# Buenaventura Suarez, S.J. (1679-1750) Part 1: Telescope maker, Jovian satellites observer

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During the first half of the $18^{th}$ century, Father Buenaventura Suarez performed a series of astronomical observations in the Jesuit Reductions of Paraguay. His observations were published in prestigious European journals such as the Philosophical Transactions of the Royal Society and the Acta of the Royal Scientific Society of Uppsala. Working in the antipodes of the Jesuit astronomical centers of Europe and Asia, Suarez was not cut off from their mainstream activities. Educated at Cordoba, present day Argentina, under the Jesuit scholarly tradition, he was familiar with the observations and astronomical knowledge of his time. In spite of being an untutored astronomer he was capable of constructing his own telescopes, perhaps the first telescopes ever built in the Americas. Our present work analyzes the happy local circumstances that allowed him to produce his own astronomical instruments in Paraguay. By examining factual evidence from fictitious tales we show that, contrary to the common belief, Suarez was not provided with English telescopes for his observations. In addition we examine the circumstances and context of his observations on Jupiter's satellites, and the accuracy of his measurements. We show how his observations reached the Royal Society of London. Our findings prove that the politics of the Royal Society facilitated him this communication and it was not through a rather complicated network that Suarez sent London his data as was previously published. By examining factual accomplishments from alleged deeds we try to breakdown the mythology associated to this extraordinary personage.

*Keywords:* Buenaventura Suarez; early telescopes; history of science; Jesuit astronomy.

Durante la primera mitad del siglo 18, el Padre Buenaventura Suarez realizó una serie de observaciones astronómicas en las Reducciones jesuitas del Paraguay. Sus observaciones fueron publicadas en prestigiosas revistas europeas tales como las Transacciones de la Real Sociedad y el Acta de la Real Sociedad Científica de Upsala. Trabajando en las antípodas de los centros astronómicos jesuitas en Europa y Asia, Suarez no estuvo aislado de sus actividades convencionales. Educado en Córdoba, en la actual Argentina, bajo la tradición académica jesuita, él estuvo al tanto de las observaciones y conocimiento astronómico de su época. A pesar de no haber sido entrenado como astrónomo, fue capaz de construir sus propios telescopios, tal vez los primeros telescopios construidos en las Américas. El presente trabajo analiza las circunstancias propicias locales que le permitieron fabricar sus instrumentos astronómicos en el Paraguay. Mediante un examen de evidencias reales entre falsedades mostramos que contrariamente a la creencia popular, Suarez no fue aprovisionado con telescopios Ingleses para sus observaciones. Además analizamos el contexto y las circunstancias de sus observaciones sobre los satélites de Júpiter así como la precisión de sus mediciones. Mostramos como llegaron sus observaciones a manos de la Real Sociedad de Londres. Nuestros estudios muestran la manera en la Real Sociedad facilitó que Suarez les enviara sus datos y mostramos que no fuea través de una compleja red, como se publicó previamente.Mediante un examen de sus logros reales sobre hechos imaginados, tratamos de romper la mitología asociada a este personaje.

*Descriptores:* Buenaventura Suarez; early telescopes; history of science; Jesuit astronomy.

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## 1. Introduction

The closing decades of the $17^{th}$ century and the early ones of the $18^{th}$ witnessed a great surge in the astronomical activities of the members of the Society of Jesus. Among them, Buenaventura Suarez Altamirano S.J. made astronomical work during the first half of the $18^{th}$ century at the Jesuit Missions of Paraguay otherwise known as the "*Reductions*" of Paraguay (from 1609 to 1767) [1]. In this paper we shall examine part of his work.

Most of what we know about Suarez's deeds and achievements is due to his biographer Guillermo Furlong Cardiff S.J. (1889-1974) who wrote a series of biographical articles and a long chapter in his book *Glorias Santafesinas* (from now on "Glorias") [2]. The latter work, in spite of its hagiographic tone gives a useful account of Suarez's life in the *Reductions* and permits a glimpse into his astronomical work [3]. However a very limited amount of information is available in English language. There are a couple of complimentary and imprecise notes on Suarez, published in scientific journals in English language [4], [5], as well as two extensive papers in English. The first paper written by the late Troche-Boggino is an inaccurate biographical narrative of Suarez life [6]. The second paper, by de Asúa, adequately deals in particular with the publication of Suarez's astronomical data by other authors in European journals but mistakenly speculates on how his data came to be known in Europe [7]. Our present work analyzes the circumstances and context of Father Suarez inquiries, the accuracy of his measurements, his motives and scope, with the purpose of establishing what was the reach of part of his lifework. In a following second article (Buenaventura Suarez Part 2) we shall analyze his only surviving book, entitled "*Lunario*". Here, we will limit ourselves to break down Suarez's factual acts from alleged episodes which are presently encountered in scientific and popular literature; this with the aim of ending the myths associated to this extraordinary personage.

It is not the scope of the present article to repeat what has already been said on Suarez personal life. We refer those interested readers in Suarez's personal details to Furlong's book "Glorias". Here is sufficient to state that Father Suarez was born in 1679, in Santa Fe de la Veracruz, then part of the Viceroyalty of Peru, now present day Argentina. He went to Jesuit school at the *Collegium Maximum* of Cordoba, Argentina, and was sent in the early years of the $18^{th}$ century to the *Reductions* of Paraguay, where he made his astronomical observations and spent most of the rest of his lifetime among the Guarani natives. He never traveled abroad and died in 1750, in one of the Jesuit *Reductions.*

For our purposes we have organized the present work into ten sections, opening the first section with this introduction. Then the second section will give a brief account of the Society of Jesus and its regulations. This will place our discussion in the possible educational background received by Suarez while attending the seminar. Afterwards, in the third section we will focus on the Jesuits astronomical knowledge that was shared among those members of the order, Suarez included, with a particular interest in this field of knowledge. Thereafter we continue in this same section describing the Jesuit observatories, thus showing that in a short time span some of the Jesuits became involved in global astronomical activities. We then proceed in the fourth section, to explain how Suarez might have made his astronomical instruments. Then in section five we establish that, contrary to the common belief, Suarez was not provided for his observations with English telescopes. Later, in section six, we will turn our attention to the importance and methods for assigning latitudes to geographical locations in the $17^{th}$ and $18^{th}$ centuries. These methods were directly related to astronomical observations such as Solar, Lunar and Jovian satellites eclipses. In this form we shall ascertain, in section seven, part of the motives and scope of Suarez work as he used his own astronomical records to calculate the longitude of his Mission town, San Cosme. In the eighth section we shall give our version on how the Suarez's astronomical observations reached the Royal Society of London. Our findings prove that the politics of the Royal Society facilitated the link between Suarez and the London Institution. First through the South Sea Company and later through the Society's members abroad and it was not through a different network that Suarez dispatched London his data as was previously published [8]. Suarez has been praised by many authors as an outstanding astronomer on the grounds of dogmatic reiteration without checking how accurate his observations were. Therefore in the ninth section we examine the exactitude of Suarez's Jovian satellites observations. Final comments are given in the last section.

