive committee which decides the program and implement it. Of course, there are faculty advisors and Professor Amit Dutta happens to be one of the advisors. So today I would request professor Dutta to introduce the speaker, I do not do it.

Professor 2: Okay, it is a great honor and privilege for me to introduce the Professor Amitabha Ghosh. And I invite writer, one from faculty sides and other than this very nice link will be heard by our physics society representative, he is actually the sponsor of the (())(01:16) department in the city right there. So if I did this, how long the lecture that will go? So I briefly tell that out of those things, no introduction here. Though he started his career teaching his art, (())(1:32) West Bengal, shifted to BE college those days, now (())(1:37). That is I understand and now, then he moved to IIT Kanpur in 1971 when I was two and half years I think.

And he spent long 36 years here, his working place immensely to teaching results, completing fast growth. He settled in India, he published (())(2:00), wrote five books and attributed to every aspects of this. Okay. So I am inviting him with honor, we have been mentioning one paragraph, I just mention he is the elected member fellow of four academies. And also his interest goes beyond mechanical engineering, physics and you can see ancient and medieval, early telescopic era. Everything connects ancient history times of those days to the modern science and (())(2:38).

So I gave a very brief account. Anybody interested can just Google Amitabha Ghosh, you will get every detail in the site. I was (())(2:50). When I, as (())(2:55), so when I joined in 2003, there was a course (())(3:03) and I did (())(3:07) because I was selected for (())(3:09). His name used to appear in Bengali newspapers from where I get to know of him. And then (())(3:16) is the

same person who was the director. He is sitting in the main lecture with me, taking the ego here, no (())(3:22) director for this case or that case.

And he used to go for this, (())(3:27) into the table and complete the table sitting in that time. We used to take (())(3:31) those and those are the majors, it is, I also involved for some (())(3:36). So I learned many things. First, I learned mechanics. Second, I learned from Professor Ghosh what is IIT Kanpur, that here even the person of such a stature, generates younger dream like this just equal. Third, I would say what would be dedication to keep teaching and fourth, most important of all things, I learned Photoscope T, which you know by this syllabus. So professor?

Amitabha Ghosh: Thanks for this. So very good evening to all of you and for me it is homecoming because I spent 30, not 36, more than 36 years and from 1970 December till 2007 December. And last time I taught the course here science selective, was also these two. So I am extremely thankful to physics department for giving me the opportunity to come back home. So when you grow, you will realize what is the meaning of that.

And for all practical purposes IIT Kanpur is my first home, not second. So I think when I was requested by Professor Manna to spend some time, I come to Allahabad for the academy meeting, then I decided that rather than sitting idle if I can give a series of lectures on this very fascinating topic which normally we do not come across because it is over in our curriculum or so. But I think when I myself worked or studied this for last 7-8 years, then what happened that Ramakrishna Mission Institute of Culture, Calcutta and the National Academy of Science, they plan to bring out an 11-volume series on history of science in India.

The, primarily the chief editor was Professor Sharma who was earlier INSA President, NASI President. MG (())(6:12) and SK Joshi. So their directive was that there are books very I will say, very (knowledge), very important books. But they are not within the reach of common students or common reader. So we were told, is it possible that you write all of us, that means we were quite a few authors. It was on physics, mathematics. This is the part on astronomy which I wrote.

So it is, the whole thing was released in the month of March. I thought that since we worked, I had to work quite a lot, why not I share some of the things I read, studied and really feel not only fascinated but also proud. So therefore this lecture, five lectures which I have planned will be primarily based on the book and I have brought one extra copy. I want to give it to the PK Kelkar

Library so that anyone of you who want to read some of the things you can refer to it. So I will hand it over to Professor Choudhury, you can arrange to keep it in the central library.

“Professor-student conversation starts.”

Professor: So I think the first thing if you permit at the age of 74, I feel more comfortable if I am allowed to sit by my audience. Aapkeliye toh koi problem nahi hoga?

Student: Sure.

“Professor-student conversation ends.”

So the first point is that why this particular topic. We all know that the ancient astronomy scientifically the values, or the theories of those times are not really attainable or not much importance now, the modern astronomy. Why we study this or why we listen to this? So the point is why I think you should or any Indian should do it, is that you will find it amazing the brilliance of the mind of our ancestral scientists and philosophers.

That is one thing. Another very important point is that astronomy is something which attracts even the primitive people, is not it? Because every day they find sun rising, moon is rising in a different shape, they are changing. All those things attracts the attention and they start observing. So one of the earliest branch of science which gets developed in any civilization is astronomy. Secondly, astronomy also particularly in India it had lot of link with our cultural activities, sacrifices, various festivals, all such things. That means it is closely linked with the society.

So if you get the glimpse of the astronomy of the ancient times, you get lots of ideas about the concurrent society or the contemporaneous activities of the country. It also gives, you will see that many astronomical references can give important clue for the chronological order, that means at what time this happened. It is not difficult to find out if you look into the astronomical descriptions of that particular time.

I gave a lecture here next room on archeoastronomy and the astronomical dating of the Puranic texts. Only from the description it is possible to date, that is of course separate topic. So another important thing is that as an Indian I find that to know about the ancient activities is very important, not just for knowledge but for bringing back your self-pride and self-respect. So I

think that these five lectures I have planned, many of you I hope that you will enjoy. Otherwise, why I will expect you to spend five wonderful evenings?

Or course here evenings in the month of August not or July that pleasant. But even then I think the semester has just begun, there will be many new friends and so evenings are quite useful here. But I hope these five evenings you will not repent after spending here. So how we have planned? There will be five lectures. Each one I said one and half odd because the subject is vast, hundreds of people have worked for 4,000-5,000 years.

So therefore it is not so easy to encapsulate everything in only five lectures of one hour duration. So I suggested that let it be one and half hours so that I am not pressed too hard for time and go to quickly over certain very important issue. Second thing, I think the level I have kept at the high school level, frankly speaking. You will not require any special knowledge or any high level sterical trigonometry etcetera. We are not going to go into that directions. Our objective is somewhat different.

Those who are interested in learning how to calculate tithies, nakshatra, the book is there, you can refer it. But here it will be primarily the basic physical concept behind the whole thing. The primary source I will, as I mentioned will be this book which I am giving the copy in the central library. Anybody want, you can try to read because the references you will find in this book which are quite large and some of them are very old and complete set of references and bibliography you will get in this book.

The lecture topics will be, the first lecture what I want to do is the story, how ancient Indian astronomy was rediscovered, it was rediscovered, we all forgot but it was rediscovered by the colonial rulers came from Europe. It is a very interesting story. And then of course we have to talk little about the very fundamental rudimentary aspects of positional astronomy. Because many of the terms, etcetera which I am monomer, as a common man as you have to learn little bit of common history, so which direction sun rises, why it changes, some very basic thing will be desirable.

That I hope to finish today itself. Second session will be on pre-siddhantic astronomy. We will see that our whole ancient Indian astronomy can be divided into two periods primarily. One will be pre-siddhantic, another is siddhantic astronomy. This explanation we will come later. Pre-

siddhantic astronomy, the last book which we find is Vedanga Jyotisa which is dated as 1400 BC. So before that, that goes to pre-siddhantic. And then the first or second century AD onwards what we get that is called siddhantic astronomy.

And third lecture will be discussion on siddhantic astronomy and then after that we will discuss the medieval period when West Asian astronomers came with the new rulers from West Asia, Islamic rulers came. And with them something came to India which was actually reflected back and that also I will discuss. I will also discuss what is Zij astronomy and we will discuss little bit about Sawai Jai Singh which you are quite familiar.

And some very tragic things what happened that why Sawai Jai Singh could not be the pioneer of modern astronomy in India. And the final lecture will be on introduction of telescopic astronomy here, survey of India and interesting stories connected, the very preliminary motivations actually like the transit of Venus which really started the era of telescopic astronomy in India. And finally I will have some discussion on the debate over the originality and antiquity of Indian astronomy. So I hope that this will end and I hope to cover all these things also in this time.

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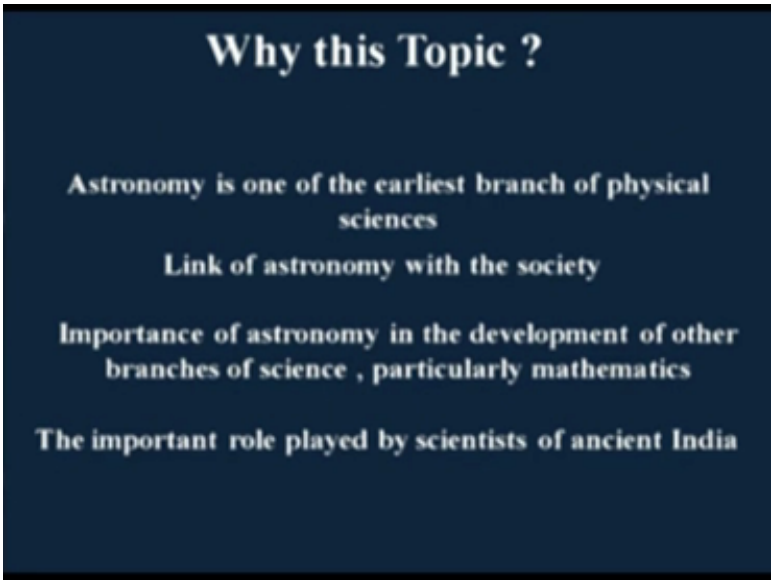

So these points I have already discussed and I am not going to repeat it.

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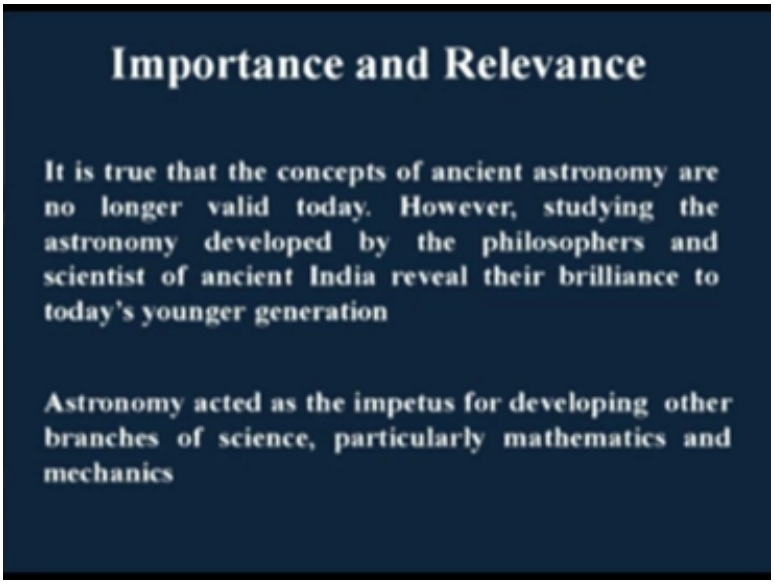

And this also I have discussed.

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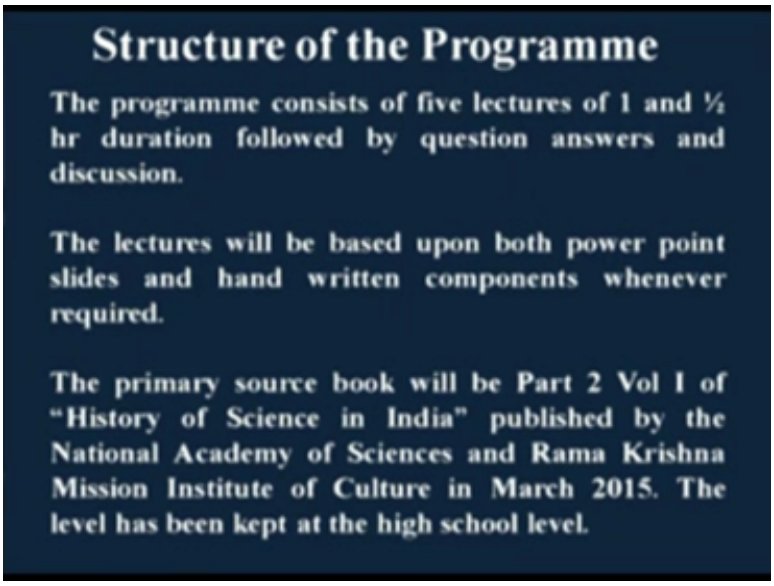

The structure I have also mentioned just now.

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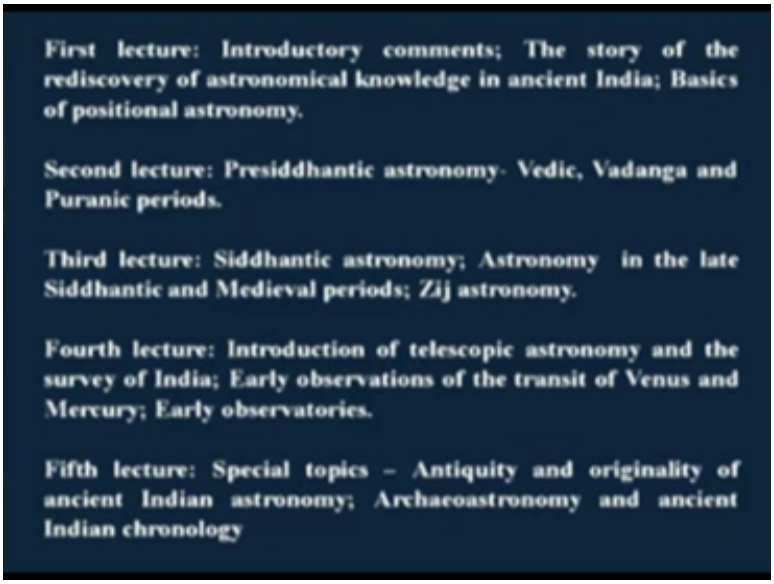

First lecture, second lecture, third, fourth and fifth lecture, that is also I mentioned.

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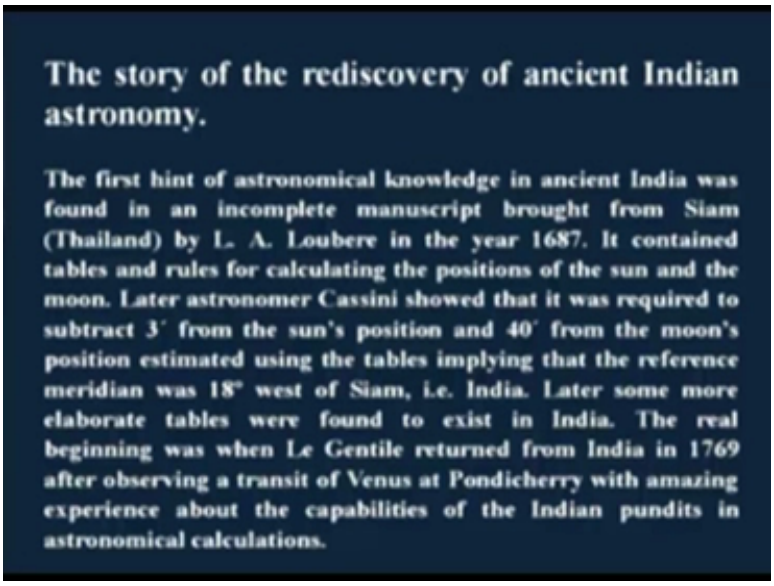

So the story of the rediscovery of ancient Indian astronomy. What happened, the first hint of ancient astronomical knowledge in India came to India in a very interesting manner. What happened that the French government sent a team to Thailand which is, which was called Siam in those days, to the king. But there was a queue in the palace and all the French people had to leave in a hurry. They brought BPL centimeter telescope which they went with, that also they came and brought back. And then Pondicherry was a French colony at that time.

So they came to Pondicherry in the year 1687 and with that those things they also brought some fragmented tables, some charts etcetera. So they did not know what is (tho), what are those things. Then I think the astronomer Cassini, he examined those tables and charts, they are in very fragmented form and showed that it was required to subtract. That means their calculations for positions of the sun and the moon, but you have to subtract 3 minutes from the sun's position and 40 minutes of earth from the moon's position.

And then he decided that it means that all the reference meridian for these tables was 18 degrees west of Siam. And that was found that it is, it matches with the meridian of Varanasi. And so the link with India of that ancient tables was established. And the another person also found some more such tables in the Karnataka, state of Karnataka and so on. But nothing much happened till when Le Gentile returned from India in 1769 after observing a transit of Venus at Pondicherry with amazing experience about the capabilities of the Indian pundits in astronomical calculations.

