Astronomy in Ancient, Medieval and Early Telescope Era of India
Prof. Amitabha Ghosh
Department of Physics
Indian Institute of Technology Kanpur
Session 03
Siddhantic Astronomy

Professor 1: Okay. Welcome to the third lecture. I will just make an announcement that the ppts, these presentation files will be available with me. My email address is dutta, whoever wants to copy please directly mail to me, I will send.

Professor 2: But give the PDF version.

Professor 1: Of course I will give the PDF version.

Professor 2: So welcome and I am thankful to you for your generosity of spending these evenings, valuable evenings with me in this room. Only two more days of suffering, not much longer. So today as I mentioned that the subject is really very vast and I am trying to present only the very essence of it because if I want to start discussing the calculation procedure, not only that some of you will not be interested in that, there is no time for it. Many other things which I would like to discuss will not be possible, so therefore I have advised that the books are there.

I have been told that already a full set of the 11 volumes of the series had been purchased and it is in the new arrival and I have also given a copy separately. So I think those of you who are interested in details of calculation, so you can see that.

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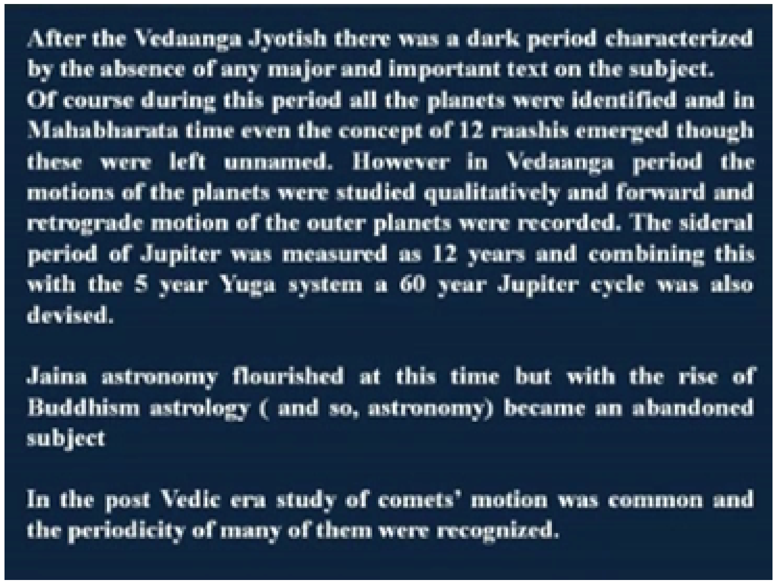

So today we will start our discussion on Siddhantic astronomy and after Vedanga Jyotisha, I mentioned this that there was long dark period characterized by the absence of any major and important development or text on the subject. And as it happens, during this period the outside disturbances started coming, rise of Buddhism where astronomy is not, or astrology is not preferred. So astronomy did not or it lost its primary impetus.

And all these things were there, that is in general you will find that even after the I think 14th or 15th century BC, there is not much known about it, it is a dark period. So but one thing is found that even in the Mahabharata's time which is around 1500, 1600 BC approximately, the concept of 12 raashis emerged though of course separate names were not given. But the planets were all known, their motions were all analyzed qualitatively.

That means whenever they are having a retrograde motion, it is found that Mangal is in vakri and so on. During this period another thing happened which I will take up in the last lecture which is very interesting. Astrology is not scientifically very important at least personally to me. But I think in the past astrological references sometimes become very useful. One such thing is exaltation of Mars, exaltation means when a particular planet is very bright.

The stars do not change their brightness but the planets do depending on the distance from the earth. Now Mars or Mangal when it is in its perihelion position, it is neatest to sun. And when earth is in aphelion position, it is furthest from the sun. When these two positions are side by side, the distance between earth and Mars is the minimum and the brightness of that planet is very large. That was three to four times more than what is normally we find and that is why the astrologers call Mangal Uchha or exaltation of Mars.

Now the importance of this is that if and they also say that Mangal is uchha against this nakshatra. That nakshatras are our reference point. Moment they say that, we know that was a situation where if you draw a line from earth to Mars, it will go to that particular nakshatra. And Mangal or Mars is in perihelion position and earth is in aphelion position. So you can calculate when it happened.

So one scientist who is no more, Professor Rana, he was in (())(04:41). So he also wrote some books. He has done lot of research on that and said that such astrological references are found which are around 1100 or 1200 BC. So during that period astrology et cetera in a fragmented form we get and we can use them for the chronological ordering of events then.

"Professor-student conversation starts."

Student: Can you talk about, so this stellar Jupiter or Mercury's or Venus time to get?

Professor: Not Venus, Jupiter.

Student: No, this Jupiter but you said about Venus yesterday, time period of Venus you mentioned.

Professor: Oh, that was, yeah that…..

Student: Yesterday?

Professor: Yeah.

Student: So this purely from the geocentric point of view?

Professor: Of course.

Student: Because that you will see in constellation?

Professor: Yeah, exactly. Now these periods are all sidereal periods. In case of planets they are generally sidereal periods, that means against the particular star. And as I mentioned that

Vedanga period, the motion of planets were qualitatively studied and the Jupiter's period was approximately 12 years, so they also developed a yuga system with 5 year yuga system with 60 year Jupiter cycle. That was also devised but they are not very relevant and not neither, it does not have matching time.

"Professor-student conversation ends."

And that time Jaina astronomy flourished. There are lots of text, the names are somewhat difficult to pronounce like Surya Prajapati, Jyotisha (())(6:13), then Chandra Prajapati, Jambudweep Prajapati like that. And Jaina cosmology et cetera, they all developed, those of you who have interest, you can go through that. But normally it is not considered very important from the point of view of astronomy. And at the same time as I mentioned that with the rise of Buddhism the astrology lost its importance and so the main impetus for doing astronomy also was gone.

So in very fragmented form things were going almost for thousand years. In the, the study of comet's motion as I mentioned yesterday was there and many comets were found to be periodic in nature. And the periods are found out and many astronomers' names were associated with those comets. And like say for example, some of the comets had period which one astronomer could identify or analyze during his lifetime. And so they were named after those astronomers.

So this requires definitely very accurate observation and prolonged observation. So the observation of many European scholars that Indian, ancient Indians were not having the capability to observe et cetera is absolutely not tenable.

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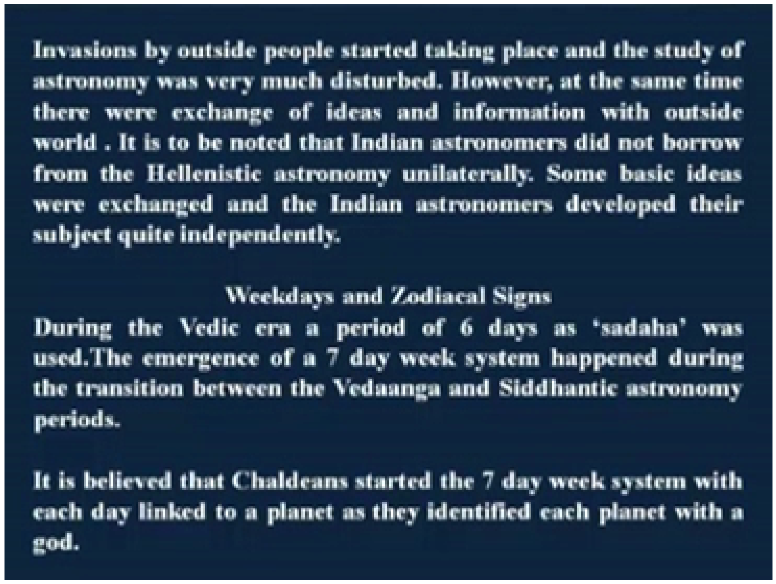

And as I mentioned that north India was being disturbed very much, so astronomy stopped. Because astronomy requires peaceful environment where person can observe day after day the positions et cetera accurately year after year. So this kind of situation did not, but at the same time what happened, with the coming of Alexander and later his other persons like Seleucus and other Greeks like Megasthenes, Arrian, so exchange of ideas started taking place also.

So many ideas of Hellenistic astronomy we find in Indian astronomy but they have, it has been found that it was not a copy because the things were only very basic similarity but otherwise in details they are very different which we will discuss in the separate section of discussion about the originality of Indian astronomy. That will be in the last lecture. Antiquity, using astronomy we will find out the dates when these kind of things were there and we will also discuss the points about the originality, which parts are original, why it is considered original and so on. That will be later.

And now I think what first thing you notice in the siddhantic astronomy was matured in the 4th, 5th century AD and the first major famous astronomer in the siddhantic period was Aryabhatta I. There are two Aryabhattas, so to distinguish that one is called, the earlier one who is more famous is Aryabhatta I. Much later there was another Aryabhatta, Aryabhatta II. So we find the first occurrence of weekdays and the names of the zodiacal signs.

But surprisingly the names of the weekdays and names of the zodiacal signs were very similar to that of those found in Hellenistic astronomy. In the Vedic era as I mentioned yesterday that there was the shada kind of thing. That means a week of six days. And the emergence of 7-day week system happened during the transition between Vedanga and Siddhantic astronomy.

It is believed that Chaldeans they started the 7-day week system. What happened, the you can easily guess why 7-day because 7 planets are there, sun, moon, Mercury, Venus, Mars, Jupiter et cetera. So they, each planet was associated with a God. And the 7 days which we had system based on the 7 planets and 7 Gods, I will tell you how it happened. And they linked each planet with planet God.

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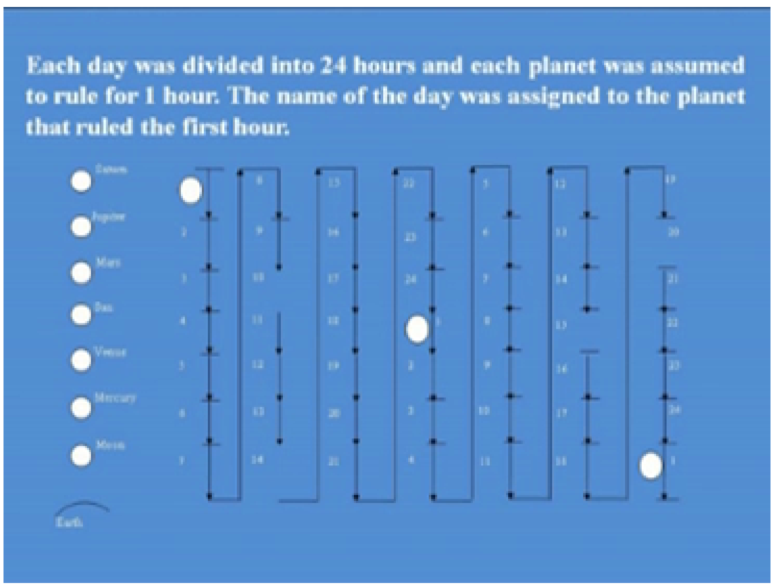

And the system was like this. In their system they found that every day was divided into 24 hours. The every hour was ruled by one planet God in series. And planets were placed in order in the ancient idea about the distance from the earth. So you can see this is earth nearest to moon, next is Mercury, next Venus, then sun, then Mars, Jupiter and Saturn. That was the perceived distance from earth in the ancient astronomy.

Now I think if you start here say for example, the first hour is ruled by Saturn. So that particular day out of the 24 hours…….