## 2. The Society of Jesus

Early in the 16th century a reaction to medieval Roman Catholic doctrines and practices began to emerge in an attempt to reform the Church. This movement known as Protestantism quickly spread over central and northern Europe. The reactions of the ecclesiastical and political leaders at that time, led to a schism between traditional Catholics and those who founded new churches based on their own understanding of the Scriptures. By mid XVI century, Íñigo López de Loyola (1491- 1556) founded a Roman Catholic religious order and called it, *Societas Jesu*. The "Society", as is also known, was founded chiefly to strive for "*the defense and propagation of the faith by means of public preaching, lectures...*" [9]. Although the Society was not created with the avowed intention of opposing Protestantism the Jesuits naturally endeavored to counteract the spread of the splinter movement. They became the main instruments of the Counter-Reformation. Before long they realized that the struggle in defense of the Catholic faith claimed learned scholars as members of their Society. To a certain extent, as a consequence of these needs, Jesuits became involved in several scholarly activities: opening educational institutions, teaching in colleges and universities, participating in public debates, and gathering knowledge in their mission territories.

Loyola established a set of fundamental principles known as the Jesuit *Constitutions* [10], adopted in 1554. The *Constitutions* assumed much of its severe discipline from military models which created a tightly centralized organization and stressed total obedience to the Pope and their religious superiors. In addition to all this, the *Constitutions* endorsed an essential resolution that the Society systematically set up: the maintenance of regular internal correspondence so as to keep distant companions – at every stratum of the hierarchy and at all points of the globe- united and well-informed about each other's activities. The epistolary exchange functioned according to prescribed rules at regular intervals. This remarkable sort of primitive "World Wide Web" - which interconnected the Society's extensive provinces between them and to their headquarters in Rome- was an extraordinary source of knowledge on every conceivable branch of learning, by allowing the flow of mail, to and from far-off lands, and also the transfer of: printed editions, manuscripts, translations, cartographic maps, botanical samples and scientific instruments. Besides, as one would expect, intercultural exchanges among Jesuits were a natural consequence of been, the Society, a multicultural and polyglot organization.

Jesuits were so well aware of the importance of printed matter in the diffusion of ideas, that some members of the Society were relieved for a time from regular communitarian responsibilities to be assigned as *Scriptores*, that is, Jesuits devoted entirely to any such activities as producing devotional literature, render teaching manuals or authoring books [11]. Those assigned to the apostolate of *Scriptor*, more often than not, dwelled in Jesuit colleges. These were educational institutions and places of knowledge, centers of intellectual productivity and learned exchange, gathering scholars of all veins: theologians, historians, mathematicians, philosophers, astronomers, etc. Every college had its own library and often some establishments included an astronomical observatory and regularly a museum for curiosities such as: antiques, minerals, and specimens of flora and fauna. In their mission lands outside Europe and in the overseas territories of the Americas, colleges were frequently used as a "base of operations" for apostolic activities.

The *Collegio Romanum* founded in 1551, was the Society's finest educational institution. It played a fundamental role in the writing of a set of rules known as the *Ratio Studiorum* (whose definite version was published in 1599). [12] The *Ratio* outlined what had to be studied: logic, natural philosophy, astronomy, mathematics. Advanced courses could be arranged for talented students in particular fields. This educational system provided a reasoned, although Aristotelian, description of the world, encouraging future Jesuits to analyze the universe workings and understand its laws.

## 3. Jesuits and early observatories

The active involvement of Jesuits in teaching astronomy, their concern in participating in public cosmological debates, sometimes with a more or less inquisitive attitude about new ways of thinking, and the their vigorous activity of gathering knowledge in their overseas astronomical observatories, produced among them, renowned astronomers. Many Jesuit scholars are associated with important discoveries in the history of astronomy [13].

Among those scholars we find Christoph Scheiner (1575–1650) better known for his discovery of sun spots independently of Galileo. But what concerns us here is Scheiner's facet as optical instruments maker. In the late 1610s, Father Scheiner constructed a novel telescope, based on Kepler's book *Dioptrice*. [14] Kepler's design overcame the problem of the narrow field of view of Galilean telescopes by widening it. [15] So from the 1630s onwards the use of keplerian telescopes spread rapidly in Jesuit colleges. First, astronomical observations with small transportable telescopes were carried out, but soon formal sites were established in the Society's colleges. Instruments in these formal astronomical observatories were installed permanently and a Jesuit was appointed as director, in most cases a Mathematics professor.

Two of these earliest observatories were those established at the College of Avignon in 1632 and at Ingolstad about 1635. One of the astronomers at Ingolstad was Father Nicasius Grammatici S.J. also known as Grammaticus (ca.1684-1736). He and his mentor Father Joseph Falk S.J. (1680-1737) were the first in Germany to develop a method to calculate solar and lunar eclipses based on Isaac Newton's *Theory of the Moon's Motion* (1702). Grammaticus printed (anonymously) Newton's manuscript at Ingolstadt [16]. Essentially this book shows a geometrical method to calculate the Moon's longitude making use of epicycles but not using Newton's laws of motion or gravitation [17]. Consequently this book found readily acceptance among open-minded Jesuits who were afraid of encountering opposition amid intolerant colleagues. Grammaticus version of Newton's book was introduced into China by the missionaries and it came to be used in there for the purpose of eclipse prediction, and not as was the case in Europe, for the finding of longitude [18]. We shall come back to Grammaticus further ahead on in this paper, for the reason that he was correspondent to Buenaventura Suarez.

In Asian countries, a number of observatories were installed with great success as Chinese and Indian rulers had great interest in astronomy. Jesuit astronomers were welcome to their courts. Over a short time span the Society became involved in global astronomical activities [19]. Through their epistolary exchanges, college astronomers were able to participate at distance in the works of other scholarly institutions. From the observatories of Lyons after 1682, from Avignon since 1684 and from still other locations, Jesuits regularly sent memoranda of their astronomical observations to the "*Académie royale des sciences*" in Paris. They also sent regular contributions to the *Journal des sçavans* and corresponded with the Royal Society of London [20].