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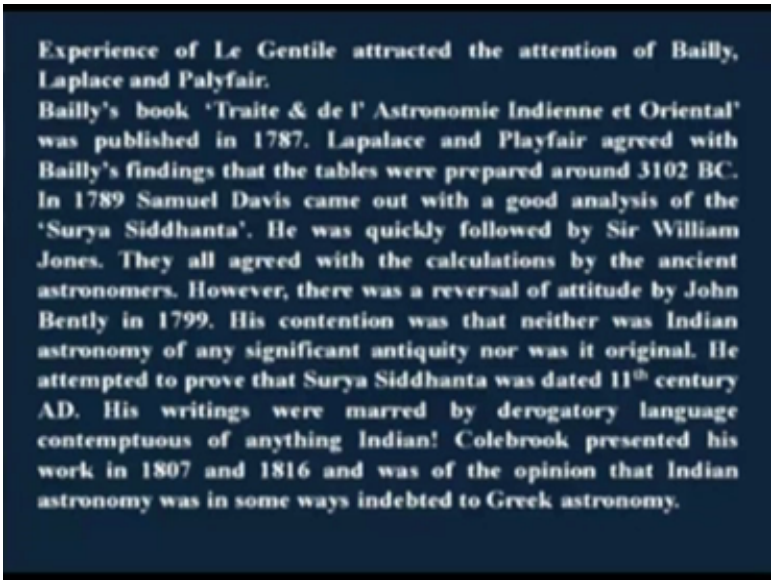

So experience of Le Gentile attracted the attention of Bailly, Laplace and Playfair. So what happened, the Le Gentile one day called one pundit and gave him some task that can you find out the eclipse time and position. So pundit sat on the floor with some kuddies, kuddies means some snails and some tables and palm leaf tables. After 45 minutes he brought the whole result and Le

Gentile was amazed to see that they are very accurate, not only that the time, position, everything is told, also the various phases of the eclipse also that he looked into.

The further amazing fact was that pundit was not very educated person and he was completely unaware of the principles on which these tables have been made. So therefore he was very amazed and realized that it must be based on some ancient knowledge which is now lost. However I will not spend too much time. Then lot of researchers started studying but there are two groups among them. One group was saying that yes, there was very extensive knowledge base in astronomy in India in the ancient times. Another group was there, they say that all non-sense they are all copied from Greek etcetera and so on.

The problem you see, like say Laplace originally was very impressed and later being influenced by others, now they said okay, perhaps they are accurate but they may not be very old. Then good analysis of Surya Siddhanta was by, in 1789 by Samuel Davis and all the calculations they found that the ancient astronomers they are excellent quality, excellent accuracy. But then what happened that Surya Siddhanta, why they were having this kind of problem I am telling you. In one group they are saying that it is impossible to believe that these guys they used to call us neigers in those days that they could do something, some science so many years back which contains so much of truth which is impossible. That was a perception. But when they calculated, the results were very accurate.

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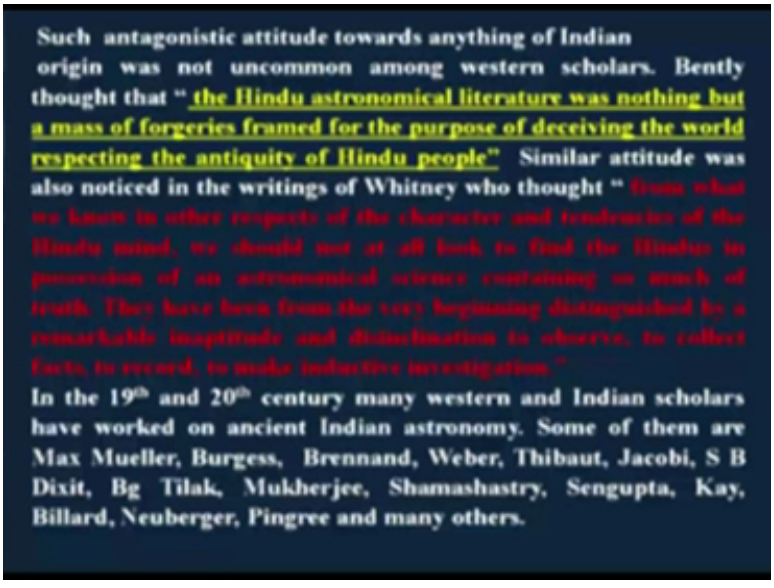

So and now see that such antagonist attitude I mentioned just now towards anything Indian origin was not uncommon among western scholars. Bentley thought that the Hindu astronomical literature was nothing but a mass of forgeries framed for the purpose of deceiving the world respecting the antiquity of the Hindu people. That was his contention that it is a complete forgery, it is very recent but they have done it so that rest of the world think that yes, in ancient times they were great people.

Similarly, attitude was also noticed in the writings of Whitney, he was an American astronomer when the Surya Siddhanta was published by Burgess I believe in 1856. So he writes, I have those books actually. From what we know in other respects of the character and tendencies of the Hindu mind, we should not at all look to find the Hindus in possession of an astronomical science containing so much of truth. They have been from the very beginning distinguished by a remarkable ineptitude and discrimination to observe, to collect facts to record, to make inductive investigation.

So funny, you see and I do not blame them because the society at that time in the 18th and 19th century was so degenerated if you read the history of our society at that contemporary society. I will not blame the European scholars to feel this way. In the 19th and 20th century, many western and Indian scholars have worked on ancient but the problem, another problem was the knowledge on Sanskrit which is the principal source of all the knowledge on ancient astronomy was not that good.

They had to depend quite a lot on pundits and others to translate. Secondly, a large amount of writing, they are in allegorical form. That was a character of all our ancient text, they are in allegorical form. And to extract the real meaning requires a kind of knowledge, kind of mindset which they did not possess, that was also another difficulty they had.

So many others like say in the 19th century Max Muller, Burgess, Brennand, Weber, Thibaut, Jacobi, S B Dixit, he now among the Indian, the primary work which I have found. One is Shankar Balkrishna Dixit, then Bal Gangadhar Tilak, Kalinath Mukherjee and 20th century Shamashastry, B. C. Sengupta, and J. R. Kay, that they are the 20th century people and rest are all 19th century.

These books are available but only thing that the best book I think is Shankar Balkrishna Dixit, 1896. You cannot find that, it was published in Marathi and later in 1940 meteorological department of India, Government of India, they published a translation. After a lot of travel I could trace a copy in the positional astronomy library in Calcutta and I got a copy but it is not available either in the Internet or in any library.

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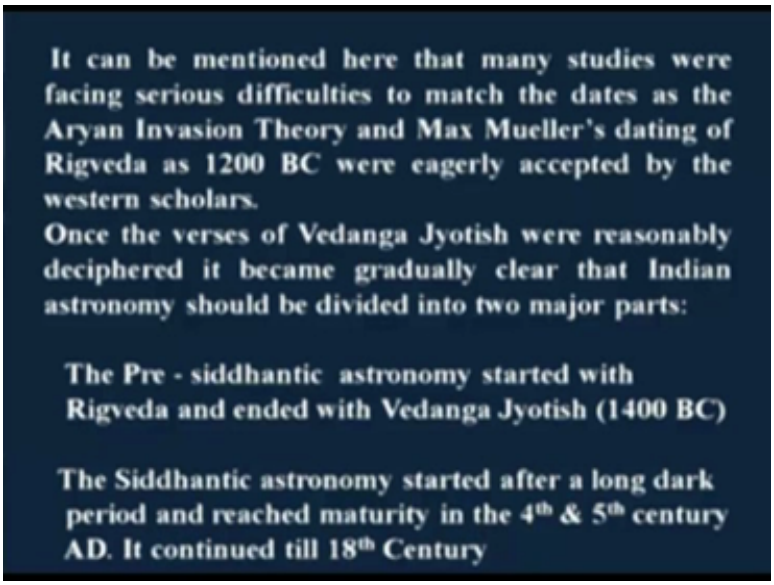

So it can be mentioned here that many studies were facing serious difficulties to match the dates. Another problem was that Max Muller's Aryan Invasion Theory. He hypothesized that 1500 BC all the Aryans came through Khyber Pass and they started the Vedic civilization. And he had an ad hoc assumption about the date of Rigveda as 1200 BC which was the first and indirect 200 BC. So the dates were conflicting with this hypothesis and lot of scholars who had lot of faith in this theory, so they were finding very confused.

Once later and the verses of Vedanga Jyotish, you will find Vedanga Jyotish when I come later to Pre-siddhantic astronomy tomorrow. It is like Rig Jyotish and Yajur Jyotish. There are in total 49 verses, very difficult but when it was deciphered, they are nothing but algorithms for calculation. And after all the things of Vedanga Jyotish is complete, they decipher, now it is found that it was written around 1400 BC. That is accepted by all people. We will come to this much later.

But once this work by (Balkrish) SB Dixit was over, the Indian astronomy, ancient Indian astronomy could be divided into two major parts, Pre-siddhantic astronomy starting with Rig

Veda, ended with Vedanga Jyotish. And siddhantic astronomy started after a long dark period, that also I will mention quickly later and risk maturity in the 4th and 5th century AD and the first great astronomer you have heard about is Aryabhatta I.

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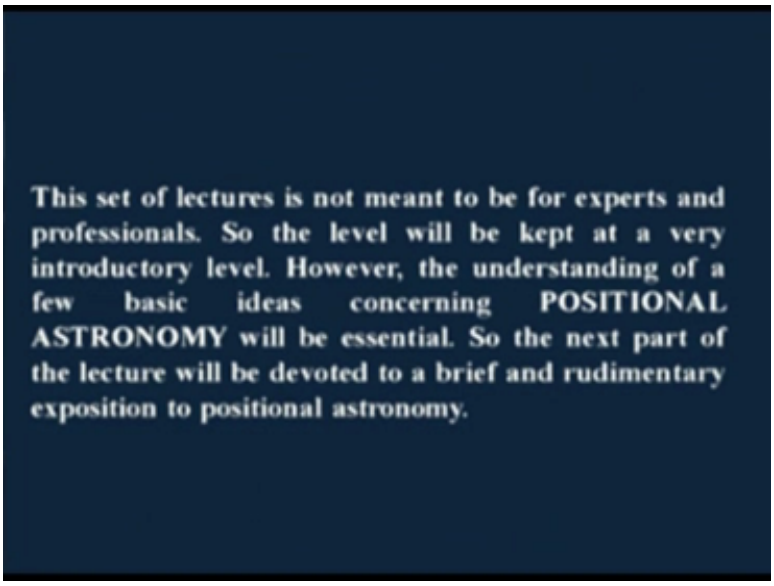

The set of lecture is not meant as I mentioned for experts and professionals, I will not teach you the calculation procedures, they are in the book. But it is primarily the whole phenomena or the physics behind the whole thing. And some very basic idea about the positional astronomy is necessary. Even as a common man we should have this knowledge, and I will take some time for that.

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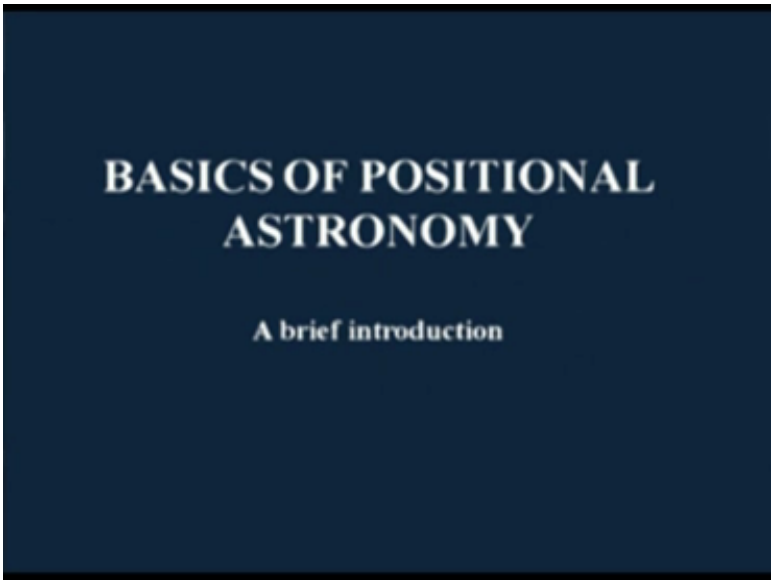

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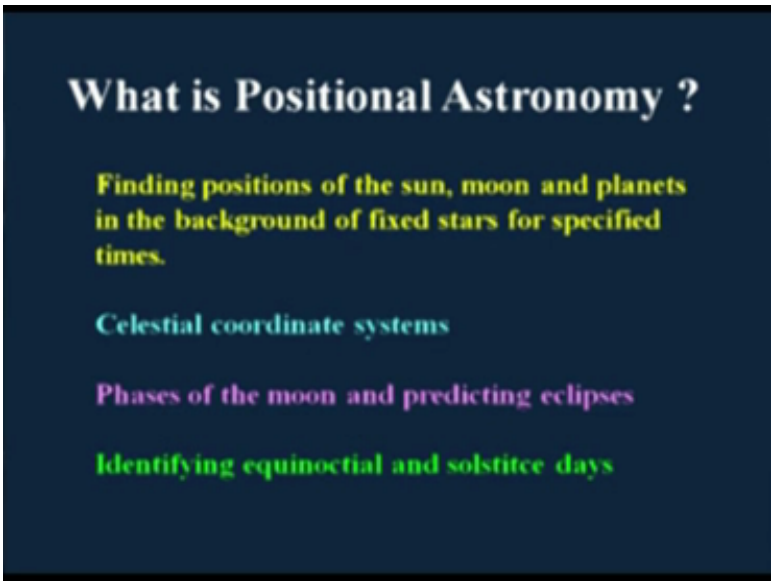

So basics of positional astronomy. What is positional astronomy? You may ask. It is the finding the positions of the sun, moon and planets in the background of fixed star for specified times. Then celestial coordinate system, how to use the coordinate system to identify its location. Phases of the moon and predicting eclipses, identifying equinoctial and solstice days, these are what are the primarily duties of positional astronomy.

And nowadays you know positional astronomy is very much used which of course far more sophisticated software for panchang creation by the Government of India. The positional astronomy center, their main job is to create the panchang.

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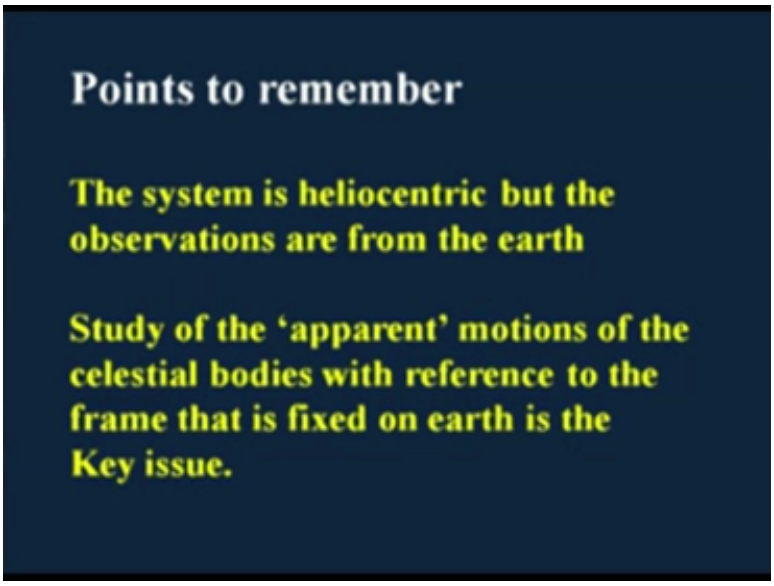

The points to remember, as I mentioned that the system is heliocentric we all know but the observations are from the earth, that we have to keep in mind. And study of the apparent motions of the celestial bodies with reference to the frame that is fixed on earth is the key, that we have to always keep in mind.

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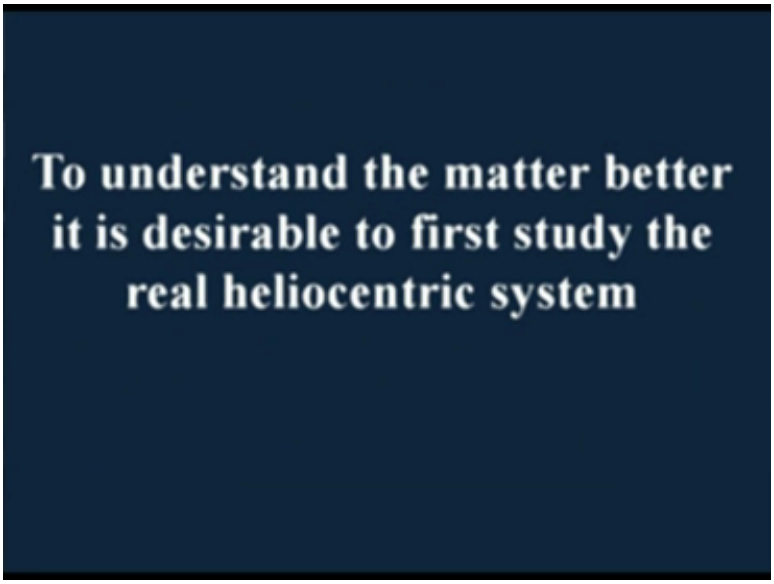

To understand the matter better, it is desirable to first study the real heliocentric system.