“Professor-student conversation starts.”

Student: Sir, Venus will be closer to the earth.

Professor: No, ancient astronomy was like this, you see. Yeah, it is not the heliocentric boundary, this geocentric model and that was their perceived way of doing it. So……

Student: Venus is closer to earth than Mercury, Mercury is the first.

Professor: Yeah, but I think the moon, then Mercury, then Venus. That was the way they were doing in those days. I think so, unless I am mistaken to see that. But I think basic idea is like this that whichever planet God rules the first hour, the day is named after that. So you can see if you start your day with Saturn ruling the first hour, okay, then next is to another planet. So you have to complete 2, 3, 4, up to this and up to 24 hours.

Next day's first hour is ruled by sun. So you can see that this is ruled by Saturn, then Jupiter, then Mars, then sun, then Venus, Mercury, then moon. Then you go to next will be again Saturn, again Jupiter and so on. Again Saturn, Jupiter and so on. Again Saturn, Jupiter, Mars and day is completed here. Next day's first hour is ruled by sun, so the day will become Sunday. Okay. So there you see again, you go 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, the day is over, 24 hours.

So where the next day's which planet rules? It is moon. Moon is Som, Monday. So that is the scheme by which we get the names of the days and week. Is it clear? And even in Indian system we are following the same, Saturn is Shanivar, Sunday is Ravivar, Monday is Somvar, Som is moon. Next day you will find if you do after 24 hours or 24 slots, then next day the first hour is going to be ruled by Mars, so it will be Mangal, Tuesday.

So this system which is felt that it was developed by Chaldeans and Chaldeans their thing was or the texts were translated into Greek. I think the person who did it is (())(14:14) in the 6th century BC. He translated this astronomical text into Greek and the system got adopted in Greek astronomy. That when the Greeks came to India with that, this exchange of idea, this 7-day week system came and their Siddhantic astronomers started following it.

Student: Sir….?

Professor: Yeah.

Student: Who were the Chaldeans?

Professor: Who were? Chaldeans were like in the ancient civilization has many like Babylonians, Chaldeans, all those people. You have to see that Middle East and near is border in Europe close to Egypt.

Student: Of which region they will be?

Professor: It will be somewhere near I think Syria.

Student: The Central Asian.

Professor: Uhh?

Student: The central Asian.

Professor: No, this is not central Asian, definitely not. Syria is not in central Asia.

"Professor-student conversation ends."

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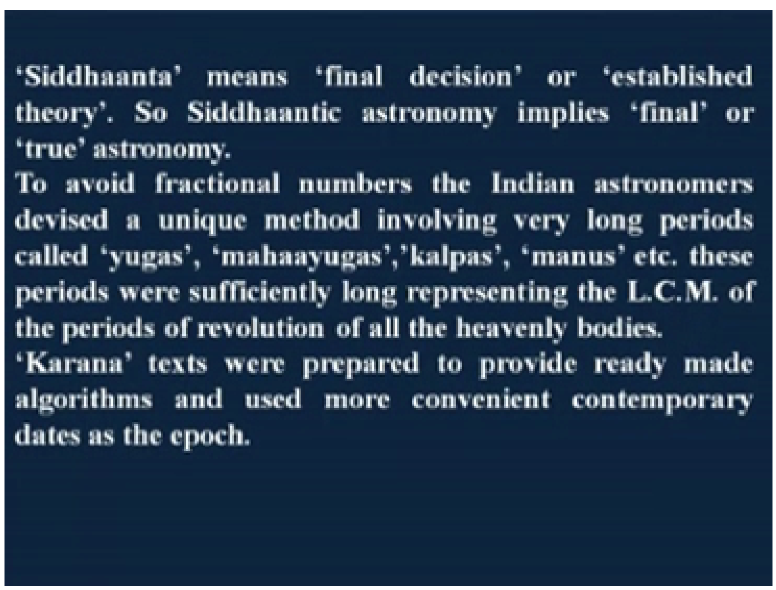

Now I think as I mentioned about why we call it Siddhantic text, because siddhant mean final decision. And each astronomer when he wrote something, he thought that is the final decision or final astronomical text. So they used to give the name siddhant. Everyone used to call siddhant after his name as you will see very soon. Another feature you will find that the 12 zodiacal signs, those names also were originally given by the Greek people following Chaldean calendar and that also got transmitted through Indian siddhantic astronomy.

We started following raashis. At the same time people started following nakshatra. So it was a mixture of solar, because raashi means that sun takes that position and then 12 times you divide the ecliptic. So each part is one raashi. Sun takes and spends there time every month, solar month. So this mixture but we were also using tithis, nakshatras et cetera. So it continued to be a mixture.

Even I think you will find later, I will come to that, not now, so I got enough boundary in that. So you see the Babylonian first divided the ecliptic into 12 divisions and they get the names of the raashis as Bull, Lamb and all kinds of things, Scorpio and that got translated and that also came to India. So that is the general belief that the week-day system was first started by Chaldeans and the raashi and 12 zodiacal signs, their names were given by the Babylonians.

And all those things came to India by the Greek. Now there is interesting point we have to mention here. One basic tenant of siddhantic period astronomy was to avoid what they did. To avoid the occurrence of fractional numbers, they consider a period when all the planets will make integer number of revolutions. That means it is a kind of LCM kind of thing you can see. And so therefore the yuga system which they developed is much much longer period than what yuga system they developed astronomers in the Vedic period.

So you will find and it was a unique method which will involve very long periods, yugas, mahayugas, kalpas, manus, et cetera. So therefore this was a mathematical requirement with LCM thing. Sometimes therefore I personally believe, by mistakenly we think that really our history goes back like that, that millions of years in the past and mahayuga, kalpa. I am not so sure that if that really happened or on the other hand it was a mathematical requirement by the astronomers to avoid fractional numbers.

You will see more details, we will come to that. Now is this point clear? This is a very confusing thing in our history that when you say mahayuga, they think actually our history also goes to mahayuga but it may not be so. It could be mathematical requirement. Now this siddhanta texts, they are quite massive things. And they describe many things, the system of the universe, the calculation and other kinds of thing like determination of eclipse. All these things were there.

And these siddhantas also used to be very so big that many times the authors of the siddhantas created a smaller version, what we can these days made-easy kind of thing which will be quickly used for calculating things. They used to be called as Karanas. They are nothing but simple texts which will be used only for calculating your or preparing the panchang or the calendar. So these Karana text were prepared primarily to give readymade algorithms and used more convenient contemporary dates of the epoch. It means, I will come to that when I discuss what is epoch and what is era.

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Post Vedaanga Jyotish astronomy in India can be divided into periods as indicated in the table below.

Period	Duration
Early Siddhānta period	100 BC – 400 AD
Siddhānta period	**400 AD – 1100 AD**
Late Siddhānta and Medieval period	1100 AD – 1800 AD
Modern period	**1800 AD –**

So the Post Vedanga Jyotisha astronomy in India can be divided into periods as indicated in the table. The first period we call early siddhantic period which started around 100 BC which is not very clearly known and continued up to 4th century AD. Then siddhanta period, when you first find Aryabhatta I, can be put in this range 400 AD to 1100 AD. Late Siddhantic period and Medieval period, 1100 AD to 1800 AD. And after 1800 AD, it is called the modern period when telescopic astronomy was there. So this is the way it is divided.

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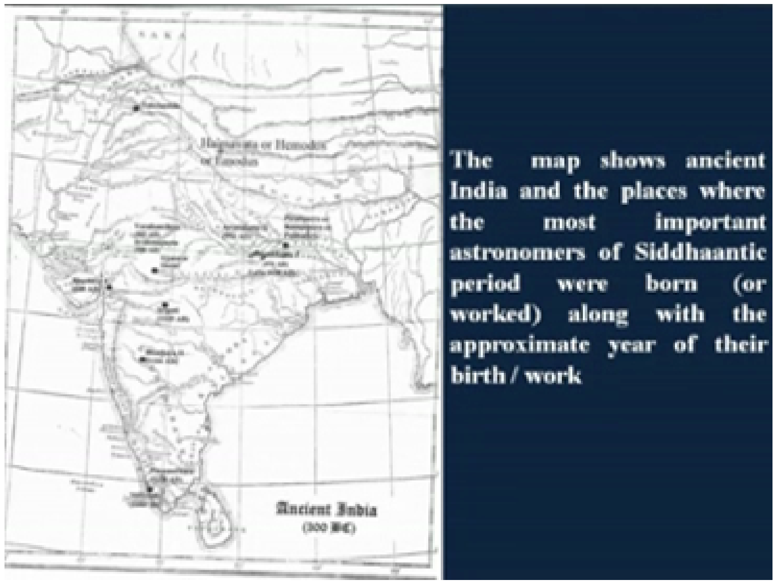

And this map shows ancient India and the places where the most important astronomers of siddhantic period were born or worked because it is not known sometimes whether the fellow was born there or he worked there. And along with the approximate year of their birth or work. So you can see this is not very clear, this is the Himalaya which is old name was Himmanta, Mahahimmanta, Himmanta. That is the old Sanskrit name of Himalaya.

And the Himmanta, the Greek people started saying that as Hemodos. And Hemodos again got distorted into Emodos. Even today if you go to Italy, you will see a station where you have to get down to go to Vesuvius and that is called Ercolano. Actually it is Herculaneum, so it has changed to Ercolano. It always happens. So it is Emodos or Hemodos or Himmanta is the Himalaya. This is Tambapanni. Tambapanni was the old Sanskrit name of Lanka. That they, Greek used to call it Taprobane, so like that.

So here important places where we have the most distinguished astronomers of siddhantic period, one is you can recognize this part, Patliputra or Kusumapura. Actually Patli is a kind of flower and that is why quite often many astronomers or many philosophers used to call Patliputra also by the name Kusumapura. And it is known that Aryabhatta worked at Kusumapura which is Patliputra because Patli is a kind of flower after which the name was given.

Maybe Patliputra had lot of flower gardens, somewhat different from today’s Patliputra. Then we have the place near Ujjain, actually Ujjain for long time was our like venue which had the meridian 0. Then in Gujarat where Brahmagupta worked and born, also very famous person.

“Professor-student conversation starts.”

Student: Sir, Bhaskara.

Professor: Bhaskara, yeah Bhaskara. And this is I can read from here.

Student: Sripati.

Professor: Sripati was there. And Varahamihira what could we generally all know, he was one of the navratnas. Sripati was somewhere in Vidarbha area, then Bhaskara too was there in Telangana what we call today southern part of, they call it Marathawada region and of course finally, Kerala. What happened, more and more disturbances came here and most of the academic pursuit gradually shifted towards the south and ultimately (())(23:55) here.

“Professor-student conversation ends.”

So all the next stage siddhantic very famous astronomers, Nilakantha and others, they were all from Kerala. So this is, that will give, this is actually ancient India. This map has been drawn which is contemporary at 300 BC but they were of course not 300 BC, they are much later. But the names which have been given, they belong to 300 BC.