## 4. Suarez Astronomical Observatory and Instruments

Europe and Asia were not the only continents to have Society's observatories, in the early years of the $18^{th}$ century Buenaventura Suarez created a modest iterant observatory at the "Reductions", in the borderlands of what are now Paraguay, Argentina and Brazil. The precise location of Suarez's observatory varied as he was obliged by the circumstances to travel around the mission territories. Some of Suarez's observation places were registered in the Transactions of the Royal Society. The reported observation sites are the Reductions of: San Angel Custodio, Santa Maria Mayor, San Ignacio, San José, San Miguel Arcangel, San Cosme and Damian. All astronomical observations were performed during the period from circa 1706 to 1750, but most of his observations were done at the San Cosme Reduction [21].

To set up his iterant observatory, Buenaventura Suarez had to make his own astronomical instruments. In the introduction to his work *Lunario* he asserts the following:

*"I could have not performed such observations due to the lack of instruments (that are not brought to these provinces, since Mathematical sciences studies are not blooming here) if I have not fabricated with my own hands the necessary instruments for such observations"*. [22]

Then he registers the instruments he made:

*"...which are, pendulum clock with first minutes hand and seconds hand: Astronomical quadrant, to reduce, equalize and adjust the clock to the true sun's time,* [its dial] *each degree divided into minutes: Telescopes or spyglasses all of two convex lenses of several grads from eight to twenty and three feet"*. [23]

The quadrant was a very simple instrument that was used to measure the elevation (also called altitude) over the horizon of a celestial body. It can be used to find the latitude of a location. Suarez in particular used it to measure the solar hour angle in degrees from the solar noon. Since the earth is rotating, this angular displacement represents the "*true sun's time*" nowadays known as the observer's local time. Once Suarez could follow the advance of the local time he could calibrate his pendulum clock and check its accuracy.

The pendulum clock of the kind mentioned by Suarez, that is, with two hands for minutes and seconds is a complicated timekeeping machine. Unfortunately Suarez gives no further description of it but we can safely suppose that this clockwork might have had an anchor escapement which was of regular use in the late $17^{th}$ century. In addition we expect that there were certainly cogwheels and pinions to rotate synchronously the minute hand and second hand of the clock. All in all considered, Suarez required skilled craftsmanship to fabricate all these components in the Reductions.

We know that among the indigenous population of the Reductions there were some true skilled artisans. For example, of the many testimonies to that effect, we can cite one from Father Anton Sepp S.J.(1655–1733) a German missionary from the Tyrol residing at the Santo Tomas Reduction, who wrote,

" *. . . I came across a silver maker. He makes silver and gold chalices. . . he casted a bell that weighs 50 quintals. I cannot tell the difference between a sundial made by him and one imported from Europe. Not only does he repair old organs, he makes new ones"*. [24]

Turning now our attention to Suarez's telescopes, we can establish from his passing description previously cited above ("*. . . all of two convex lenses of several grads . . .*") that these were Keplerian type telescopes. In effect, these are plain optical devices consisting of two convex lenses of unequal focal lengths, which were, as we have already mentioned, first fabricated by the Jesuit astronomer Christoph Scheiner. So it is of no surprise that Suarez knew how to design this optical device since telescope making was knowledge held-in-common among Jesuits. The focal lengths ("*grads from eight to twenty and three feet*") of the lenses produced by Suarez went from 2.4 m to 6.9 m. Here, it is interesting to point out that the astronomers of the time characterized their telescopes by mentioning their focal length in contrast to today's astronomers citing their apertures. The modern reader may wonder how these long and slender telescopes were maneuvered [25]. The long focus objective implied long telescope "tubes". Usually "tubes" of this length themselves were not hollow light-tight cylinders but they were made up of long planks joined together to make an L-section; at one end was mounted the objective and at the other the eyepiece. The great length of the "tubes" was manipulated by hanging the tube from a tall building or mast by a series of riggings of pulleys and ropes. This type of telescope was euphemistically known as "aerial telescope". [26] We may suppose that Suarez used the same type of arrangement.

On the other hand, Suarez needed to produce good quality convex lenses. In the chronicle *Paraguay Natural* (1771) written by Suarez's contemporary colleague, Father José Sanchez Labrador S.J. (1717-1799) we can read,

*"When rock crystals are water clear or transparent and spotless, they can serve to make glass lenses. In fact, Father Buenaventura Suarez, missioner of the Guarani Indians and celebrated mathematician, superbly polished them and made some very clear"* [27]

Rock crystal is the transparent and colorless variety of quartz ($SiO_2$). This hard rock material can be 7.0 on the mohs hardness scale. Quartz does not self-grind well thus, still harder rocks are needed to grind and polish these materials. Emery is found to be useful for this purpose (a variety of corundum $Al_2O_2$, with mica and iron oxides), its hardness varies from 7.5 - 8.5 on the mohs scale. It is a known fact that emery was used by missions' natives - the Guarani Indians- to polish precious stones [28]. Rock crystal is widely distributed in the region of the Missions in Paraguay and Brazil and emery sands are to be found in Parana River. Europe knew of the rock crystal stone resources of the region. The Jesuit educated Voltaire (1694-1778), for example, in his novel *Candide* mentions goblets of rock-crystal belonging to the Paraguay Missions [29].

All these favorable circumstances together with the availability of talented native laborers allowed Father Suarez to fabricate his own astronomical equipment. Suarez mentions in his book Lunario that he made several telescopes of different focal lengths, namely of: 8, 10, 13, 14, 16, 18, 20 and 31 feet.

## 5. English Telescopes for Suarez?

The general belief of all Suarez's biographers is that he was awarded by the Jesuit Superiors two English made telescopes in 1745. We doubt this to be true.

According to Furlong (Suarez's biographer) and followers, by 1745 the Jesuit Order superiors acknowledged Suarez superb astronomical work by providing him with a pair of commercial telescopes made in England. Furlong also claims that Father Juan José Rico, Procurator of the Jesuit province of Paraguay, while spending a time in Europe (from 1739 to 1745) tried to buy the astronomical instruments that Suarez "*lacked*" (Furlong's words) [30]. Then Furlong states that on arrival of Father Rico to Madrid he made an effort to find the instruments that "*Suarez desired*" [31] (again Furlong's words), but his attempts were fruitless. Procurator Rico then wrote a letter to the Jesuit Procurator in Lisbon asking to find and buy the astronomical instruments for Suarez. The Procurator in Lisbon replied him in a letter dated in March $7^{th}$ 1745, stating that those "*English sundries*" are difficult to find in Lisbon, but asking Father Rico "*how long that missionary Father will be willing to wait?*" [32] It is important to remark that the name of that "*missionary Father*" is not mentioned in the Lisbon Procurator's letter to Rico. If this letter refers to Suarez, then the inquire on "*how long that missionary Father will be willing to wait?*" is -to say the least- very odd if not ridiculous, since to fulfill this request Father Rico in turn had to ask Suarez, who resided in Paraguay, if he was willing to wait and then await for Suarez reply. We sustain that the question is absurd since $18^{th}$ century sea mail from Europe to South America and back took several months.