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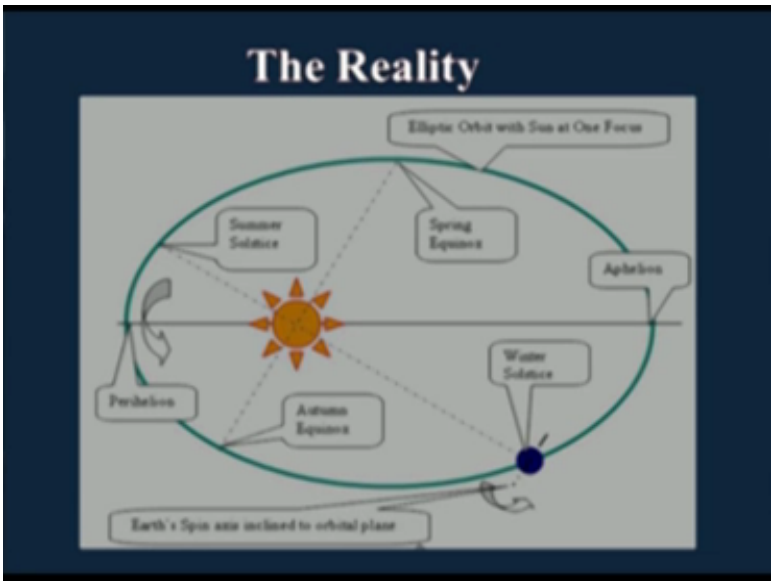

You see, you all know these things, you must have studied in that there is sun and around sun, the earth is going in an elliptic path. Of course, the eccentricity is very small. And it is also, its axis is inclined to this plane of the orbit at 23 and half degrees, it is spinning and at the same time it is revolving around the sun. So here you will find that this plane in which earth goes around the sun is called the plane of the ecliptic. This is, why it is called ecliptic? That whenever moon is on this plane and it in conjunction or opposition, there is an eclipse.

That is why this plane is called the plane of the ecliptic. And then there are four important positions. One position when the inclination of the earth's axis inclines towards the sun directly, that is the summer solstice in (north), Northern Hemisphere it is summer. So this is the summer solstice when the axis is inclining towards the sun, the day is the longest. And opposite to that when it is tilting away from the sun, that is the winter solstice. Solstice word has come, sol means sun and solstice indicate it is stationary.

You will find that the sun is going from north to south during this period. Now when it reaches the extreme end, it appears to be stationary for few days. And then it, that is called Dakshinayana or Uttarayana and it starts going back. Again it will come here and it will slowly stop and then again, so therefore these are the positions when the sun's motion appears to be stationary and so it is solstice. One is summer, one is winter.

Two important days are there. When the inclination, sun is here and it is inclined this way, so both the hemisphere, they get equal sunlight and they are called equinox. Equinox word has come, equinox is Latin, nox means night. When the night is equal to day, that is why it is called equinox. One is spring equinox and this is autumn equinox.

"Professor-student conversation starts."

Professor: You can judge that which direction earth is revolving, you can easily find out. Can you tell me clockwise or anticlockwise?

Student: You have already spoken that.

Professor: No.

"Professor-student conversation ends."

Because you see that the spring equinox and after that only summer solstice will come, then will be the autumn equinox we are approaching 22nd September. Then we will be the winter. So it has to be like this. Two other important positions are there. One is called perihelion, that means the position nearest to Helios, that is sun. Another is aphelion which is away from the sun. So this is the real thing.

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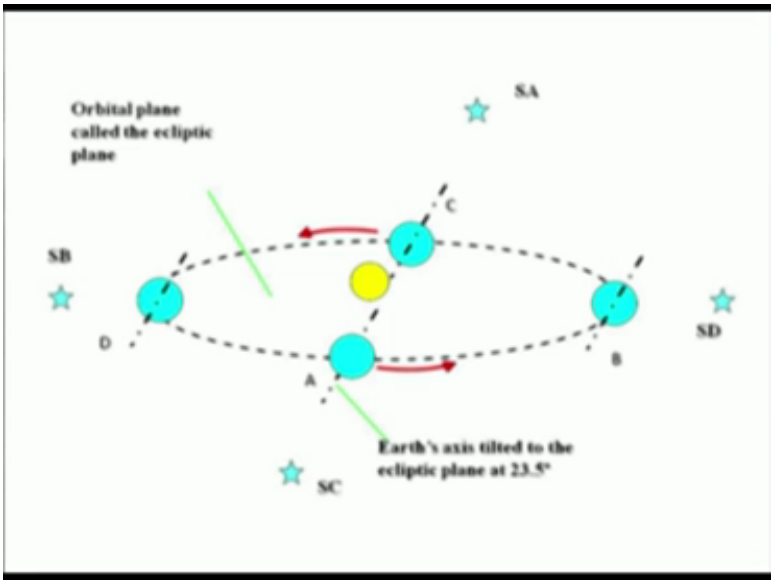

And the same thing what I have shown there. Now here one thing we have to now discuss a little bit. Now what is our background? Background is the fixed star. Now you will say they are not fixed, they are moving at tremendous speed of 200-400 kilometer per second. But their distance is so large that even in the whole human civilization the movement is not perceptible. The Great Bear Saptarshi Mandal, all the stars are moving with large tremendous speeds just like the sun.

But for thousands of years it will look like the same because the amount of distance you will see it to move in few thousand years is imperceptible. So that is why apparently they are all fixed and it is called the background of the fixed star. All the things and position movement we see of sun, moon and planets, that backdrop is called the star fixed, the background of fixed star. There so how do you locate? Say for example, we tell that there is a star here.

You find a full moon against this star. So it means what that we are in this position because full moon means moon must be opposite to sun. And if full moon is against this star, you know that this is the configuration. So after six months what will happen? After six months earth will go here and you know then that sun is against this star though you cannot see that. Because sun is so bright you cannot see that. So this is the way astronomers tell where is sun, where is moon. Moon is very easy but in case of sun you have to consider what happens after six months. So that way there are such markers in the sky to locate the position in the sky which is other way absolutely vacant, nothing is there.

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When viewed from the earth, the sun along with the rest of the heaven appears to rotate.

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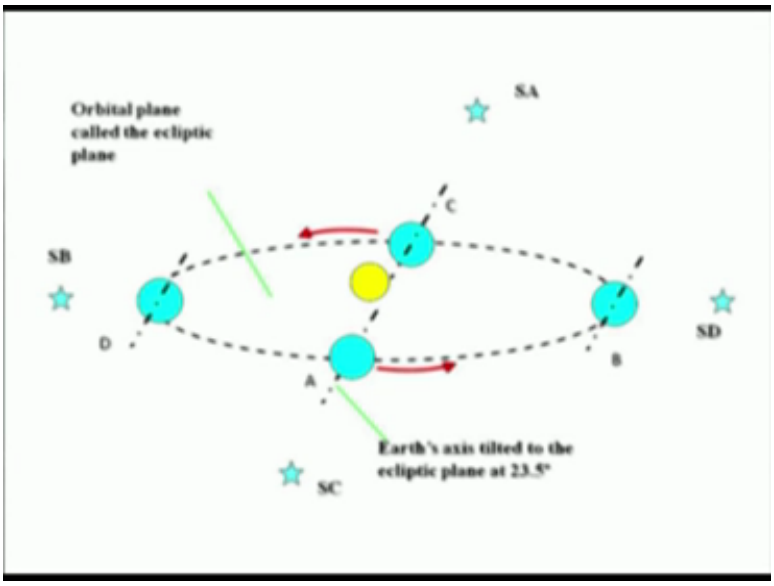

That means it was the reality, the sun here and earth going like that.

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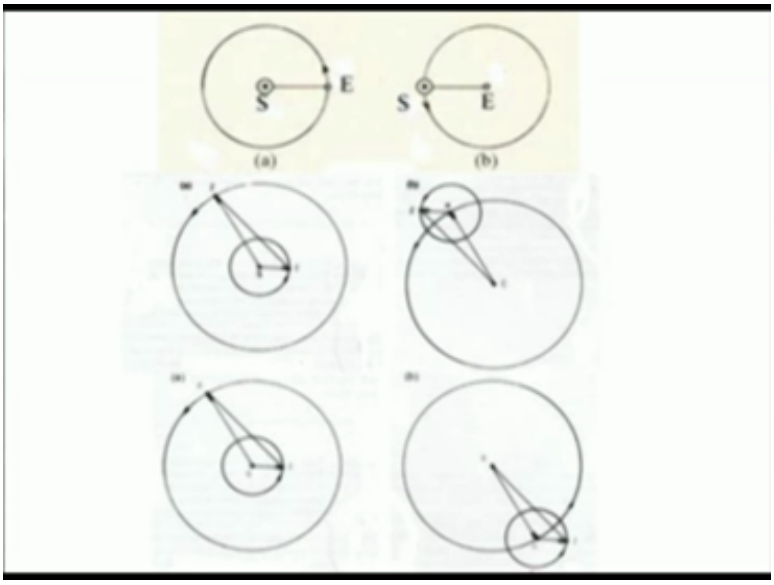

But actually what you see that rather than sun and our going, it appears as if we are here at sun. (())(32:34) it is equivalent. So that is why it looks that sun is going down, the whole universe is rotating.

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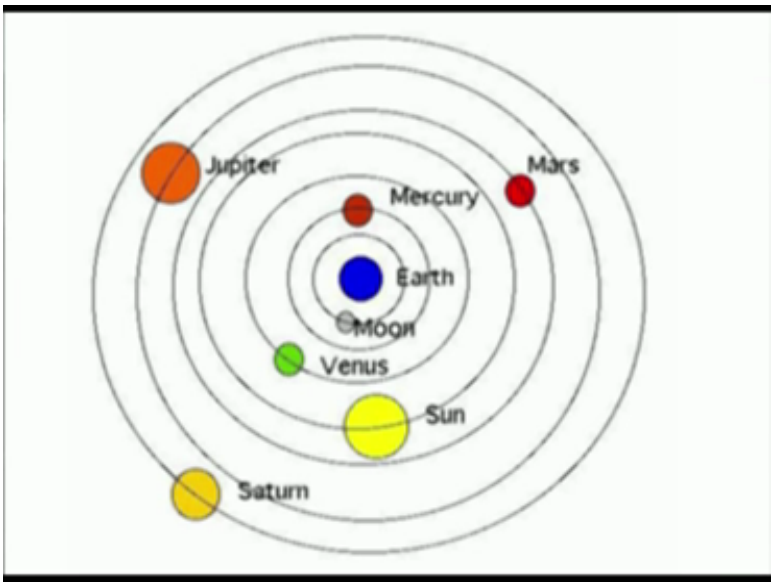

And this is what is the apparent, to the ancient astronomers, this was the situation. Earth is at the center, then Moon, then Mercury, then Venus, then Sun, then Mars, Jupiter and Saturn. These are the only planets or because sun and moon is to be also considered as planets. So these seven planets they had.

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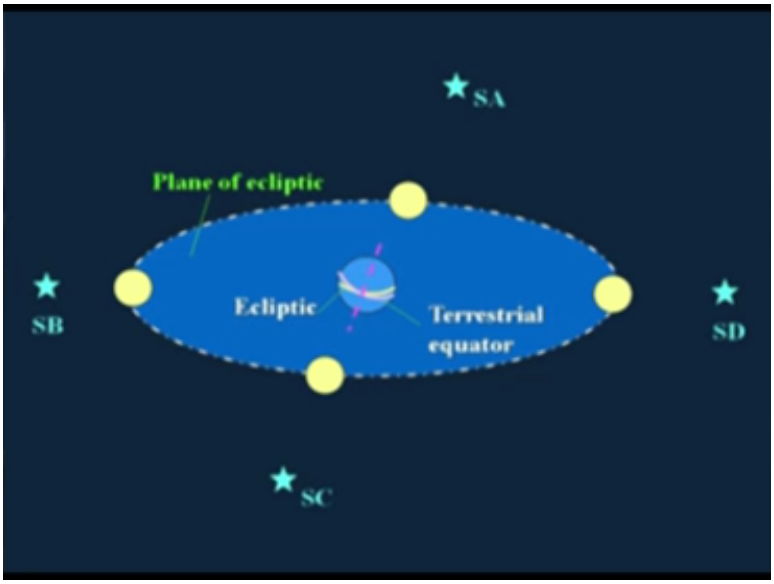

Now I will see, as I mentioned that just now that now I will define few things. This is the plane of the ecliptic where earth goes but from earth it looks sun is going, so it is the same thing. Sun appears to go like this around sun apparently. Now and earth is at the center spinning around its axis which is titled. Now there will be two circles. One circle which is the equator of the earth, this one. Another one is the intersection of the earth surface or earth's spherical surface with the plane of the ecliptic. So this is called the ecliptic, the yellow one. Now so what happens, you see interesting that sun will be always appearing to be on the ecliptic, is not it?

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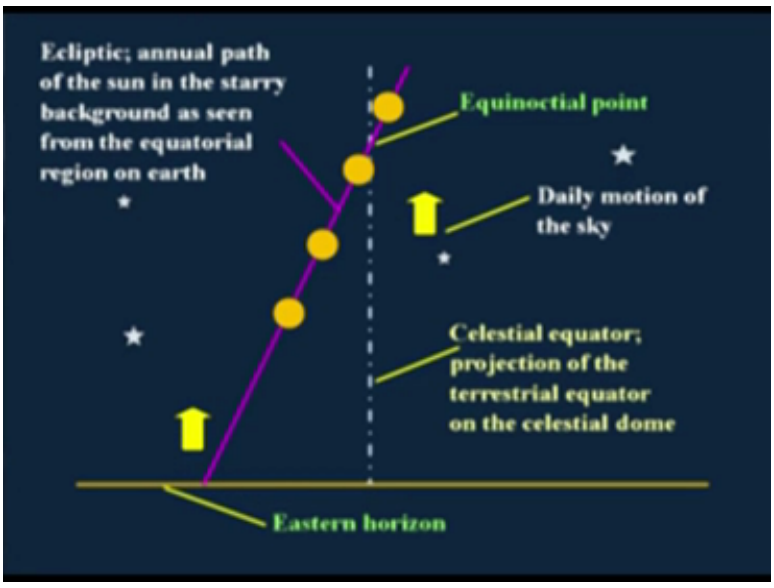

And so you see, today you go and you find because this is the horizon and the heaven is going like that, the whole heaven is rotating, actually the earth is rotating. So say sun is here, sun will go like this, all the stars go. After a few days, you will find sun will be here, it will go up like this. After another few days sun will be here, again it will appear to go.

So you will find if you trace the sun's location on the starry background of the sky, it will draw a curve and it is nothing but the ecliptic. This line is called the ecliptic which is a very important thing. Another line is very important that if you take, consider the equator of the earth and imaginarily expand it and take it to the celestial sphere, so you will have, you get another circle or line that we call as the celestial equator. It is nothing but the projection of the terrestrial equator and it is also nothing but the intersection of earth surface with the ecliptic plane that circle you have expanded that and this is nothing but the path which is taken by the sun.

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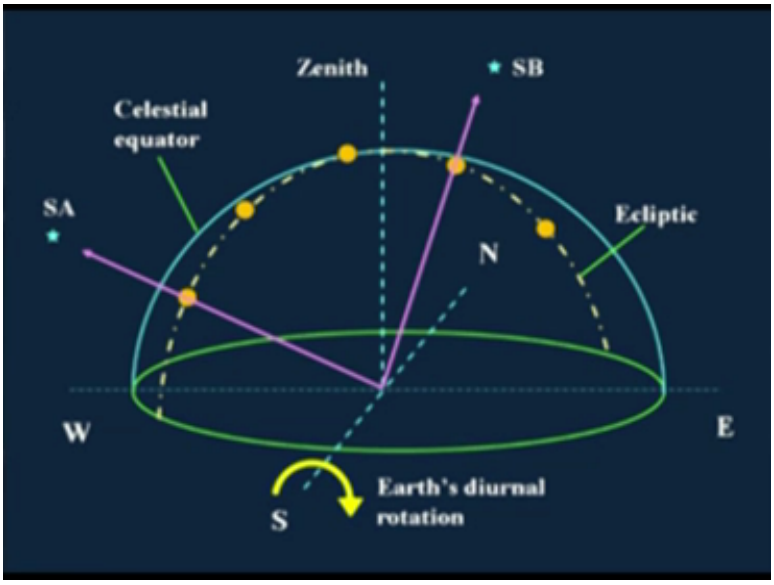

And since most of the planets because of the origin of the solar system, all the planets etcetera, they are more or less located in one plane slightly this way, that way. So therefore all the planets, moon etcetera are never far away from this line which is ecliptic, that is also another point to be noted. So what happened that this is the earth rotating, this is our horizontal plane, this is the eastern direction, western direction, northern direction, southern direction and this is the zenith.

So you can see that this is the ecliptic and another is the celestial equator. And sun is on the ecliptic on different location at different days of the year and location is defined by the star

against which sun is there which you will be able to notice or record after six months locating the full moon's position.

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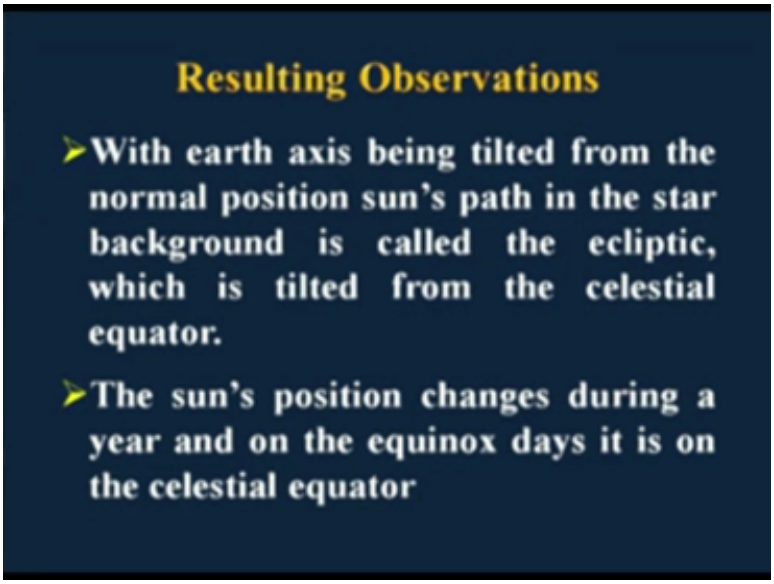

Resulting observation will be with earth axis being tilted from the normal position. Sun's path in the starry background is called the ecliptic which is tilted from the celestial equator, we have seen that. The sun's position changes during a year and on the equinox days it is where, it will be the intersection point of the ecliptic and the celestial equator. There are two nodes. And these are the two points where sun is there on 21st March nowadays and 22nd September.

