Transmission of the Calculus from Kerala to Europe
Part 2: Circumstantial and documentary evidence

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Part I proposed to take a legal view of the evidence for the transmission to Europe of the calculus that had developed in the works of the mathematicians and astronomers of the Aryabhata school between the 14th and 16th centuries. We established strong motivation for the transmission in the needs of navigation and the calendar reform, which were recognised as the most important scientific problems of that age in Europe. We also established that Europeans had ample opportunity to access the texts and calendrical almanacs in which this information was to be found, not only in the straightforward sense that they knew the local languages well, but also in the sense that trained mathematicians were sent for the express purpose of collecting the knowledge available in these texts.

Given this it would seem a foregone conclusion that the Indian mathematical manuscripts incorporating the calculus had already reached Europe by around 1580. Nevertheless, it is important to detail the circumstantial and documentary evidence, for it helps also to understand how this knowledge, after arriving in Europe, diffused in Europe. (Apart from historical curiosity, this is also a matter of contemporary pedagogical significance, since it enables us to assess, in a non-destructive way, the possible impact of introducing today the study of calculus with a different epistemological basis.)

We know too little even to conjecture anything about the accumulation of knowledge in Coimbra , nor exactly what happened to this accumulated knowledge after Jesuits

[1] The Aryabhata Group acknowledges financial support from the School of Education, University of Exeter, in the work that led to this paper.

took over control of the university after about 1560. After 1560, in line with the above reasoning, our working hypothesis, or scenario, is that over a 50 year period, say from 1560 to 1610, knowledge of Indian mathematical, astronomical and calendrical techniques accumulated in Rome, and diffused to nearby universities like Padova and Pisa, and to wider regions through Cavalieri and Galileo, and through visitors to Padova, like James Gregory[2]. Subsequently, it also reached Paris where, through the agency of Mersenne, and his study circle, it diffused throughout Europe.

Mersenne, though a minim monk, had received a Jesuit education, and was closely linked to Jesuits. Mersenne's correspondence reveals that Goa and Cochin were famous places in his time,[3] and Mersenne writes of the knowledge of Brahmins and "Indicos",[4] and mentions the orientalist Erpen and his "les livres manuscrits Arabics, Syriaques, Persiens, Turcs, Indiens en langue Malaye".[5] Mersenne's study circle included Fermat, Pascal, Roberval etc., and Mersenne's well-known correspondence with leading scientists and mathematicians of his time, could have helped this knowledge diffuse throughout Europe. (Newton, as is well known,[6] followed Wallis, and Leibniz himself states, he followed Pascal.) Of course, acquisition of knowledge of Indian mathematics could hardly have been a controlled process, so that many others, like the Dutch and French, for instance, could have simultaneously acquired this knowledge directly from India, without the intervention of Rome.

(1) Circumstantial evidence

With this scenario as the background, we can ask: what sort of circumstantial evidence can we *hope* to find? Certainly it would be absurd to expect citations in

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[2] See H W Turnbull, *James Gregory Tercentenary Memorial Volume*, London , 1939. "Gregory spent three or four years (1664-1668) in Italy....having stayed most of the time in Padua, where Galileo taught." (p 4). That Gregory acquired his knowledge through other sources is made plain by A. Prag, "On James Gregory's Geometriae Pars Universalis", pp 487-509, in H W Turnbull, *James Gregory Tercentenary Memorial Volume*, London , 1939: "James Gregory published *Geometriae Pars Universalis* at the end of his visit to Italy in 1668. This book is the firs attempt to write a systematic text-book on what we should call the calculus. Gregory does not suggest that he is the actual author of all the theorems in this work …We cannot judge exactly how much Gregory borrowed from other authors, because we do not know which books he may have read and to what extent he had knowledge of the unprinted work of his contemporaries."

[3] *Correspondance du P. Marin Mersenne*, 18 volumes, Presses Universitaires de France, Paris, 1945-. ; A letter from the astronomer Ismael Boulliaud to Mersenne in Rome, Vol XIII, p 267-73.

[4] *Correspondance*, Vol XIII, p 518-521.

[5] *Correspondance*, Vol II, p 103-115.