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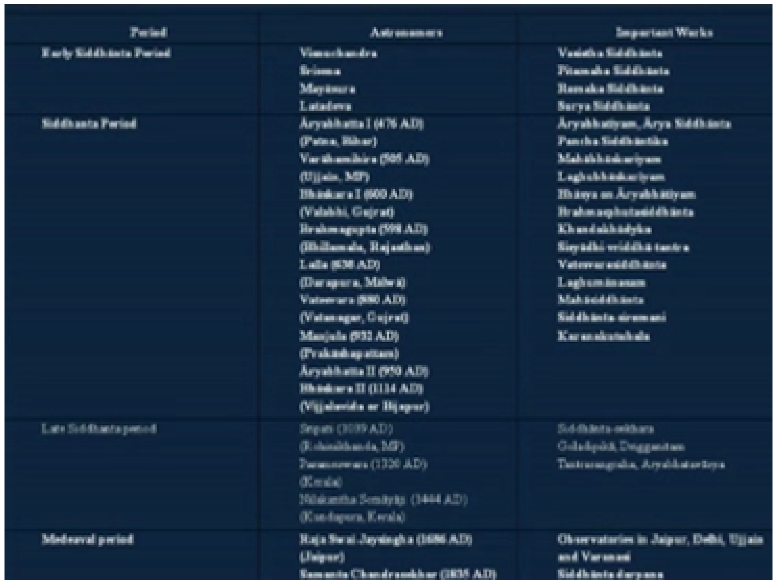

Period	Astronomers	Important Works
Early Siddhānta Period	Vimuchandra Srisena Mayāsura Latadeva	Vasistha Siddhānta Pitamaha Siddhānta Romaka Siddhānta Surya Siddhānta
Siddhanta Period	Āryabhatta I (476 AD) (Patna, Bihar) Varāhamihira (505 AD) (Ujjain, MP) Bhāskara I (600 AD) (Valabhi, Gujrat) Brahmagupta (598 AD) (Bhillamala, Rajasthan) Lalla (638 AD) (Dasapura, Malwa) Vatesvara (880 AD) (Vatanagar, Gujrat) Manjula (932 AD) (Prakashapattam) Āryabhatta II (950 AD) Bhāskara II (1114 AD) (Vijjalavida or Bijapur)	Āryabhatiyam, Ārya Siddhānta Pancha Siddhāntika Mahābhāskariyam Laghubhāskariyam Bhāsya on Āryabhātiyam Brahmasphutasiddhānta Khandakhādyka Sisyādhi vriddhā tantra Vatesvarasiddhānta Laghumānasam Mahāsiddhānta Siddhānta siromani Karanakutuhala
Late Siddhanta period	Sripati (1039 AD) (Rohinikhanda, MP) Paramesvara (1320 AD) (Kerala) Nilakantha Somāyāji (1444 AD) (Kundapura, Kerala)	Siddhānta-sekhara Goladipikā, Drgganitam Tantrasangraha, [illegible]
Medieval period	Raja Swai Jaysingha (1686 AD) (Jaipur) Samanta Chandrasekhar (1835 AD)	Observatories in Jaipur, Delhi, Ujjain and Varanasi Siddhānta darpana

So these are the important astronomers of different periods. Early Siddhanta period we have Srisena, Mayasura, Latadeva and I think these are the people who are before Aryabhatta and they did some work during the transition period. Then also it is told that Romaka Siddhanta is there maybe and then the (())(24:55) Siddhanta is there. They are all during the transition period. Then Aryabhatta I, 476 AD, he was in Patna, Bihar.

Varahamihira maybe was the next, 505 at Ujjain. Bhaskara at 600 AD in Gujarat, Brahmagupta, 598 AD in Rajasthan. Lalla and Malwa. Then Malwa means (())(25:26) which is near, I think what will be Malwa for, Indore and those places we can call Malavati. But Vateshwar, 880 AD in Gujarat. Manjila was very important one, (())(25:44) south. Aryabhatta II, 950 AD. Bhaskara II, 1140 AD and in the late siddhantic period we have Sripati in Madhya Pradesh, Parameshvara in Kerala and Nilkantha Somayaji, very famous one in also Kerala.

And medieval period siddhantic astronomy was done mixed with Zij astronomy, Maharaja Sawai Jai Singh. And the last, it is not coming here. The last siddhantic astronomer was from Orissa, Samanta Chandrasekhar. And you can see they are texts, Vasishtha Siddhanta, Pita Maha Siddhanta, Romaka Siddhanta, Surya Siddhanta and Aryabhatta stated with Aryabhatiyam or Arya-Siddhanta. And Varahamihira found, he studied all I think, 26 siddhantas he found. And most of them were inaccurate or not much use.

Actually what was happening, Vedanga Jyotisha, after that all those steps were inaccurate. We have seen the way we calculate, very approximate and they are not of much use. So therefore they are not used and they are completely forgotten. Only Vedanga Jyotisha remained because of that name Vedanga. It was treated as a part of religious text. Otherwise, perhaps it could have not survived also.

And Aryabhatta, then what we found, only five of those siddhantas were of use and he wrote text called Pancha Siddhantika, Varahamihira. Varahamihira's main occupation was of course astrology. So his work in astronomy was primarily compilation, not much fundamental work. Then of course Varahamihira, then Bhaskara, then Braham, this Brahmagupta is considered to be one of the best and his siddhanta was Brahma Siddhanta or Brahmasphuta-siddhanta. Both are the same. And he had a karana which was also very popular, that is Khandakhadyaka. They are all translated into Arabic language and that stated the Zij astronomy then and so on, we will not go.

The last siddhanta we have Siddhanta Darpana, that is written by Samanta Chandrasekhar, that is the last and that is used even today. His calculations were so accurate, the Puri Temple, Jagannath Temple, all things are done according to Samanta Chandrasekhar's calculations.

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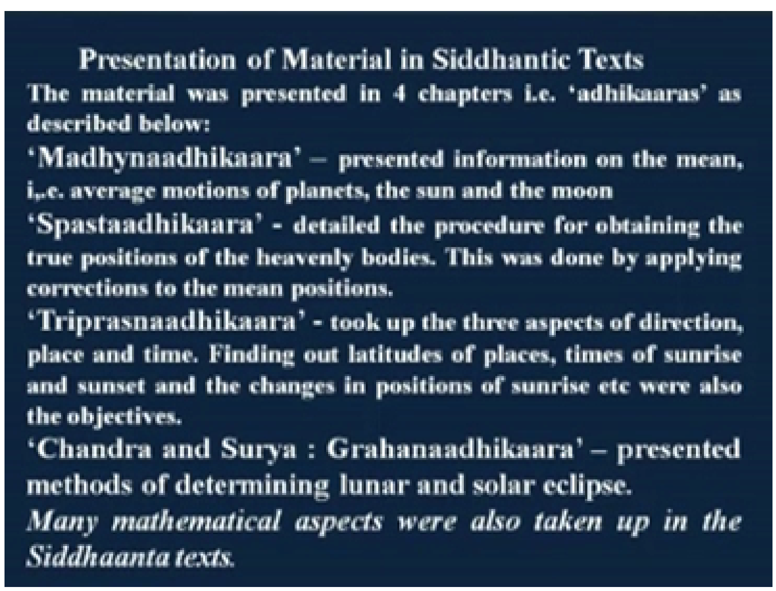

Now how text were arranged in siddhantic. The material was presented in four chapters generally in siddhantas. The chapters in Sanskrit are called adhikaaras and first used to be

Madhynaadhikaara. So these used to give the method of calculation and data et cetera for mean positions. In all astronomical text whether in India or in Greece, the final position is the main important objective of positional astronomy, you know that, finding out the position of sun, or moon or planet.

In Vedanga Jyotisha, only sun and moon's position calculations were there, planet calculation was not there in Vedanga Jyotisha but they were in Siddhanta. Siddhanta, the position of the planets, 5 planets and sun and moon, all were included. Now the technique generally used to be like this: first we find out the mean position. How mean position is found out? You take the average speed of rotation and you find out at a particular time where it is going to be, that is the mean position, not the real thing. Then you make corrections on that to get the exact true position, they used to do, I will come to that.

So Madhynaadhikaara's main purpose was to calculate the mean position of a planet or sun or moon and he detailed the procedure for obtaining the true position of the and Spastaadhikaara was the detailed procedure by applying the corrections which they call samskaras to get the real, true, correct position of the heavenly bodies. And I will come to that. There are primarily two types of corrections. One is Manda correction, and then Sighra correction.

Manda correction was for sun and moon and it took care of the non-uniform speed of the heavenly bodies. Because you know being on elliptic orbit and the distance from the sun being different and according to Kepler's first law, they will, second law, they will definitely have different speeds. So therefore they do not move with a constant speed or mean speed. So therefore you need to correct it. So that was for sun and moon.

The sighra correction was important for planets. Of course, for planet manda correction was also there but you have to also do sighra correction. That used to take care of, because you see real system is heliocentric but we are observing sitting on the earth as geocentric system. So that needed samskaras and they are called sighra samskara, they are for the five planets not for sun. There was another third chapter, that is Triprasnaadhikaara. This took out the three aspects of direction, place, time, finding out latitudes of places, times of sunrise, sunset and the changes of position of sunrise et cetera. That was the objective of Triprasnaadhikaara.

And last was Chandra and Surya, Grahanaadhikaara, that presented the method for determining lunar and solar eclipse. Many mathematical aspects were also taken up. Actually mathematics also developed during this period because it involve calculation et cetera. Particularly trigonometry, they developed during this period.

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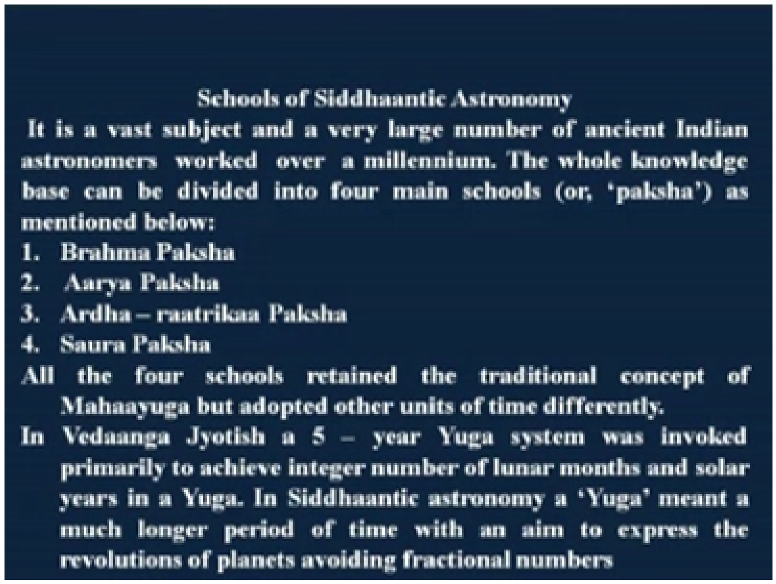

Now they are four schools of siddhantic astronomy. It happens…..

"Professor-student conversation starts."

Professor: Yeah.

Student: So the Greeks used to call it epicycles. Did they have some word like epicycles for?

Professor: Yeah. Not only that as I will show you later, Indian epicycles were somewhat different. Greek epicycles were fixed size. Indian epicycles, the size used to vary and that was more accurate description. Because epicycle is actually fantastic, it was not a reality. So Indian epicycle system was more advanced, it took care of further approximation by giving the variation in the epicycle. It was not like the Greek epicycle.

"Professor-student conversation ends."

So actually as I mentioned when I discuss the originality of Indian astronomy, all these points will come, that how much was taken directly and how much actually got developed indigenous.