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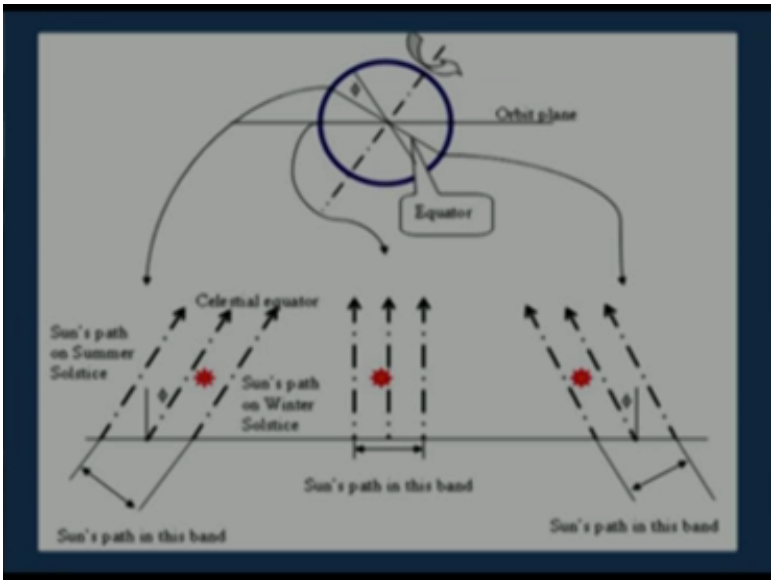

So then what happens, sorry, we find suppose if you are standing here at latitude 5, you will find on the equinox days sun comes here and goes like this over and sets. On the summer solstice day you will find the sun to rise to the extreme left or extreme north and this will be the line which will be taken by the sun. On the winter solstice day it will be rising at the extreme right or extreme southern point and move like this.

So sun is always in this band throughout the year. If you are standing on the equator, you will find on the equinoctial day sun is going like this and on summer solstice it will go like this, winter solstice will go like this. If you are in Australia somewhere, it will appear to be something like this.

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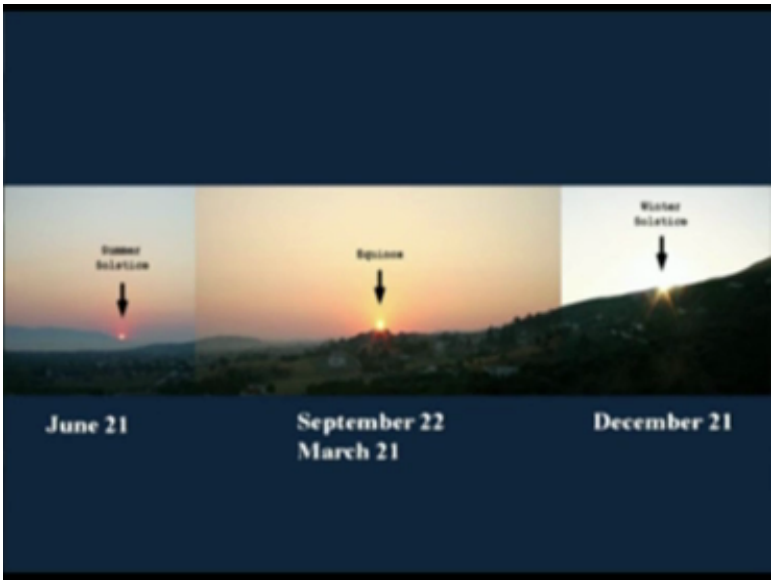

So you can see a photograph taken from the same location on four days of a year. On June 21st, you will find that is the summer solstice day, sun you will find to rise here. On the equinoctial days you will find sun to rise here and on December 21st winter solstice, you will find. So you can see sun is rising here on the summer solstice and here on the winter solstice. These are the photograph taken from the same location on these four days at the sunrise.

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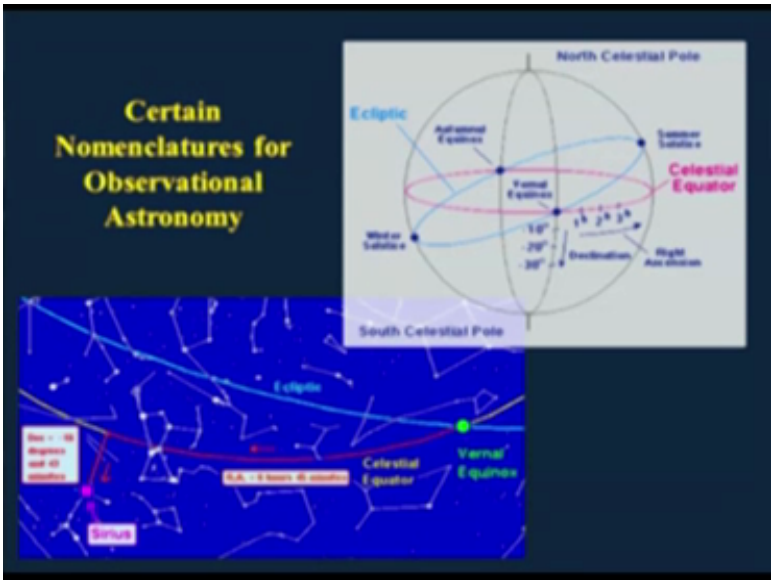

And so therefore now let us see, this is the celestial dome, our sky. This is the celestial equator, it is nothing but the expanded form of terrestrial equator and projected on the celestial dome. This

is the ecliptic which is the intersection that circle of the earth's sphere with the ecliptic plane expanded and projection, projected on the celestial. So therefore these are the important things and these are the two equinoctial points, these are the solstice points.

Now how do you record the position, that I will discuss later in more details. But you can see that you have to locate the position of any planet or sun or anything on the celestial dome. Now say for example, one way of observation of astronomy nomenclature is that how to locate the position. So what you do, you go along the celestial equator and then again you go along the longitude kind of thing and wherever you are it tells you.

So this tells you the declination like our latitude and this one, longitude is told by right assumption. And since it comes back after 24 hours, right assumption is generally given in terms of the time, so many hours, minutes, seconds. And declination is given in degrees either south which is negative and north is positive. So like say currently if you say serious, this is the location of the serious. How do you say? Now this is the ecliptic and this is the celestial equator. So along celestial equator you go, how much? 6 hours, 45 minutes. And then declination is minus 16 degrees and 43 minutes.

"Professor-student conversation starts."

Professor: So this is the way it is, now you are saying that it is going in this direction, why it is plus? Can somebody tell me?

Student: (())(40:35).

Professor: Yeah, actually it is, you have to see any sky map, you have to see this way, then only you will find it will not be confusing. We will come to these things little later again.

"Professor-student conversation ends."

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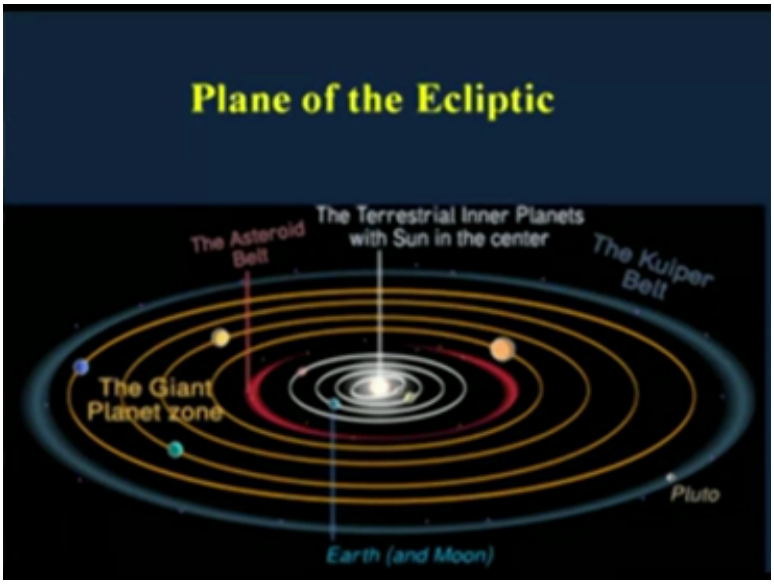

So the plane of the ecliptic, I have already mentioned. So you all know that.

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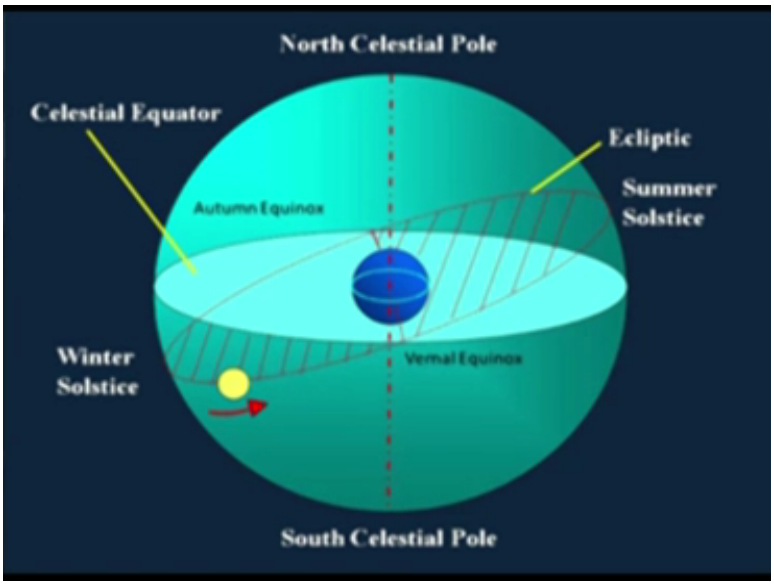

And this is the celestial dome, this is the celestial equator, this is the ecliptic and these are the equinoctial point and these are the solstice points. The South celestial pole, North celestial pole.

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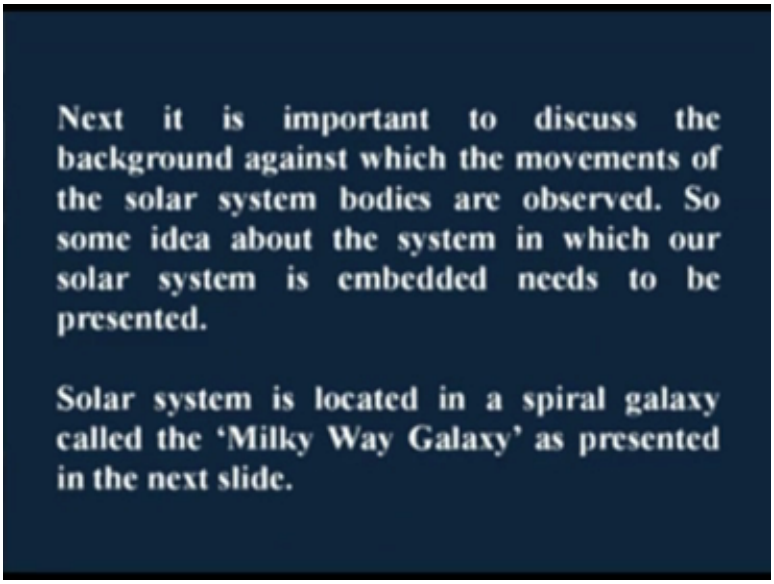

Next it is important to discuss the background against which the movements of the solar system bodies are observed. So some idea about the system in which our solar system is embedded, we should know that. Solar system is located in a spiral galaxy called Milky Way Galaxy as presented in the next slide.

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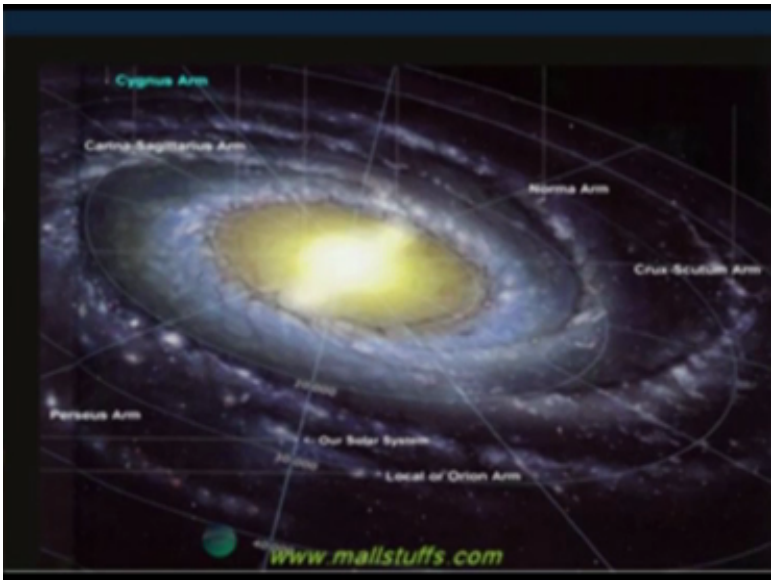

So this is our Milky Way galaxy, this is the galactic center and sun is somewhere here. This is our solar system. You know that diameter of our milky way galaxy is about 1,00,000 light years and we are approximately at 30,000 light years away from the center.

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This is the Milky Way you know, I will not discuss. You all know about Milky Way.

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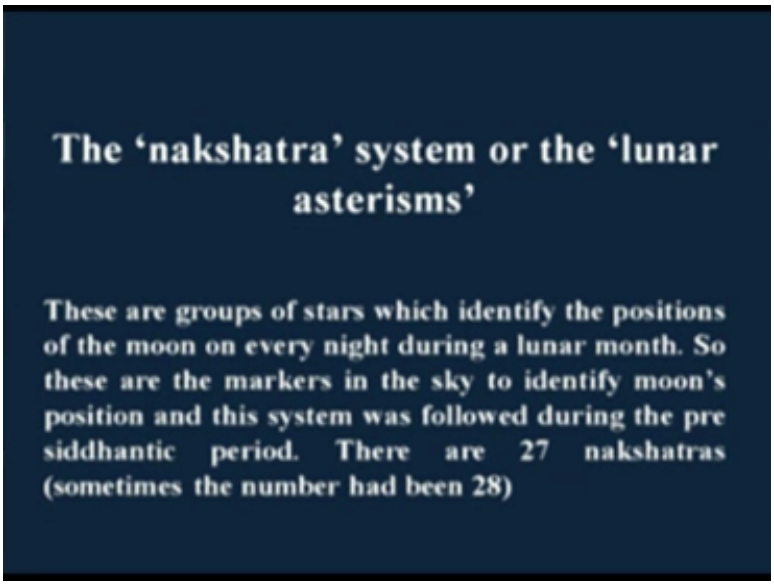

Now the nakshatra system or the lunar asterisms which are very important. You see, you consider yourself 5,000 years back. Night sky you observe that sky, the moon every day looks different. So you observe that today it is thin creation, or now it is somewhat bigger half moon, then it is becoming thicker and ultimately a full moon. So you notice it but how do you also locate the position of the moon?

You notice because today the background stars are like this, tomorrow when I see I will find different background stars. So what the ancient astronomers in India did, what was the easiest and obvious to do, they took every day and the moon takes 27 days to come back to the same group of stars in the background. So they found 27 groups of stars along which moon is going through the whole period, they call this as nakshatras. Nakshatra is not one star, a group of stars or that is called lunar asterisms.

So these were the earliest markers in the sky ancient Indian astronomers found and it is purely an Indian system. So this 27 nakshatra system decide the whole astronomy as you will see soon in the pre-siddhantic period. Siddhantic period we go to sign system or rashi system, that is later. So these groups of stars which identify the positions of the moon every night during a lunar month, this is not a lunar month actually, this less than lunar month as you will see.

This is the position of, the moon takes 27 and few days and few hours to come back to the same position in the sky. But the lunar month is called from one full moon to another full moon. So that is little longer, 29 and half days. So you will see that later why it is so. So therefore 27 nakshatras, sometimes it was 28 but mostly it is 27 nakshatra, that is the defining coordinate system or marker system in the old.