Eventually just four days after sending the above mentioned letter to Father Rico, the Procurator in Lisbon purchased the astronomical instruments. The Lisbon Procurator dispatched to Rico a second letter on March $11^{th}$ giving the good news: "*Concerning the petition of the Father mathematician I have commissioned two telescopes, one of 16 feet of combined day and night-time usage, and the other of 8 feet; as the craftsmen ask for each palm of length a "escudo" for instruments of such size... so the cost for both came to 36 portugueses* [escudos]" and finally he adds "*... If he* [the Father mathematician] *can wait longer I will be willing to serve him punctually*." [33] We must emphasize again that the Procurator is acting as if the "Father mathematician" lived next door to Father Rico (*i.e.* in Madrid) and not in Paraguay.

Who was this unmentioned "*Father mathematician*"? Furlong wrongly assumes that he must be Suarez. Obviously he is mistaken and we affirm that the instruments were meant to another Jesuit Father, Joseph Quiroga y Mendez (1707-1784) who at that time was stationed in Spain and was waiting to be sent off to South America to accomplish the Royal and Supreme Council of Castile instructions of exploring and mapping the coasts of Patagonia.

Below we transcribe a text that discloses the identity of this missionary:

"*In the year 1745 the Procurator Father Juan Jose Rico stopping over Madrid carried the special assignment, to obtain from Philip V some help so the Jesuit missionaries could reach the Patagonia, with the purpose of founding new missions. The Procurator's plan agreed with the plan of the Council Minister Carvajal and even complemented it. It was long ago that the crown court thought about the means to fortify or defend the Patagonia's coasts against possible attacks by foreign nations. The Spanish authority immediately promised, a frigate and the necessary pilots, and the Jesuit Procurator, to provide Missioners for the Reductions that could be established. It seems that in Spanish authorities had previously chosen Father Quiroga for the assignment as he had already studied in the navy (it is said that he was a seaman), before his departure to Buenos Aires in 1745 he was provided with many instruments for possible observations. In effect, among the report on expenses that Father Rico made, there is an annotation that reads:*" [34]

"*Three hundred Portuguese coins to buy some mathematical instruments that, as a result of a Council ruling, I was requested to buy them in England and bring them via Lisbon for Father Joseph Quiroga*" [35](underlining is ours).

Furlong in his book *Glorias* acknowledges that it was the same Father Rico who brought Buenaventura Suarez the English telescopes meant for him to Buenos Aires in July 1745 [36] but in a different book, *Los Jesuitas y la Cultura Rioplatense*, Furlong now tells us that Quiroga arrived in 1745, bringing with him two telescopes of 8 and 16 feet, that is, of the same focal length that those presumably purchased for Suarez. If that is true, then 1745 witnessed the arrival to Buenos Aires of four telescopes, two for Suarez and two for Quiroga! We think that Furlong misled himself, perhaps thinking that Suarez was not capable of manufacturing high quality telescopes. In Furlong's *Glorias* (p 104) we can read: "*The merit of making these instruments, although being coarse and inaccurate, is singularly great and deserves applause of posterity*" (underlining is ours). Unfortunately all authors that write about Suarez's telescopes keep on mentioning the English telescopes, *magister dixit*.

Returning to the Father Quiroga's Royal assignment, we must mention that on board of the same ship that brought him to Argentina, also arrived Fathers Joseph Cardiel and Matias Strobel, also assigned to participate in the expedition to Patagonia [37]. Quiroga and Cardiel performed excellent cartographic work in South America determining the latitudes of geographical accidents of the Patagonian coasts [38]. The problem of determining exact geographical latitudes was of upmost importance during the $18^{th}$ century and it was closely linked, as we shall see in the next following section, to astronomical observations.

## 6. The latitude problem

Jesuits' activity in astronomy had a practical bonus for them, namely the option of calculating the geographical latitude of a location in their provinces. This was of great advantage if we consider that one of the primary aims of the Society was to expand their faith to new territories. Expansion was also the magic word for the two Iberian powers whose aim was to spread out their dominions to the newly occupied lands in the Americas. This enterprise also created for both of them -the Crown and the Society- the necessity for reliable geographical charts. Cartography in turn required the precise determination of latitudes and longitudes of geographical places. As we have already hinted in the previous section.

Finding out the latitude of a place was a simple task [39]. However finding longitudes required a more elaborated procedure. By the end of the 17th century most astronomers realized that there was a sole method to determine the latitude of a location with respect to another. It was based on measuring the time at which one recognizable astronomical event was recorded at two distant places. In few words, the record of the chosen event was timed locally against the local noon transit of the sun and the result was compared to published timetables for the same event, referred to an arbitrary prime meridian. [40]

As for longitude assessments there was a pair of astronomical events currently used at that time for that purpose, namely: lunar eclipses and the eclipses of Jupiter's satellites. These two events can be observed simultaneously from whatever part of the Earth they are visible. Before the invention of the telescope, moon's eclipses were used as astronomical events from which longitudes were derived, but they have the disadvantage of been occasional and in addition the entrance of the moon into the Earth's shadow can't be very accurately timed. The second alternative was suggested by Galileo soon after his discovery of the Jovian satellites in 1609. Galileo‘s idea was that these satellites could be regarded as a universal clock, visible - under certain circumstances – everywhere. Jupiter's satellites immersions or emersions, duly tabulated against a prime meridian‘s time, could be timed locally against the local noon transit of the Sun. The difference between the locally recorded time and the tabulated one, gives the latitude difference between both locations. In practice the observer was meant to view a satellite as it enter or left the shadow of the planet. Usually a whole series of such observations were performed to improve the exactitude of the results. This was the prevailing method for longitude allocations in *terra firma* well into the eighteen century. A minor drawback of this method is the fact that it was never possible to view the satellites during daily hours, when the planet was either absent from the sky or overshadowed by the sun‘s light.

A third method suggested in 1644 by Michel Florent van Langren (ca.1600 -1675) intended to use the illumination or darkening of lunar craters that could be observed from all points of the Earth. He based his procedure on the fact that the sun, from the new to the full moon, progressively illuminates the different lunar formations from east to west (in the northern hemisphere), the same formations disappearing in the course of the last lunar phases. During his lifetime the method was never put into practice. However the Spanish crown interpreted Van Langren's idea as to utilize the phases of the moon instead of its eclipses or darkening of the lunar mountains, to find the location's longitude [41].