[6] E.g. Carl B. Boyer, *A History of Mathematics*, Wiley, 1968, p 424; C. H. Edwards, *The Historical Development of the Calculus*, Springer, 1979, p 113.

published work! The tradition in Europe of that time was that mathematicians did not reveal their sources. When they could get hold of others' sources, they copied them without compunction. The case of e.g. Cardan is well known, and there are well documented cases against, e.g. Copernicus,[7] Galileo[8] etc., of copying from others, whether or not such copying amounted to "plagiarism". Under these circumstances, mathematicians naturally kept their sources a closely guarded secret: they published only problems, not their solutions, and challenged other mathematicians to solve them.

(a) Fermat and Pell's equation.

One such challenge problem was proposed by Fermat, and has come to be known as Pell's equation (for no fault of Pell). "In a letter of February 1657 (*Oeuvres*, II, 333-335, III, 312-313) Fermat challenged all mathematicians (thinking in the first place of John Wallis in England) to find an infinity of integer solutions of the equation $x^2 - Ay^2 = 1$, where A is any nonsquare integer."[9] Mathematicians in Europe were unable to solve Fermat's challenge problem for over 75 years, until Euler published a general solution in 1738. In February 1657, Fermat also wrote a letter to Frenicle, where he elaborated upon this problem:[10] "What is for example the smallest square which, multiplied by 61 with unity added, makes a square?"

As Struik further notes, Indian mathematicians had a solution to this problem. In fact, strangely enough, *exactly* the case of A=61 is given as a solved example in the *BeejGanita* text of Bhaskara II. This coincidence is not trivial when we consider that the solution x = 176631904, y = 226153980 involves rather large numbers.[11] A similar problem had earlier been suggested by the 7th century Brahmagupta, and Bhaskara II provides the general solution with his *chakravala* method. Thus, Fermat's challenge problem, strongly suggests a connection of Fermat with Indian

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[7] George Saliba, cited earlier.
[8] William Wallace, *Galileo and his Sources – The heritage of the Collegio Romano in Galileo's Science*, Princeton University Press, 1984, has direct evidence of Galileo borrowing heavily from Jesuit sources in the Collegio Romano.
[9] D. Struik, *A Source Book in Mathematics*, cited earlier, p 29.
[10] D. Struik, *A Source Book in Mathematics*, cited above, p 30.
[11] For an modern introduction to details of Bhaskara's *chakravala* method, see I. S. Bhanu Murthy, A Modern Introduction to Ancient Indian Mathematics, Wiley Eastern, new Delhi, 1992. Also see C.Selenius, 'Rationale of the Chakravala Process of Jayadeva and Bhaskara II', *Historia Mathematica*, **2**, 1975, 167-184

mathematics: Fermat probably had access to some Indian mathematical texts like the *BeejaGanita*.

Euler certainly knew about Indian astronomy (hence mathematics), for Giovanni Cassini, then the most reputed astronomer of France, had already published an account of "Hindu astronomy" in 1691, and Euler wrote on the "Hindu year" [12] (sidereal year; the pope's bull was still not acceptable e.g. to Protestant Britain, until 1752). Since numerous Indian astronomical texts deal with "Pell's" equation, Euler had presumably learnt about this as well. However, we are not aware that he acknowledged this when he published his solution to what he called Pell's equation.

This suggestion that Fermat knew something about Indian mathematics is reinforced by Fermat's friendship not only with Mersenne, but with Jacques de Billy (1602-1669), a Jesuit teacher of mathematics in Dijon. Fermat also had the habit (then a general proclivity) of searching for knowledge in ancient books.[13]

(b) Fermat, Pascal and the calculus

"One of Fermat's most stunning achievements," continues Aczel, "was to develop the main ideas of calculus, which he did thirteen years before the birth of Sir Isaac Newton [in 1642]." Fermat's and Pascal's approach to the calculus reinforces the belief in a connection with Indian mathematics. It was at Mersenne's place that Pascal met Descartes who remarked in his *La Geometrie* of 1637 about the impossibility of measuring the circumference of a circle: "The ratios between straight and curved lines are not known, and I even believe cannot be discovered by men, and therefore no conclusion based upon such ratios can be accepted as rigorous and exact." Therefore, there was not, at this point of time, anything that could be called an indigenous or acceptable tradition of calculus.