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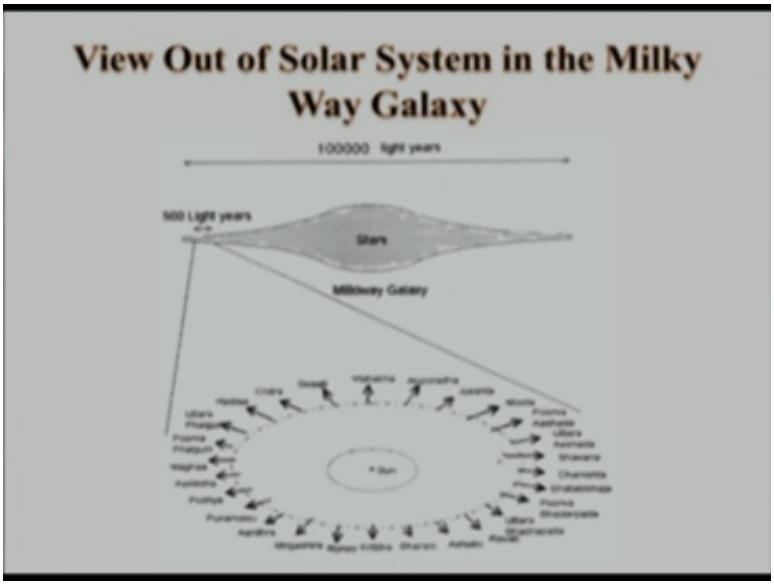

So we see now how to do it. Our galaxy if you sideways, it will look like this. You are all modern students you all know that. We are here, so naked eye we cannot see beyond 500 light years or

250 light years. So obviously in those days without telescope our universe is confined to only this region which is 500 light years across. If you expand it and you will find that the groups of stars in the galactic this region they get names like Jyeshta, Moola, Purvasadha; you have heard all these names. So these 27 groups of stars they are identified as 27 nakshatras and they are named like this.

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So the zodiacal signs are the constellations which span the positions of the sun during every solar month during a solar year. So there will be 12 of them. So we will discuss these things later.

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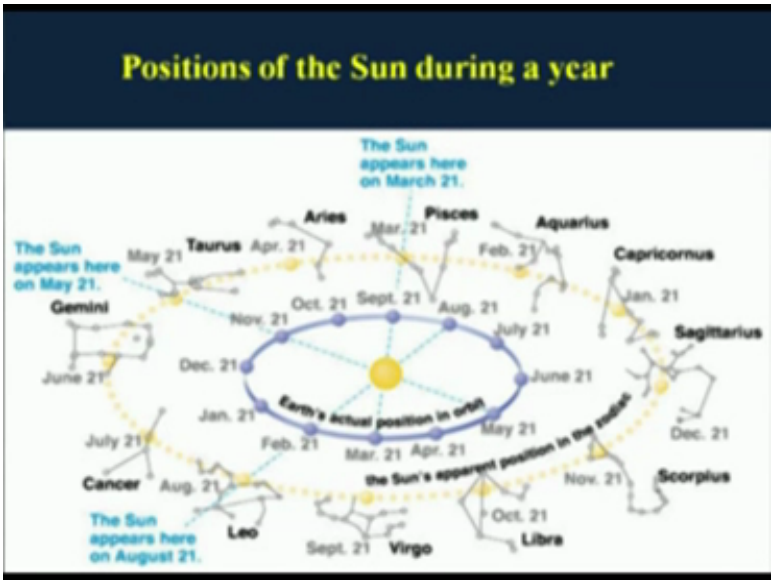

So it looks like this that sun is here, earth is here and so for example, say July 21st sun is against what? Sun is against cancer, so that is the summer solstice time, it is very hot. Then in winter say December 21st, sun is against what? Capricorn. So in same days they were very surprised that why it is happening when sun is, in Capricorn it is cold, when it is cancer, it is hot. That is why astrology came into picture as a subject but that is not our concern.

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So the 12 zodiacal signs are these. You have, perhaps you are familiar with the 12 zodiacal signs.

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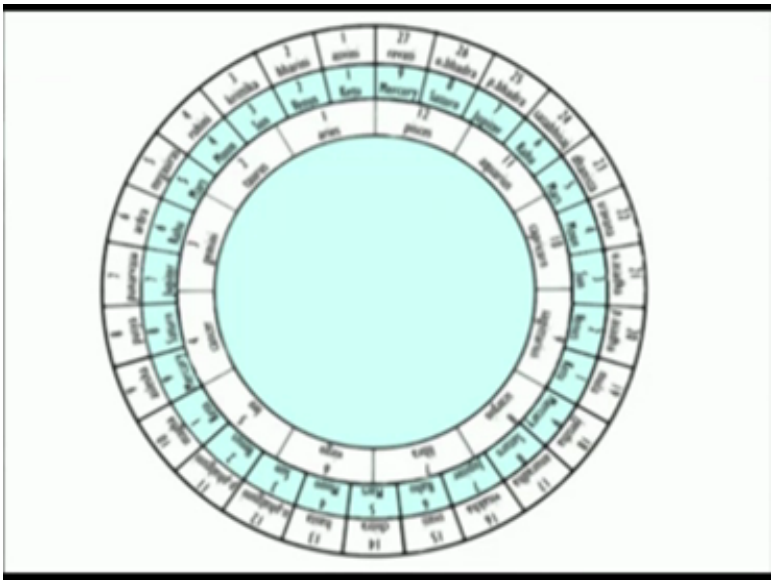

And this is the relative location of the zodiacal signs and also the nakshatra system in India. So this is the Aries, this is the Taurus and so on. This is the Mesh rashi like that, Mesh, Vrishabha and so on. There are 12 and these are the Aswini, Bharini or Krittika; these are the nakshatra. Their relative position-wise they are located in the sky like this.

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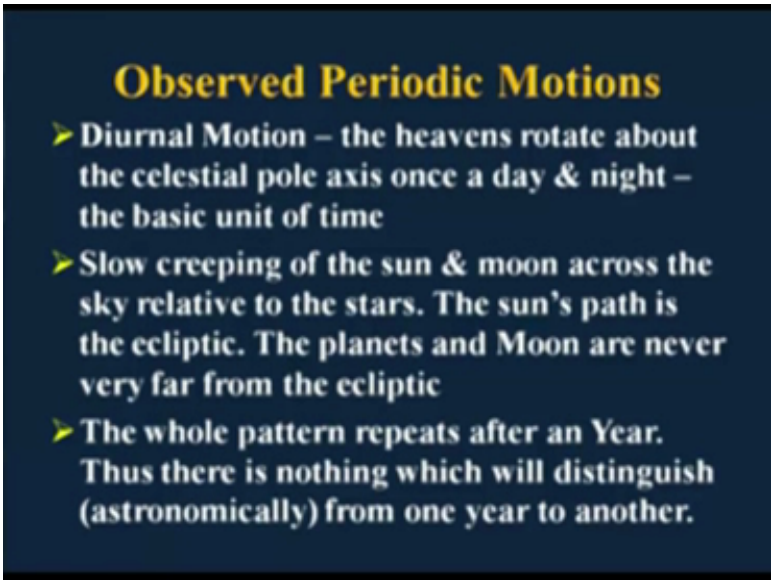

Now observations of the periodic motions are as you know diurnal motion, heavens rotate about the celestial pole axis once a day and night – the basic unit of time. Then slow creeping of the sun and moon, then they notice that the in the fixed background of the star their position is

shifting and they also notice some other star like objects are shifting or wandering, that is why they are called planets. In Greek language, planet means wanderer.

So these five planets or seven planets, they ultimately considered as the moving bodies in the sky and they are always very near the ecliptic. Sun is on the ecliptic. And the whole pattern repeats after a year. Thus, there is nothing which will distinguish one year to another, astronomically of course. This year you are in first year, next year you will be in second year obviously.

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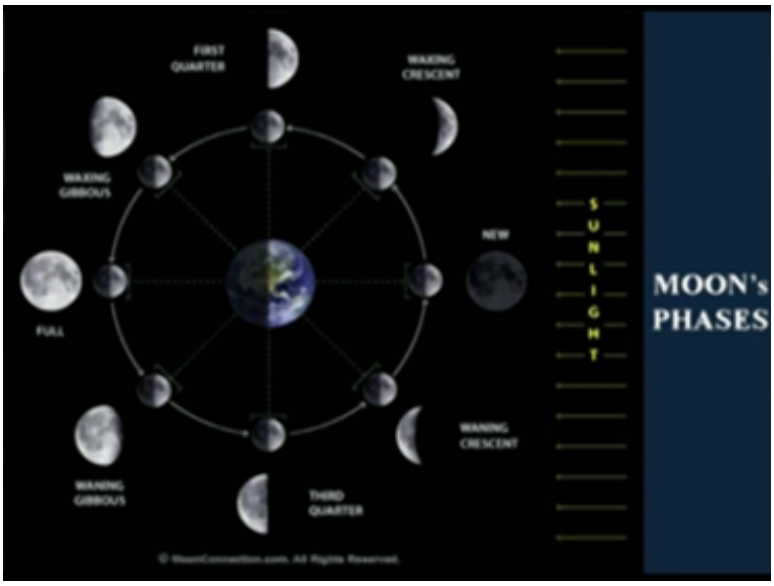

And the Moon’s phases also you know that this is the earth and sun is from this side. So here it will be new moon, then as it goes this will be works in creation, then this is the first quarter, the Waxing Gibbous, then this is the full moon because sunlight falling completely and you can see the full circle. And this is the Waning Gibbous, third quarter and Waning Crescent. So these are the moon's phases.

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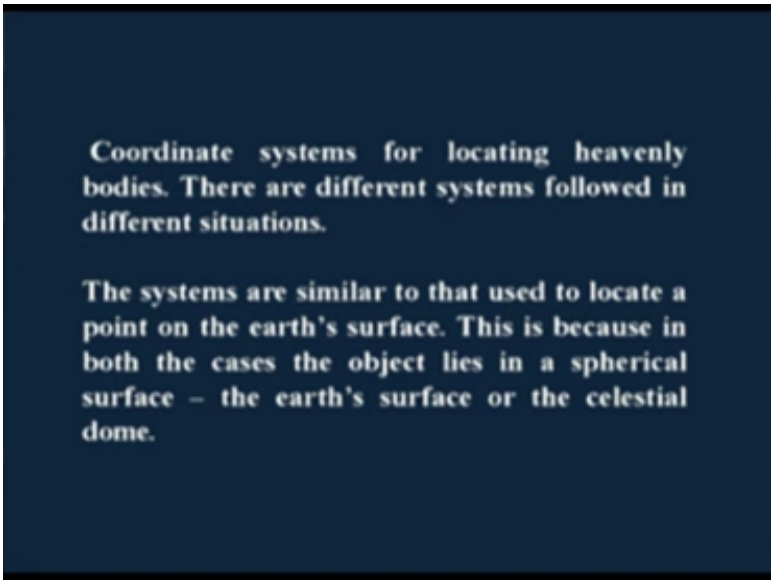

So coordinate systems for locating heavenly bodies. There are three different systems which are used. We will not go into details but it is better that you just follow it. The systems are similar to that used in locate a point of the earth's surface like latitude, longitude kind of thing. Because this is a spherical surface and celestial dome is also a spherical surface.

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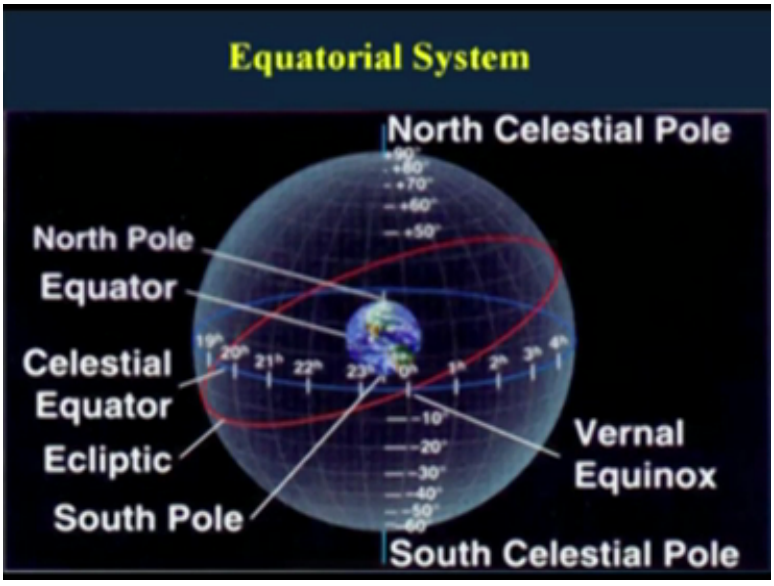

So as I showed that one is called the equatorial system. You go along the celestial equator, this one hour, two hour, three hour, that is called the right ascension. Traditionally why they are doing it? You can say easily they could say degrees, 1 degree up to 360 degree perfectly all right. But

that is the tradition in which they did. And the latitude is something like that, declination that is minus or that could be plus.

And while the origin that is very important. Origin of the coordinate system is always the vernal equinox. Now you see here I will tell that ancient Indian tradition, the origin is a fixed place. In the European or the Greek astronomy it is always the vernal equinoctial point. But due to the precision of the equinox, it is 26,000 years as I will say later. So the vernal equinoctial point also shifts. So our system the origin is always fixed, the first beginning of the rashi Aries. They call Meshadi, adi point means beginning. So this is the fixed, that is why it is called Nirayana system.

Indian system is very peculiar, it is nirayana, the our coordinate is fixed. In western system, it is sayana system where the starting point is the vernal equinoctial point which shifts approximately 1 degree in a century kind of thing. So that is different. So these two terms you should be familiar with, sayana system and nirayana system. In Indian astronomy we always adopt the nirayana system.

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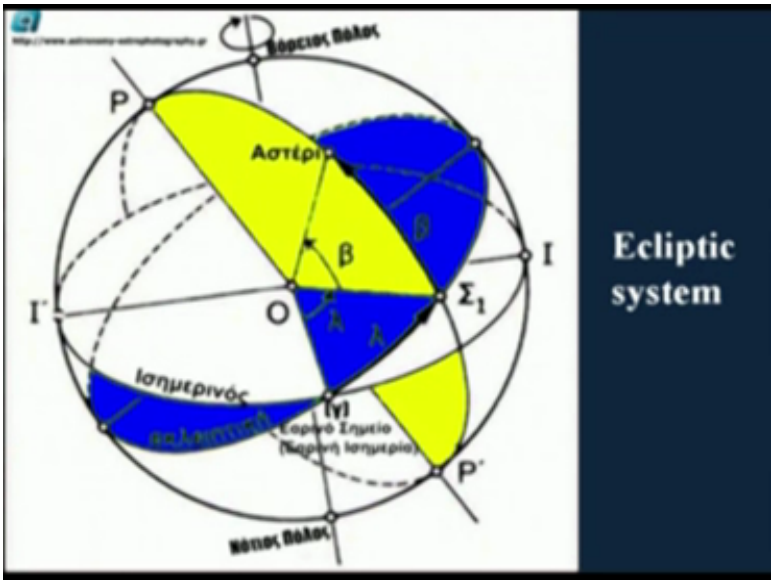

This is ecliptic system, another system where again you start from the vernal equinox and go along the ecliptic and that is in degrees. And perpendicular direction you go something like latitude. So this is another system.

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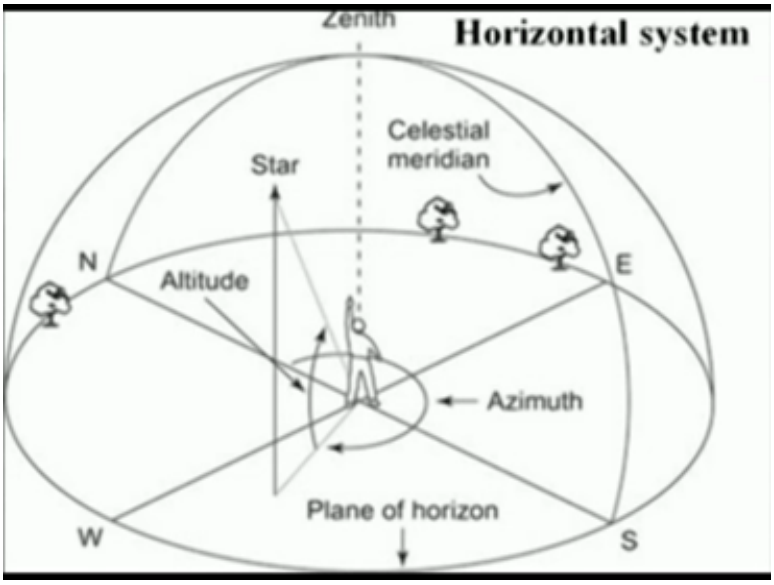

Another system which is very useful is that you are locating, you have a vertically up, east, west, north. So that is another system which is called horizontal system where, sorry, you are standing here. This is your zenith, this is the northern direction, north pole. So to locate a position of a star, what you do? You find out star point. If you project here on your horizontal and this line you get, then this is called the azimuth and this angle which you get from horizontal to that position that is called altitude. So azimuth and altitude system is very commonly, most of the telescopic things you do, you can use this system. It is convenient.