So the four schools or paksha they call were Brahma Paksha, Aarya Paksha, Ardha-raatrikaa Paksha and Saura Paksha. And all the four schools retain the traditional concept of mahayuga but adaptive units of time and epoch are different as you will see.

In Vedanga Jyotisha, you have seen that we had a five year yuga system primarily to achieve integer number of lunar months and solar years in a yuga. That we have discussed yesterday. In siddhantic astronomy yuga meant a much longer period of time with an aim to express the revolutions of planets avoiding fractional numbers.

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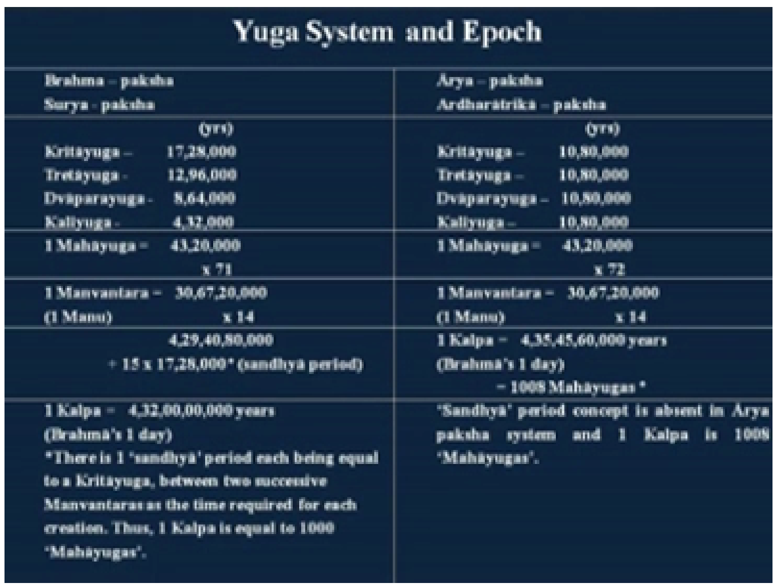

Yuga System and Epoch

Brahma – paksha Surya - paksha	Ārya – paksha Ardharātrikā – paksha
(yrs) Kritāyuga – 17,28,000 Tretāyuga - 12,96,000 Dvāparayuga - 8,64,000 Kaliyuga - 4,32,000	(yrs) Kritāyuga – 10,80,000 Tretāyuga – 10,80,000 Dvāparayuga – 10,80,000 Kaliyuga – 10,80,000
1 Mahāyuga = 43,20,000 x 71	1 Mahāyuga = 43,20,000 x 72
1 Manvantara = 30,67,20,000 (1 Manu) x 14	1 Manvantara = 30,67,20,000 (1 Manu) x 14
4,29,40,80,000 + 15 x 17,28,000* (sandhyā period)	1 Kalpa = 4,35,45,60,000 years (Brahmā's 1 day) = 1008 Mahāyugas *
1 Kalpa = 4,32,00,00,000 years (Brahmā's 1 day) *There is 1 'sandhyā' period each being equal to a Kritāyuga, between two successive Manvantaras as the time required for each creation. Thus, 1 Kalpa is equal to 1000 'Mahāyugas'.	'Sandhyā' period concept is absent in Ārya paksha system and 1 Kalpa is 1008 'Mahāyugas'.

So you see that was the yuga system and epoch in siddhantic astronomy. Now you can see that in the Brahma Paksha and Surya Paksha followed one set of data and your Aarya Paksha, Ardha-raatrikaa Paksha started another set of data. Kritayuga was 17,28,000 years, Tretayuga was 12,96,000 years, Dwaparayuga was 8,64,000 years. Kaliyuga is supposed to be 4,32,000 years. So in total one Mahayuga had 43,20,000 years.

In Aarya Paksha and Ardha-raatrikaa Paksha system was they divided all yugas equally and they were of 10,80,000 years. In total again one mahayuga was 43,20,000 years. Then 71 mahayugas made one Manvantara or Manu and that was obviously multiplied by 71 and you get such a big number. Now I do not want to read it. In other system school, they had 72 mahayuga made one Manvantara or 1 Manu. And 14 Manus make one kalpa. So you can see in this school one kalpa is so many years which is considered Brahma’s one day and 1,008 mahayugas.

Now there you find that we had got ultimately the same number you will find but they added some Sandhya period. One yuga, mahayuga to another mahayuga, they used to add one intercalary yuga or they used to call it Sandhya period, evening period. So maybe comitant dusk, is not it? Something like that. From one revolution you are going to a revolutionary period and it is never an abrupt change, there will be always a comitant dusk, or (())(36:07) rakta usually in Bengali or Sanskrit where lot of killing et cetera goes on.

So you see, that is the way they got a huge number, 1 kalpa is this much in this paksha, the school. And here it was this, 1 kalpa is this much, somewhat different. Sandhya period concept is absent here and 1 kalpa is 1,008 mahayugas. Here there is a sandhya period, each being equal to Kritayuga between two successive Manvantaras. And the time required for each creation, thus 1 kalpa is equal to 1,000 mahayuga in this case.

So this is the kind of thing but point is to I am not so sure, I will leave it to you to judge that whether these are really our history goes like that or it is the mathematical requirement to avoid or taking a large period so that you express all the numbers in integer forms like LCM. So I personally believe it was a mathematical requirement, not that but I think since everything you have to do, if you put everything in purely mathematical form, people do not like it. So you give it a kind of reality by giving these things that Brahma is there, his 1 day is 1 kalpa et cetera all kinds of things.

“Professor-student conversation starts.”

Student: Interestingly this 4 billion years is interesting because now 15 billion years is the age of the present time.

Professor: And that is the danger. Immediately people will say we all knew about Big Bang and so on. So that creates some maturity. Such coincidence it is not, but I think you have seen perhaps I feel it is primarily mathematical requirement to express the revolutions in integer numbers et cetera. Just like a five year yuga, a simple case where the solar revolution and lunar revolutions all both were integer numbers.

Student: And the 71 and what was that 71, 72, 14?

Professor: They followed different, there are all calculation, that is what I am saying. They found, they calculated that way. Ultimately their objective was to find out the position of a planet in a particular day and time. That is all, nothing else.

“Professor-student conversation ends.”

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Use of Mahaayuga System

Object	Number or, Number of revolutions in one Mahāyuga
The sun	4,32,000
Stars	1582237800
Sāvana days	1577917800
The moon	5775336
Mars	2296824
Jupiter	364220
Saturn	146564
Civil months	51840000
Lunar months	53433336
Tithis	1603000080

So the use of mahayuga system, the number or number of revolutions in one mahayuga, say the sun revolves so many times. Stars revolve so many times. Now stars revolution is nothing but revolution of the earth, is not it? Earth rotation is the stars rotation. Then Savannah days, this much, the moon, savannah days will be little less because we have seen one savannah takes little bit more time. As I told when you are here seeing the sunrise, coming back to the same position next sunrise you do not find, you have to do little bit more because sun has gone little bit because of the orbital motion.

So that is why savannah day numbers are little less than the rotation of the earth. The moon rotates so many times, Mars, Jupiter, Saturn, then civil months, lunar months and tithis. So in one mahayuga these are the numbers they used to get.

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Comparison of Numbers in Different Systems
The number sidereal revolutions in one 'Kalpa'

Object	Modern Surya Siddhānta	Bhaskara	Āryabhatta I
Sun	4320000000	4320000000	4320000000
Moon	57753336000	57753300000	57753336000
Mars	2296832000	2296828522	2296824000
Mercury	17937060000	17936998984	1793702000
Jupiter	364220000	364226455	364224000
Venus	7022376000	7022389492	7022388000
Saturn	146568000	146567298	1465640000

The comparison of numbers in different systems. I think Bhaskara and modern Surya Siddhanta and Aryabhatta I, so the data varied little bit not very much but the system was slightly different. So you can see this is same by all the astronomers. This also appears to be same. In case of Mars it is different you can see. Mercury also you get. When you go to planets, the sun and moon, they are same. And Jupiter again you find that they are little different for each one. And here again Venus, you find they are different. So these are the three major systems where we follow these are the numbers. Numbers are nothing but the revolutions. Everything was on that.

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Identifying an era or, epoch is essential for preparing 'Panchaangas'. The commonly used eras in Indian astronomy are

1. **Kali**
2. **Vikrama Saka**
3. **Saalivahana Saka**
4. **Kollam**

After the Islamic invasion Hijra era had been used by the Islamic Scholars. For each era there is a 'zero-point' i.e. starting point i.e. 'epoch'

Aryabhatta I started the 'Kali' era counting the mid night of 17th – 18th February, 3102 BC as the epoch. The epoch of Vikrama Saka is 58 BC. 78 AD is the epoch for Saalivahana era. The epoch for Kollaam era is 824 AD.

Now I will explain the term which we call epoch and era which is very important. Now when you calculate the position, how you do? You start with Num position on a certain day and then I say that on such and such date. Now such and such date means you have to count the number of days to the desired position date. So where you start? So the starting date for your all calculations is called the epoch.

So they, the Indian astronomy, they commonly used eras. Eras means like Christian era, shaka era, they are called eras. And epoch is the starting date. So the panchangas were primarily created where these eras were commonly used. One is kali, Aryabhatta used kali era, that means when the kaliyuga started. Then vikrama saka was there, is another one. Shalivahana shaka is another era and Kollam which was followed in Kerala.

Of course when the Islamic invasion came, then I think Hijra also became another era which was used by astronomers. Now for each era there is zero-point or starting point as I mentioned, that is called epoch. Aryabhatta-I stared the Kali era counting the midnight of 17^{th}- 18^{th} February, 3102 BC as the epoch. And so yeah.

"Professor-student conversation starts."

Student: This 3100 BC…..

Professor: 3102.

Student: All right. Does it help in such calculation or why this?

Professor: Yeah, actually, these dates are actually currently our dates.

Student: Right.

Professor: But they did not have the BC kind of thing.

Student: But it is 3,000 years before this right time?

Professor: Before, yeah, it was 3102. And it says that I will come to that. Aryabhatta wrote, Arya was born when I think it was 26^{th}, 36 I think. I will come to that when I come Aryabhatta. So Aryabhatta started, took this as the epoch. That means all his calculations he started at that point.

And you will see that when you calculate the technique of doing it, I will explain next. So you should be clear that why they needed the starting date or epoch.

Student: Starting date is right but why go by arbitrarily 3,000-4,000 years?

Professor: No, because he thought that it is the beginning of Kali and mistakenly many people used to think that all the planets were in (conjunct) in one line, they had one meridian but it was not correct. But that is, many people suspect that, that was their impression. Maybe they are not exactly in one line but very near, so they thought that is a nice time to start with.

"Professor-student conversation ends."

Because if all the planets are in one line and if you take as the starting point, it gives you some obvious advantages. The epoch of Vikrama Saka is 58 BC and Shalivahana era's epoch was 78 AD and epoch for Kollam era is 824 AD. Similarly Bengalis, they also used one era and I think that is something, that is 593 AD is the Bengali era starting point.