In any case the Society, thanks to its astronomical capacity, was deeply involved in the cartographic effort by performing the pertinent astronomical observations which played a fundamental role in the mapping of new lands.

## 7. Suarez observations of Jovian Satellites

Before going into details we shall mention that Suarez's records on the periodicity of Jovian satellites were published in one of several ephemerides appearing in Europe since the middle of the $17^{th}$ and all along the $18^{th}$ centuries. The reasons for the frequent appearance of ephemerides were the enduring need for reliable maps and the practicality of Galileo's method. This produced in turn a constant improvement of detailed astronomical records of Jovian satellite eclipses. The earliest table listings were those of Giovanni Battista Hodierna (1597-1660) the *Menologiae Iovis compendium seu ephemerides Medicaeorum* published in 1656 and the *Ephemerides Bononiensis Mediceorum syderum* of Giovanni Domenico Cassini (1625-1712). The latter table led in the early 1670's to the determination of the speed of light by Ole Rømer [42]. Other astronomers produced their own tables among them Edmund Halley that in 1749, based on the observations of James Bradley (16931762). James Bradley determined the presence of several small periodic inequalities in the motions of the Jovian satellites, now known thanks to Lagrange to be due to the slight eccentricities of the satellite orbits and mutual gravitational interactions between the satellites [43] But what concern us here are those published by Pehr Wilhelm Wargentin (1717-1783) given that Suarez's data appeared published in one of his tables.

In 1741 Anders Celsius (1701-1744), then the astronomy professor at Uppsala University, encouraged his young student Wargentin to investigate the periods of the Jovian satellites. Wargentin took a long series of careful timings of the eclipses of the satellites, comparing them with older observations and established the synodic periods of them. In 1745, Wargentin published his own results in, "Tabulae pro calculandis eclipsibus satellitum Jovis" [44]. In 1748 Wargentin issued extensive records from 1668-1742 now including worldwide observations [45]. In this work he compared the period of the first Jovian satellite with data obtained across different parts of the world [46]. Among them we find Suarez's observations.

In the introduction to his book Lunario, Suarez comments,

*"…the immersions and emergences of the four Satellites of Jupiter, that I observed for a period of thirteen years in the Town of San Cosme, and came to one hundred and seven* [47]*…I send them to P. Nicasio Grammattici of the society of Jesus…"* [48]

We have already mentioned in section 3, that Suarez Jesuit correspondent in Europe was Grammaticus (Grammattici). It was from him that Suarez learned how to predict eclipses since the European astronomer was well acquainted on how to perform such calculations, (see section 3) and it was also trough him that Suarez observations of the Jovian Satellites were known and published in Sweden by Wargertin. Suarez's results came to Wargentin indirectly thru Celsius who in one of his travels in Europe came across them while visiting Grammaticus [49]. It is interesting to observe that Wargentin, in spite of having vast information on the periods of Jupiter's satellites, did not add or improve any analytic theory, to explain the small periodic inequalities found by Bradley, but he apparently obtained good results on a purely statistical basis. [50]

On the other hand, using his own records on the Jovian satellites Suarez calculated the longitude of his Mission town, San Cosme. He adjusted and compared his own data to those records of Koegler (in Pekin), De la Isle (in Peterburg) and Grammaticus (Madrid and Amberga present day Baviera) dispatched to him by the latter. In addition he used records from observations made at Lima, Peru, and transmitted to him independently by Pedro Peralta y Barnuevo (1663-1743). In Suarez's words,

*"…and I came to the knowledge of the true longitude of San Cosme's Meridan , that is 321 degrees , and 45, minutes*

*numbered from the Ferro island in the Canaries.*" [51]

With the knowledge of San Cosme's latitude, Suarez established the latitudes of neighbor towns within the Reductions. These were in turn used by Father Jose Quiroga y Mendez S. J. (1707-1784) to make a map of the region [52].

## 8. All Roads leading to the Royal Society?

We now wish to recall that Suarez's astronomical measurements appeared not only reproduced in Wargentin's publication but also they were published in London. Suarez was able to send London some of his astronomical observations through the intermediacy of a South Sea Company employee. In 1711 the British Crown granted a trade monopoly to the mentioned Company to perform mercantile activities in Spain's South American Colonies. For this reason this company established a net of Factors around Brazil and the Spanish colonies. At the same time, the Royal Society was trying to make links with educated residents in South America [53]. For this purpose the Royal Society used the good offices of the Company's Factors. The 1730/31 Journal Book of the Royal Society mentions that a "*Mr. Pym* - who was one of these Company's Factors - *sent to London observations on Jupiter's satellites* (1720-26) *made by Father Suarez*" [54].

Once established the communication with the Royal Society the delivery route changed and later on other Suarez's observations were sent to the Royal Society through Dr. Matthew Sarayva a Fellow of the Royal Society (FRS 1743) of Portuguese roots stationed at Rio de Janeiro, in Brazil. The observations were presented to the Royal Society by Dr. Jacob Castro Sarmento M.D., another Portuguese living in London and Fellow of the Royal Society [55].

This comunication route was not exclusively used by Suarez, as Dr. Sarayva also sent a historical account of Paraguay written in 1744 by Father Pedro Luzano (sic) a Jesuit missionary at Cordoba, Argentina [56]

On April 10, 1746 Dr. Jacob de Castro Sarmento presented the Royal Society with a Spanish account of Paraguay and was asked to digest its contents and report them at a later meeting [57]. The following year (14 May 1747), Dr. Castro Sarmento read observations made between April 12and May 17, 1744 on a comet appearing at the town of San Ignacio in Paraguay. The observations had been made by father Suarez and sent to the Society by Dr. Matthew Sarayva of Rio de Janeiro [58]. Father Buenaventura sent further astronomical observations from Paraguay made in 1746: of a Comet seen near the end of 1748, of two lunar eclipses, and other astronomical data, all of which were referred to James Bradley for further study [59].

Suarez's obituary mentions that he corresponded with individuals from: Lima, Ingolstadt, Brazil and London (*Glorias* p 114). In effect, we have already mentioned that Suarez exchanged directly letters with Grammaticus at Ingolstadt, Pedro Peralta y Barnuevo at Lima and Sarayva in Rio de Janeiro, Brazil, so Suarez probably kept up straight correspondence with the London-based Castro Sarmento, given that a cooperation was established between both, as the first made a translation from Portuguese into Spanish of a Castro Sarmento's book on the theory of tides based on Newton's gravitation law [60] while the second presented Suarez's observations at the Royal Society. We shall come back to this point after analyzing Suarez book, entitled Lunario, in a following second article (Buenaventura Suarez Part 2).