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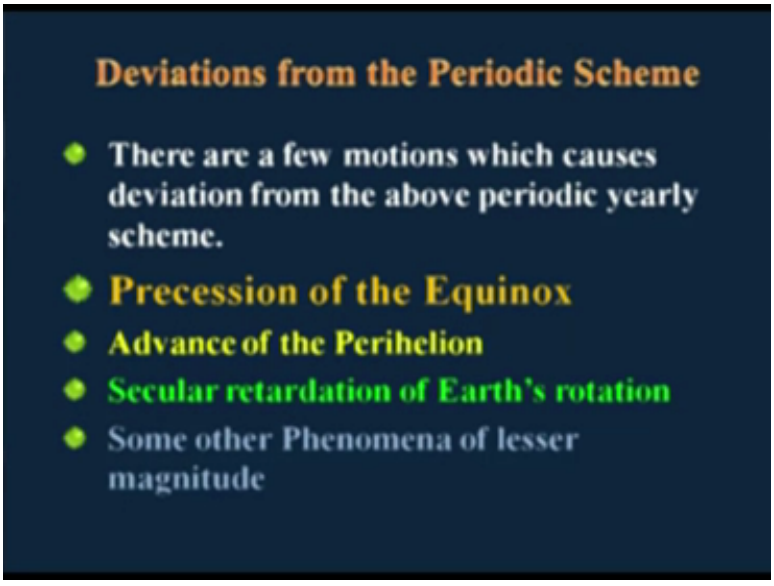

Now deviations from the periodic scheme just now I mentioned. One is precision of the equinox due to which the equinoctial point shift in the fixed star background. Of course, advance of the perihelion, that is against the perihelion point, aphelion points also shift in the star background. And secular retardation of Earth's rotation. Earth is slowing down, so obviously the time will gradually slow down, this is another change. And some other phenomena like 23 and half degree is not constant, it oscillates with a period of 44,000 years. Eccentricity of our, electricity of the earth's orbit also changes. Everything is actually periodic except this secular retardation which is not periodic.

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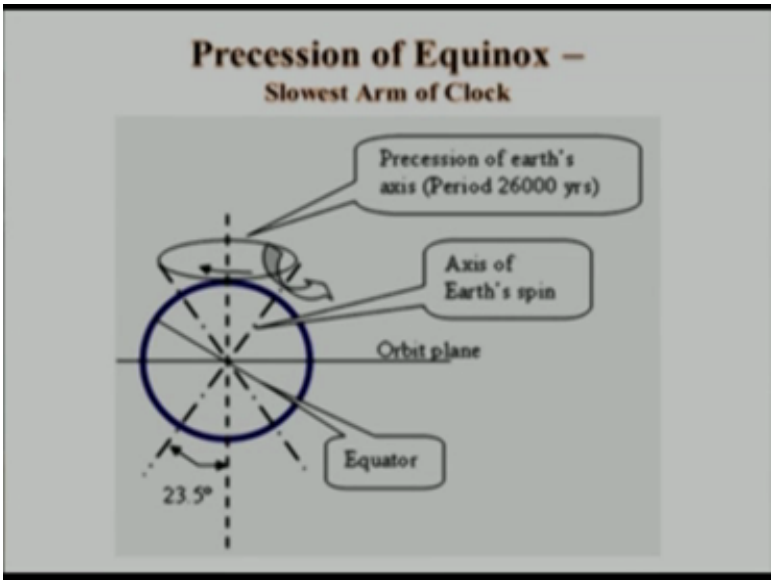

So this is the axis of the earth which is moving in a cone. It move, if it is spinning in this direction like a top, then precision in the opposite direction from east to west. And our spinning motion or daily rotation is from west to east.

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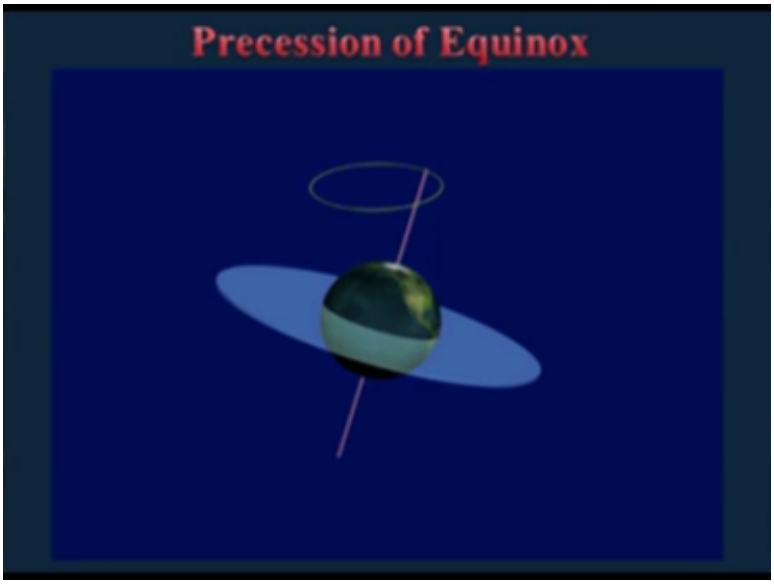

So these videos were there but I think I will not waste time in this.

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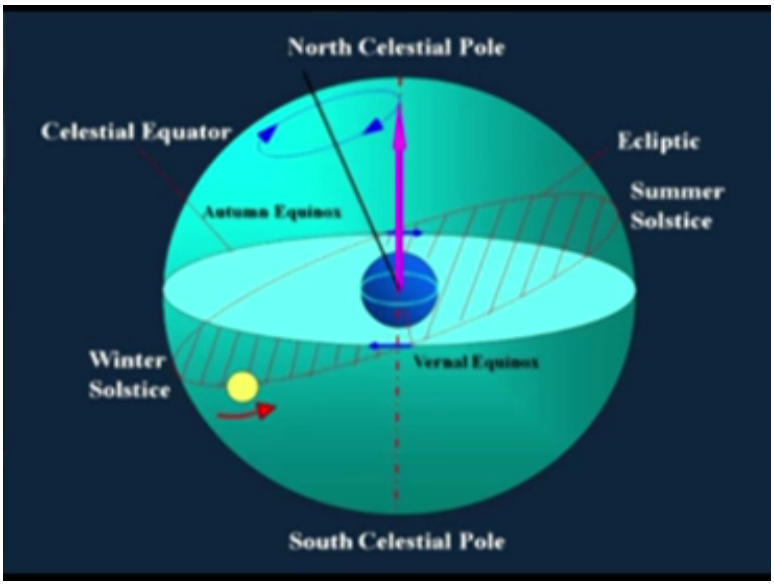

So what happened due to the precision of the equinox? This point if you draw an arrow, our rotational axis if rotational vector, so this point will trace a circle in the celestial dome. And or since the whole thing is ecliptic is there and therefore since this whole thing is also changing like this, this point, vernal equinoctial point shifts to the west.

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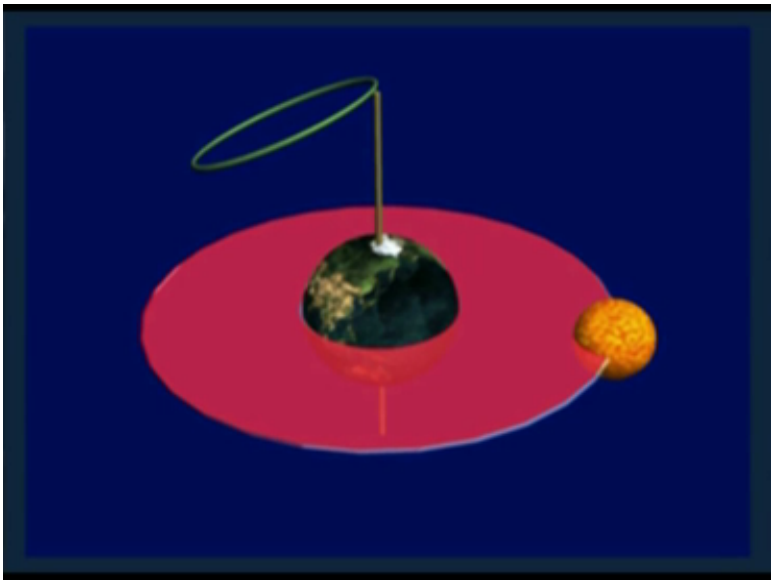

This is also that video, I will not show here.

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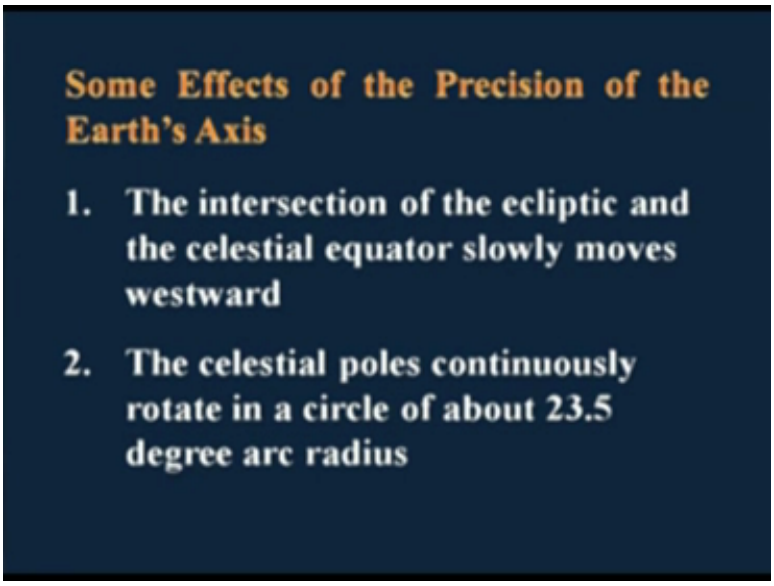

Now some effects of the precision of the Earth's axis. The intersection of the ecliptic and the celestial equator slowly moves westward. And the celestial pole continuously rotate in a circle about 23.5 degree arc radius. This is quite obvious.

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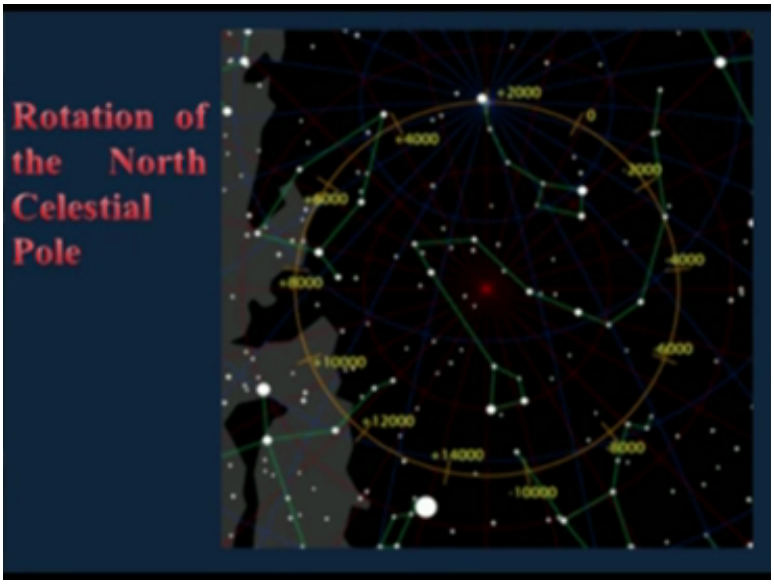

So what happens? Today the celestial pole is here about which our axis is puncturing the celestial dome there. And there is luckily a star here, we call what? Polaris. But I think 0 AD there was nothing, there was no pole star. Again when you go 3,000 BC, then you get a star that is called Thuban, another pole star. So 3,000, then if you find any record of any pole star in the ancient text, it has to be around that time because after that there was a long time there was no pole star. Again I think, so therefore see that we are lucky to have a big pole star now. But most of the time there is no pole star.

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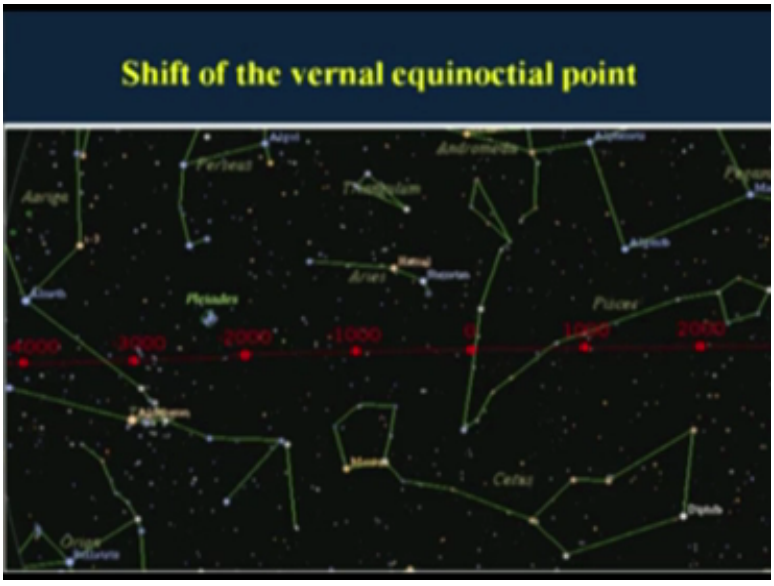

Say the shifting of the equinoctial point, you can say it is here today. 1,000 BC it was here, 2,000 BC it was here, like that. And today it is here, 2,000 AD. So therefore you can see the equinoctial point is shifting.

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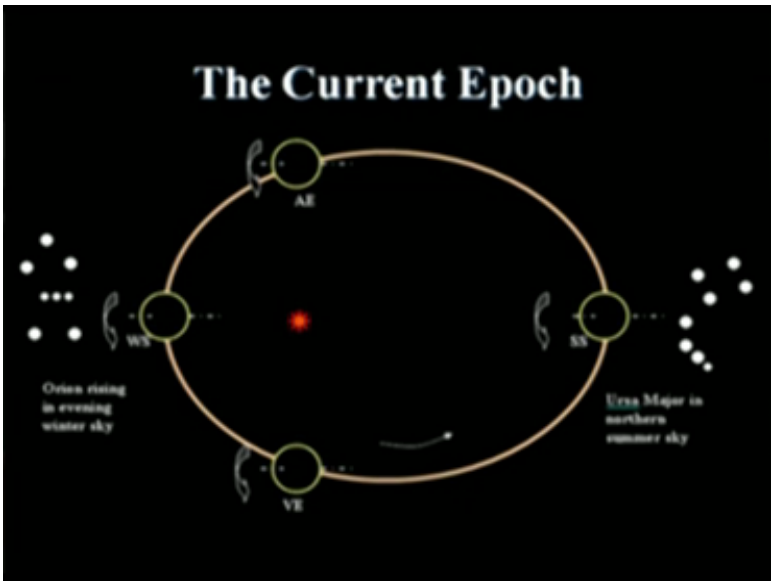

So again this precision gives a different because what happens now if you look into the eastern direction in the December or end, beginning January when it is cold, you will find a very important constellation called Orion is rising in the east, Kaal Purush we call India. 13,000 years hence it will be just the opposite. Pick summer you will find Kaal Purush is rising in the east, in the northern horizon it is summer.

So this is the kind of change which seasons the relative position of the star's constellations and the seasons they change because seasons depend on the equinoctial point and solstice points and they change in the background of the fixed stars.

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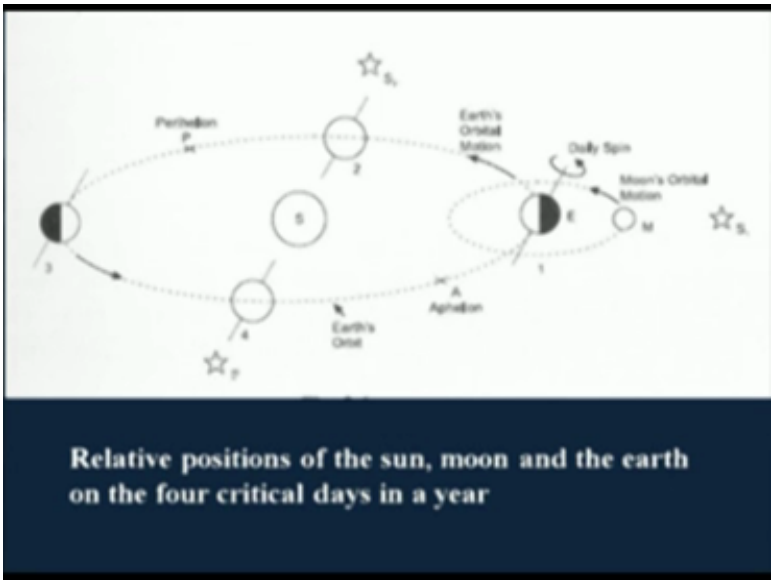

Another thing is that moon and earth is very important. You know that moon is going around the earth like this and earth is also moving like this. And moon's orbital motion, you will find this orbital plane is about 5 degree different, it is not the same plane as the ecliptic.

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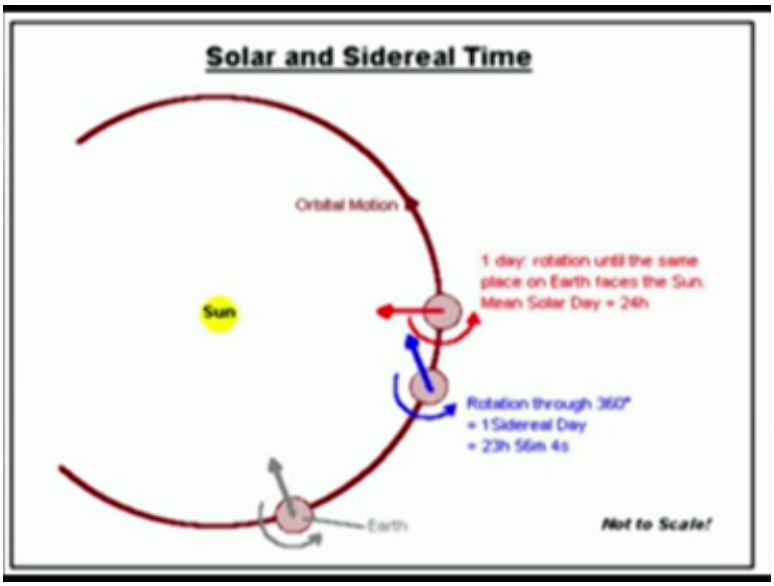

Now you see solar and sidereal time it is another thing. Anything which is reference to star you call sidereal like say for example earth is here, sun is in this direction. So sun will be apparently against some star here. So after some time, sun will again appear to be again in this direction, so

it is this. So when again this happens, that is called a sidereal day. Like say that it has rotated, this point has again come and sun is found to be again in the same direction.