However, in Indian mathematics, from the time of the *sulba sutra*-s, because of the different epistemological base, measuring the length of a curved line by laying a rope (*sulba*) along it, and straightening it (or measuring a general area by triangulation) has

[12] Euler's paper on the "Hindu year" was an appendix to *Historia Regni Graecorum Bactriani* by T. S. Bayer; see G. R. Kaye, *Hindu Astronomy*, 1924, reprinted, Cosmo Publications, 1981, p 1.

been quite an acceptable process, used to obtain a value of π. In fact, Aryabhata states that the area of a general plane figure should be obtained by triangulation,[14] before going on to give an improved measure of the (curved) circumference of a circle in terms of the diameter (a straight line), in the next verse.[15] In the very next verse he explains how his sine table is derived by approximating small arcs by line segments.[16] It is therefore quite natural to find this eventually developing into the calculus in the *Tantrasangraha*, whose author Nilkantha belonged to the Aryabhata school, and wrote a lengthy commentary on the *Aryabhatiya*, almost exactly a thousand years after it.

Nilkantha's younger contemporary, Jyeshtadeva, author of the Malayalam *Yuktibhasa* ("Discourse on Rationales"), has a chapter on the circle, explaining the method of deriving the improved sine table stated in the *Tantrasangraha*. The key step in this derivation[17] is the evaluation:

$$\lim_{n\to\infty} \frac{1}{n^{k+1}}\sum_{i=1}^{n} i^k = \frac{1}{k+1}, \quad k = 1,2,3,... \tag{1}$$

This is also exactly the approach to calculus adopted by Fermat, Pascal etc. to evaluate the area under the parabolas $y = x^k$, or, equivalently, calculate $\int x^k\, dx$. As Pascal remarked, about this formula, it serves to solve all sorts of problems of the calculus. "Any person at all familiar with the doctrine of indivisibles will perceive the results that one can draw from the above for the determination of curvilinear areas. Nothing is easier, in fact, than to obtain immediately the quadrature of all types of parabolas and the measures of numberless other magnitudes." This formula has been

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[13] Amir D. Aczel, *Fermat's Last Theorem*, Penguin, p 5.

[14] *Ganita*, 9 a-b. Aryabhatiya of Aryabhata,(ed and Tr.) K. S. Shukla and K. V. Sarma, Indian National Science Academy, Delhi, 1976. It may be recollected here, that area is not defined anywhere in any well-known version of the Elements, and that Hilbert's synthetic approach to the Elements, which dfines neither length nor area, hence fails beyond Proposition 1.35 of the Elements. See C. K. Raju, "How Should `Euclidean' Geometry be Taught in Schools?" Paper Presented at the International Workshop on History of Science, Implications for Science Education, Homi Bhabha Centre for Science Education, TIFR, Mumbai, 22--26 Feb 1999. To appear, Proc.

[15] *Ganita*, 10. *Aryabhatiya*, cited above.

[16] *Ganita*, 11. *Aryabhatiya*, cited above.

[17] C. K. Raju, "Approximation and proof in the Yuktibhasa derivation of Madhava's sine series", cited earlier.

attributed to Fermat in 1629; Roberval, another member of Mersenne's circle, also worked on it. Earlier Cavalieri, a student of Galileo, had stated this formula, without proof, in 1635, after waiting five years for Galileo to write on infinitesimals. John Wallis, who visited Pisa, verified the formula for a few values of k, and obtained his value of π using similar series expansions.

The curious thing is that though so many European mathematicians seem to have suddenly "discovered" this formula at about the same time, the formula had no natural epistemological basis in European mathematics, either of that time or for the next two centuries, for European mathematics was oriented towards "proof" rather than "calculation", and shared the Greek "horror of the infinite". Even today, despite the compelling changes of technology, due to widespread use of supercomputers, the situation has not entirely changed, and as in the time of Clavius, calculation continues to be regarded as "inferior" to "proof".

