Mathematics in India: From Vedic Period to Modern Times

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Lecture - 40
Mathematics in Modern India 2

So this lecture, we will continue with the story of Mathematics in modern India. So I will start with the continuation of how our Indian scholars started rediscovery our tradition of mathematics and astronomy. I will recount the names of some of the most important people then modern international scholarship on Indian mathematics and astronomy also in summary.

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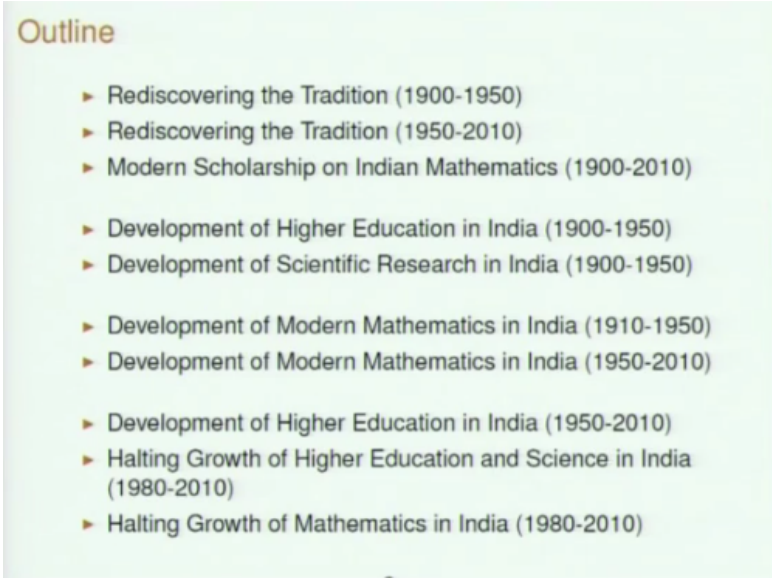

After that we will briefly discuss development of higher education research in India in the first half of 20th century. Then more importantly we will summarize some of the highlights in the development of modern mathematics in India in the last 100 years. Mostly, I will be able to give only the names of concerns rather than details of the work. So in Ramanujan's case I could summarize half a dozen researches by him even that will not be possible.

First of all, I am not technically adequately competent to do that sort of a thing also these are lot of highly technical work done by mathematicians. Finally, I would like to make an assessment of development of higher education, scientific research and mathematics in modern India in the world context. Where does India stand in the world of science and mathematics we would like to know where are we going? Where do we stand?

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So, this will be the outline of today's talk. So this study of Indian tradition continued with people like Vindhyesvari Prasad Dvivedi, Babuaji Misra, Gopinatha Kaviraja, Kapadia.

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More interestingly, the Anandasram series in Pune came up with editions on many of them. Many of them we are using in our course like Mahabhaskariya, Laghubhaskariya, Laghumanasa. Similarly, from Kerala also some of the important Kerala School were started getting published. Aryabhatiyabhashya Nilakantha was published in 3 volumes. The Tantrasangraha was published around 1950's. Karanapaddhati of Puthumana Somayaji got published.

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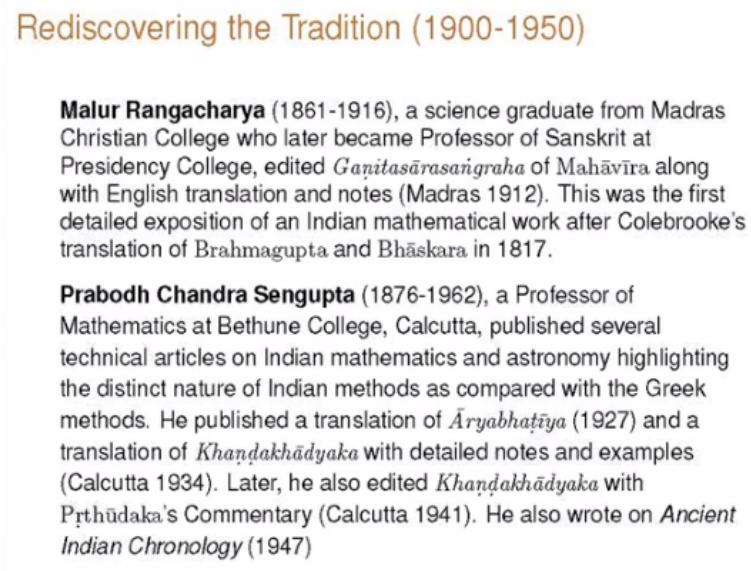

Malur Rangacharya translated, edited and translated the Ganitasārasaṅgraha about 100 years ago. He was a professor in Chennai. P. C. Sengupta was a great scholar who edited and translated Khaṇ ḍ akhādyaka.

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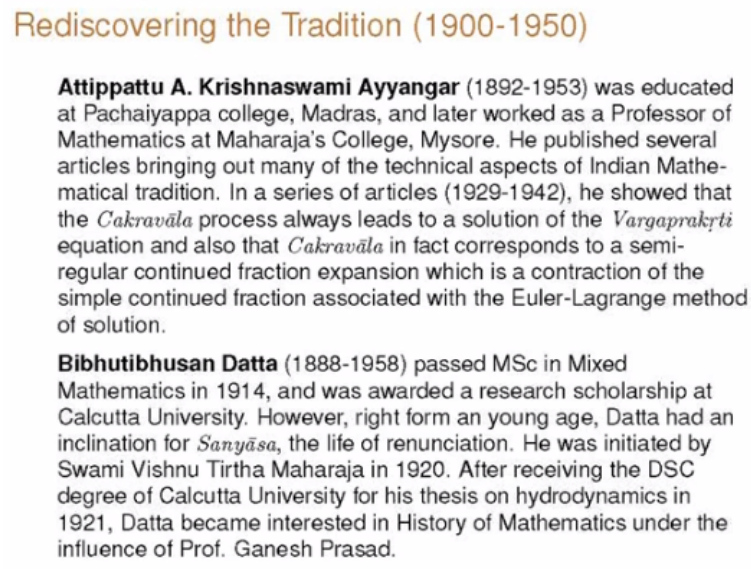

I have already spoken about A. A. Krishnaswami Ayyangar on Cakravala. Bibhutibhushan Datta is a great name. He first did a DSC in hydrodynamics in 1921. But from his young age he had an inclination for Sanyasa. He became interested in history of mathematics under the influence of Professor Ganesh Prasad.

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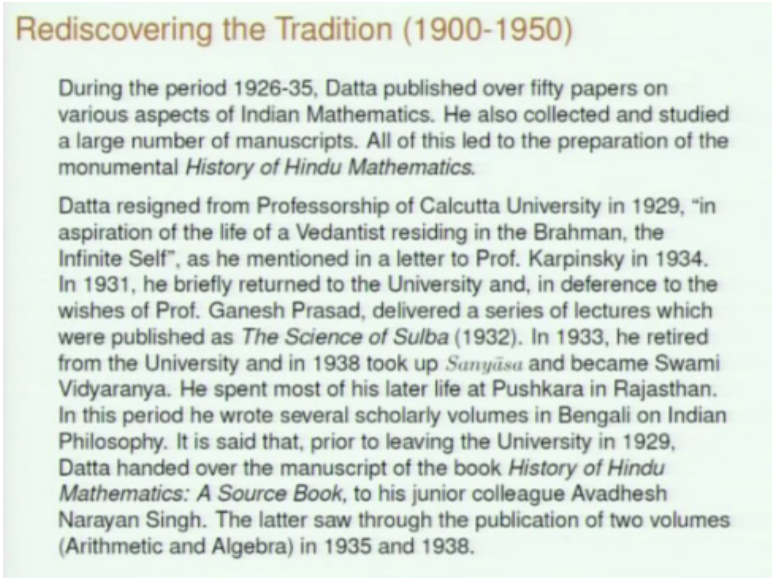

So, during the 8 years 1926 to 1935 Datta published over 50 papers on various aspects of Indian mathematics and he collected lot of manuscripts and this constituted the great magnum opus history of Hindu mathematics which was published in 2 volumes. Soon enough Datta left the university and he took up Sanyasa he has written a huge number of books on Vedanta in Bengali.

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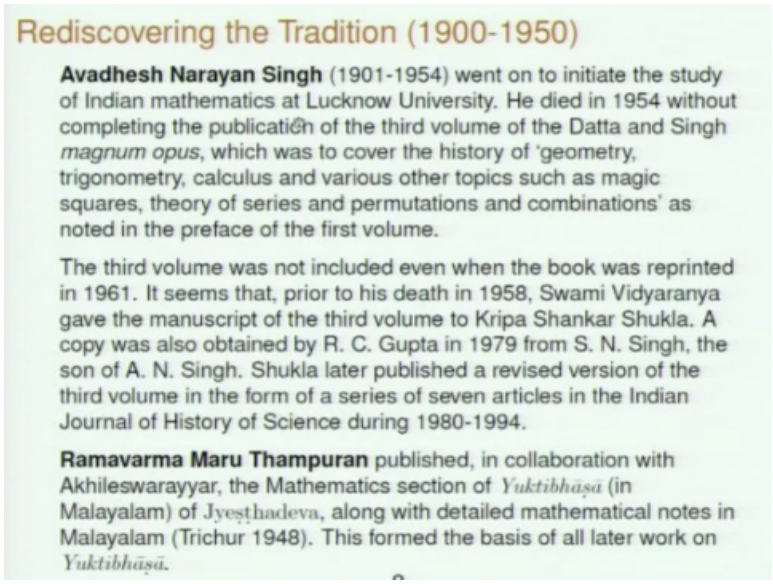

Afterwards he handed over this manuscript of the History of Hindu mathematics to his junior colleague Avadhesh Narayan Singh. Avadhesh Narayan Singh started this group on Indian Mathematics in Lucknow. He was a professor in Lucknow. He got the 2 volumes published 1935 and 1938.

But there was a third volume the manuscript of which existed which was supposed to contain geometry, trigonometry, calculus and various other topics such as magic squares, theory of series, permutations and combinations. This did not get published. Even when the book was reprinted from Bombay in 1961 this was not published. Later on due to the effort of R. C. Gupta and K. Shukla this appeared as a series of articles in the Indian Journal of history of Science.

Ramavarma Maru Thampuram from a royal family in Kerala edited the mathematics part of Yuktibhasa in 1948 with copious Malayalam notes and in fact this was the basis for all the works on Yuktibhasa by Professor Rajagopal and others.

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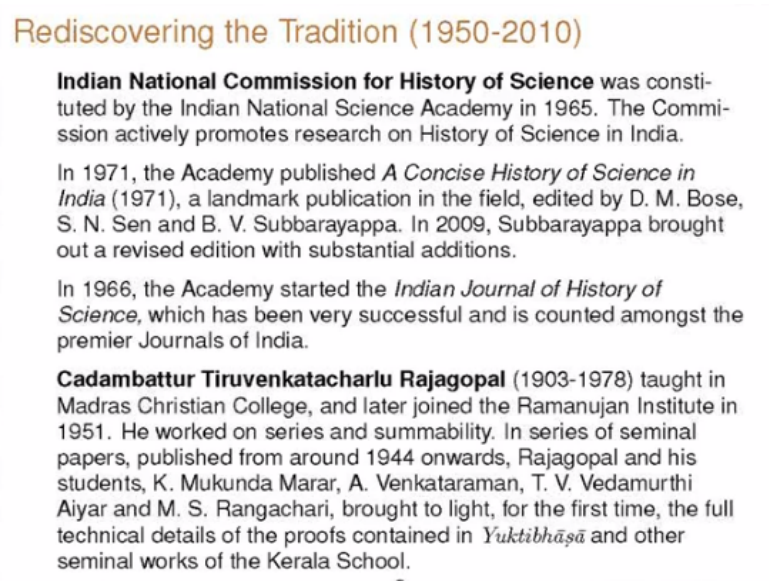

So, this was the pre-independence period. In the post-independence period the major effort to study Indian mathematics and astronomy, the main promoter of such study is what is called Indian National Commission for History of Science established under the Indian National Science Academy in 1965. In 1971 they came up with a landmark publication called A Concise History of Science in India.

Which even today remains the only available book summarizing evolution of science in India, edited by Bose, Sen and Subbarayappa. Subbarayappa brought out a revised edition now published by the universities press. The academy started the journal, Indian Journal of History of Science, which is the leading journal in which technical articles on History of Science in India are published.

And mathematics and astronomy do take a prima place there may be about 30% of the articles or even 50% would be in mathematics and astronomy. C. T. Rajagopal, I already mentioned his work on infinite series in Kerala mathematics.

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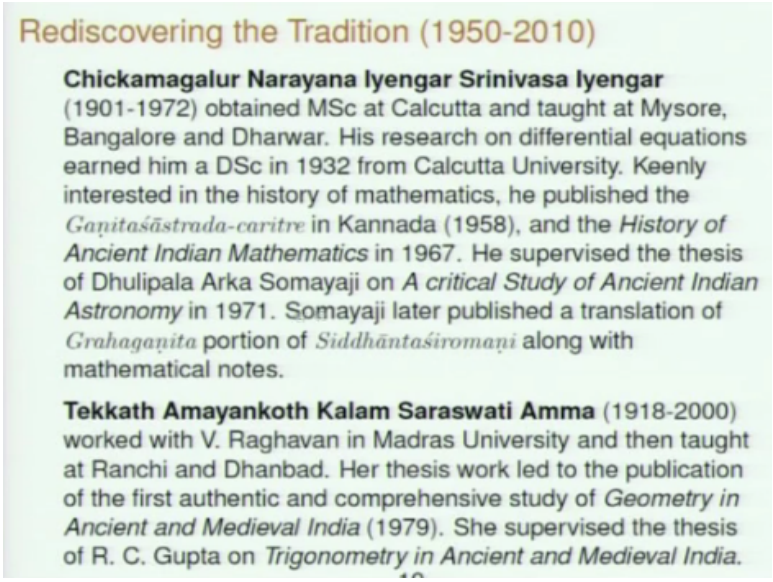

C. N. Srinivasa Iyengar, his book on History of Ancient Indian Mathematics in 1967 is a beautiful short book which all students can read and understand. He in fact, directed a thesis on Indian Astronomy also by Somayaji which is also a very beautiful work publish from Karnataka university. Saraswati Amma was a Sanskrit scholar who went to Professor Raghavan and said I want to do PhD.