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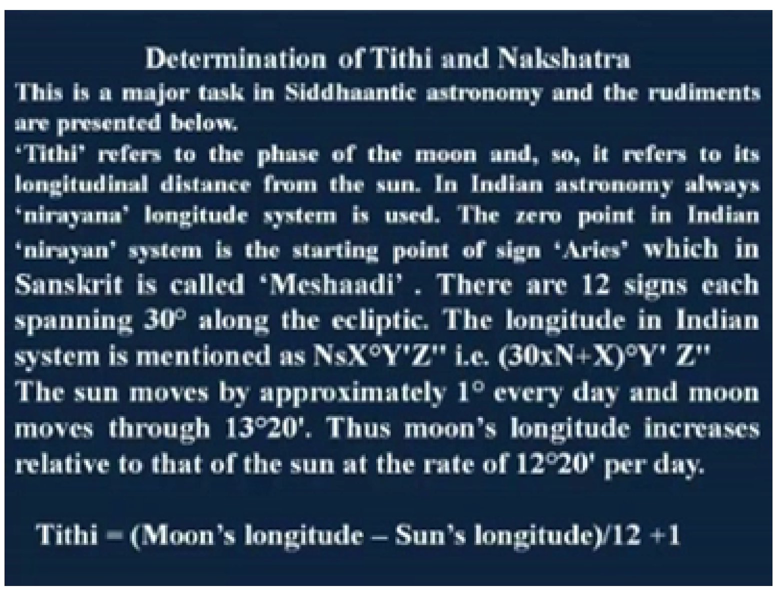

Now this is the point that you have to do two things. One is determination of tithi, at particular day what is the tithi and what is the nakshatra. That means where is the moon. Nakshatra means all the nakshatras are there, so that particular day's nakshatra means when which nakshatra the moon is there. And tithi is what? Tithi means what is the phase of the moon, phase of the moon depends on the longitudinal difference of moon with the sun, is not it?

When it is 0, that means they are together, that is a new moon day, then tithi is 1 or 0. So then as you go, when it goes opposite 180 degrees, then tithi is the purnimaa as you know. So phase of the moon and tithi, they are linked. And nakshatra means the position of the moon with the ecliptic. So this is a major task in siddhantic astronomy and the rudiments are like this:

Now tithis refer to the phase of the moon as I mentioned just now. And so it refers to its longitudinal distance from the sun. If sun is at 10 degree, then if the moon is at 30 degree, then the difference of longitude between moon and sun is 10. And how to then use it for finding tithis, I will give it. So Indians always use nirayana longitude system as I mentioned, that means they had a fixed starting point, Meshaadi, starting point of raashi Aries.

The zero-point in Indian nirayana system is the starting point of Aries, Meshaadi. And there are 12 signs each spanning 30 degrees, 12 into 30 is 360 degrees. So if you divide the ecliptic into 12 divisions, each division will be 30 degree, that is each raashi. The longitude in Indian system is mentioned this way: it will be NsX 6X. The s indicate sign and each sign is 30 degrees. So therefore Ns means N into 30 degrees. Then X degree, so you have to add that.

So NsX degree means 30N plus X degrees, Y minutes, Z seconds. And the sun moves by approximately 1 degree every day because 365 days it takes 360 degrees. Approximately 1 degree and the moon moves every day by 13 degrees 20 minutes, you can easily find out. And thus moon's longitude increases relative to sun every day at the rate of 12 degree and 20 minutes. Here today if it is new moon, so tomorrow the moon will be 12 degrees 20 minutes ahead of sun and so on.

And now what is a tithi? It is the longitudinal difference with the sun. If the longitudinal difference is 0, then tithi is 1, pratipada or new moon. Next day it will be pratipada and so on. So how to find out that? Very simple. What is moon's longitude, subtract sun’s longitude and divide by 12, so that will give you the, and so therefore you will find that, and whatever is the quotient that will be kept and added on.

Suppose if you find the difference is 12, that means what is the quotient? 1. So longitudinal difference is 1 tithi and so current tithi will be another 1 you have to add, so it will be Dwitiya, so on. So this is the tithi calculation was done like this, difference will be to longitude divide by 12 and take the quotient, add 1. Nakshatra of a particular instance is the particular asterism occupied by the nirayana moon as I mentioned.

So each nakshatra occupies 13 degrees 12 minutes along the ecliptic. Because they are 27 of them and 360 degree if you divide by 27, you get 13 degrees 20 minutes. So how do you find out nakshatra? Starting from 0 point. So what is the nirayana longitude of the moon in degrees, find out and divide by 13.333 which is 13 degrees 12 minutes, take the quotient and add 1. So that gives you the current nakshatra starting from the beginning nakshatra of the moon, very simple calculation. And that is the way the nakshatra of that particular instant is calculated which specify the position of the moon in the ecliptic.

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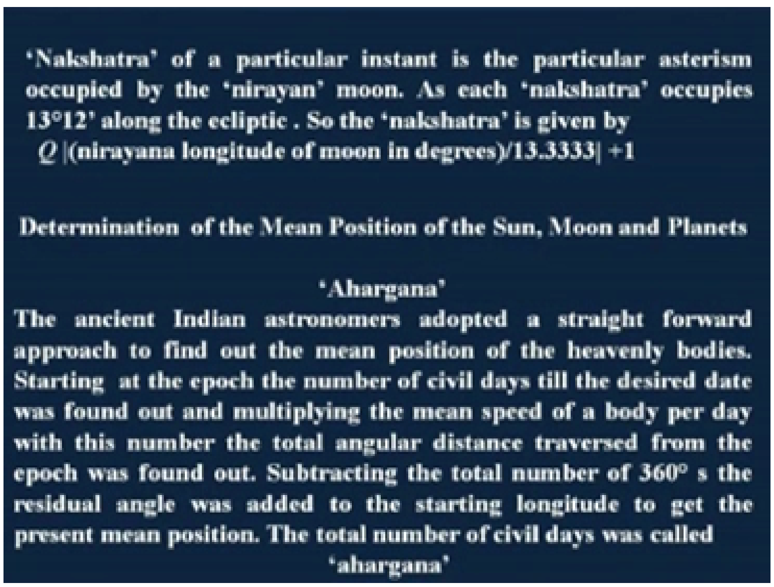

Now I think the main thing, another very important task as I mentioned was the determination of the mean position of the sun, moon and planet. That is the job of madhynaadhikaara. First you have to, even in Greek astronomy always, yes….

"Professor-student conversation starts."

Student: 13 degrees 12 minutes or 13 degrees 20 minutes? Because 13 degrees 12 minutes will be 13.2, I think it is 20 minutes.

Professor: 20 minutes. I think previous stage I think.

Student: Last time you said 13 degrees 12 minutes.

Professor: Yeah, 20 minutes, I do not know why I said that, thank you for correcting it.

"Professor-student conversation ends."

Now you see that how to find out the mean position, that now becomes our next task. So they took a very straightforward approach, Indian astronomers. What they did, from starting point which you assume which we call as the epoch, find out how many rotations or revolutions it has gone through. You know the mean rotation speed per day of any heavenly body. If I say 2 degrees per day or 30 seconds per day, so that is the, so if you can find out the number of days from this epoch to a particular day, I say on such and such date, it means starting from the epoch how many days have elapsed, that we have to find out.

And you have to multiply it by the mean motion, so you get the mean position, very straightforward. The problem came because in Indian astronomy the mixture of solar and lunar thing, that created most of the complications. Otherwise it is a straightforward thing. If you know the number of days to the particular day you are interested in from the epoch and you give the position at epoch, then you just find out the number of days and how much movement is possible in so many days. Divide by 36 degrees because that will give you the so many full cycles and take the residual. So it has advanced that much. Is it clear? So I think that is what they did but the only problems were there because the mixture of it.

Because observationally they used to depend on tithi and that kept the lunar day tithi and year was solar and number of civil days are there and mean motions were known as for civil day. So what you have to do, you have to calculate first number of civil days, that is called ahargana. Ahar is a day and ahargana means count, count of that. How many day count, that is called ahargana and that is the first thing you have to do.

So at the, starting at the epoch, the number of civil days till the desired date was found out and multiplying the mean speed of a body per day with this number gives the total angular distance, divide by 360, so you then subtract the full cycles and take the residual and add to the starting longitude to get the present mean position. And total number of civil days as I mentioned is called ahargana, the count of days.

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Sl.No	Rasi	Nirayana Longitude	Sl.No	Nakshatra	Nirayana Longitude
1	Mesa	0° - 30°	1	Aswini	0°00' - 13°20'
			2	Bharani	13°20' - 26°40'
2	Vrisabha	30° - 60°	3	Krittika	26°40' - 40°00'
			4	Rohini	40°00' - 53°20'
3	Mithuna	60° - 90°	5	Mrigasira	53°20' - 66°40'
			6	Ardra	66°40' - 80°00'
4	Karkata	90° - 120°	7	Punarvasu	80°00' - 93°20'
			8	Pusya	93°20' - 106°40'
			9	Aslesa	106°40' - 120°00'
5	Singha	120° - 150°	10	Magha	120°00' - 133°20'
			11	Purva Phalguni	133°20' - 146°40'
6	Kanya	150° - 180°	12	Uttar Phalguni	146°40' - 160°00'
			13	Hasta	160°00' - 173°20'
7	Tula	180° - 210°	14	Chitra	173°20' - 186°40'
			15	Svati	186°40' - 200°00'
8	Vrscika	210° - 240°	16	Visakha	200°00' - 213°20'
			17	Anuradha	213°20' - 226°40'
			18	Jyestha	226°40' - 240°00'
9	Dhanus	240° - 270°	19	Mula	240°00' - 253°20'
			20	Purvasadha	253°20' - 266°40'
10	Makara	270° - 300°	21	Uttarasadha	266°40' - 280°00'
			22	Sravana	280°00' - 293°20'
11	Kumbha	300° - 330°	23	Dhanistha	293°20' - 306°40'
			24	Satabhisaj	306°40' - 320°00'
12	Mina	330° - 360°	25	Purvabhadrapada	320°00' - 333°20'
			26	Uttarabhadrapada	333°20' - 346°40'

So how do you find out ahargana? I will show that. But before this I think this is a table which gives the position of the various raashis. And the other hand this table gives the position of the various nakshatras. So Mesha is from 0 degree to 30 degree, then Vrishabha is 30 degree to 60, Mithuna from 60 to 90 and so on. And 27 nakshatras, they are like Aswini nakshatra you start with that in Indian system, that is the nirayana longitude, that is 0 degree to 13 degree 20 minutes.

Bharani, Aswini, Bharani, Kritika, Rohini, moment you start saying that people will immediately say it is astrology. First, I have found that whenever you utter these words, people think it is astrology because astrologers show you moon is in this nakshatra, et cetera, they do it in a manner that this gets associated. But they have nothing to do with astrology, there are nothing but the markers in the ecliptic. And the position of each nirayana longitude of each nakshatra is given. So this is the way you calculate the mean position.