Though the European mathematicians were unable to prove the formula (1), or provide a rigorous rationale for it within their epistemology,[18] even the techniques by which they attempted to prove formula (1) suggests transmission. For example, Pascal tried to establish[19] the formula (1) using the so-called Pascal's triangle, for the binomial coefficients. The triangle appears as the *meru prastara*, in Pingala's Chandahsutra of (-3 century CE), and another 1200 years later in the work of his 10th century CE commentator Halayudha.[20] It was known to the Arabs and the Chinese.[21] Among Renaissance European mathematicians it is found in the arithmetic of Apian, and in the work of authors like Bombelli[22].

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[18] E..g. Cavalieri's statement is now termed a conjecture, while Wallis is said to have stated the formula without proof. Edwards, cited above, p 114; Boyer, cited above, p 417.

[19] E.g. Edwards, cited above, p 109-113.

[20] S. N. Sen, "Mathematics", in D. M. Bose, S. N. Sen, and B. V. Subbarayappa (eds), A Concise History of Science in India, Indian National Science Academy, Delhi, 1971, pp 156-157.

[21] Photographs of a 1303 Chinese depiction of Pascal's triangle have been provided by Joseph Needham, *The Shorter Science & Civlisation in China*, Vol 2, Cambridge University Press, 1981, p 55.

[22] Bombelli acknowledged the transmission of Indian mathematics to the West. From J. Fauvel and J. Gray, *The History of Mathematics*, Macmillan, 1987, we have (page 264) from the preface of Bombelli's *Algebra* " …a Greek work on this discipline has been discovered in the Library of our Lord in the Vatican, composed by a certain Diophantus of Alexandria, a Greek author, who lived at the time of Antoninus Pius. When it had been shown to me by Master Antonio Maria Pazzi, from Reggio, public lecturer in mathematics in Rome…..(we) set ourselves to translate it … in this work we have found that he cites Indian authors many times, and thus I have been made aware that this discipline belonged to the Indians before the Arabs."

(c) The Ahargana and the Julian day-number system

The use of Julian day numbers is another kind of evidence. These day numbers, used in scientific specification of dates, are named, somewhat ambiguously, after Julius Scaliger, the father of Joseph Scaliger. Joseph Scaliger was a well-known opponent of Christoph Clavius, and he, too, introduced his numbering system from 1582.

Now, from at least the time of Aryabhata, all dates in Indian astronomy are specified in this way, using day numbers. This eliminates any possible ambiguity due to calendrical differences; such ambiguities did exist because of the variety of calendars in use. These day numbers are specified as *Ahargana* or "heap of days". Understanding the first stanza of the *Aryabhatiya* requires us to know about this system; in fact, the day number system could have been transmitted by absolutely any Indian astronomical text.

The difference between *Ahargana* and Julian day numbers is only this: the *Ahargana* count starts from the beginning of the Kaliyuga, (17 Feb -3102 CE) whereas the Julian day-number count starts from 1 Jan -4713 CE (an astronomically convenient date, presumably related to the date of Biblical creation). Thus, the *Ahargana* differs from the Julian day number by exactly 588,465 which is the Julian day number for the start of the Kaliyuga. Of course, the system is simple enough and could have been invented by anyone at any time. The strange thing is that the system was allegedly invented in Europe at *exactly* the time, in 1582, when it could have been transmitted through a stated earlier desire to learn about Indian calendrical techniques. If our conjecture about transmission of the day-number system is true, it would seem that well before their conquest of Cochin, the Dutch had independent sources of information from India.

(d) Planetary models and elliptic orbits

There are many other key instances that should count as circumstantial evidence. For example, Nilkantha's planetary model, in the *Tantrasangraha*, is exactly the "Tychonic" model (Tycho was a contemporary of Clavius), except that it involves elliptical orbits. (It is now known that Tycho's student, Kepler, obtained his elliptical orbits by computing his "observations".[23]) We do not go into these for reasons of space, since we first need to give an exposition of all the relevant planetary theories.

We hope to find compelling evidence through a statistical analysis of various sine tables. This analysis is, at present, being carried out, so it is not included in this paper.

(2) Documentary evidence of the role of the Jesuits

In this section we document how this knowledge may have been transmitted from the Malabar coast by the Jesuit missionaries.