And he asked her you have a BSc degree why do not you work on something different than Kavya or Alankara or Vyakarana. Why do not you do some work on mathematics and that work became a very nice work and ultimately resulted in this really first comprehensive study of geometry in ancient and medieval India in 1979. Saraswati Amma also guided R. C. Gupta in his thesis on trigonometry.

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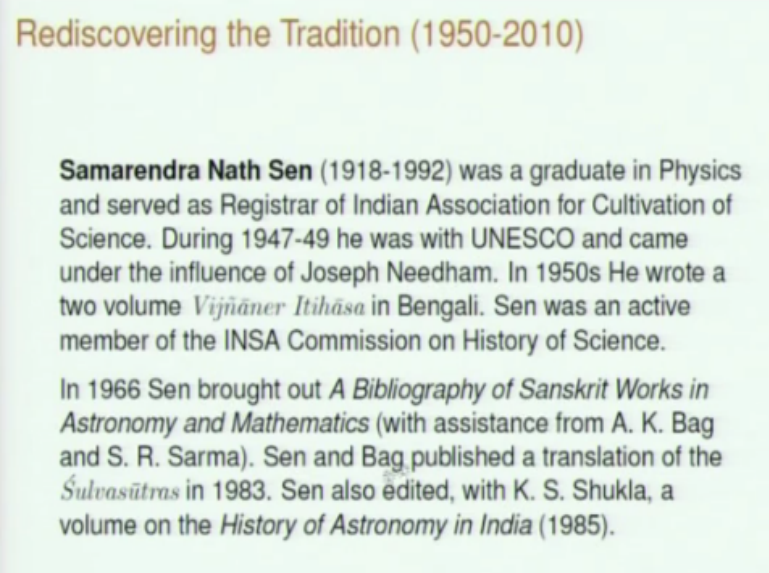

S. N. Sen was in the Indian Association of Cultivation of Science. He came under the influence of Needham when he was in UNESCO and he was associated with the Indian National Science Commission and he has edited and published several books.

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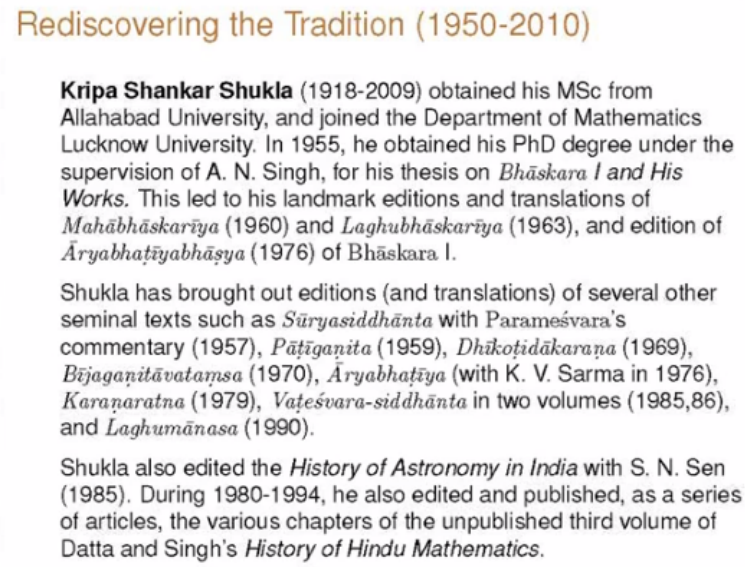

Kripa Shankar Shukla is one of the most important scholars of Indian Astronomy and Mathematics in the second half of last century. He has edited and translated several works especially the works of Bhaskara, Mahabhaskariya, Laghubhaskariya, Aryabhatiyabhasya but also Vatesvara-siddhanta, Laghumanasa and he is one of the and he also published the third volume of the Datta and Singh in the forum of a collection of articles.

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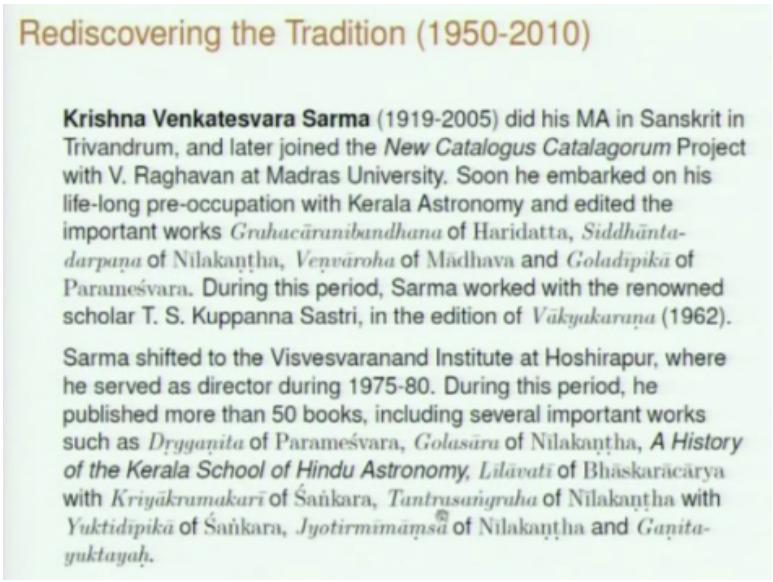

Other great name in History of Astronomy and mathematics or in the study of Indian Mathematics and Astronomy in the second half of last century is of Professor K.V. Sarma from Chennai. He was with the new Catalogus Catalagorum and at that time itself he got interested in the works of Kerala school and published the Goladipika, Venvaroha and Siddhantadarpana.

He worked with Professor Kuppanna Sastri on Vakyakarana. Then he shifted to Hoshirapur. There he really published over 50 works which have really brought to light the entirety of the Kerala School of Mathematics and Astronomy Drgganita, Golasara, Kriyakramakari, Tantrasangraha with Yukidipika, Jyotirmimamsa of Nilakantha and his last was the magnum opus Ganitha Yuktibhasa and its English translation which got published in 2008.

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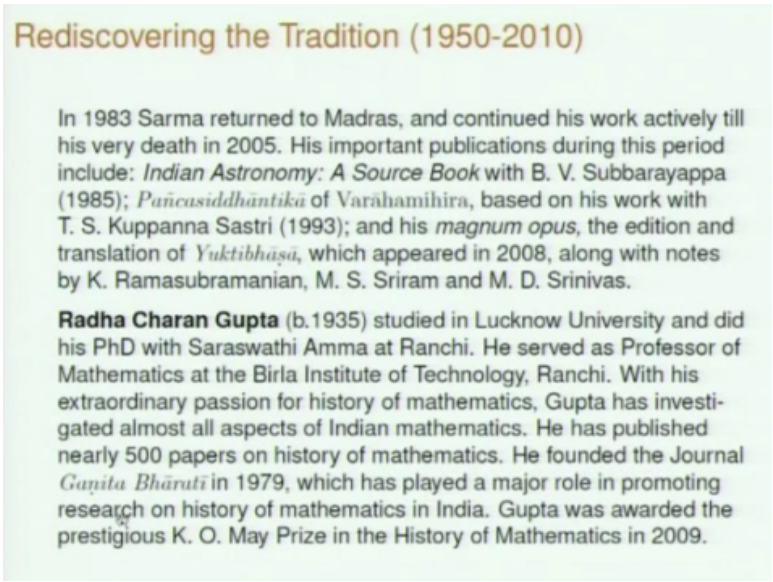

R. C. Gupta was a student of Saraswathi Amma in Ranchi and he started the journal Ganita Bharati in 1979 which is really one of the important professional journals devoted to History of Mathematics in India. Gupta himself has authored more than 500 papers on various aspects of History of Mathematics in India and the world. He was awarded the K. O. May Prize in 2009.

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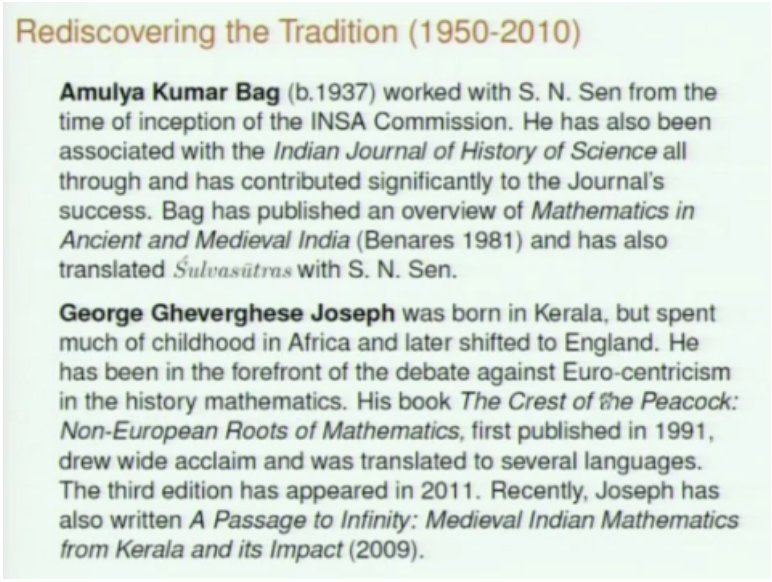

A. K. Bag has been running the Indian Journal of History of Science as its editor for the past 30-40 years. George Joseph many of you would have seen his book The Crest of the Peacock: Non-European Roots of Mathematics whose third edition has come is being translated into several languages. He has been in the forefront of the debate against Euro-centricism in the history of mathematics.

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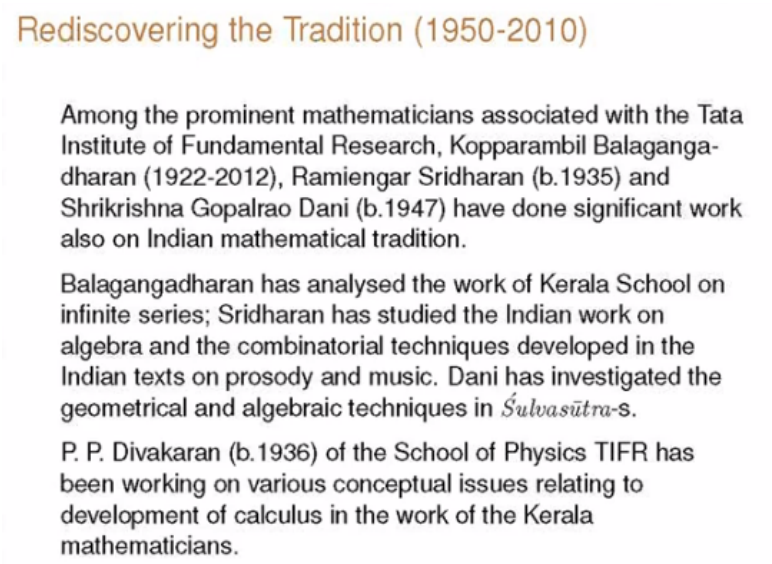

Recently, of course several scholars in Tata Institute like Professor Balagangadharan, Sridharan, Dani, etc. Prof. Divakaran have also done interesting work, I mean they are professional mathematicians and have done interesting work on Indian and tradition of mathematics.

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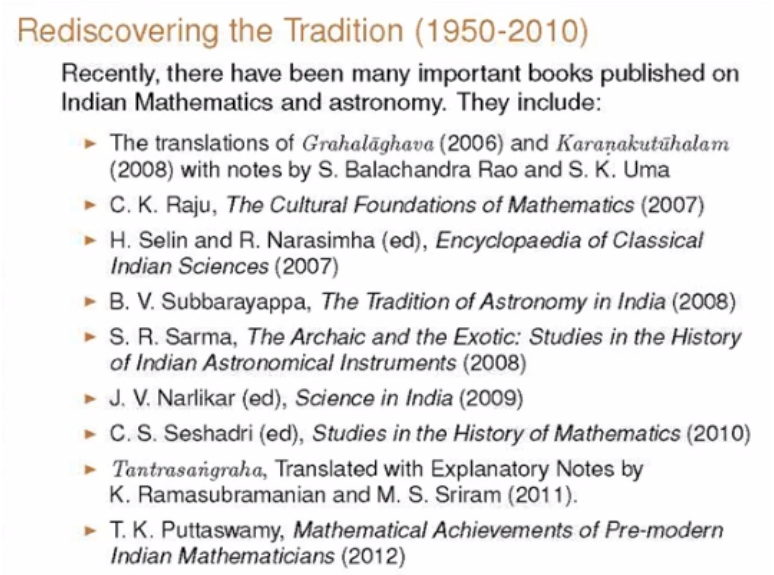

And here are some of the books which have appeared on the subject in the last 7-8 years from various Indian Scholars.