Before closing the present section we must mention that in a recent paper on Suarez it has been suggested that Suarez's astronomical data was sent to Europe through the mediations of scholars at the Jesuit College of St. Anthony in Portugal, just because some of these scholars happened to have published some works in the Philosophical Transactions [61].

## 9. Appraising Suarez Jovian observations

Suarez has been praised by many authors as an outstanding astronomer on the grounds of dogmatic reiteration without checking how accurate his observations were. Perhaps the simplest way to assess the accuracy of the Jovian satellite events measured by Suarez would be to compare them with the times predicted from modern algorithms, such as the one used for the Lieske's almanac. [62], [63]

In the 1980's J.H. Lieske of the Jet Propulsion Laboratory, Caltech, gathered a substantial collection of Jupiter satellite eclipse observations for the purpose of checking and fine-tuning the long-term behavior of his satellite ephemerides that now form the basis of the satellite eclipse predictions in his almanac. His collection contains 16,802 observations, of which more than 7,000 are before 1800, culled from 418 different sources and measured from 432 different sites. Each one of the actually observed times of the events contained in this compilation are compared to predicted times of the corresponding eclipse, in this way an error is assigned to each observation. Fortunately the compilation contains 102 measurements on Jovian satellites obtained by Suarez each with its respective error.

Table I shows a compilation of Suarez's measurements that we have gathered from Lieske's work. The first field labeled # refers to Lieske's own classification number of the event. The next three fields show the year, month and day of the event in the Universal Time system were the day begins at midnight. For each set of events their headings indicate the standard deviation of the event in seconds labeled $\sigma$.The last two fields abbreviated "Pub." and "Loc." give the publication source and the observation location respectively. We have used the same notation as in Lieske's tables. The sources are labeled as follows AY = Sampson R (Delambre) Mem. R. Astrom. Soc. 59:26 (1910); CR = Sarmento J de C Philos. Trans. Abridge. 10(T):121 (1756); CY = Paris Obs. Manuscripts A 51 –A 58 "Delisle Manuscripts. The locations are labeled as follows: RA = San Cosme, Paraguay; UW = San Ignacio, Paraguay; WM = San Miguel, Argentina; XK = San Ignacio, Argentina.

On examination of the graphs contained in Lieske's ephemerides, it is interesting to note that most pre-1800 observations of Jupiter I (Io) fall within a 180-second error band (that is errors ranging between -90 and +90 seconds). That means that Suarez's observed times were remarkably accurate (within 50 seconds). The conventional observations for Jupiter II (Europa), reported in the mentioned ephemerides fall within a slightly smaller error band (about 150 seconds) and there is a very noticeable increase of observations of this satellite during the last quarter of the $18^{th}$ century. Lieske gives no explanation for this but it may have been caused by the fact that eclipses of Europa take place at a greater distance from Jupiter's disk than those of Io. The influence of Jupiter's glare is then somehow reduced, which may perhaps explain the slight decrease in error. With respect of Suarez's measurements on this satellite, his error again stands well within the normal inaccuracies of the leading astronomers of the epoch. It is noticeable that $18^{th}$ century observations of the two outer Galilean satellites are far less in number than those of the inner pair and their error bars are substantially larger. This fact is also reflected in Suarez's measurements. This error increase might be due to the method of recording the time of the event. Observers time the "last speck" of light for eclipse disappearances and the "first speck" for reappearances. The unclear edge of the penumbra of Jupiter's shadow increases with the distance and limits the accuracy of the timings. But to conclude, we can affirm that Suarez's measurements were remarkable.

TABLE I. Jovian Satellites ' eclipses (see text for explanation)

| Disappearance of Jupiter I ($\sigma$ = 50 sec) | | | | | |
|---|---|---|---|---|---|
| # | Year | M | Day | Pub | Loc |
| 2282 | 1722 | 5 | 1.99391 | CY | RA |
| 3171 | 1729 | 11 | 4.32808 | CR | UW |
| 3188 | 1729 | 12 | 22.11103 | CR | UW |
| 3197 | 1730 | 1 | 7.03845 | CR | UW |
| 3202 | 1730 | 1 | 14.11853 | CR | UW |

| Reappearance of Jupiter I ($\sigma$ = 50 sec) | | | | | |
|---|---|---|---|---|---|
| # | Year | M | Day | Pub | Loc |
| 2973 | 1728 | 1 | 31.95527 | CY | WM |
| 2976 | 1728 | 2 | 8.03522 | CY | WM |
| 3091 | 1729 | 1 | 17.01065 | CR | UW |
| 3122 | 1729 | 2 | 19.02246 | CR | UW |
| 3129 | 1729 | 3 | 6.95249 | CR | UW |
| 3141 | 1729 | 3 | 14.03226 | CR | UW |
| 3219 | 1730 | 2 | 7.99238 | CR | UW |
| 3240 | 1730 | 3 | 10.08114 | CR | UW |
| 3244 | 1730 | 3 | 17.16100 | CR | UW |
| 3248 | 1730 | 3 | 26.01079 | CR | UW |
| 3255 | 1730 | 4 | 2.09064 | CR | UW |
| 3264 | 1730 | 4 | 18.02016 | CR | UW |
| 3269 | 1730 | 5 | 3.94881 | CR | UW |
| 3273 | 1730 | 5 | 11.02834 | CR | UW |
| 3348 | 1731 | 3 | 22.04926 | CY | XK |
| 3355 | 1731 | 3 | 29.12970 | CY | XK |
| 3366 | 1731 | 4 | 6.97936 | CY | XK |
| 3459 | 1732 | 4 | 17.94386 | CY | XK |
| 3461 | 1732 | 4 | 25.02262 | CY | XK |
| 3462 | 1732 | 5 | 2.10326 | CY | XK |
| 3473 | 1732 | 5 | 18.03271 | CY | XK |
| 3482 | 1732 | 6 | 2.96189 | CY | XK |
| 3486 | 1732 | 6 | 10.04141 | CY | XK |
| 3491 | 1732 | 6 | 18.89231 | CY | XK |
| 3494 | 1732 | 7 | 3.05199 | CY | XK |
| 3496 | 1732 | 7 | 11.90057 | CY | XK |
| 3499 | 1732 | 7 | 18.98037 | CY | XK |
| 3555 | 1733 | 7 | 18.98514 | CY | RA |