(a) The arrival of the Jesuits. The period after Vasco da Gama's arrival in Calicut in 1498 and the establishment, shortly thereafter, of a Portuguese colony with bases in Cochin, Cannanore and Goa, by Afonso de Albuquerque in 1510, laid the foundations for Catholic missionary work in the Malabar coast.

Among the various missions, the Jesuit one was the most important in respect of transmitting local knowledge to Europe. While there is a paucity of literature on this subject (mainly due to the, as yet, uncatalogued nature of a vast quantity of oriental manuscripts in Portugal), this is not the case with French missionary work.[24] That the French Jesuits were actively engaged in the acquisition of Indian astronomy is reported by Otto Spies.[25] Spies makes explicit reference to Calmette's study of local astronomy "A notable part of his activity turned Calmette to the astronomy and he speaks for a long time and in technical form in this and other letters."

The earlier Jesuits in the Malabar coast did the same and we offer substantial evidence to support this claim.

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[23] "Planet fakery exposed. Falsified data: Johannes Kepler" *The Times* (London) 25 January 1990, 31a, including large excerpts from the article by William J. Broad, "After 400 years, a challenge to Kepler: He fabricated his data, scholars say". *New York Times* 23 January 1990, C1, 6. The key article is William Donahue, "Kepler's fabricated figures: Covering up the mess in the *New Astronomy" Journal for the History of Astronomy*, **19** (1988) p 217-37.

[24] E.g. Gérard Colas, *Les manuscrits envoyé de l'Inde par les jésuites français entre 1729 et 1735*, Bibliothèque nationale de France, Paris.

[25] O. Spies, "Il P. Calmette e le sue Conoscenze Indologiche", *Studia Indologica*, Bonn, 1955, p 53-64.

(b) Jesuit mastery of vernacular languages and of Brahmin culture. It was Jesuit policy to aim to master vernacular languages such as Malaylam.[26] Prominent Jesuits who became fluent native speakers included De Nobili who spoke Sanskrit and Tamil (the language spoken in Trichur) and Diogo Gonsalves who spoke Malaylam. The attempt by Jesuits to learn the vernacular was so widespread that they frequently used Malaylam to sign their names in letters to the Society of Jesus headquarters in Rome.[27] The rationale for learning the vernacular languages was to aid their work in converting the local populace to Jesuit Catholicism by understanding their science, culture and customs and, of course, by facilitating communication. The former was important for the Jesuits and this included, at the very least, awareness of *jyotisa*--- de Nobili, for instance, in 1615, wrote[28] a strong polemic against the Vedanga Jyotisa, a work that had been discarded as obsolete by Varahamihira, a thousand years earlier. To formalise the policy of educating Jesuit workers in the local culture, 'local' subjects such as astrology or *jyotisa* were included in the curriculum of the Jesuit colleges in the Malabar coast[29]. The Jesuits' study of the vernacular languages was not merely intended to facilitate their work in conversions. It was also intended to enable work on transmitting this knowledge back to Europe. This is supported by the acquisition of translations of Malyalam and Sanskrit manuscripts:

"In Portuguese India, hardly seven years after the death of St. Francis Xavier the fathers obtained the translation of a great part of the 18 Puranas and sent it to Europe. A Brahmin spent eight years in translating the works of Veaso (Vyasa)……several Hindu books were got from Brahmin houses, and brought to the Library of the Jesuit college. These translations are now preserved in the Roman Archives of the Society of Jesus. (*Goa* **46**)"[30]

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[26] *Documenta Indica,* **XIV** p 425 and **XV** p 34*, and D. Ferroli, *The Jesuits in Malabar*, Bangalore, 1939.

[27] see, e.g., the letters contained in the manuscript collection *Goa* **13** at the Archivum Romanicum Societate Iesu in Rome.

[28] V. Cronin, *A Pearl to India – The Life of Roberto de Nobili*, Darton, Longman and Todd, 1966, p 178-180

[49] *Documenta Indica,* **III**, p 307.