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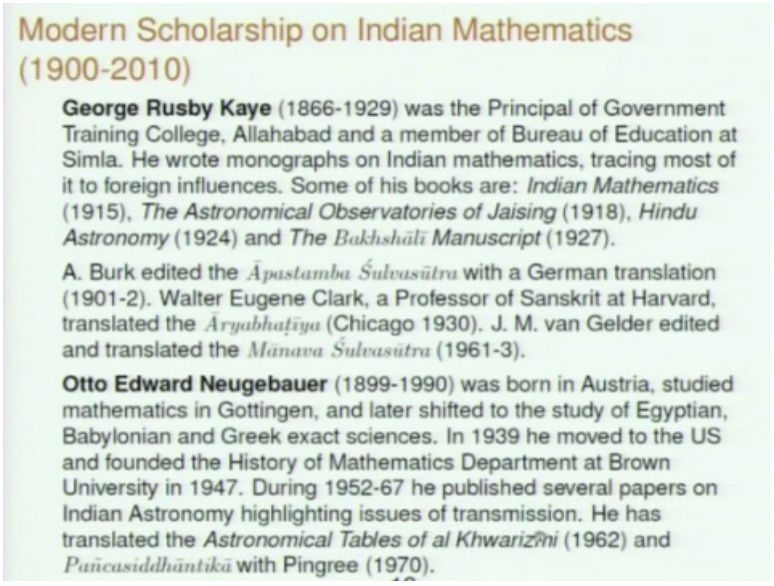

Now about the modern international scholarship George Kaye was a name came up in the context of Bakhshali Manuscript, I think that he was one of those who was dismissive of the Indian tradition and traced most of it to Greek and other sources. He wrote couple of works in

early part of 20th century. Neugebauer was a major scholar of History of Astronomy and Mathematics.

He was a mathematician trained in Gottingen but then he shifted to United States since founded the famous history of Mathematics Department in the Brown University. He has published huge amount of material on Babylonian, Greek and other civilizations the History of exact sciences. He has produced Pancasiddhantika and the Astronomical Tables of al Khwarizmi which have based upon Indian Astronomy.

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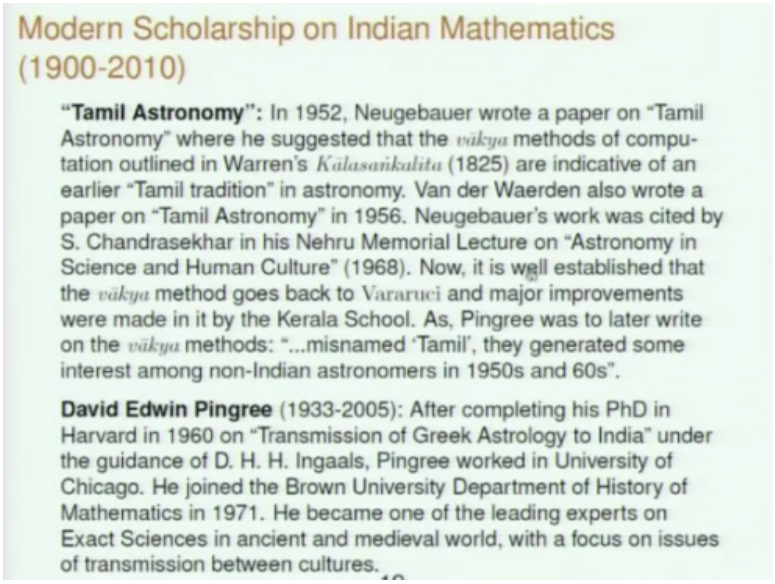

Neugebauer wrote a paper on Tamil Astronomy in 1952 where he suggested that the vakya methods which were given in Warren's Kalasankalita are indicative of an entirely different older Indian tradition which he called Tamil tradition. Another great historian and mathematician Van der Waerden join the Van der Waerden and he also wrote a paper on Tamil Astronomy in 1956.

And they were sort of approvingly cited by our professor S. Chandrasekhar in his famous Nehru Memorial Lecture on Astronomy in Science and Human Culture delivered in Delhi in 1968. Of course now it is well established that the vakya method is goes back to Vararuci and major improvements in it were made by the Kerala School and so today Pingree writes that the vakya methods misnamed Tamil.

They have generated some interest among the non-Indian astronomers in the 1950s and 1960s. David Pingree is one of the most well-known names in the history of astronomy

specializing in Indian Jyotihsastra astrology also and he focused mainly on the issues of transmission between different cultures. Ingaals later back in Chicago then came to the History of Mathematics Department in Brown.

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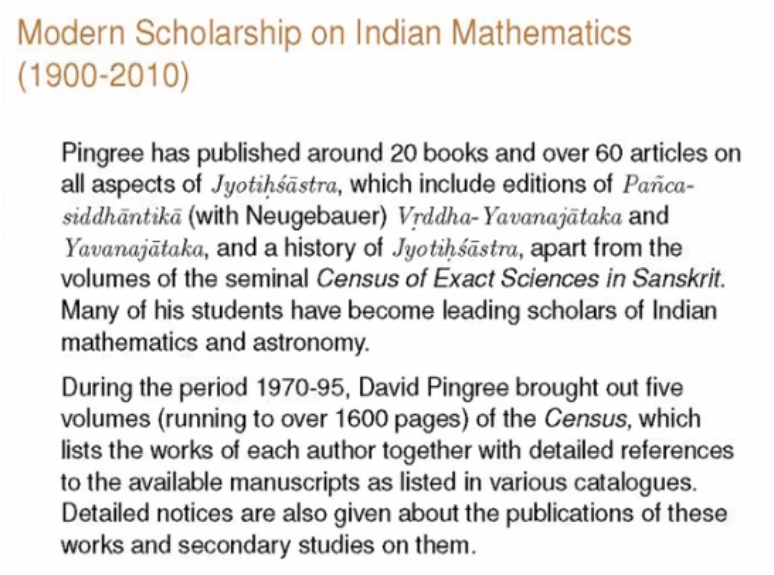

He published more than 20 books and several articles edited and translated Pancasiddhantika, Vrddha-Yavanajataka, written history of Jyotihsastra but his main work is the Census of Exact Sciences of which 5 volumes have appeared. They list alphabetically all the works in Indian mathematics and astronomy along with the detail references to the manuscripts that are available in a different manuscript catalogues as published by the various universities.

They also giving permission on the publications of these works.

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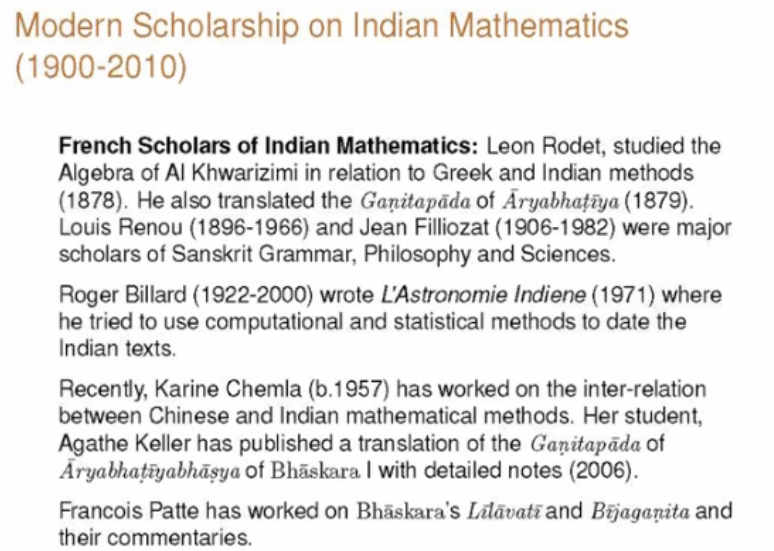

French Scholars have also be in working systematically the older said Renou and Filliozat are wrote important papers on Sanskrit Grammar, Philosophy and Sciences. Then Billard wrote on the History of Indian Astronomy and recently an interesting thesis by Agathe Keller translating the Ganitapada of Aryabhatiyabhasya of Bhaskara with detailed notes has appeared.

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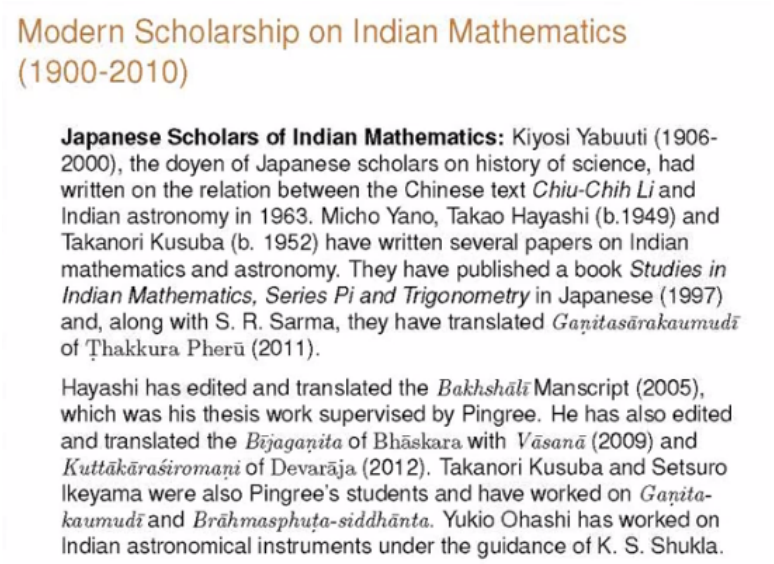

Interestingly there is school of Japanese Scholars working on Indian Mathematics and Astronomy. Kiyosi Yabuuti was one of the older school who worked on the relation between Indian and Chinese astronomy. Yano, Hayashi and Kusuba whose names we have heard already. They have written a book in Japanese on Indian Mathematics.

They have translated the Ganitasarakaumudi of Thakkura Pheru together with S. R. Sarma the authors in that called Sarma, Kusuba, Hayashi and Yano. Hayashi himself has edited Bakshali Manscript, Bijaganita, Kuttakarasiromani and Kusuba and Ikeyama have worked on Ganitakaumudi and Brahmasphuta-siddhanta. There is one Japanese scholar Ohashi who had with Professor Shukla on astronomical instruments.

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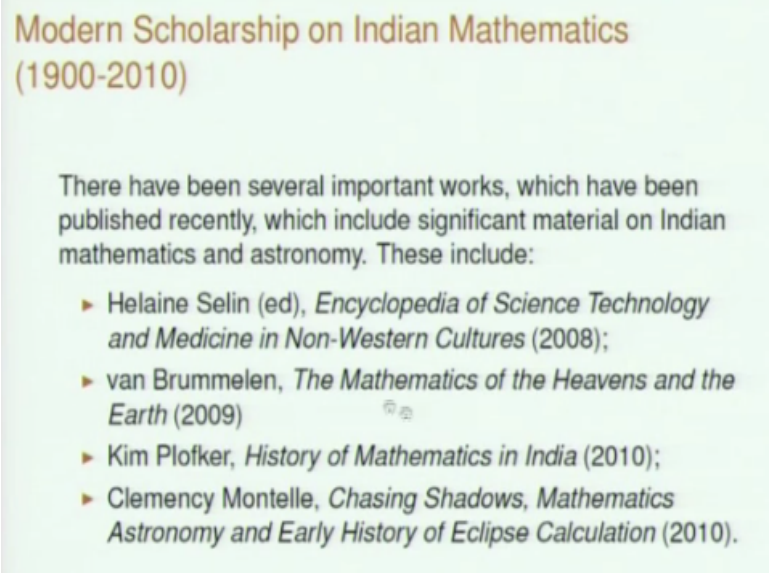

So, it is a big school compared given the number of people working on this kind of feature. These are some of the international books which have been published on Indian Astronomy and Mathematics in recent times.

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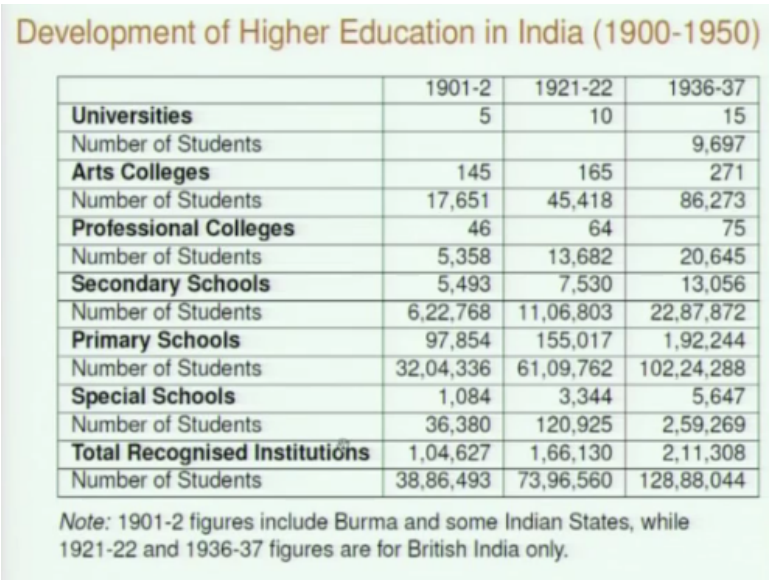

	1901-2	1921-22	1936-37
Universities	5	10	15
Number of Students			9,697
Arts Colleges	145	165	271
Number of Students	17,651	45,418	86,273
Professional Colleges	46	64	75
Number of Students	5,358	13,682	20,645
Secondary Schools	5,493	7,530	13,056
Number of Students	6,22,768	11,06,803	22,87,872
Primary Schools	97,854	155,017	1,92,244
Number of Students	32,04,336	61,09,762	102,24,288
Special Schools	1,084	3,344	5,647
Number of Students	36,380	120,925	2,59,269
Total Recognised Institutions	1,04,627	1,66,130	2,11,308
Number of Students	38,86,493	73,96,560	128,88,044

So, between 1900 and 1950 the growth in higher education was only modest 5 to 15 universities. Colleges going up from 145 to 270 students going up to 85,000, professional colleges students going to 20,000.

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The Indian Institute of Science was set up in 1909 with munificent donations of the Tata's and the government of Mysore. The Indian's Congress Science Congress Associations was started in 1914 with the first session in Calcutta.

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The Indian Academy of Sciences was founded by Raman in 1934 with 65 founding Fellows. It has about 1060 Fellows now. The Indian National Science Academy was started around 1935. Sir Lewis Fermor was its first president, Meghnad Saha became the first Indian president shifted to Delhi in 1951.

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While setting up the Indian Academy of Science Raman try to give an agenda for the academies or for the Indian Scientific Community. Essentially he was trying to highlight the importance of building a national scientific community and associated institutions for fostering scientific research in India.