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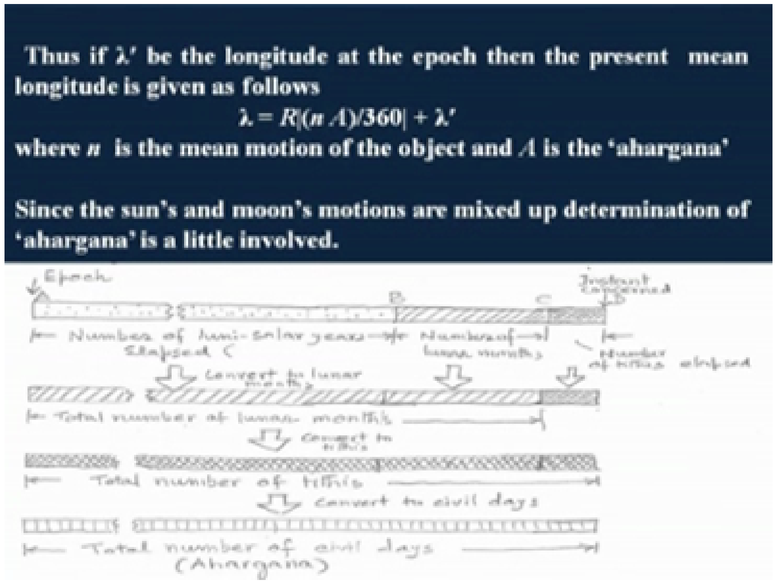

So if lambda be the longitude at the epoch, your starting day of a particular heavenly body, then the present mean longitude is given as follows: So you divide the mean speed by ahargana, number of days, divide by 360, take the residual, remove the integer numbers because they represent only full cycles and then add the original longitude that gives the current longitude. Really straightforward classify exercise, is not it?

So now I think when n is the mean speed and A is the ahargana, now since sun's and moon's motions are mixed up, that is little bit problematic and I think what they did was that this: Suppose this is the epoch at A and number of luni-solar years elapsed, you know that. Then number of lunar months elapsed because Indian astronomy months used to be always lunar months not solar months because it is very easy to see a lunar month, one full moon to next full moon or one new moon to next new moon.

So it was, so therefore the number of luni-solar years, then you added that number of lunar months and then number of tithis because they always worked on lunar month and tithi not solar day as we do to modern system. Now of course they are different units. How do you make the ahargana? So convert this number of luni-solar years into number of lunar months. So that way you get the total number of lunar months by converting these luni-solar years into lunar month.

That can be done just by multiplying. Then this number of lunar month and lunar month only, so you can directly add with the same unit and this is the number of tithis. Now what they used to do, this total number of lunar months, they used to convert into tithis, that is by multiplying by 30. So therefore you get up to this total number of tithis and add this number of tithis, so it is the same unit now. So total number of tithis you get.

And then you know how much, how many civil days will be there, that you can get by dividing this by the that number which relates now tithi with this civil day, that is there you can easily find out. So that is what the basically the principle is you will say on such and such year on such and such month and such and such tithi, what is the position. And to do that, you first convert this into lunar month, lunar months are already there, you add, then again you convert all these lunar months into tithis and tithi you get everything in tithi. Then you convert everything into civil days. And these total number of civil days is called ahargana.

If we had the system to work with only civil days and solar system, solar astronomy, all these complications should not happen easily but we always depend on the lunar month and lunar tithis and then solar year. That is how, why it is whole thing conversions done this way. Is it clear? That is the basic scheme. Now actual calculations you do, that is different but the basic scheme or philosophy under the whole thing was this, to find out the mean position. Okay.

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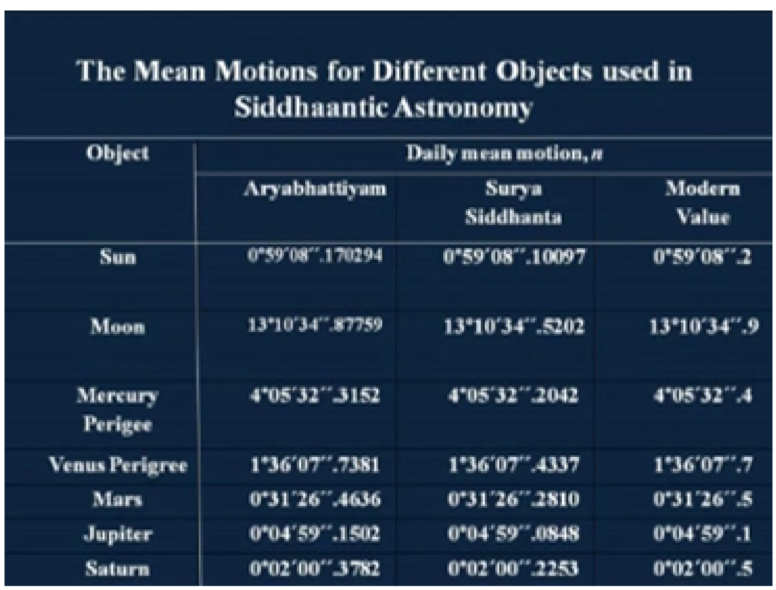
The Mean Motions for Different Objects used in Siddhaantic Astronomy

Object	Daily mean motion, n		
	Aryabhattiyam	Surya Siddhanta	Modern Value
Sun	0°59′08″.170294	0°59′08″.10097	0°59′08″.2
Moon	13°10′34″.87759	13°10′34″.5202	13°10′34″.9
Mercury Perigee	4°05′32″.3152	4°05′32″.2042	4°05′32″.4
Venus Perigree	1°36′07″.7381	1°36′07″.4337	1°36′07″.7
Mars	0°31′26″.4636	0°31′26″.2810	0°31′26″.5
Jupiter	0°04′59″.1502	0°04′59″.0848	0°04′59″.1
Saturn	0°02′00″.3782	0°02′00″.2253	0°02′00″.5

So the mean motion of different objects in the heaven in Siddhantic astronomy what various people asking about did, like say per day motion of sun was this much by Aryabhatiyam, in Surya Siddhanta it was this much. In modern value is this much. So you can see that how naked eye astronomy, so amazing accuracies they could achieve, you believe. Moon of course is much faster, 13 degree 10 minutes 34.87759 seconds. It is 13 degrees 10 minutes 34.5202 seconds and modern value is 34.9. So you can see that Aryabhatiyam is much nearer to modern value which is accurate value.

So these are the, then they also had the perigee motion, Venus perigee motion, Mars, Jupiter, Saturn. In case of Mercury and Venus, since they are inert planets, so inert planets will never go around completely, is not it? So they worked with the perigee motion. It is a little bit complicated but I think you can recognize that fact. But they are not planets which go around the earth continuously, they do not. You have seen it is always near the sun going this way, that way.

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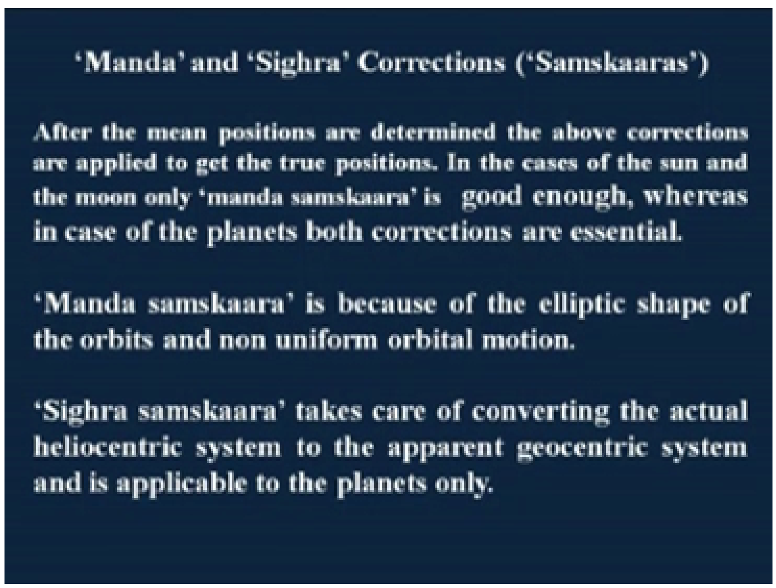

Now manda and sighra corrections or samskaaras I mentioned. After the mean positions are determined, the above corrections are applied to get the true position, actual position. In the cases of sun and mean, moon, only manda correction was there because in that case the changeover from heliocentric to geocentric did not create any problem. But the other planets which are going around the sun and you are observing from moon, with earth which is also going around the earth, you needed the corrections.

And that is why the sighra corrections or sighra samskaaras were necessary for planets, you needed both manda and sighra. In case of sun and moon you needed only. So here things become more complicated and I do not think that we need to go to this converting the system from this.

Those who are interested, the whole detailed thing how it is done, the theory behind it, you will find in the book, it is primarily kinematics.

And little involve, not much but those who are interested can always find that how it is done. But the basic idea is this that these corrections are to find out the true position. Since they are not really moving with constant speed, varying speed, so correction is needed for that. Another is changeover from the reference range from earth to sun, that also you need some corrections.

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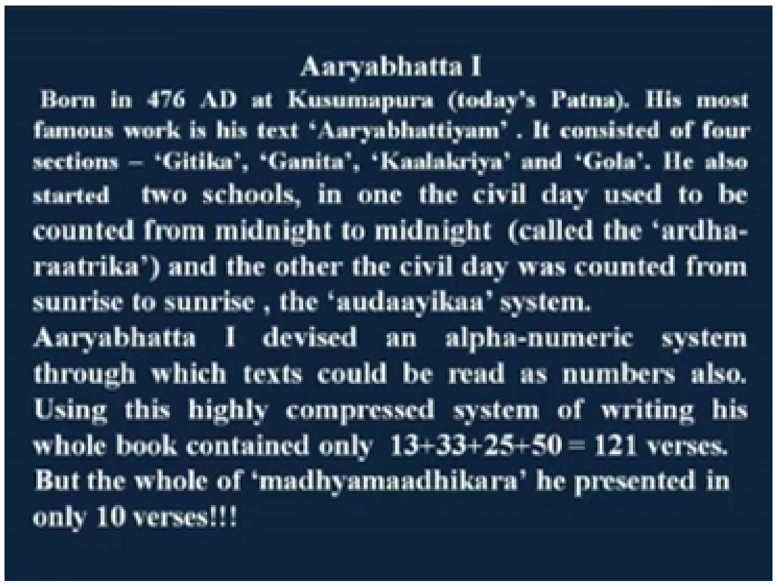

Now I think you will find in the book that why doing these corrections, they have to have the epicycles or cycles. So there all these things, another correction was necessary, it was that which was relatively minor which was called bhujanatara correction for the planets and that bhujanatara correction they did because of the eccentricity of the orbit of the earth, another correction was needed and that is called bhujanatara correction which was minor or small but still they did it, Indian astronomers.

And your lagna is one thing which you have heard and you should know just for the sake of knowledge but it has no scientific significance. Lagna is the time when the nakshatra when the moon rises, it is used mostly in astrology. It has no astronomical significance. Now I think let us go to some of the important astronomers which is very important, we must discuss that.

The first one obviously is Aryabhatta-I, he was born in 476 AD at Kusumapura, today's Patna and consisted of four sections, his Aryabhatiyam. The four sections are Gitika, Ganita, Kaalakriya and Gola. He also started two schools himself. One, in one the civil day used to be from midnight to midnight just like our current international system and that is called Ardharaatrika system. And the other was one civil day was counted from sunrise to sunrise, that is the audaayikaa system, from uday, suryoday.

So these are both the systems were developed by Aryabhatta and calculations will differ a little bit obviously because count of day et cetera are different. And he devised an alpha-numeric system which is very interesting where a word or letter represented a number. I will come little bit of that, it is very interesting. And it is nothing but a compression technology.

They will give a slope but it is a mathematical formula or mathematical quantity. That way they used to remember. Now you see amazing thing is that whole book, Aryabhatiyam which had Gitika, Ganita, Kaalakriya, Gola, everything, description of the universe, calculation of the madhyamaadhikara, mean position, calculation of the exact correct position, then various tithi calculation, kaalakriya, all those things plus direction, eclipse finding, all those things.