[50] D. Ferroli, *The Jesuits in Malabar*, 1939, Vol 2, p 402

Further evidence of this knowledge acquisition is contained in the ARSI collections *Goa* **38**, **46** and **58**. The last being the work of father Diogo Gonsalves and contains detailed notes on the judicial system and on the sciences and mechanical arts of the Malabar region.

(c) The arrival of Matteo Ricci. Arithmetic, astronomy and timekeeping were particular areas of interest to the Jesuits as is shown by the many references in the *Documenta Indica*[31]. The arrival of Matteo Ricci in Goa in September 13, 1578 was significant in this respect. Ricci had previously studied at the Collegio Romano (as did all Jesuit fathers); in particular he studied mathematics under the renowned Christopher Clavius. Furthermore, he studied the *Cosmographia* and nautical science. This knowledge made Ricci a candidate for discovering the knowledge of the colonies and he had specific instructions to investigate the science of India. The Jesuit historian Henri Bernard states that Ricci

"…had resided in the cities of Goa and of Cochin for more than three years and a half (September 13, 1578-April 15, 1582): he had been requested to apply himself to the scientific study of this new and imperfectly know country, in order to document his illustrious contemporary, Father Maffei, the 'Titus Livius' of Portuguese explorations."[32]

Bernard reports that Ricci had begun his task prior to arriving in India by setting about a study of nautical science. It is also known that Ricci had enquiries about Indian calendrical science; in a letter to Maffei he states that he requires the assistance of an "intelligent Brahmin or an honest Moor" to help him understand the local ways of recording and measuring time (lit. *jyotisa*).

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[31] See, for example, *Documenta Indica*, **IV** p 293 and **VIII** p 458.

[32] Henri Bernard, *Matteo Ricci's Scientific Contribution to China*, Hyperion Press, Westport, Conn., 1973, p38. It is relevant to point out that it was Maffei (I. Petri Maffei, *History of the Indies*, in book 1, Venice 1589) who details the navigational help received by da Gama to cross the Arabian sea and arrive at Calicut.

"Com tudo não me parece que sera impossivel saberse, mas has de ser por via d`algum mouro honorado ou brahmane muito intelligente que saiba as cronicas dos tiempos, dos quais eu procurarei saber tudo."[33]

(d) Printing presses and translation work. The Jesuits established printing presses all over the Malabar region; in 1550 in Goa which used Roman types, in 1577 in Vaipicota using Tamil and Malyalam types, in 1602 Vaipicota using Syro-Chaldic, and in 1578 in Tuticorin with Tamil types. The aim of these presses was to publish the catechism so essential for missionary work; for example, St Francis Xavier's catechism was published in 1557 by the Goa press. The aim was also to translate the local science into Portuguese prior to transmission to Europe; for example, Garcia da Orta's *Colloquios dos simples e drogas he cousas mediçinas da India* published in Goa in 1563[34]. There were many other publications of this type but they remain obscure because, as Sarton points out

"A Portuguese book printed in Goa could not attract much attention outside the Portuguese world."[35]

(e) A possible source for Jesuit acquisition of Indian mathematics and astronomy. After the 1580 annexation of Portugal by Spain and subsequent loss of funding from Lisbon, the rationale for transmission acquired another dimension, that of profit[36] but how might the Jesuits have obtained key manuscripts of Indian astronomy such as the *Tantrasangraha* and the *Yuktibhasa*? Such manuscripts would require the Jesuits being in close contact with scholarly Brahmins; there is concrete evidence that they were in contact with such people. There is plenty of evidence of the Jesuits being in contacts with kings across the country. We establish that the Jesuits

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[33] Letter by Matteo Ricci to Petri Maffei on 1 Dec 1581. *Goa* **38** I, ff 129r--30v, corrected and reproduced in *Documenta Indica*, **XII**, 472-477 (p 474). Also reproduced in Tacchi Venturi, *Matteo Ricci S.I.*, *Le Lettre Dalla Cina 1580-1610*, vol 2, Macerata, 1613.
[34] T. J. S. Patterson, 'Science and Medicine in India', in Eds Pietro Corsi and Paul Weindling, *Information Sources In The History Of Science And Medicine*, Butterworths Scientific, 1983, p 437-456.
[35] D. Sarton, 1955, *The Appreciation of Ancient and Medieval Science During the Renaissance (1450-1600)*, University of Pennsylvania, 1955, p102
[36] D. Ferroli, *The Jesuits in Malabar*, 1939, volume 2, p 407.

had close relations with the kings of Cochin, and that the latter were knowledgeable about mathematics and astronomy in the tradition of Kerala.