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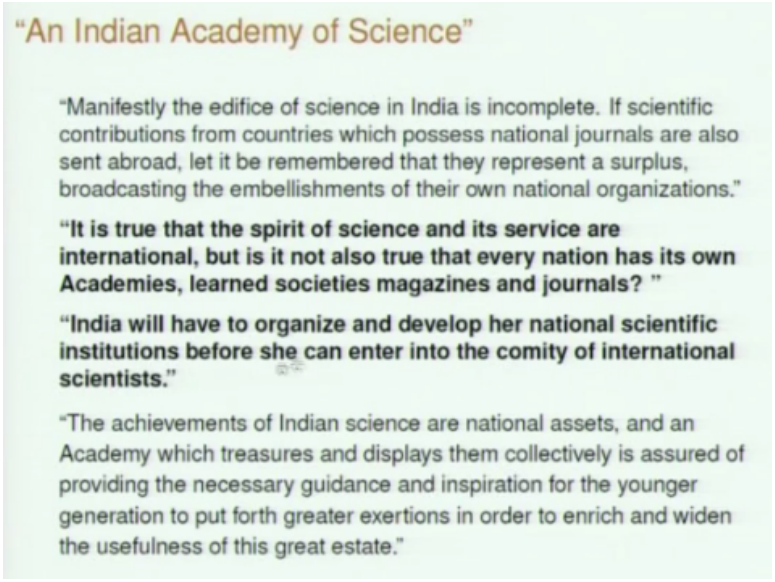

A detailed editorial which you can see I have put it down here. One of the main things Raman is trying to say is that it is true that the spirit of science and its service are international. But is it not also true that every nation has its own Academies, learned societies, magazines and journals. India will have to organize and develop her national scientific institutions before she can enter into the comity.

This was a call to the scientific community to work as a national scientific group that will be there.

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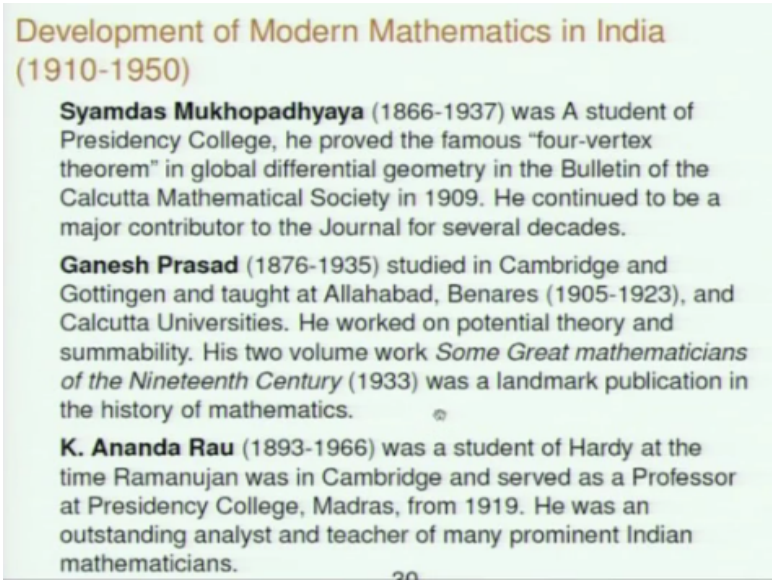

Now I will quickly tell about the important names in the development of mathematics. This will only be names now. Their work I cannot really discuss in this short period but perhaps it is good to know these names. Prior to independence we have Syamdas Mukhopadhyaya and Ganesh Prasad both in Calcutta. Ananda Rau was a very important professor in Presidency College.

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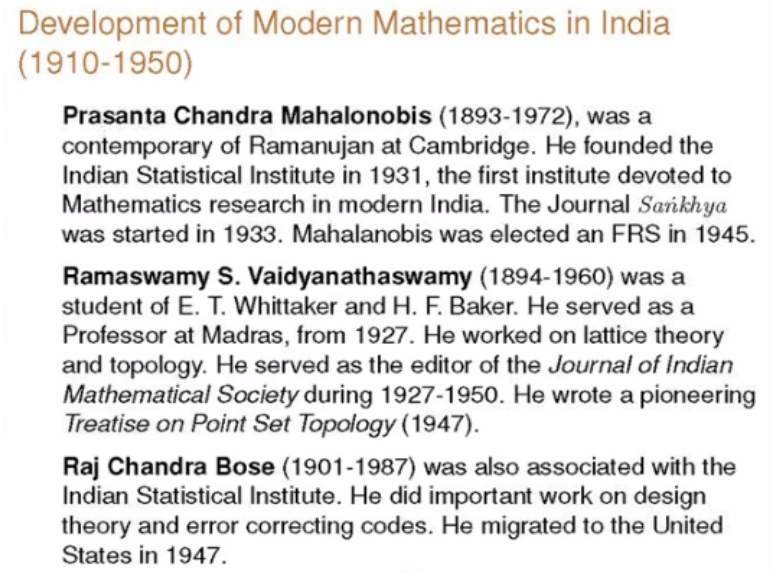

Mahalonobis who founded the Indian Statistical Institute. Professor Vaidyanathaswamy who was here in Chennai, Raj Chandra Bose who was in the Indian Statistical Institute.

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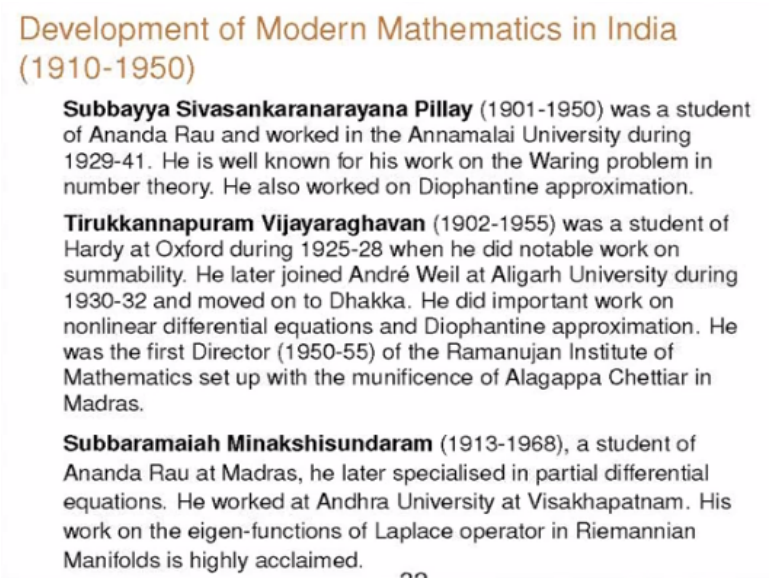

SS Pillay who worked in Annamalai University, T Vijayaraghavan whose name you came across in the discussion on magic square. Minakshisundaram he is also very famous mathematician, he worked it.

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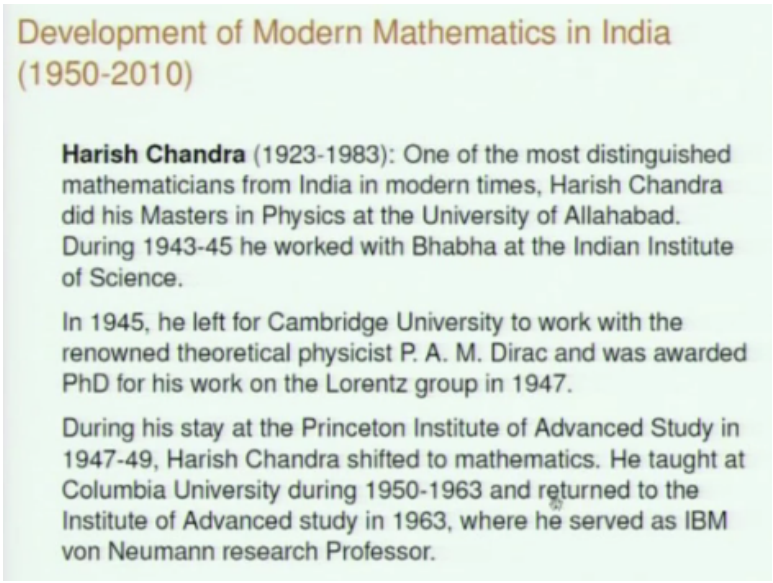

But in the last 50 years in our post independent era the most famous Indian mathematician has been Harish Chandra. Harish Chandra was a student of Physics from Allahabad then he went to Bhabha. Then he left to Cambridge with to work with the renowned Dirac. He did his thesis on Lorentz group and then during his stay in institute for Advanced Study in 1947 to 1949 Dirac was also visiting.

Harish Chandra shifted to mathematics. Then he taught in Columbia later on came back to institute for advanced study.

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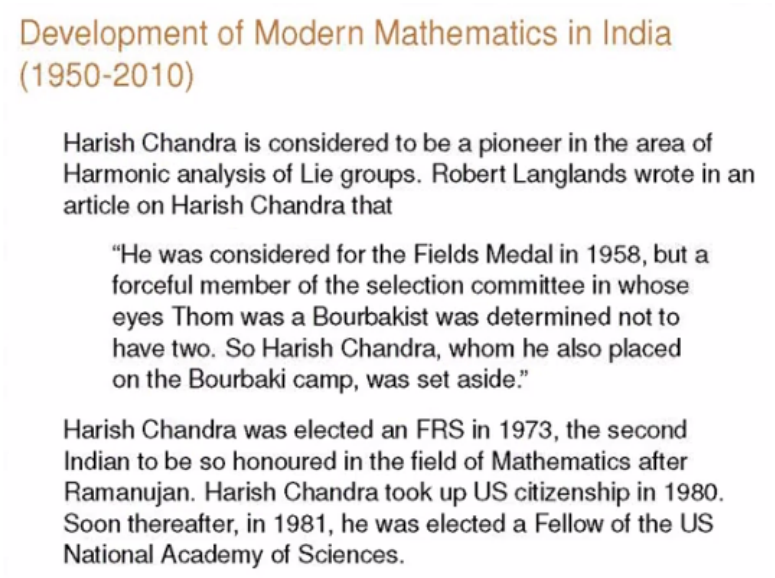

And he is really a pioneer in the field of what is known as the field of Harmonic analysis of Lie groups. His name was considered for the famous Fields Medal that is to be given before the age of 40 and it is equivalent to its thought of as the Nobel Prize in mathematics. So, Harish Chandra was born in 1923, I think. 1923, so in 1958 he was due.

But somehow it was thought that already is getting and he belong to the Bourbakist group and people did not want more than 1% from the Bourbakist camp to get and Harish Chandra did not get the Fields Medal. Got of course FRS and late towards the end of his life also became a Fellow of the US Academy of Sciences.

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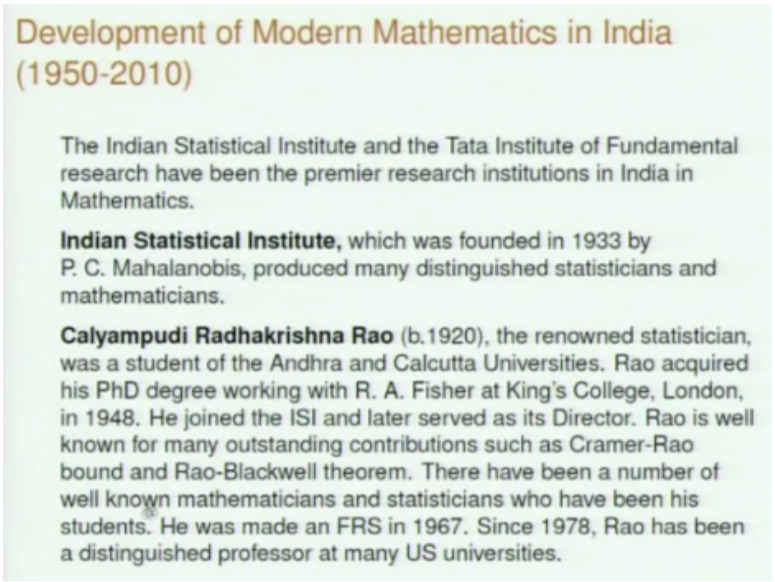

The 2 premier institutions which have posted mathematics research in India have been the Indian Statistical Institute and the Tata Institute of Fundamental research. The Indian Statistical Institute was founded in 1933. It also started the journal Sankha or Sankhya. The Professor C. R. Rao, a famous statistician he was a student of Fisher in London. He trained most of the famous mathematicians and statisticians in Calcutta.

He is well known for his work on Cramer-Rao bound, Rao-Blackwell theorem, etc. Since 1978, Rao has been a distinguished professor in many American Universities.

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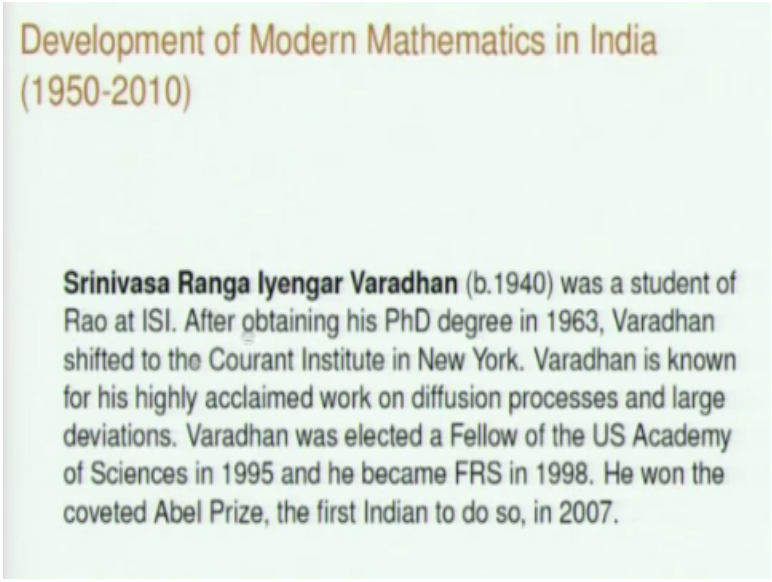

Professor S. R. S Varadhan, he was a product of the statistical institute. He going to Courant Institute in New York. In 2007 Professor Varadhan was the first Indian to be awarded the coveted Abel Prize.