| Disappearance of Jupiter II ($\sigma$ =50 sec) | | | | | |
|---|---|---|---|---|---|
| # | Year | M | Day | Pub | Loc |
| 2200 | 1720 | 2 | 28.09119 | AY | RA |
| 2205 | 1720 | 3 | 13.30408 | AY | RA |
| 2242 | 1721 | 2 | 3.27098 | AY | RA |
| 2243 | 1721 | 2 | 10.37839 | AY | RA |
| 2246 | 1721 | 3 | 7.25274 | AY | RA |
| 2247 | 1721 | 3 | 25.02164 | AY | RA |
| 2248 | 1721 | 4 | 1.12840 | AY | RA |
| 2274 | 1722 | 3 | 26.06838 | AY | RA |
| 2276 | 1722 | 4 | 2.17594 | AY | RA |
| 2281 | 1722 | 4 | 27.05364 | AY | RA |

| Reappearance of Jupiter II ($\sigma$ = 50 sec) | | | | | |
|---|---|---|---|---|---|
| # | Year | M | Day | Pub | Loc |
| 2207 | 1720 | 3 | 24.06999 | AY | RA |
| 2210 | 1720 | 4 | 7.28303 | AY | RA |
| 2215 | 1720 | 5 | 2.15733 | AY | RA |
| 2224 | 1720 | 5 | 27.03340 | AY | RA |
| 2229 | 1720 | 6 | 3.14029 | AY | RA |
| 2233 | 1720 | 6 | 20.90980 | AY | RA |
| 2234 | 1720 | 6 | 28.01706 | AY | RA |
| 2240 | 1720 | 7 | 30.00315 | AY | RA |
| 2253 | 1721 | 5 | 3.20791 | AY | RA |
| 2257 | 1721 | 6 | 4.18980 | AY | RA |
| 2261 | 1721 | 6 | 29.06505 | AY | RA |
| 2264 | 1721 | 7 | 23.94096 | AY | RA |
| 2265 | 1721 | 7 | 31.04858 | AY | RA |
| 2268 | 1721 | 8 | 24.92550 | AY | RA |
| 2293 | 1722 | 6 | 15.91061 | AY | RA |
| 2305 | 1722 | 7 | 17.89583 | AY | RA |
| 2309 | 1722 | 8 | 1.11049 | AY | RA |
| 2316 | 1722 | 8 | 25.98797 | AY | RA |
| 2371 | 1723 | 7 | 26.07506 | AY | RA |
| 2379 | 1723 | 8 | 12.84444 | CY | RA |
| 2388 | 1723 | 8 | 19.95412 | AY | RA |
| 2394 | 1723 | 8 | 27.06244 | AY | RA |
| 2407 | 1723 | 9 | 20.94154 | AY | RA |
| 2416 | 1723 | 9 | 28.04964 | AY | RA |
| 3258 | 1730 | 4 | 8.93638 | CR | UW |

| Disappearance of Jupiter III ( $\sigma$ =105 sec) | | | | | |
|---|---|---|---|---|---|
| # | Year | M | Day | Pub | Loc |
| 2204 | 1720 | 3 | 13.11119 | CY | XK |
| 2225 | 1720 | 5 | 30.93789 | CY | XK |
| 2231 | 1720 | 6 | 7.10339 | CY | XK |
| 2237 | 1720 | 7 | 12.93566 | CY | RA |
| 2244 | 1721 | 2 | 27.22384 | CY | XK |
| 2245 | 1721 | 3 | 6.39202 | CY | RA |
| 2251 | 1721 | 4 | 11.21729 | CY | RA |
| 2259 | 1721 | 6 | 19.04686 | CY | RA |
| 2306 | 1722 | 7 | 20.97959 | CY | XK |
| 2414 | 1723 | 9 | 23.92795 | CY | XK |
| 2428 | 1723 | 11 | 5.92963 | CY | RA |
| 2582 | 1725 | 8 | 19.11480 | CY | XK |
| 2634 | 1725 | 11 | 5.96366 | CY | XK |
| 3484 | 1732 | 6 | 9.92883 | CY | XK |

| Reappearance of Jupiter III ($\sigma$ = 105 sec ) | | | | | |
|---|---|---|---|---|---|
| # | Year | M | Day | Pub | Loc |
| 2226 | 1720 | 5 | 31.05715 | CY | RA |
| 2254 | 1721 | 5 | 9.97330 | CY | RA |
| 2255 | 1721 | 5 | 17.13865 | CY | RA |
| 2262 | 1721 | 6 | 29.13447 | CY | RA |
| 2266 | 1721 | 8 | 3.96326 | CY | RA |
| 2307 | 1722 | 7 | 21.07465 | CY | RA |
| 2378 | 1723 | 8 | 12.05799 | CY | RA |
| 2415 | 1723 | 9 | 24.06204 | CY | RA |
| 2429 | 1723 | 11 | 6.06878 | CY | RA |
| 2635 | 1725 | 11 | 6.10204 | CY | RA |
| 3265 | 1730 | 4 | 21.02461 | CR | UW |
| 3487 | 1732 | 6 | 10.04179 | CY | RA |

| Disappearance of Jupiter IV ($\sigma$ =150 sec) | | | | | |
|---|---|---|---|---|---|
| # | Year | M | Day | Pub | Loc |
| 3249 | 1730 | 3 | 27.96627 | CR | UW |

| Reappearance of Jupiter IV ( $\sigma$= 150 sec) | | | | | |
|---|---|---|---|---|---|
| # | Year | M | Day | Pub | Loc |
| 3241 | 1730 | 3 | 11.05587 | CR | UW |

## 10. Final Comments

Looking back into the life and deeds of Buenventura Suarez, we have proven that with the use of his own made telescopes he was a very competent astronomer, and thus it follows that he was also a good telescope maker, perhaps the very first to make a telescope in the Americas. Regrettably we have found that a great deal of what has been said on his life has been written in a hagiographical tone, taking for granted what his biographers have written of him, without making any questioning, perhaps on the grounds of *magister dixit*. Suarez was indeed an extraordinary man so there is no need to fantasize on him. Suarez died at the brink of the Society of Jesus expulsion from the Spanish American Colonies (1767). But certainly his latitude determinations served in part to the two Iberian powers to trace maps. Ironically, these maps in turn served in negotiations between Spaniards and Portuguese to share the formerly Jesuit occupied territories after their expulsion. Today there are no remains left of Suarez's telescopes, instruments, or his observatory, only his book *Lunario* survives and the ruins of the Jesuit *Reductions*. He was a lone star in a forthcoming dark firmament.