Total number of verses were only 121. 13 were in Gitika, 33 were in Ganita, 25 in Kaalakriya, 15 Gola. And his madhyamaadhikara which I was explaining, that means finding out the mean position, he used only 10 verses. That was, can you imagine that the whole information, mathematical information, he compressed into only 10 verses.

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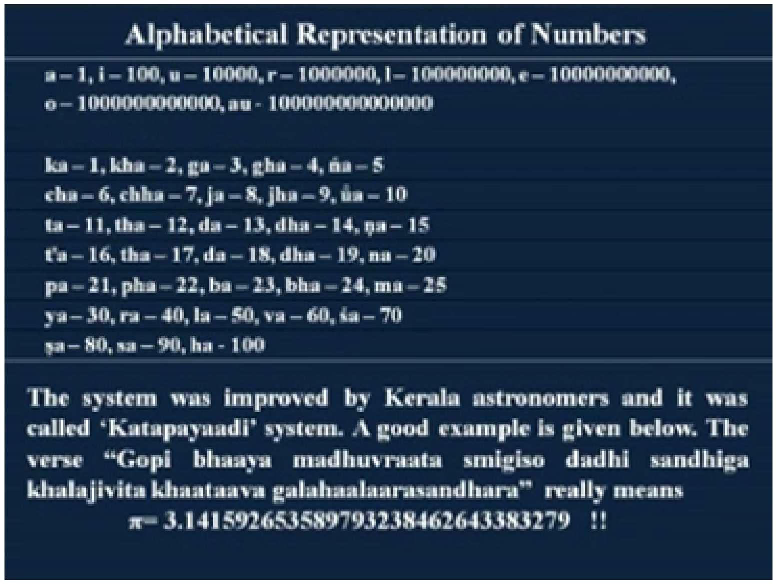

So the alphabetical representation of numbers, what Aryabhatta and that system followed, like say a was 1, i was 100, u was 10,000 and so on. ka was 1, like that. So this system was improved by Kerala astronomers and it was called Katapayaadi system. A good example given by Shankaracharya is that this verse in Sanskrit, Gopi bhaaya madhuvraata smigiso dadhi something. And this really means value of pi up to 30 decimal places using that system Katapayaadi system. Those who are interested you can go to Shankaracharya's texts and you can see how it happened. That actually the value of pi up to 30 decimal places is represented by this one line of shloka using that alpha-numeric system.

"Professor-student conversation starts."

Student: Can you explain it?

Professor: I cannot. I am not an expert in that.

Student: (())(66:04).

Professor: Uhh? Yeah, it is a Sanskrit shloka, Gopi bhaaya madhuvraata smigiso. In general money and large, they used to also have a meaning. That is why you could remember. It is not just some alphabets. That is the credit, how it is possible to create a verse but which actually also had lot of mathematical problem like content. Aryabhatta, that is why Aryabhatiyam takes this extremely difficult for the subsequent astronomers, he is not very happy at all. Aryabhatta-I also found out, yeah….

Student: You see the first one use decimal, this is by decimal system in this, not?

Professor: Not. You see decimal system was there by that time. Aryabhatta found the value of pi as 3.1415, four decimal places. And Greeks always use the value of pi as 22 by 7 for very long time. The modern mathematicians are amazed because to find the value of pi up to 4 decimal places require inscribing regular polygon with 768 sides. Then only you will be able to, how it was done? You draw a circle and inscribe a regular polygon, count the number or the length of the each side, add and divide by the radius, you get the value of pi.

“Professor-student conversation ends.”

To get the value up to 4 decimal places, it was necessary to inscribe a regular polygon with 768 sides, is not very easy task. So this is the most accurate value in ancient time as used by Aryabhatta in the 5th century AD.

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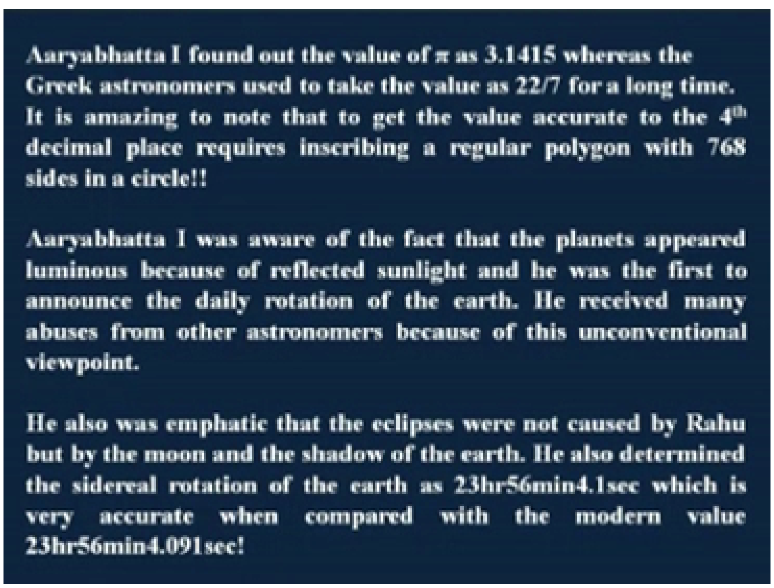

Aryabhatta-I was aware of the fact that the planets appear luminous because of reflected sunlight. And he was first to announce the daily rotation of the earth and this received of course many abuses. And he, later you will see that he calculated the rotation period, sidereal rotation of the earth as 23 hours 56 minutes 4.1 seconds which is very accurate when compared with the modern value, 23 hours 56 minutes 4.091 seconds.

So you imagine their brilliance by naked eye observations you and they did not have clock et cetera also. So finding out the values quantitatively up to this is really something amazing, unbelievable in my words. He also was very emphatic that the eclipses were not caused by Rahu but by the moon and the shadow of the earth. He received lots of abuses not only by other astronomers of the later period, by even those who followed his schools and liked his recitals.

Luckily we did not have the system of burning somebody alive, perhaps he could have been, he could have had the same fate like Giordano Bruno, the way his revolution or the ideas were rejected by the subsequent astronomers for a very long time. So Aryabhatta-I in my opinion stands much higher compared to many others. They are also brilliant like Varahamihira, Varahamihira used very abusive language about Aryabhatta-I. Then Brahmagupta, Bhaskara, they are all brilliant astronomers but nobody can match the merit of Aryabhatta-I maybe.

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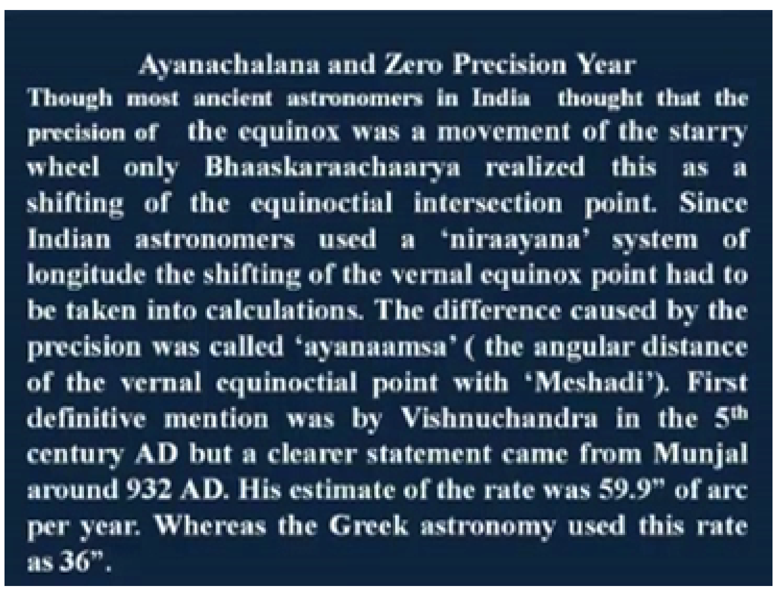

Now another thing is as I mentioned precision of the equinox, ayanachalan and the zero-precision year. We discussed little bit that earth not only spins about its axis but the axis of spin also slowly précises because of which our vernal equinoctial point slowly shifts towards west in the starry background. And in the ancient time it was, it is not found and only Bhaskaracharya realized, earlier people observed that but they thought that to be a motion of the starry background not of the planets or anything.

But only Bhaskaracharya first realized that it is a shifting of the equinoctial intersection point. And since the Indian astronomers used nirayana system, and the western system we always start from that vernal equinoctial point but here we start from Meshaadi. So I think this which was necessary to take into calculation of the shift, how much it has shifted from Meshaadi to the current vernal equinoctial point and then the rest.

So this variation, this difference caused by the precision was called ayanamsa, that is the angular distance of the vernal equinoctial point at present with the Meshaadi, that is the starting point of the sign Aries. And the first definitive mention was by Vishnuchandra in the 5th century AD of that. But much clearer statement came from Munjal around 932 AD and his estimate of the rate was 59.9 seconds of arc per year. Whereas the Greek astronomy used it at 36 second, but 59.9 is much nearer the correct value, about I think 56 seconds per arc is the actual value.

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The year when the VE coincided with 'Meshadi' is called the 'zero precision year. The Indian astronomers considered the following as the 'zero-precision year'

Author/Text	Zero precession year, Saka year
Munjāl	449
Modern Surya Siddhanta	421
Karan Kutuhala	445
Graha Lāghava	444
Second Arya Siddhānta	527
Dāmodara	342

So the year, when the vernal equinox coincided with Meshaadi or which is called the zero precision year, Indian various astronomers consider the following as the zero-precision year: Like Munjal took 449 shaka year as the zero-precision year. Modern Surya Siddhanta takes 421 shaka year as the zero-precision year. Then Karan Kutuhala, Graha Lighava, Second Arya

Siddhanta and Damodara, they all have different shaka year as the zero-precision year in their calculations.

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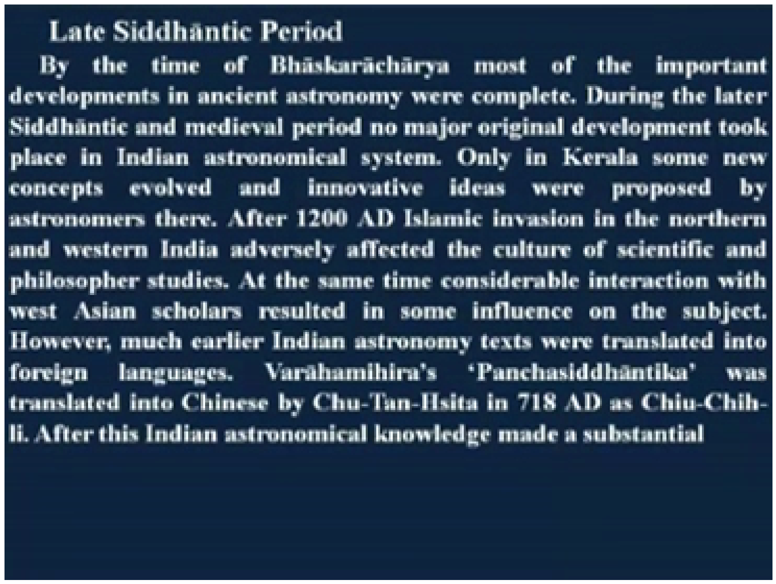

Actually that is why there are so much of eras and relations. And later time Meghnad Saha was very emphatic that some major corrections or major work is needed to take care of that. Now when we come to the Late Siddhantic Period, by the time of Bhaskaracharya most of the important developments were done. And during the later siddhantic and medieval period no major original development took place in Indian astronomical system.