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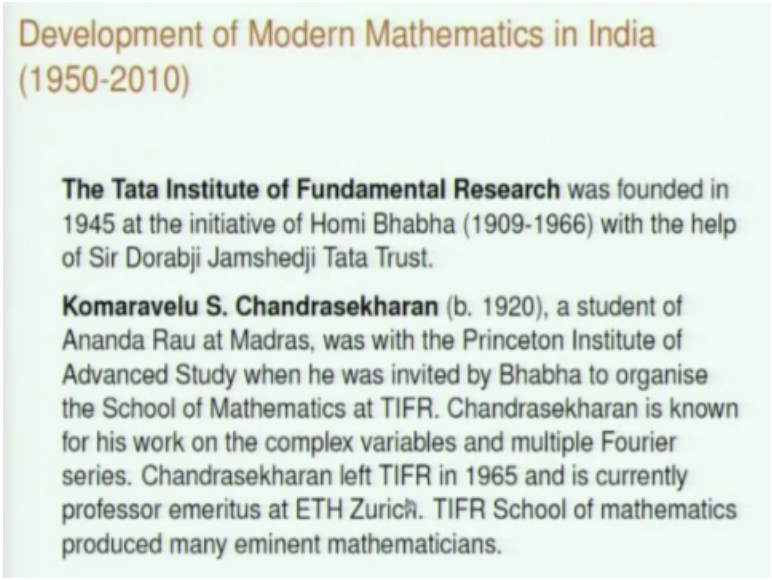

Tata Institute started a mathematic school and Bhabha invited professor Chandrasekharan who was then in Princeton Institute of Advance Study to come in and start this school and many, many important mathematicians were trained in this school.

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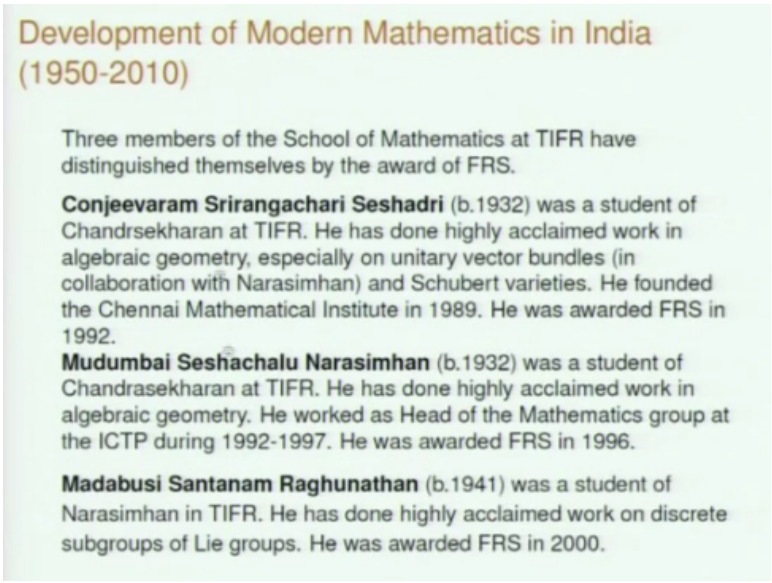

3 of the Tata Institute mathematicians have been awarded the distinction of Royal Society. C. S. Seshadri, who founded the Chennai Mathematical Institute here. M. S. Narasimhan and M. S. Reghunathan have all be awardees of the FRS. So, this has some of the major names, I mean one could go and list many more names and but one should also describe their work.

So in the next 25-30 minutes, I will try to give you an assessment of the growth of science and the growth of mathematics in India and place it in the global context as to where does

India stand in higher education? Where does India stand in global scientific research? Where does India stand in global mathematics research?

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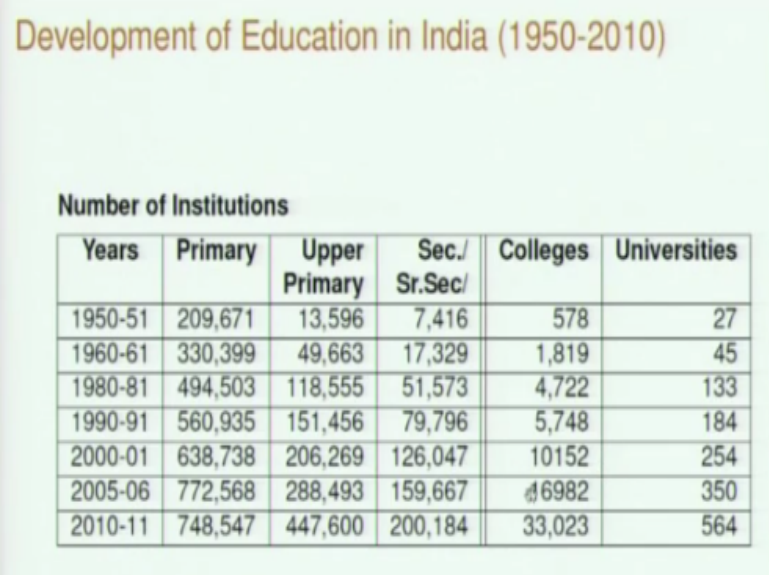

Years	Primary	Upper Primary	Sec./ Sr.Sec/	Colleges	Universities
1950-51	209,671	13,596	7,416	578	27
1960-61	330,399	49,663	17,329	1,819	45
1980-81	494,503	118,555	51,573	4,722	133
1990-91	560,935	151,456	79,796	5,748	184
2000-01	638,738	206,269	126,047	10152	254
2005-06	772,568	288,493	159,667	16982	350
2010-11	748,547	447,600	200,184	33,023	564

As you can see the development of education in India has been phenomenal from independence 27 to 564 universities have come. From 600 colleges to some 33,000 colleges are there. Secondary schools have grown even more about 2 lakhs. The primary schools have also grown from about 2 lakhs to 7.5 lakhs. So, there has been a big growth of education in India.

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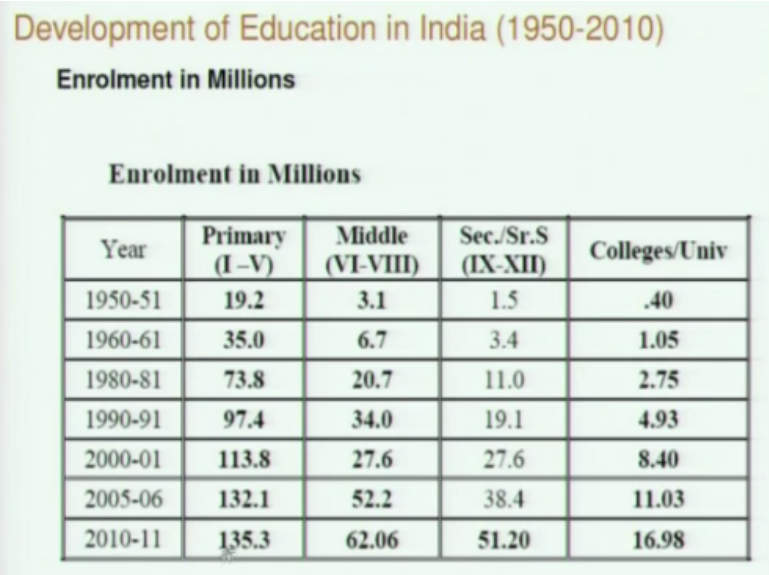

Year	Primary (I –V)	Middle (VI-VIII)	Sec./Sr.S (IX-XII)	Colleges/Univ
1950-51	**19.2**	**3.1**	1.5	**.40**
1960-61	**35.0**	**6.7**	3.4	**1.05**
1980-81	**73.8**	**20.7**	11.0	**2.75**
1990-91	**97.4**	**34.0**	19.1	**4.93**
2000-01	**113.8**	**27.6**	27.6	**8.40**
2005-06	**132.1**	**52.2**	38.4	**11.03**
2010-11	**135.3**	**62.06**	**51.20**	**16.98**

And the number of students studying there has also gone up significantly. In 1950-1951 there were only about 4 lakhs students in colleges. Today there are about 170 lakh students in

studying in higher education, 1.7 crores by I mean, I am saying today this all refers to 2010-2011, so in the last 2 years this number would have gone up further.

13.5 crores students in the 5 primary, 6.2 crores in the middle school, 5.1 crores in the senior secondary and 1.6 crores - 1.7 crores in the colleges. This is the kind of enrollment that we have. But this enrollment has to be understood in relation to the demography of India that how many of the people in that corresponding age group are attending this institution because India is a today it has a population of 120 crores.

So, we have to understand to see the progress in education.

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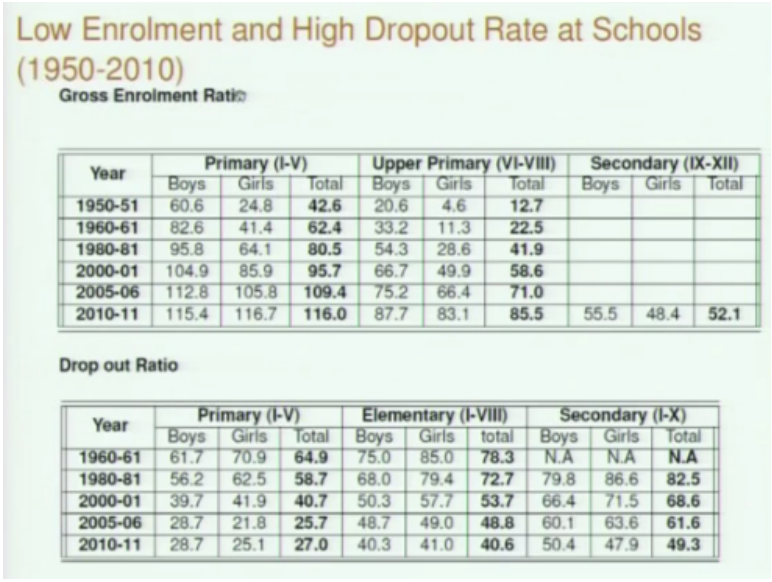

Year	Primary (I-V)			Upper Primary (VI-VIII)			Secondary (IX-XII)		
	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total
1950-51	60.6	24.8	**42.6**	20.6	4.6	**12.7**			
1960-61	82.6	41.4	**62.4**	33.2	11.3	**22.5**			
1980-81	95.8	64.1	**80.5**	54.3	28.6	**41.9**			
2000-01	104.9	85.9	**95.7**	66.7	49.9	**58.6**			
2005-06	112.8	105.8	**109.4**	75.2	66.4	**71.0**			
2010-11	115.4	116.7	**116.0**	87.7	83.1	**85.5**	55.5	48.4	**52.1**

Year	Primary (I-V)			Elementary (I-VIII)			Secondary (I-X)		
	Boys	Girls	Total	Boys	Girls	total	Boys	Girls	Total
1960-61	61.7	70.9	**64.9**	75.0	85.0	**78.3**	N.A	N.A	**N.A**
1980-81	56.2	62.5	**58.7**	68.0	79.4	**72.7**	79.8	86.6	**82.5**
2000-01	39.7	41.9	**40.7**	50.3	57.7	**53.7**	66.4	71.5	**68.6**
2005-06	28.7	21.8	**25.7**	48.7	49.0	**48.8**	60.1	63.6	**61.6**
2010-11	28.7	25.1	**27.0**	40.3	41.0	**40.6**	50.4	47.9	**49.3**

We should look at what is called the gross enrollment ratio which is the ratio of the number of students in the particular section divided by the corresponding age group in which the total number of children in the corresponding age group. So, the enrollment in primary is almost more than 100 that means that the age group data many more students are studying in the primary schools.

But the enrollment in upper primary which, enrollment even in primary is very low in 1950 it was 40%. It has only around 2,000 that it is crossing 100%. Enrollment in upper primary has gone up from 12 to about 85 but in secondary education itself you see the enrollment is only 50%. That is from 9 to 12 classes only 50% of the children of the corresponding age group are going.

And there is something called the dropout ratio in India by the 5th standard about quarter of children dropout. By 8th standard about 40% of the children dropout by 10th standard almost half the children dropout from the education stream. This also very important indicate.

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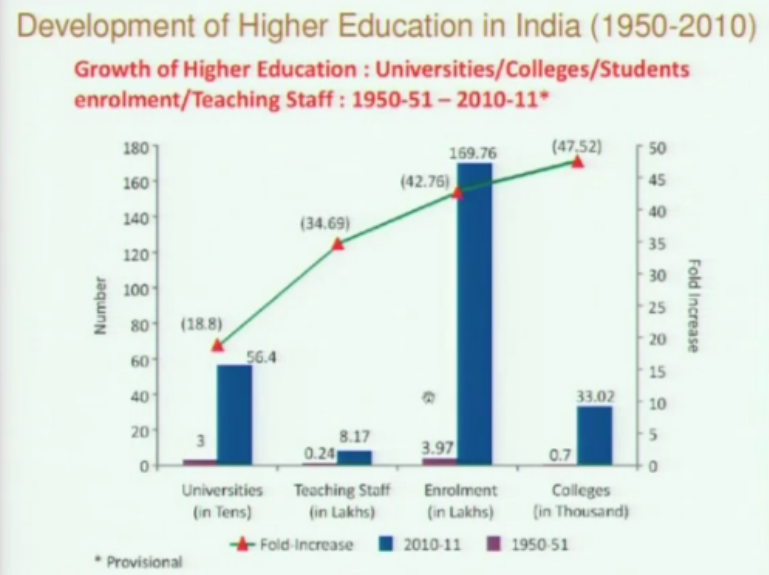

But now we quickly come to higher education only. The school and other education systems we will not bother. So, this already I told you, 33,000 colleges and about 564 universities about 8 lakh teachers about 1.7 crores students that has been the growth.