Here is better to use. You will find that when you come back to another position where sun is again, appear to be against the same star position, then it is called sidereal year. They are slightly different. And day is from one sunrise to another sunrise. Why it becomes different? Because if it is, you are here when there is a sunrise. It is rotating like this. You are coming from the dark region, just sun rises here.

When you go to the next sunrise, earth has moved here. So you will find that you will have to rotate little bit longer extra. So day will be slightly longer than 360 degree rotation. So that is called mean solar day 24 hour sunrise to sunrise. Whereas sidereal day will be slightly different, it is 23 hours 56 minutes. When sun appears to come back to the same position in the sky, that time is slightly different, slightly less because of the earth's orbital motion like this.

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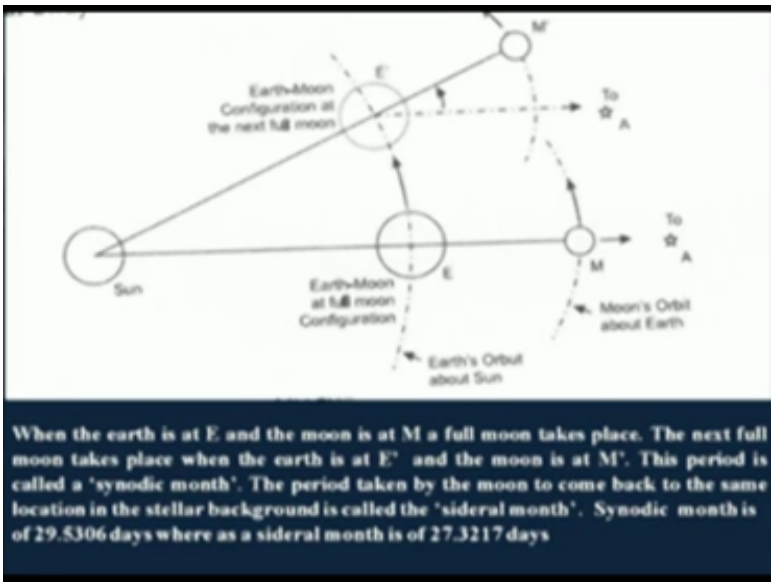

When the earth is at E and the moon is at M a full moon takes place. The next full moon takes place when the earth is at E' and the moon is at M'. This period is called a 'synodic month'. The period taken by the moon to come back to the same location in the stellar background is called the 'sideral month'. Synodic month is of 29.5306 days where as a sideral month is of 27.3217 days

Say, moon say for example, again the same thing. So here this is the moon, this is earth, this is sun. So it is a full moon day. Now full moon is against this star. So what happened, the next full moon, that means when it is again in opposition, whenever it is diametrically opposite, it is called opposition. So earth has moved here and moon has to go here to be in (oppo), so it rotates 360 degrees plus these extra degrees.

So one full moon to another full moon is somewhat a longer period than when moon comes back to the same position on the sky to star again. So therefore this is called a sidereal the earth moon, full moon configuration. It is the next full moon configuration. And that is why you can see one is called, the period is called as synodic month when it goes from here to here, one full moon to another full moon, synodic month to lunar month.

Another one is called sidereal month, that means when the moon comes back to the same position in the sky. That means when it will be here but moon will be here so that you see it against the star because this is parallel of course. So therefore sun is here, earth is here and moon is here, that means it has not rotated that much. So it is little bit ahead of the full moon position. So that is called the sidereal month and full moon to full moon is synodic month.

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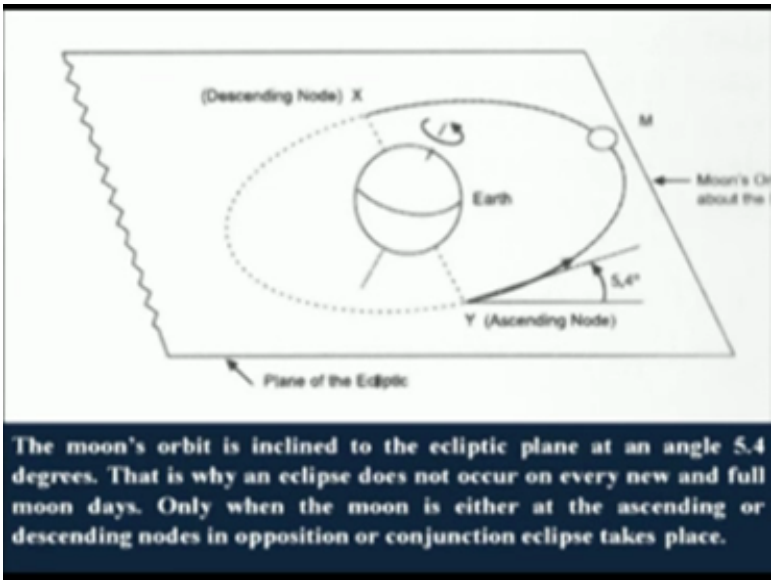

Again as I said that the orbital plane of the moon is slightly inclined, 5.4 degrees with the ecliptic plane. And there are two points where it intersects the plane of the ecliptic, they are called nodes. So when it is going like this, it is called the descending node and when it coming up like this, it is called the ascending node, x and y. Now how to, how can you get an eclipse? For eclipse moon has to be either in opposition or in conjunction, that means they must be in one line.

And moon has to be also in the ecliptic plane, then only it will be possible to have an eclipse. So this x, y must be in the direction of the earth-sun direction. So luckily what happened that this plane is also rotating. So this x, y line is also rotating.

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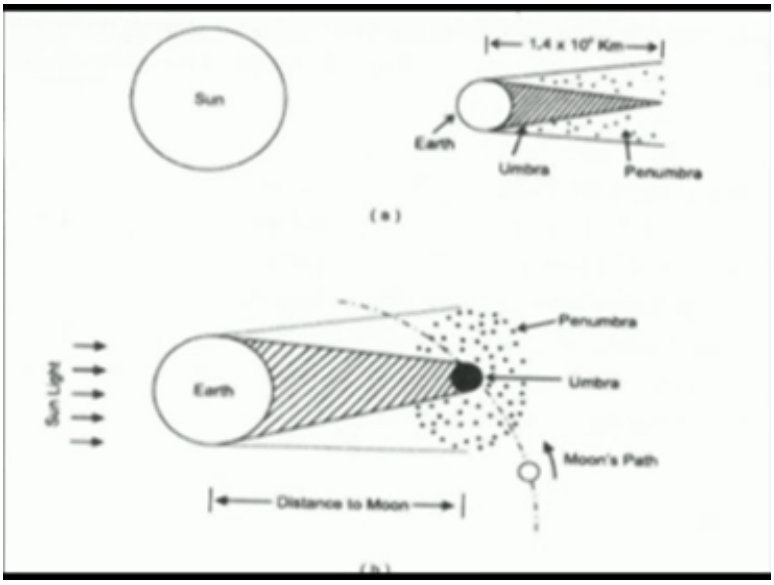

And so when, this is all eclipse you know.

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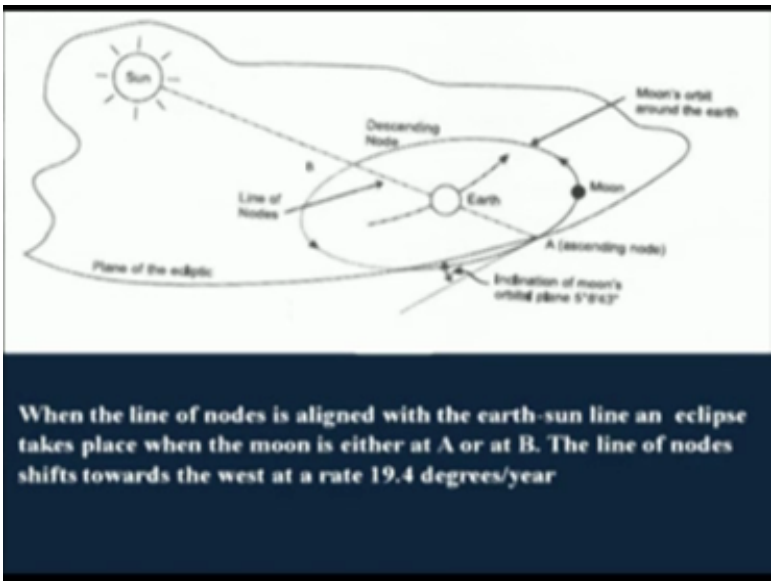

So when the ascending node, descending node and ascending node and they are in the same line along the earth-sun, then this is the right situation for having an eclipse either lunar or solar. So and this period of this rotation is, and it rotates at 19.4 degrees per year, so this line is rotating. So note that every full moon will be eclipse or every new moon will be an eclipse.

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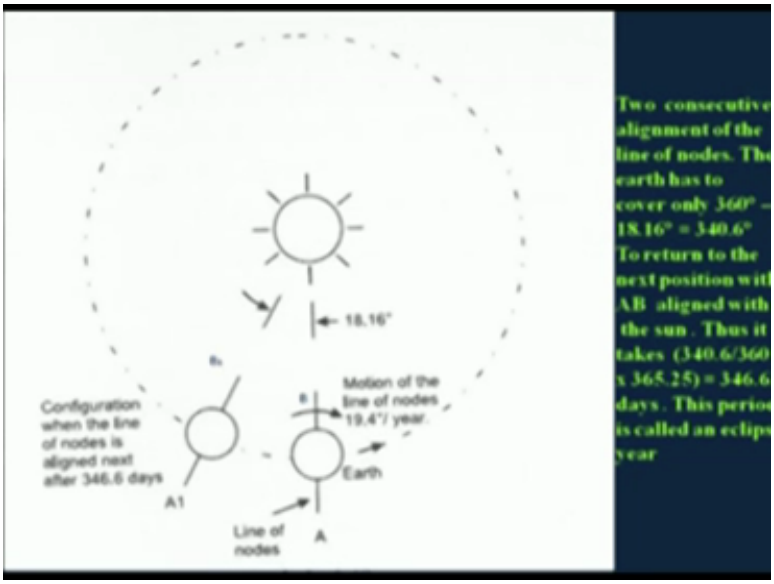

So for example, say now this is an ecliptic situation, that means this line is line of nodes is towards the sun. But it is rotating 19.4 degrees per year. So when again this kind of situation will come? When earth is going like this, when it has come here, by that time line of nodes has rotated by 19.4 degrees. And you will find that this is the situation for having next time, then they will be along the sun-earth. Another, so this particular period, 346.6 days is called an ecliptic year kind of thing. This is called the eclipse year. So after that again the eclipse will start taking place.

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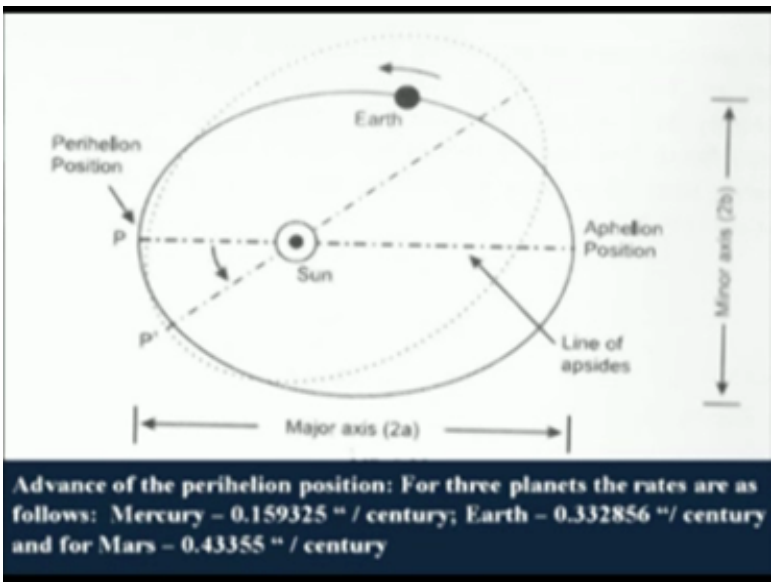

So the advance of perihelion position for the planets at rates are as much, this is the so much per century for Mercury which is quite noticeable. For earth, it is this and for Mars, it is this. So this phenomena also you know.

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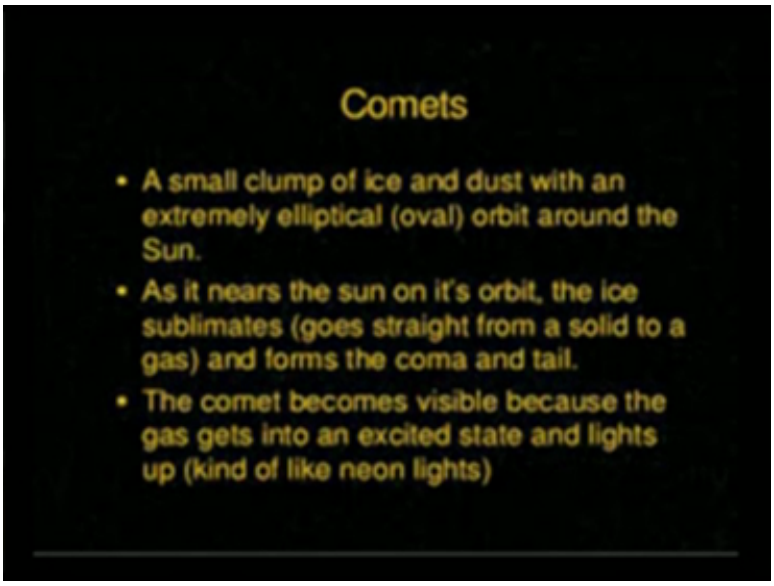

So comets you know, they are a small clump of ice and dust. They do not have much importance unless you are observing a periodic comet. And this is very important that in ancient Indian astronomical text, there are reference to comets which are periodic. And comet periods are pretty large you know, Halley's comet is 76 years or so. So you can realize that the observation of European scholars that they are not observant is not correct. And in those days if some says or some astronomer noticed a periodic comet, it is to get the name after that particular astronomer.

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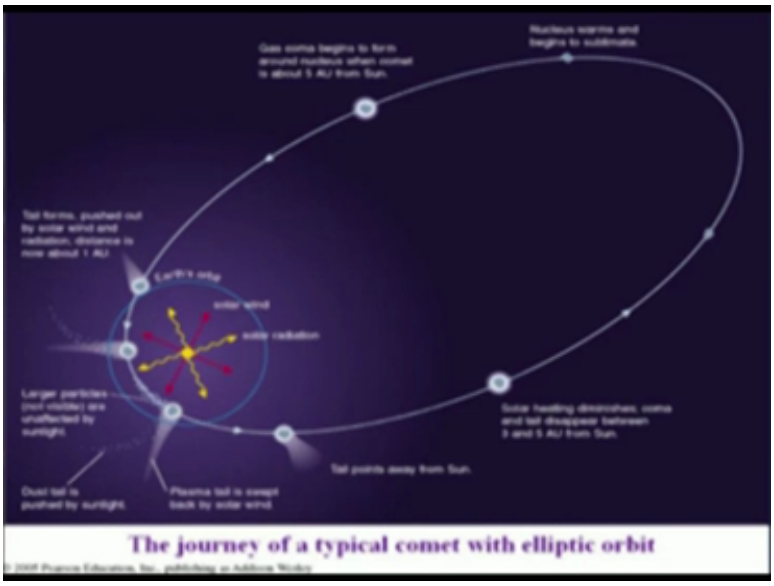

And this you know, this the comets follow large elliptic path and how the tail comes, you are all student of science and you know that.

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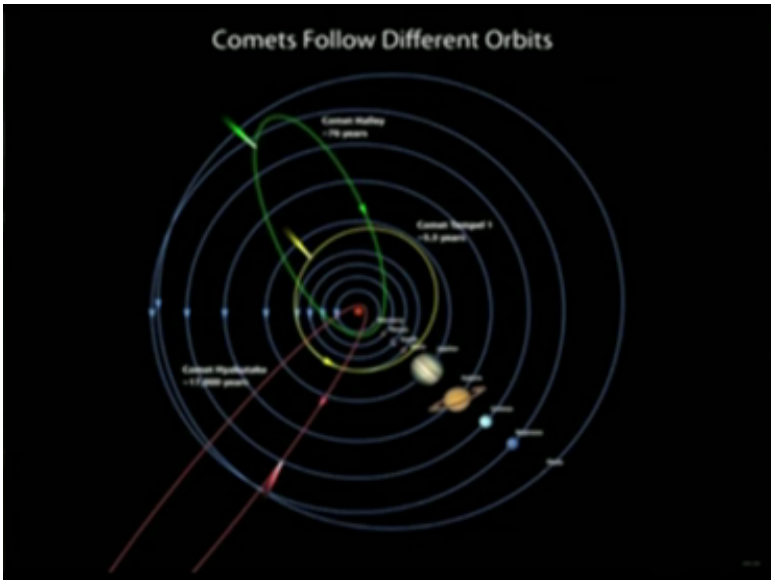

So these are some of the, this Halley's comet, this is another comet. So there are different path, different like there is another comet which has a period of 17,000 years.