Only in Kerala some new concepts evolved and the innovative ideas are proposed by astronomers there. Now actually after the Islamic invasion, the 13th century AD, the northern and western India was somewhat disturbed and again, even then there are (())(73:15) and there in the Sanskrit the havoc temporarily. Again when Mughals came, it was stabilized, like that it happened.

The considerable interaction with the West-Asian scholar took place of course in that time. So influence, there was some positive influence. But Indian astronomy texts were translated into foreign languages as I mentioned and I will discuss it in much more details in tomorrow when I discuss the medieval period. And Panchasiddhantika was also translated into Chinese by Chu-Tan-Hsita in 718 AD and its name was Chiu-Chihli. After this Indian astronomical knowledge made a substantial influence on Chinese astronomy.

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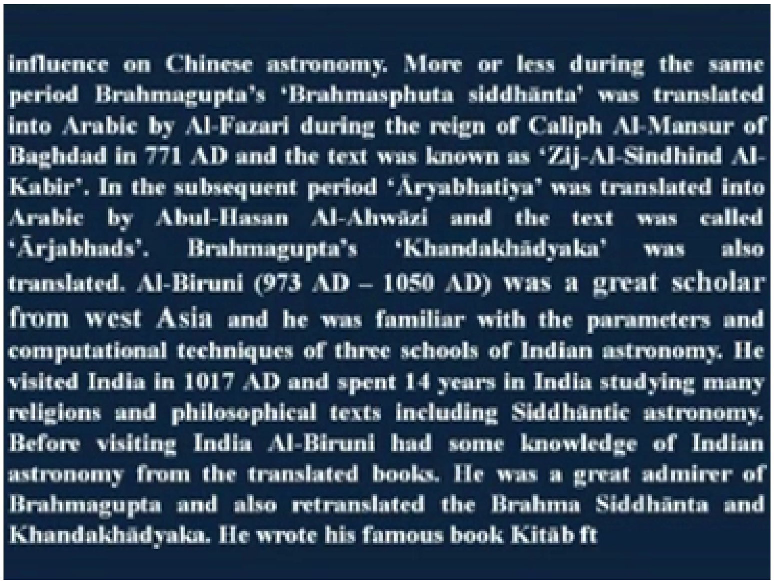

More or less during the same period Brahmagupta's Brahmasphuta Siddhanta was translated into Arabic and that called Sindhind at the time of Caliph Al-Mansur of Baghdad. And the text was known as Zij-Al-Sindhind Al-Kabir. And subsequently Aryabhatiya was also translated into Arabic by Abul-Hasan and the text was called Arjabhads. And Brahmagupta's Khandakhadyaka was also translated. Al-Biruni was very important person and great scholar who visited India and wrote lot about Indian science and astronomy. He was here for 14 years.

And he knew, he was an exponent in many languages including Sanskrit. So he not only translated Indian Sanskrit text into Arabic but also Arabic, Persian text into Sanskrit, that also he did. And he was great admirer of Brahmagupta, in his opinion he was truly an outstanding astronomer and he translated Brahma Siddhanta and Khandakhadyaka.

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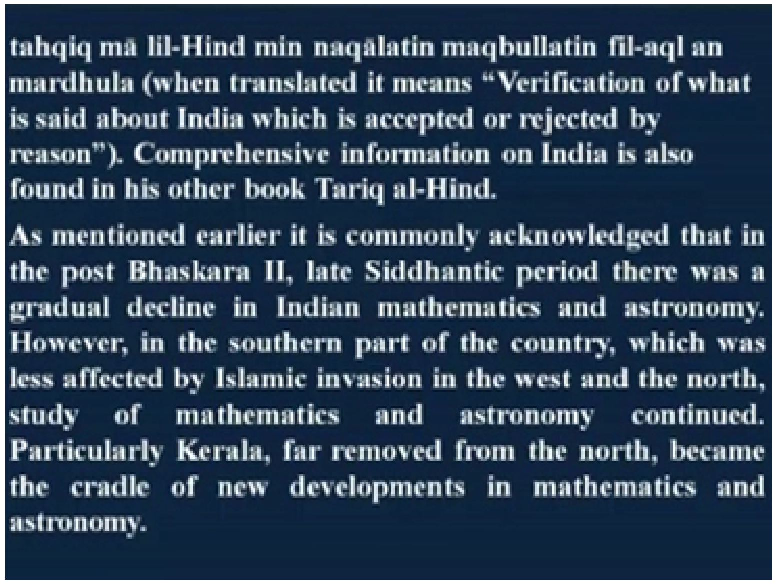

And his famous book, Kitab tahqiq ma Iil-Hind min, my god! It goes quite long, it is better not to attempt. So it means verification of what is said about India which is accepted or rejected by reason. That is the name of the book. So it is something like he is striking in chemistry department. Comprehensive information on India is also found in his other book, Tariq-al-Hind. And nowadays you can read Alberuni's India, there is a good book in English, it is available. You can read about Alberuni's whole writing on India. It is very interesting.

As I mentioned earlier it is commonly acknowledged that in the post Bhaskara II, late Siddhantic period there was a gradual decline in Indian mathematics and astronomy. However in the southern part of this country which was less affected, work continued. And actually in Kerala they developed astronomy which was same as typographic, typo, typographic system. That means typographic system was the earth is stationary, sun is going around the earth and all other planets are moving around the sun.

Same kind of because it is, you will find if you study little bit, kinematically the observation will be same whether it is the real heliocentric system or geocentric system or the typographic or Kerala system. So Kerala astronomy also evolved a system where sun goes around the earth and all other planets go around the sun. And I think I am not sure, I could not find but it is said that there were hints of heliocentricity in many of the works they did.

And data was very clear because if you see the epicycle sizes which are nothing but the orbital radius, their ratios are very similar to the astronomical index, that means which we use for telling the radius of the orbit of various planets. In the book you will find the whole thing but still the whole thing escaped their mind. I think I was being asked by Professor Bhattacharya that how come this happened that they never really, because they are so busy with accurate determination of the position, the physics behind the whole thing perhaps they were, they missed the point.

Secondly the reason why the Aryabhatta's rotating earth or these things were Aristarchus's heliocentric system or not, because the laws of physics were not ready for people to accept. Inertia, the first law of inertia, until and unless you had first law, you cannot accept a moving earth. Everybody will say that if it is moving, if I drop a stone, why not the stone falls far behind? So it is only when concept of inertia, first law of inertia by Galileo and Descartes came, it was not possible for people to accept the moving earth or rotating earth.

So I think I will stop here. If you have few questions, I can discuss and tomorrow we will start the medieval period and we will end that. Final day will be the story of how interestingly, interesting and some of these are very pathetic also you will see, they are known as tragedies in astronomy. We will see that and some discussion on the originality and antiquity of Indian system. So any question on today's topic?

"Professor-student conversation starts."

Student: Sir, I am supposed to compare, purchase.

Professor: Yeah.

Student: So if you use a software to see that extremely Greek value, 31 have been proved you see….

Professor: Okay, just a moment.

Student: It tells me something.

Professor: Which period you want to go?

Student : 13.042.

Professor: Oh!

Student: Point that is achievable to me, must be something happening in your mind.

Professor: Oh, accha. No, no I think…..

Student: Right now we can easily get to check this.

Professor: Yeah, I think it is being suspected that they felt that something like that happened but really it did not happen that because you are expecting to get all the planets at one point, is not it? Yeah, I do not think it happened that way.

Student: In one theory that is the Mahabharata kind of something like that.

Professor: You said your date was minus…..

Student: Minus 1302.

Professor: Yeah.

Student: And February 17th.

Professor: Minus 3107.

Student: 02.

Professor: 02. 3102, 02 and February…..?

Student: 17th.

Professor: February 17th. We have to go to midnight, hours 12.

Student: 03.

Professor: 0, it shall be, no, 17th, 18th 0.

Student: Sir 18th 03.

Professor: No, you can leave it. Okay, ready?

Student: Yes, position is….

Student: Location.

Professor: Location of course you can say 80 degree. Our longitude is 80 degree east, is not it? Yeah, 80 degree east.

Student: 39 days.

Professor: 80 degree east and 23 degrees 45 minutes approximately the latitude north.

Student: 26.

Professor: Uhh?

Student: 26 Gulf coast. 26.

Student: No, Patliputra.

Professor: Patliputra.

Student: Delhi is what is…..

Professor: It is with 24?

Student: No, Patliputra, we want…..

Student: 26.

Professor: 26?

Student: Kanpur is 26.

Student: Patna may not be 26.

Student: Patna maybe is there.

Professor: Okay, let us see, it should not change. With latitude the meridian of the thing, yeah, it should not affect, yeah.

“Professor-student conversation ends.”

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So I think but only thing of course, then sun also has to be there. So we have to see where the sun is. February means it will be after the winter solstice, let us view it. This software cricket really wonderful, it gives the feeling yes, we are in darkness. It looks one planet we saw green one, that is the planet. It has been checked. They found it is not correct. Oh, this is the Saturn but they are not very different. You can see this is Saturn, this is I do not know another one. Not (ma), this is Mars. Mars and Sun very near. Moon is also very near and Jupiter also is very near.

“Professor-student conversation starts.”

Professor: So I think there is a point. You can see only few degrees.

Student: Yes sir. Four of them.

Professor: I think Jupiter, moon and Mars….

Student: One more, what is that the blue?

Professor: Yeah, so…….

Student: Electra. That is…..

Professor: At least four I could see.

Student: Again the blue is coming up, Electra.

Student: On the ecliptic what was there?

Professor: This is Jupiter and blue is something. Now modern time means it will be some Uranus, Neptune, thing can be there. And this is sun and this is Mars. So you can see there are 1, 2, 3, 4, 5 and moon and Saturn, this. So I think there is a point, they are very near, they are not exactly in one line. They are very near.

Student: If there was Neptune….

Student: Neptune was but is there some place….

Professor: There is some meridian in it though it is not exactly correct. There within few degrees all the planets were together at that time.

Professor 2: Okay, other questions? Okay, I have one question.

Professor: Yeah.

Professor 2: So Aryabhatiya, he gave the name Aryabhatiya himself or somebody else? Normally they do not give the name on this after themselves. Was the book written as name was Aryabhatiya?

Professor: I do not know his father's revenue. Otherwise I could say that. Actually bhatta means Aryabhatta, it is still not known that whether he is from south or he actually worked. He worked in Kusumapura.

Professor 2: I see.

Professor: But since Aryabhatta's school was very ardently followed in the south not in the north, so many think that actually he was from south, not much.

Student: Region called Ashmaka, Ashmaka is associated with Aryabhatta. And Ashmaka is supposed to be somewhere in the south.

Professor: No, even people suspect Aryabhatta also from the south because in south only his whole…..

Student: Work is….

Professor: Paksha was followed strictly but he worked in Kusumapura and Kusumapura is considered to be in Patna.

Student: Patna.

Professor: Because Patli is a flower, trumpet flower.

Professor 2: Okay. Any other question? So if not, just thank you as it whistles.

Professor: Thank you.