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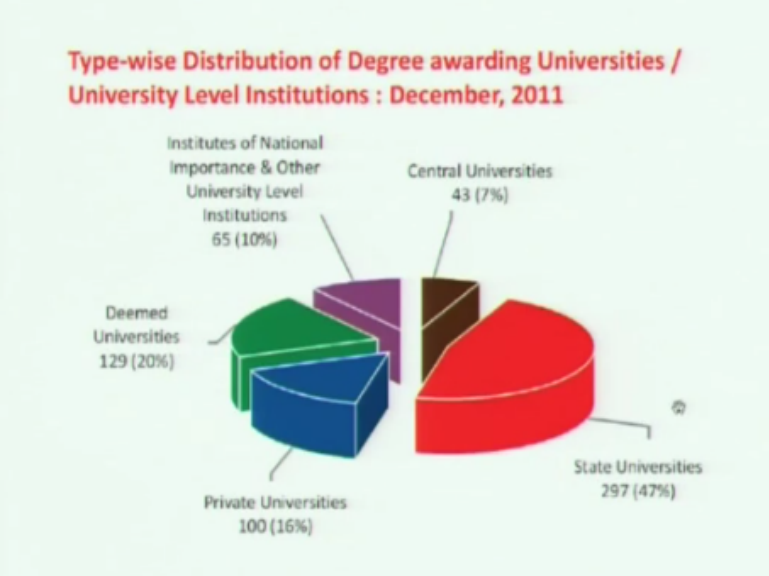

So, our universities which we counted it around 600, 300 of them are State Universities, 43 are Central Universities, 65 are Institutions of National importance, 130 Deemed Universities, 100 Private Universities. So, these are the degree awarding institutions.

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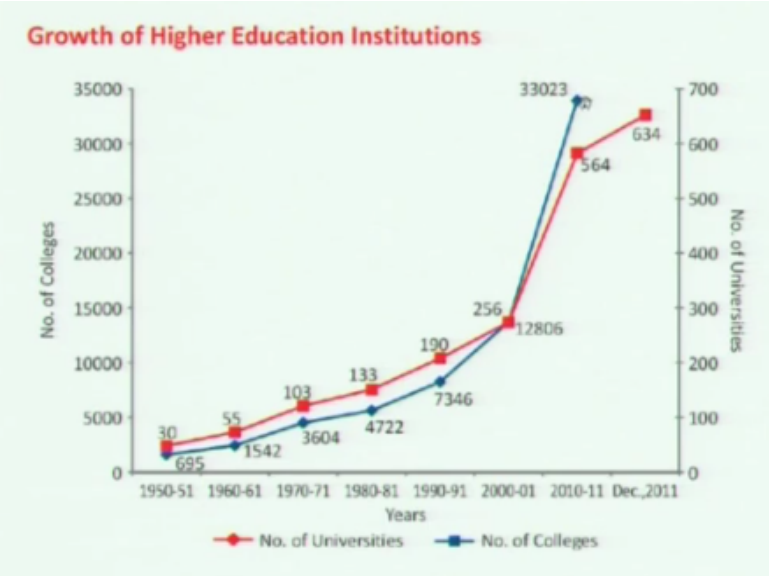

And of the 33,000, 634 universities and 33,000 colleges. You can see the number of colleges has grown in the last 2 decades. In 1990-1991 there was only 7000 colleges. There were 12,000 in the beginning of the last decade and now there about 33,000 colleges.

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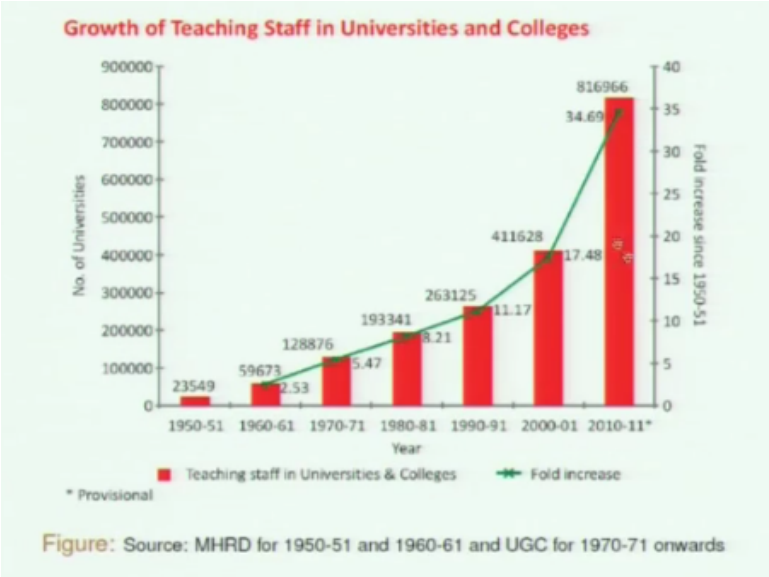

Figure: Source: MHRD for 1950-51 and 1960-61 and UGC for 1970-71 onwards

Teachers have also gone up to about 8 lakhs.

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So, first is the gross enrollment ratio in higher education. So, you take the age group 18 to 24 what is the total population there and you take the number of students enrolled in higher education. So, divide the later by the former as a percentage that is called the gross enrollment ratio in higher education. It was very low in 1951 it was raising. So, it close to almost 5% by 1980.

But afterwards it has been sort of growing rather slowly. It has grown 7 times in the first 30 years. In the next 30 years, this figure is actually contested, so it has hardly grown 3 times.

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But now to understand this we should understand it in the global context. So, what is the gross enrollment ratio in various countries in the world that is the with which we have to

compare. So, this is the UNESCOs Global Education Digest up 2012. So, they are giving 18% GER per India with 20.75 million, 2 crores this is more than the 1.7 crores I mentioned.

I think they are taking it to account students in the distance educations scheme also and things like that. So, that is I think what we will make in 2 crores and that gives an enrollment ratio of 18%. The world average is 29%. And East Asia Pacific, Korea is 100%, Japan 60%, Thailand 48, Malaysia 40, Indonesia 23 and of course China which has a total enrollment more than ours we have 20 that is 2 crores they have about 3 crores in their colleges.

It had a very low gross enrollment ratio of 3% in 1992. It has risen to 16% in 2002 and it has risen to 26% in 2010. So, the moment they have decided to go for higher education in a big way they have been able to move very fast. USA, of course has 76% gross enrollment. So it has a total enrollment, India is second in the world in this data. Chinese have about 3.1 crores India is about 2.1, USA has about 2.05.

So, that is where we stand in the gross enrollment in the world as a whole and next is how do we stand in higher education.

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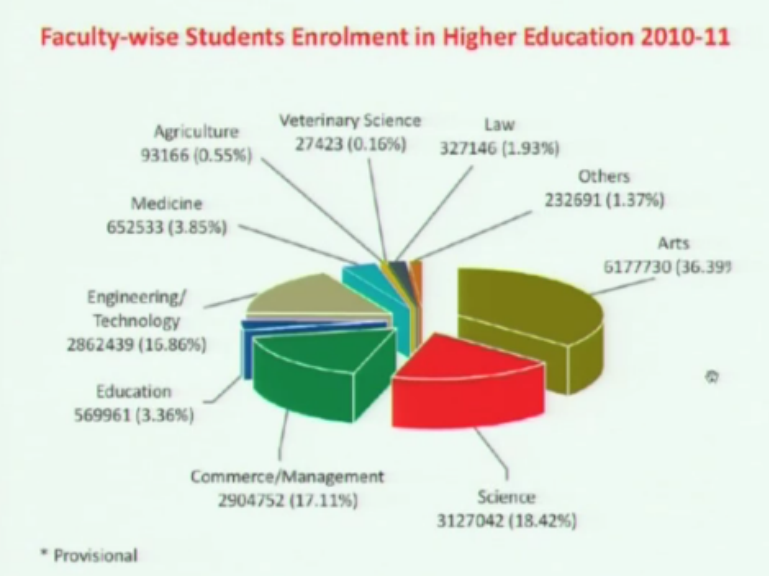

So, the break up for this higher education is something like this. About 18% of all students studying in higher education study science, about 36% study arts, about 17% study commerce and management, about 4% medicine, about 2% Law, 3% study education. That is the distribution by subject.

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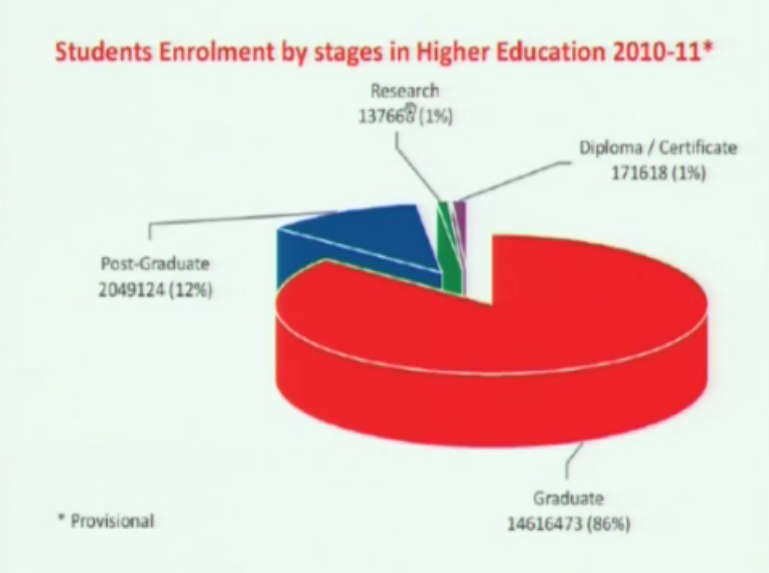

So, 86% of the higher education students are what we call us under graduates. Only 12% about 20 lakh students are in post graduate institutions and < 1% about 1.3 lakh students are in research. So, this is the kind of break up. And therefore consequently the total number of PhD's in India is of the order of 10,000 of which 3,000 each year, I mean this is the year of 2009 and 2010.

Science PhD's is about 3,742, arts is 3,500, engineering and technology is about 1,000, medicine is 337. So, this is the growth in quantity. So, what is the output? So, output is usually measured one in terms of scientific publications and another in terms of patents, etc. I am only looking at since we are looking at mathematics pure science, we will look at the output in terms of scientific publications.

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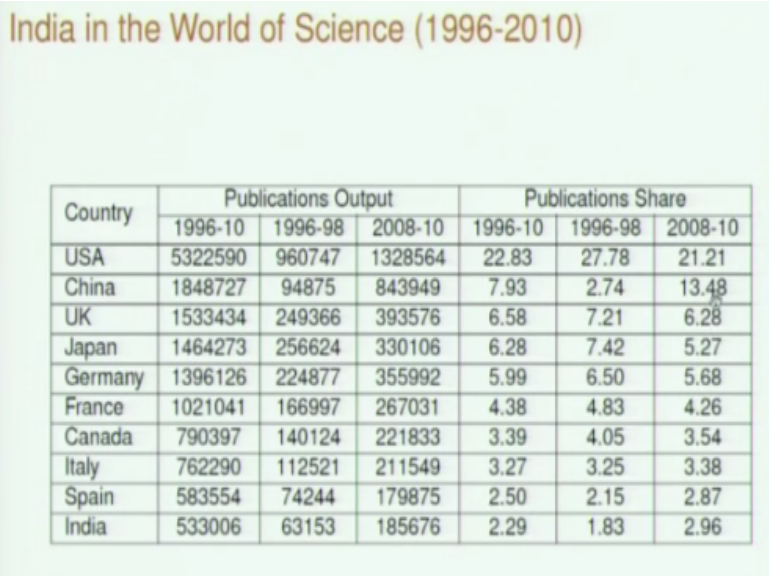

Country	Publications Output			Publications Share		
	1996-10	1996-98	2008-10	1996-10	1996-98	2008-10
USA	5322590	960747	1328564	22.83	27.78	21.21
China	1848727	94875	843949	7.93	2.74	13.48
UK	1533434	249366	393576	6.58	7.21	6.28
Japan	1464273	256624	330106	6.28	7.42	5.27
Germany	1396126	224877	355992	5.99	6.50	5.68
France	1021041	166997	267031	4.38	4.83	4.26
Canada	790397	140124	221833	3.39	4.05	3.54
Italy	762290	112521	211549	3.27	3.25	3.38
Spain	583554	74244	179875	2.50	2.15	2.87
India	533006	63153	185676	2.29	1.83	2.96

So between 1996 to 2010, where does India stand? Currently India is producing about 3% of the world scientific publications. USA is about 21 and China is about 14% - 13.5% of the world scientific publications. Moving to the next page, South Korea is producing about 2.5%.

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India in the World of Science (1996-2010)

Country	Publications Output			Publications Share		
	1996-10	1996-98	2008-10	1996-10	1996-98	2008-10
Australia	520045	68672	160286	2.23	1.99	2.56
Russia Fed	480665	92800	103677	2.06	2.68	1.66
Netherlands	435083	66747	120024	1.87	1.93	1.92
South Korea	430438	34961	152444	1.85	1.01	2.43
Brazil	328361	30163	122383	1.41	0.87	1.95
Switzerland	309549	46209	85268	1.33	1.34	1.36
Taiwan	308498	33210	104939	1.32	0.96	1.68
Sweden	304831	51144	75541	1.31	1.48	1.21
Poland	265139	34592	74501	1.14	1.00	1.19
Belgium	237081	34473	66832	1.02	1.00	1.07
World	23313577	3458215	6262939			

Data from SCOPUS in B. M. Gupta, Ind Jour Sc Tech. 2010, p.2900

But the growth from 1996 to 2008 India is more or less it was about 1.83 has gone to 2.96. The Chinese were about 2.74 in 1996, currently they are contributing about 13.5% of the world scientific output and this is in numbers. This is about 8,43,000 papers in those 3 years which means about 2.8 lakh papers per year. Indians are producing 1,85,000 which means about 60,000 scientific publications are each year are emanating from India.