The kings of Cochin came from the scholarly Kshatriya, Varma Tampuran family who were knowledgeable about the mathematical and astronomical works of medieval Kerala[37]. Rama Varma Tampuran who, in 1948 (together with A.R. Akhileswara Iyer),[38] had published an exposition in Malayalam on the *Yuktibhasa* was one of the princes of Cochin already stated; this exposition which has been the basis of most subsequent work on the *Yuktibhasa* used the *TantraSangrahaVyakhya* manuscript of the Desa Mangalatta Mana (a Namputiri household, now disbanded). This manuscript was in the keeping of Rama Varma Tampuran (who belonged to that household). Moreover, various authors, from Charles Whish in the 19th c. to Rajagopal and Rangachari have acknowledged that members of the royal household were very helpful in supplying these manuscripts in their possession.

This suggests that the former royal family in Cochin, which was in possession of a large number of MSS, had not only a scholarly tradition, but also a tradition of helping other scholars. Thus, the royal family could itself have been a possible source of knowledge for the Jesuits. Indeed the Jesuits working on the Malabar coast had close relations with the kings of Cochin[39]. Furthermore, around 1670, they were granted special privileges by King Rama Varma[40] who, despite his misgivings about the Jesuit work in conversion, permitted members of his household to be converted to

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[37] C. M. Whish, *On the Hindu Quadrature of the Circle….*, Transactions of the Royal Asiatic Society of Great Britain and Ireland, 3(3), 1835, pp 509-523. Whish states here (p 521) that the author of the astronomical work the *Sadratnamalah* is Sankara Varma, the younger brother of Raja of Cadattanada near Tellicherry and further states that the Raja is a very acute mathematician. Also C. N. Srinivasiengar, *The History of Ancient Indian Mathematics*, World Press, Calcutta, 1967. Srinivasiengar also states that Sankara Varma is the author of *Sadratnamalah* and is brother of the Uday Varma, the King of Kerala (p146) . He further refers (p 145) to the Malyalam *History of Sanskrit Literature in Kerala* which identifies the King of Cochin, Raja Varma, as being aware of the chronology of the *Karana-Paddhati*.

[38] *Yuktibhasa* Part 1, with notes (Ed) Ramavarma (Maru) Tampuran and A. R. Akhileswara Aiyar, Mangalodayam Ltd, Trichur, 1948 (in Malayalam). Most subsequent work has relied on this exposition. C. T. Ragagopal and M. S. Rangachari, On an Untapped Source of Medieval Keralese Mathematics, *Archive for the History of Exact Sciences*, **18**, 1978, 89-102. Rajagopal and Rangachari state that Rama Varma Tampuran supplied them with the manuscript material [Desa Mangalatta Mana MS of *TantraSangrahaVyakhya*] relating to Kerala mathematics. Also K. V. Sarma, *A History of the Kerala School of Hindu Astronomy*, Hoshiarpur Vishveshvaranand Institute, 1972. On page 12, K. V. Sarma points to the valuable notes added to the analysis of Kerala astronomy by Rama Varma Maru Tampuran in his 1948 exposition of the first part of the *Yuktibhasa.* His subsequent translation of the *Yuktibhasa* has utilised the same material (personal communication).

[39] see for example, *Documenta Indica*, **X**, pages 239, 834, 835, 838, and 845

Christianity[41]. The close relationship between the King of Cochin and the foreigners from Portugal was cemented by King Rama Varma's appointment of a Portuguese as his tax collector[42].

Given this close relationship with the Kings of Cochin, the Jesuit desire to know about local knowledge, and the royal family's contiguity to the works on Indian astronomy, it is quite possible that the Jesuits may have acquired the key manuscripts via the royal household.

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[40] *Documenta Indica*, **XV**, p 224
[41] *Documenta Indica*, vol XV, p 7*
[42] *Documenta Indica*, vol XV, p 667