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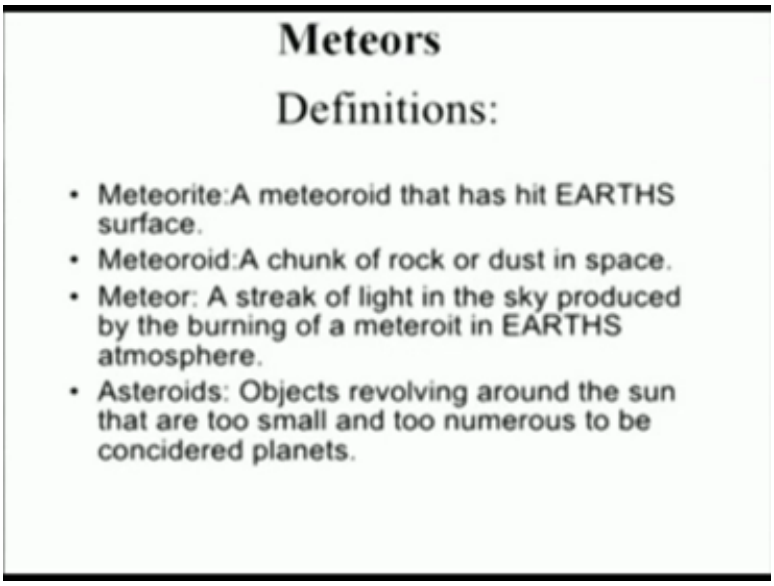

Meteors, they are again, that has hit earth, they are called meteorite. Meteoroid is a chunk of rock or dust in space. And meteor is the streak of light in sky produced by burning of a meteorite in earth’s atmosphere. Asteroids you know, they are the objects revolving around the sun but too tiny to be called as planets.

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So these are the meteor shower.

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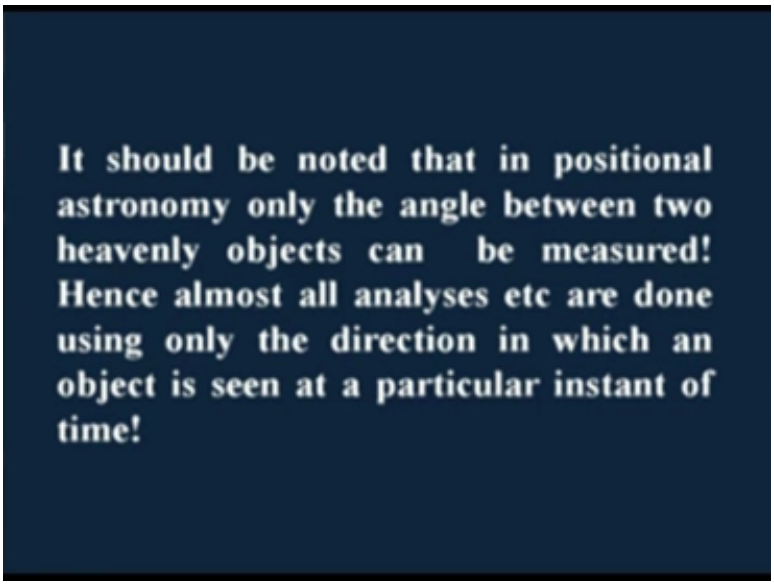

Now it should be noted that in positional astronomy only the angle between the heavenly objects can be seen, nothing else. So this is something very important to note that you can only find out angle, accuracy means that in naked eye astronomy, till the telescope it was naked eye astronomy, the highest possible accuracy was achieved by Jai Singh. It was one minute of arc. And currently do you know our present technology can find out an angle of nano-arc second to that accuracy level.

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So first session I will end here but not finish. I have something to discuss from here because I kept some time for you to ask and question. So few important things which I will tell, one is that the markers in the sky, the nakshatras they are all named and their locations are there. So therefore all the ancient Indian astronomy which was based on moon's position, they are called nakshatras.

Very interestingly you will find, something I will tell you now that when you go, how they identify? Suppose in the old days calendar you have to produce, how do you make a calendar? Calendar means what? The particular day in a year. So you have to tell the month, the day and the hour or the time. How do you identify a month? Now the ancient Indian astronomers has a very unique system that you all those nakshatras you have seen, moon's Rig Vedic name was Masa.

And whenever moon becomes full, purna masa against the particular nakshatra, that particular month is to be given that name. Like if purna masa is in Vishakha nakshatra, then will be Vaishakh. They used to identify that. That is how we got the names, Vaishakh, Jyestha. Jyestha was again Jyeshtha, and so on. And what happened, the purna masa means full moon but ultimately it we got that word Purnima, Purnamasi from the same thing. And then again what was the name of the moon, masa, it begins the word for month, we call maas.

So ancient situation was that, from one full moon to another full moon was month but it was in the very ancient times, Vedic period. Later in Vedanga period or Puranic period, it was changed from purnimanta system to amanta system. So from one new moon to next new moon was the month and name of the month will be on which nakshatra the full moon takes place. Nowadays of course, the system is not exactly this. But the names have continued from this philosophy.

So you can identify the month locating that which particular full moon is against that nakshatra. So the month is identified. Then they divided the full whole lunar month into 30 period, 30 lunar days. Lunar days has a special name in India, do you know? That is called tithi. Tithi is actually again another purely ancient Indian astronomical term. So this tithi is nothing but a lunar day. When you divide a lunar month into 30 units, we get tithis.

So you tell the name of the month, you tell, then there was a major division of paksha. So when the moon is becoming new moon to full moon, it is called Shukla Paksha. Another is from full moon to new moon, that is called Krishna Paksha. So you mention the month, you mention the paksha and mention the tithi. So you identify the day. And then within a day that kind of things that I will discuss when I discuss your pre-siddhantic astronomy there.

So that way they used, now we say on certain such day, 15th of January, say 2 O'clock we will meet, you tell your friend. So he has to know when is that time. So same thing they did, they will tell you the month, paksha, tithi and also tell the time. So this was the kind of basic structure which revolving which is very logical because observing sun is much more difficult and it was done much later. Another very interesting thing I will tell you here and you think about it. I found it in the literature and I do not know where the connection because connection with the Hellenistic astronomy that is Greek astronomy was only when Alexander came. That is how the people say that after Alexander came here and then there was some contact which was established with the Greek people and many things came.

But another thing you will find in Rig Veda, what is the term used for Venus, it is Vena. Vena in Sanskrit, Rig Vedic Sanskrit means daughter of son. And the name of Venus planet in Rig Veda is Vena. Now Vena and Venus, it cannot be a coincidence, I personally think. Again you will find in Rig Vedic time, I will come to that in details, the direction to exact south because South Pole was

not visible from northern hemisphere. They used to connect two stars, Alpha Canis Minoris and Alpha Canis Majoris.

And when you add these two star, it pointed exactly to the south in 4,000 BC not now of course. Again in Hellenistic Astronomy there they describe the Rig Veda as dogs, red-eyed dogs. And Greek astronomy again it is Canis means dogs. So but how the Rig Vedic terms go into the Hellenistic Astronomy is again a point I have not found any reference or any work on that, how that connection was there. So some of you can definitely really start thinking, finding literature and you can really bring out many new things which are still not known.

When was the connection established? It is not just during the Greek, maybe much before that. Some people have suspected that, some European astronomers and they have mentioned that perhaps the connection with Indian astronomy to western astronomy is much earlier than the Greek period. And many of them they feel that the flow was from east to west not the other way around. So that is one very important interesting thing you will see.

Now few things I have not discussed here, that is the details of the eclipse and your, the Vakragati and so on. Instruments also, naked eye astronomy, there are some very interesting thing like say if you hold one adult your hand and a normal figure, how much angle it will subtend with your eyes? So that they consider to be as, I think one degree they consider. When it is like this, they consider as 18 degrees.

If it is like this, then it is 10 degrees in normal case. And this, so this is actually they said 4 degrees and this is also 4 degrees each part at arm's length. So that is also very crude way of measuring angle of this angular distance between the planets, how they did. Of course, the very important other instruments they also used. One was the (())(72:48), that is the shanku which was used extensively. And for time measurement, eclipse, that there are three types of things, water clock, but the most common used was that pot kind of thing with a hole and when it gets completely filled up.

And they have designed that in such a way, in a whole civil day, they call (())(73:13) day sunrise to sunrise. It will, it is I think the 60 times it will get filled up like that. Another very interesting thing I found that the division of degree into 60 is original ancient Indian astronomical thing. 360

degree is very obvious. Can you find out the origin of 360? 360 days in a year kind of thing. So sun's position they thought it is 1 to 360 degree.

And they divided this degree into 60 minutes. I will come to that later. So many of the things what we do use but do not think that everything has come from the west. Many of the things which we use are actually of Indian origin. Next I think what I will start, little bit I will make use of that because here it was very simple descriptive. When I start presenting siddhantic and pre-siddhantic astronomy, then I have to go slowly because they involve new. Here I did not go slowly because most of the things are known to you. You are all science students.

That our story we will start in the Pre-historic period and in India also we have found some Stonehenge kind of system. In the ancient time, you have seen stonehenge and stone structures which were used in the primitive time for some very basic astronomical things. Like say when you see the eastern direction, what is the furthest point when the sun rises, that is the summer solstice day.

So the stone structures has to be made in such a way that, that direction was done. Why they did that, you can ask. Reason was because the seasons were associated with the sun's position. So they needed to do that, that when it is harvesting time, when you have to start the sowing, all those things. So they needed some basic clock, year clock on which you could say. Otherwise you do not know whether it is going to be right time for harvesting or right time for starting sowing et cetera.

So in India Anand Sagar, I think now Telangana, not Andhra Pradesh, so Anand Sagar is the one such unit where they have stone structures and with which you can find out the direction of the sunrise at this summer solstice, direction of the sunrise in winter solstice, also the moon's extreme northerly and southerly positions also, that has been found. Then the next when you come to next pre-historic period, that is your Harappa and Indus Valley civilization recall.

It has been now found out that the earliest settlement which has been found at Mehrgarh which is dated 6,500 BC, that means 8,500 years old. And it is a full-fledged city. So therefore from that people have tried to figure out whether they had astronomical observation which is quite obvious because they are so civilized this society cannot do without astronomy because most of their major structures they are having very accurate north-south directions just like the pyramids.

Actually the pyramid dating has been by considering the error they have made because in the ancient time a particular configuration of the northerly stars they used as fuel. Because pole star was not there, so you had to use other stars. Little it was found they used the same thing but it was wrong because things have shifted. So here also it has been found in Mohenjodaro and Harappa, the major structures are slightly, the later Mohenjodaro period they are slightly erroneous because in the very early days they used Thuban as the north star which was accurate.

But by, it was I think 2,700, 2550 when it was exact north. By 2500 BC it was already one degree away from the north and now it is 7.5 degrees away from the north. So therefore many of the structures in Indus Valley cities they are found either exactly to the north which are the very ancient structure but slightly erroneous because they used the same Thuban star as the pole star which was not.

So that is the time, so another thing they found, they found some crescent-side bone structures with 30 markings which meant it is a lunar month. And they had to keep even now, Andaman, some of the originals you will find they maintain this kind of a calendar with 30 groups. And the groups are also bigger group, smaller group, which says the phase of the moon and that kind of stone, not stone, bones they have been found even in, and another thing which was found in Kashmir valley, very interesting, there is a stone structure or piece with lot of markings and pictures.

One picture shows that hunting deer, et cetera, with two suns. It has been interpreted as one sun and one super-nova. And super-nova must have taken place very near to the ecliptic plane because otherwise it cannot be very near sun. And they have, now everything is possible with computer, they have found out that happened around 5,000 BC. There was a major super-nova which took place near the ecliptic. So it could be near the sun at some time of the year.

And that is some of the very ancient astronomical observation thing. And some Harappan seals they have shown seven stages which majority of the archaeologist, they interpret as seven stars of the saptarshi mandal. But as per things it is the seven stars of asterism Krittika. These are something. So even in Harrapan civilization they were evidence of astronomical observation and certain recordings up there.

Though we have not been able to decide for the language satisfactorily but some of the records show clearly astronomical observation. So these are the Pre-historic period but actually we will then start discussing the Vedic period what astronomical reference you find. That is the Pre-siddhantic astronomy which we will start tomorrow.

"Professor-student conversation starts."

Professor: So if you have any question, I will just……yes, please.

Student: What Rahu and Ketu are?

Professor: Rahu and Ketu are the two nodes and in the ancient times many Indian astronomers consider these also as two planets. But later even Aryabhata I knew very well that the Rahu and Ketu are not planets and why eclipse takes place due to the moon. That he mentioned in this. Yeah, please proceed one.

Student: Typography had this measurement of fonts daily, 1 in daily basis. Typography….

Professor: Typo had 2 minutes of accuracy. Yeah.

Student: (())(81:22) were greater than typography reports.

Professor: Actually you see Jai Singh, I will discuss. Jai Singh wanted to improve the accuracy and he thought that if you make the things very big, et cetera, using stone and machinery, your accuracy will be better. So he could achieve 1 minute of accuracy but unfortunately even 3 centuries before, Ulugh Beg, his system or his observatory produced more or less the same accuracy. So Jai Singh could not achieve much. Even 300 years later, he produced the same accuracy as Ulugh Beg's observatory. But his objective was primarily to improve accuracy. Yes, yeah, please.

Student: Sir, when the solar, when they start with, solar must be important there.

Professor: Actually what we find in Siddhantic astronomy, we find the 12 rashis and zodiacal signs. Names are same as the Hellenistic astronomy, that is why people think not only that, the 7-day week. In the Pre-siddhantic astronomy in Vedas, there are reference to shada, that means six days. But the 7-day week system and the same name that is actually from, they say it is, I will

discuss it day after tomorrow that is when you discuss. I will discuss in details how, Chaldeans most probably they started first, it went to Greece and then came to it. But before there was a week but for six days, shada, not saptah. Yes, anything else?

Student: (())(83:05) single type, so whether it is simultaneously approved as….?

Professor: I will tell you one thing here, why astrology came as subject. As I mentioned that people thought that when sun is in Cancer, it is so hot here. It is in Capricorn, it is so cold. The moon's phases and the tidal phenomena, the even they have that period which is also a lunar month. So that way they found that when it is poornima or amavasya, the pain, joint pains increase. They are all physical explanations.

But to believe that they also decide that when your daughter's marriage will be properly done or your son's examination will be good, this I think there is no scientific background. But the kings, remember progress of astronomy was because of astrology. Even in Italy, in Galileo's time Galileo used to earn extra money which needed badly to pay for the dowry of his two sisters. Mathematics professor's salary was not at all enough, it was one-twentieth of the salary of a medical doctor and law professor.

Student: Sir, then what……

Professor: What he did, he used to teach astrology to the medical students because it was a compulsory course. Doctors were required to cast a horoscope of a patient when he comes and see whether he has enough time to leave and then do treatment properly. Otherwise do not spend too much time. So he used to teach astronomy and astrology to medical students who used to pay quite a lot of private tuition fee to him.

So these are all old concept because the kings were interested in whether the next war he will win and his quote astronomer, he used to make predictions. Now to make predictions dependable and trustworthy, he had to do astronomy and had to predict eclipses and other things. The king, "On such and such day, the sun will be eclipsed by." And he says, "Yes, it is happening." So if he says, "King, on such and such time if you start the war with your neighbor, you will win," so he will do that. But I, personally to me astrology has no scientific basis. Yeah, please.

Student: When did the idea of Hellenistic come in the Indian astrology?

Professor: You see, Indian astronomy hints of heliocentricity is there in the late Siddhantic period and Kerala astronomy. Kerala astronomy, there was some hints. It was something like typographic system. But one thing remember, the daily rotation of the earth was told very emphatically by Aryabhata I. He has mentioned in his book, Aryabhatiya that the heavenly motion is due to earth's rotation. Sun never sets, sun never rises. He also told very clearly in the Vedic literature. But the orbital motion of the earth, it is not found anywhere. Yes, please.

Student: Ayan or nirayana, is it, nirayana is required some of the observations like they have to keep setting this sidereal or whatever it is?

Professor: Yeah, yeah.

Student: So when did that start?

Professor: That started I think, the Ayan Chalan what is called the precision, Ayan Chalan start, it is not found in pre-siddhantic astronomy. Only in siddhantic astronomy is there, Ayan Chalan is mentioned. And they accurately found out the value which was much more accurate than the Greek value. So that they did and they, as you said that they had to have a 0 precision year from which they will make their calculations. When I bring the method of calculation, so it will be seen how was there methodology, where it was required to count the number of days or gana. So there the starting point, 0 precision year, quite a few different astronomers they used differently but it is in…..

Student: Transaction now in the Indian (())(87:19), this is quite…..

Professor: Yeah, it is, there is a difference. Yeah.

Professor2: Okay, maybe we can take over these questions tomorrow. We are here for five lectures and thank you for today.

Professor: Thank you.

"Professor-student conversation ends."