There are other countries like Taiwan, South Korea, Brazil which have shown considerable growth in this period. Brazil has grown more than 2 times, Taiwan has grown about 2 times, South Korea has grown more than 2 times in the last 12 years. In 1970 the people who studied growth of science in India they almost hailed India as a Research super power in the Third World.

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There is something called the Science Citation Index which is a major database of all scientific articles and also analysis citations. So, Eugine Garfield originator of this Science Citation Index. Wrote he made an analysis of the publication data of 1973 and the citation data, citation means the number of times the paper is refer to by others in during the 5-year period and he called India a Research super power.

So, in 1973 about 3.5 lakh articles were indexed about 84% of the articles came from the First World and about 90% of all the citations also came from the First World. But then he saying amongst the top 25 countries in terms of the numbers of articles written by their authors, only 2 Third World countries appear India and Argentina, this in 1973.

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India is considered to rank third in the world in the number of researches. This an old thing, so in 1970s this would have been the key situation after US and USSR. But it ranks 8 in the number of publications. But then he is saying that Indian researchers have authored half of the 16,000 articles return from the Third World and the only other country is Argentina which is the distant second accounting for one fifth of India's output.

Clearly, India is a Research super power in the Third World. This was result of impression that the situation in 1970s was coming on the growth of science in India.

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So, this is the 1973 data. US has about 1.6 lakh papers which are cited about a million times that means 6 citations per paper amongst all these 25 countries, India which had about 8,000 papers has a citation index below 2 is of course the lowest amongst all these 25. But in terms of the volume of publications at least India ranked 8 in the world and it was the only Third World country to be significantly performing in science then in 1970s.

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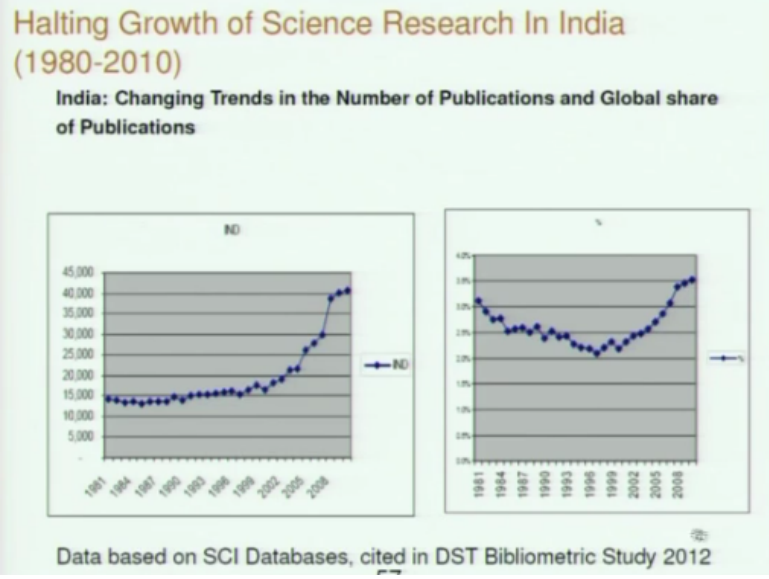

Well, this situation seems to be a totally transformed and reversed in the next 30-40 years. So, this is a DST study. This was a study made by Thomoson Reuters for the DST 2 years ago of scientific publications in various countries of the world. So, you can see the publications of India from 1981 we have gone up from about 15,000 to 40,000-45,000. The share at Indian publications in the world science publications has come down from 1981.

It was about 3% in 1981. It has come down to nearly 2% in 1996 and as again gone up to around 2% to 3% to 3.5% by 2008.

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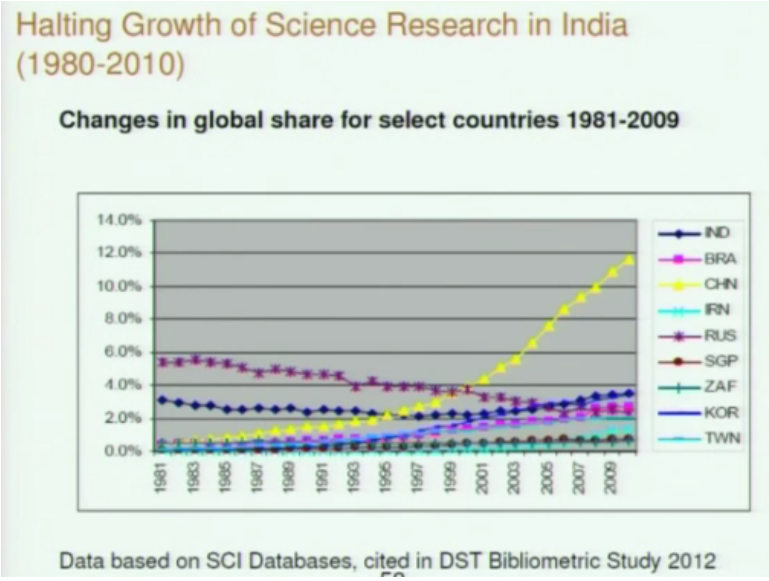

And what has happened in the same period is that many other countries have moved considerably faster and forward. So, here we have for the same period this is India, this blue

curve. Almost between 2 and 4, this yellow of course is China. It had less, although 0.2% in 1981 of the global publications share. It has gone more than 10% to 12% by 2010.

Russians are fluctuating they were about 6%. They are there but all these other countries are coming up. Korea, Taiwan, Singapore, Iran you can see all of them are raising, raising, raising and coming almost near to India if not more than the share. They are all tiny countries in comparison demographically but in terms of their scientific output they seem to be of the producing of the same order of magnitude as India in the share of publications in the world.

This, what has happened in the last 20-25 years. And the Indian situation is more than stable around between 2% and 3% of the world scientific output.

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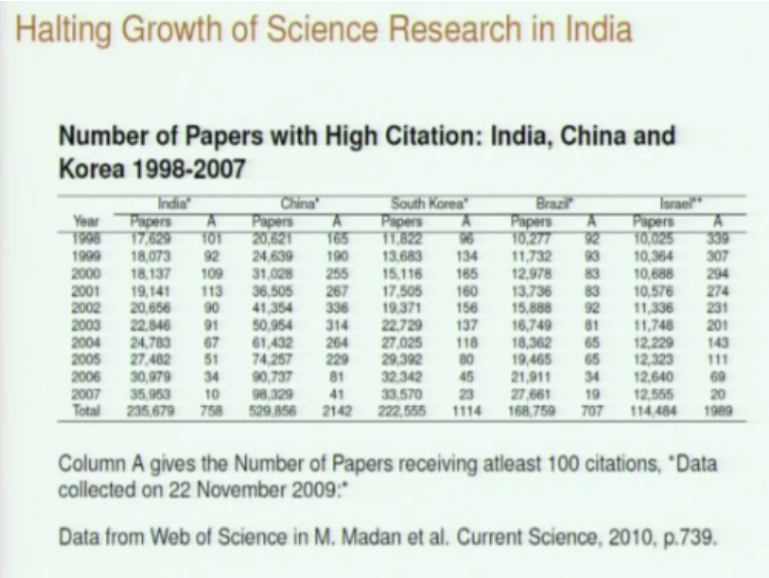

Year	India*		China*		South Korea*		Brazil*		Israel**	
	Papers	A	Papers	A	Papers	A	Papers	A	Papers	A
1998	17,629	101	20,621	165	11,822	96	10,277	92	10,025	339
1999	18,073	92	24,639	190	13,683	134	11,732	93	10,364	307
2000	18,137	109	31,028	255	15,116	165	12,978	83	10,688	294
2001	19,141	113	36,505	267	17,505	160	13,736	83	10,576	274
2002	20,656	90	41,354	336	19,371	156	15,888	92	11,336	231
2003	22,846	91	50,954	314	22,729	137	16,749	81	11,748	201
2004	24,783	67	61,432	264	27,025	118	18,362	65	12,229	143
2005	27,482	51	74,257	229	29,392	80	19,465	65	12,323	111
2006	30,979	34	90,737	81	32,342	45	21,911	34	12,640	69
2007	35,953	10	98,329	41	33,570	23	27,661	19	12,555	20
Total	235,679	758	529,856	2142	222,555	1114	168,759	707	114,484	1989

It is not nearly quantity you can analyze things in terms of quality also. The number of papers which are cited more than 100 times in the last 20 years there were only 800 Indian papers by this 2,000 Chinese, 1,000 Korean, 700 Brazilian, 2,000 Israeli papers were cited. So, it is not nearly a matter of quantity that others are moving fast. They are moving in terms of quality as the usually understood.

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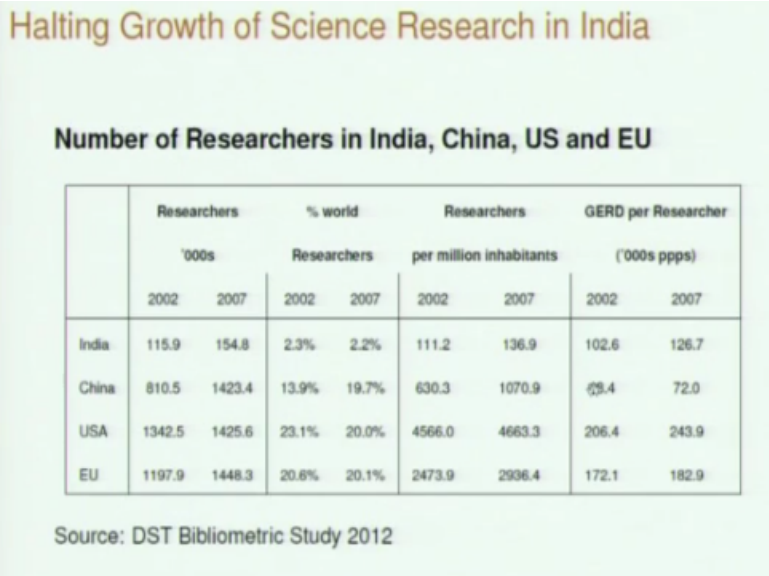

Again in terms of the total number of research personnel in the world Indian share is about 2% whereas the USA and European Union have about 20% of all researchers in the world. The Chinese have moved or moving very fast and they also now have about 20% of the researchers in the world. So, all of them have about this in thousands. So, this will be about 1.5 million China, USA and European Union.

India has about 1.5 lakh researchers about a 10th of that. But this is also significant this is called the per capital amongst them in ppp terms. Ppp terms means not the exchange term of 1 is to 55 Rupees per Dollar but in what is called the purchasing power clarity. We find that the Chinese are spending almost half of per scientist as the India. So, it is not really that we are not spending enough on our scientists some such thing.

We may not be spending enough still but others were spending much less are able to perform much more.

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Halting Growth of Science Research In India

Table: Number of Ph.D Degrees Awarded in S&T in Select Countries, 1983-2003.

Year	Number of Ph.Ds Produced in S&T								
	India	China	S.Korea	Taiwan	Japan	France	Germany	UK	USA
1983	3886	NA	281	8	2676	NA	4978	2430	19274
1985	4007	125	548	20	3088	NA	5738	2410	19663
1987	4123	218	759	35	3248	NA	6576	2580	20694
1989	4209	1024	984	42	3561	4888	7568	2940	22706
1991	4294	1198	1135	62	3874	5384	10465	3150	25061
1993	4320	1895	1421	97	4438	6829	10200	3030	26640
1995	4000	3417	1920	115	5205	7027	10889	2580	27864
1997	4764	5328	2189	163	6157	8962	11728	3420	28653
1999	5317	6778	2607	150	7082	7054	11984	3670	27339
2000	5395	7304	2865	147	7089	NA	11895	4370	27557
2001	5394	8153	NA	144	7401	NA	11803	4380	27160
2002	5527	NA	3225	NA	7461	NA	11017	4380	26226
2003	6318	NA	NA	202	7581	NA	10796	3780	26891

Source NSF, Science and Engineering Indicators 2006 Appendix Tables 2.42 and 2.43 NA=Not Available.

2008: 7982 28439 3716 2005 8017 7710 11314 9470 33369

So, in the number of PhD's awarded also India had about 8,000 in 2008, China had about 30,000 South Korea which had a very low number 280 in 1983 has about 4,000, Taiwan 2,000, Japan 8,000. So, like that this is the way. So, we are not really producing adequate number of PhD's for getting that kind of scientific output that others are moving towards.

So, now that was about the position in science as a whole and by now you can guess that will be reflected in mathematics also. It will not be this situation in mathematics will not be too much different. So, this is the sort of Thomoson Reuters Web of Knowledge Database.

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India In World Mathematics Research (2001-11)

Rank	Ranking by papers		Ranking by citations	
1	USA	74,874	USA	366,539
2	PEOPLES R CHINA	36,146	PEOPLES R CHINA	111,986
3	FRANCE	26,377	FRANCE	106,239
4	GERMANY	21,078	GERMANY	84,647
5	ITALY	15,453	ENGLAND	64,474
6	JAPAN	14,412	ITALY	55,968
7	ENGLAND	13,871	CANADA	54,039
8	CANADA	13,673	SPAIN	44,712
9	RUSSIA	13,614	JAPAN	40,417
10	SPAIN	12,671	AUSTRALIA	28,928
11	POLAND	6,703	RUSSIA	22,986
12	SOUTH KOREA	6,406	ISRAEL	20,517
13	AUSTRALIA	6,259	THE NETHERLANDS	17,348
14	INDIA	5,766	POLAND	16,938
15	ISRAEL	5,427	SOUTH KOREA	16,794
16	BRAZIL	5,175	BELGIUM	16,248
17	TAIWAN	4,169	BRAZIL	16,075
18	THE NETHERLANDS	3,880	SWITZERLAND	14,970
19	BELGIUM	3,807	SWEDEN	14,107
20	TURKEY	3,379	AUSTRIA	13,725
21	SWITZERLAND	3,289	TAIWAN	12,763
22	ROMANIA	3,247	INDIA	11,794
23	SWEDEN	3,219	SCOTLAND	11,145
24	IRAN	3,134	CZECH REPUBLIC	9,395
25	AUSTRIA	3,073	ROMANIA	8,583

Source: Web of Knowledge Database cited in G. Prathap, Curr. Sc., 102, 2012, p. 1349

They ranking by papers, ranking by citations for the publications in mathematics in the last 10 years 2001 to 2011. So, USA is producing about 7,500 papers per year, Chinese about 3,500, Indians are producing about 580 papers. So, in terms of number of papers we are about

14th below South Korea, below Poland, below Spain and Taiwan, Brazil, Israel are almost on our heels even Turkey, Iran.

And by citation also India is I think somewhat lower they have 6,000 papers are cited < 2 and in I think the total world publications this will also come around 2.4% or 2.3% of the share of world publications.

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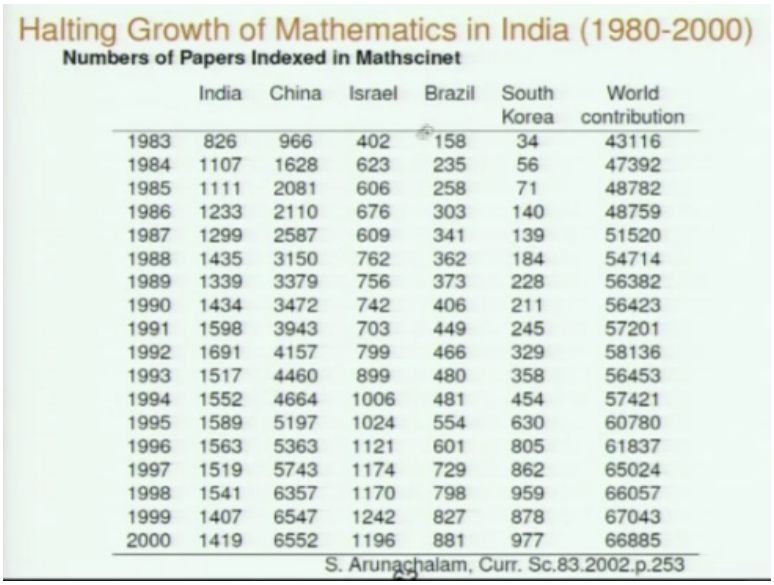

	India	China	Israel	Brazil	South Korea	World contribution
1983	826	966	402	158	34	43116
1984	1107	1628	623	235	56	47392
1985	1111	2081	606	258	71	48782
1986	1233	2110	676	303	140	48759
1987	1299	2587	609	341	139	51520
1988	1435	3150	762	362	184	54714
1989	1339	3379	756	373	228	56382
1990	1434	3472	742	406	211	56423
1991	1598	3943	703	449	245	57201
1992	1691	4157	799	466	329	58136
1993	1517	4460	899	480	358	56453
1994	1552	4664	1006	481	454	57421
1995	1589	5197	1024	554	630	60780
1996	1563	5363	1121	601	805	61837
1997	1519	5743	1174	729	862	65024
1998	1541	6357	1170	798	959	66057
1999	1407	6547	1242	827	878	67043
2000	1419	6552	1196	881	977	66885

So, this is the growth of mathematics in India compared to China, Israel, Brazil. Some other study, which is important because even 10 years ago this fact was highlighted that we are really lagging behind in our research. Our output is not adequate in terms of the fact that we are some how's where are many other countries are really moving, who are hardly considered as major forces in science in 1970s or even early 1980s.

They are moving to a situation where they are becoming major scientific powers in the world.

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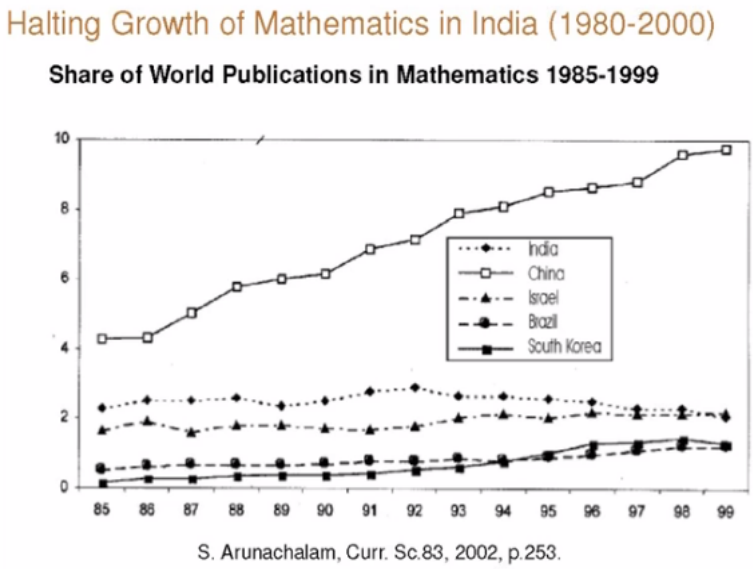

S. Arunachalam, Curr. Sc.83, 2002, p.253.

And so, here you can see between 1985 to 1999 this is the graph of Chinese publications and this is the graph of the Indian publications and others are catching up even then.

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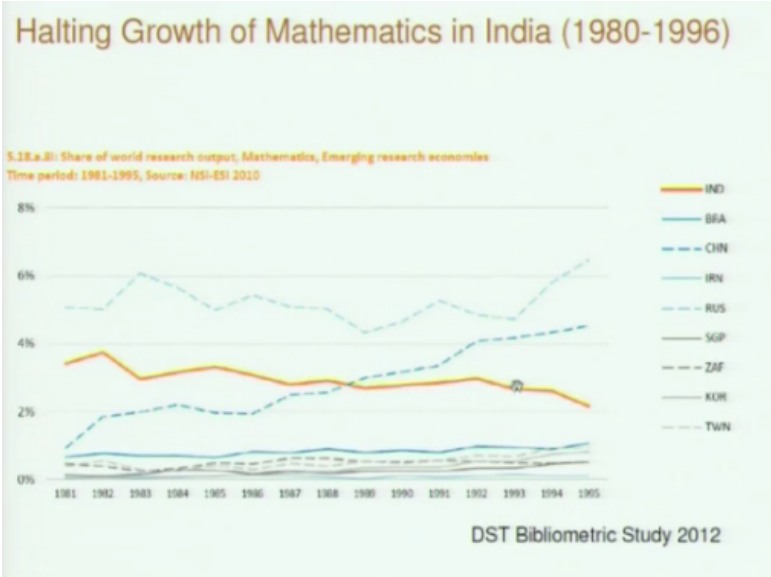

This is the more recent Reuters study. I think they have put India in Saffron color for whatever purpose. So, this is the Chinese they caught up with India around 1989 and they have moved up in 1985. This is the Russians. So, after 1996 the Chinese have gone out of this graph because this is 2%, 4%, 6%. They have gone to a different order of magnitude. The Russians are still there.

But all these others Korea, Taiwan, etc. are all coming close to India. Brazil they have a share which is that. So, this is the kind of picture that emerges I do not need to repeat it again and again.

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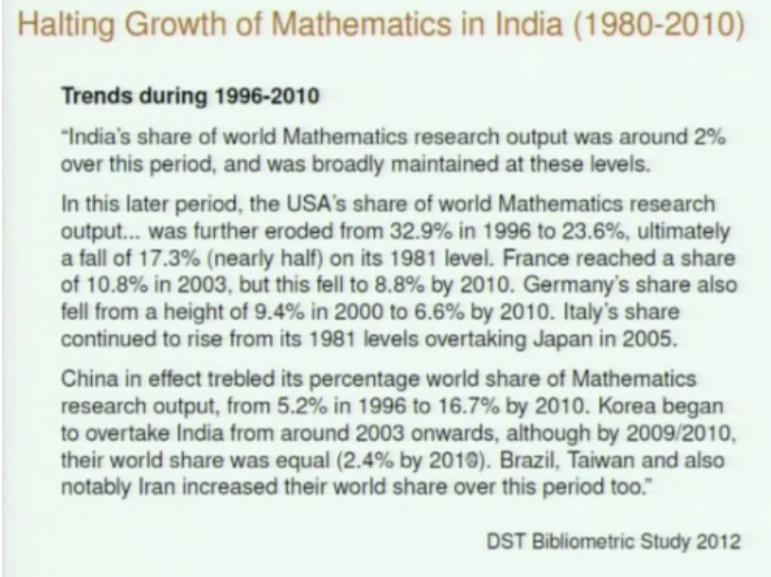

If you study these quantitative figures more carefully you will see various nuances of this picture.

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So, let us quickly try and summarize the situation as I understand from these figures of the state of higher education and research in India including mathematics. So, one is we have this low enrollment in high schools and secondary schools which is the input to our higher education. It is around 50% and at the same time we have this, 50% dropout by class 10.

Second is that the numbers enrolled in higher education is not growing really fast we have GER, gross enrollment ratio which is around 15% even that figure needs to be very well confirmed by the trends in the next few years. That means only one sixth or even one seventh

of the boys and girls in the age group 18 to 24 are getting into university, whereas the world average is about one third 29%.

There are only 550 universities which grant degrees. They are more than 33,000 colleges and an enrollment of about 17 million. So, that we leave on the average only about 400-500-600 students on the average per college.

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So, this is the general picture. On research and post graduate education only 12% of the higher education the students are going for post-graduation and < 1% of the students having PhD and in science the situation is that we are producing only about 3,700 students a year in PhD. And in terms of the output, so India which was hailed as a Research super power in the Third World in 1970 as exhibited a rather halting growth in the global share science publications in science.

It has stayed around 2% to 3% in 1980 to 2010. While many countries of Asia and Latin America have shown much higher rates of growth and they have either attained the status of India or across them. And their demographically they are sort of very, very small compared to India. In mathematics also this the same thing in fact between 1981 to 1985 it declined Indian share in world publications in mathematics.

It has stayed around 2% during 1996 to 2010 again many other countries have.

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So, this data is all standard much have it is taken from National Science Bureau Science and Engineering Indicators were 2012, UGC's Higher Education at a Glance 2012, UNESCO, Global Education Digest 2012 this were the world comparison. For our own thing that this DST's Bibliometric Study of India's Science Publications, Evidence for Changing Trends 2012 there these studies of B. M. Gupta, Madan, Arunachalam and others.

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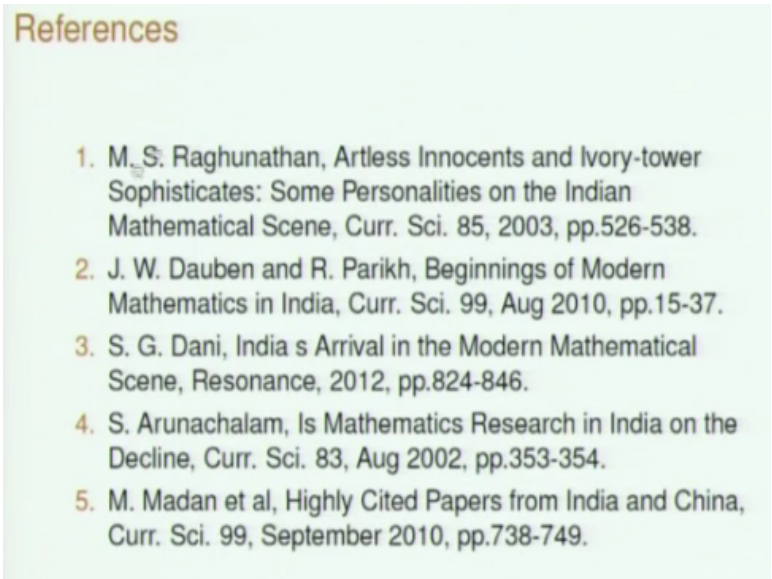

These 3 articles discuss the important figures in the development of modern mathematics in India in the first half of 20th century. People like Syamdas Mukerji, people like this Vijayaraghavan all these S. S. Pillai and all they were discussed in great detail.

So, with this sort of I come to a close up the study of Modern Mathematics in India. Modern Mathematics did take root and blessed with the native genius Ramanujan in the beginning of

last century and after independence we have foster the growth of Modern Science and Mathematics in a fairly big way. But somehow in the last 30-40 years we do not seen to have gone up with the in the way we all to have really gone about developing our higher education in research.

So, our sort of situation seems somewhat stagnant. Essentially it appears that a very small percentage of Indians are participating in this activity of higher education and research compared to the really potentially large population of youngsters that we have in our country. And that seems to be one of the problem and that gets many of the studies in various other ways and therefore that results that only there are few institutions in India which would you would be in any has doing research.

And they will not have really the kind of numbers that will be there in corresponding times of institutions all over the world, say there are several reputed universities in USA which have about 30,000 to 40,000 student's studying in the same campus. And I do not think there is any university in India where in a single campus you are training under graduates of that kind of a number.

So, like that there are various factors when which this affiliated colleges which are not willing with research and higher studies. Many, many factors which is an inheritance from the British period higher education system in India which we thought was very valuable and took it over without making any major fundamental alterations in it. So, we make few alterations but we made no fundamental alterations from it.

And sort of the limits of stagnation of that system are very, very visible in the last 2-3 decades. And unless we do that transformation now these are in this decade or in the next decade we will not be really contributing to the worlds knowledge nor we will be establishing a new sort of genre or mathematics a new school of mathematics that is where the to be in continuation with the great tradition of mathematics that I have discussed that we have discussed and described during the course. Thank you very much.