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1. "Reduction" is the transliteration of the Spanish term *reducción*, itself deriving from the Latin verb *reducere*, meaning "to lead back or together". In that sense the term "Reduction" would mean a community of originally scattered natives brought together in a settlement.
2. Guillermo Furlong Cardiff S.J. Buenaventura Suarez in "*Glorias Santafesinas: Buenaventura Suárez, Francisco Javier Iturri, Cristóbal Altamirano*" Estudios Bibliográficos (Buenos Aires Editorial Surgo), pages 79-104. From now on we will refer to it as "*Glorias*".
3. As an example of "*Glorias*" hagiographic tone, the first page of Suarez's biography starts with a quote of Juán María Gutiérrez, Rector of the University of Buenos Aires from 1861-1874 . . . se colocará a Suárez al lado de Franklyn [sic]" that is, "*. . . Suarez will be placed alongside Franklin* ".
4. Patricio A.A. Laura "*Suárez a Father of South American Astronomy*" Physics Today Vol. 57 p 18, (2004).
5. Blas Servín "*Father Buenaventura Suarez S.J. Pioneer Astronomer from South America: his work*" In VIII Reunion Regional Latino Americana de Astronomía Union Astronómica Internacional, Montevideo, Uruguay, Nov. 27-Dec. 1. *Rev. Mex. A. A. (SC)* Vol. 4, 1995, p. 152
6. Troche Boggino A. E. "*Buenaventura Suárez SJ: the pioneer astronomer of Paraguay*" Journal of Astronomical History and Heritage (ISSN 1440-2807), Vol. 3, No. 2, p. 159-164 (2000).
7. Miguel de Asúa "*The publication of the astronomical observations of Buenaventura Suárez SJ (1679-1750) in European scientific Journals* " *Journal of Astronomical History and Heritage* (ISSN 1440-2807), Vol. 7, No. 2, p. 81 - 84 (2004).
8. Miguel de Asúa *Ibid.*
9. Antonio M. De Aldama S.J. "*The formula of the Institute*" The Institute of Jesuit Sources St Louis Missouri (1989) ISBN: 978-091242255-6.
10. Loyola Ignatius "*The constitutions of the Society of Jesus*" George E. Ganss S.J. (translator) The Institute of Jesuit Sources St. Louis Missouri (1970) ASIN: B000NZ10FC.
11. The Jesuit *Constitutions* requested that "*one who has talent to write books useful for the common good*" may be allowed to do so.
12. The Ratio Studiorum: The official Plan for Jesuit Education. "*Ratio atque Institutio Studiorum Societatis Iesu"*. Claude Pavur S.J., translator The Institute of Jesuit Sources St. Louis Missouri ISBN: 978-1-880810-59-X.
13. Some of the most outstanding among them were: Johann Schall von Bell (1591-1666), Mario Bettini (1582-1657), Christoph Clavius ( 1537-1612), Honoré Fabri (1607-1688), Athanasius Kircher (1602-1680), Matteo Ricci (1552-1610), Christoph Scheiner (1575-1650), Gaspar Schott (1608-1666) and Grogorius a St. Vicento (1584-1667).
14. In 1611 Kepler published a book entitled *Dioptrice*. This work was in essence a handbook on optical instruments. Kepler's booklet proposed a new kind of telescope, one that would overcome the problem of the Galilean telescope. (See theorem no 86 of Dioptrice).
15. In a Galilean telescope the field of view is limited by the diameter of the objective and the greater the magnification, the smaller the field of view gets. On the other side, in Kepler's design the field is independent of the objective's diameter. A Galilean telescope is composed of a convex objective lens of relatively long focal length and a steeply curved concave eyepiece lens placed just inside the focus of the objective. Kepler's

design is composed of two convex lenses of unequal focal distances. The objective has a longer focal length than the eyepiece and the telescope‘s magnification is just the ratio of the two.

16. Charles E O'Neill and Joaquín M$^a$ Domínguez "*Diccionario histórico de la Compañia de Jesus"* Tomo II Universidad Pontificia de Comillas, Madrid (2001) ISBN 84- 8468- -038-X (t.II)
17. See N Kollerstrom "*Newton's Forgotten Lunar Theory, His Contribution to the Quest for Longitude: Includes Newton's Theory of the Moon's Motion*" Green Lion Press (2000) ISBN: 188800908X
18. N Kollerstrom "*How Newton Inspired China's calendar*" *Astronomy & Geophysics* vol. 41, 1ssue 5 p.21 (2000).
19. Udías, Agustín (2003). "*Searching the Heavens and the Earth: The History of Jesuit Observatories"*. Astrophysics and Space Science Library, Springer Berlin. ISBN 140201189X.
20. C. Reilly," *A catalogue of Jesuitica in the* '*Philosophical Transactions of the Royal Society of London*', *1665-1715*," Archivum Historicum Societatis Jesu (1958), **27**, 339-362.
21. Observations are reported in the following locations: San Ignacio (November 1706, 1729, 1730), San José(December 1713) , San Miguel Arcángel (Feb 1728), San Cosme [and Damian](1717), Colegio Fluentino (unaided observation 1700 vulgo Corrientes). In Castro Sarmento, J. de, 1748. Observationes astronomicae variae factae in Paraquaria, regione Americae australis, ab anno 1706 [1700] ad annum 1730. *Philosophical Transactions of the Royal Society*, 45: 667-674. And in [Castro Sarmento, J. de], 1749-1750. Observationes aliquae astronomicae a Reverendo P.P. Suarez e S.J. in Paraquaria habitae, et per D. Suarez M.D. [sic] cum Soc. Regali Communicatae. *Philosophical Transactions of the Royal Society*, 46: 8-10.
22. *"No pudiera haver [sic] hecho tales observaciones por falta de instrumentos (que no se traen de Europa a estas provincias, por no florecer en ellas el estudio de las ciencias Mathematicas) a no haver [sic] fabricado por mis manos los instrumentos necesarios para dichas observaciones,..*" Suarez B. Introducción "Lunario de un Siglo" Editor F. da Silva, Lisbon 1748.
23. *"... quales son, Relox de péndulo con los índices de minutos primeros y segundos: Quadrante astronómico, para reducir, igualar y ajustar el Relox a la hora verdadera del sol , dividido cada grado de minuto en minuto: Telescopios, o anteojos de larga vista de* [sic] *todos* [de] *dos vidrios convexos de varias graduaciones desde ocho hasta veinte y tres pies"*. Suarez B. ibid Introducción.
24. An Account of a Voyage from Spain to Paraquaria;/Performed by the Reverend Fathers/ Anthony Sepp and Anthony Behme;/Both German Jesuits/. . . / Taken from the letters of the said Anthony Sepp, and publish'd by his own brother Gabriel Sepp. /Translated from the high Dutch original, printed at Nurenberg, (1697).
25. Since these instruments have no field lenses to their eyepiece their field of view is very limited. For aiming purposes this limitation required very stable arrangements.
26. Fred Watson " *Stargazer: the life and times of the Telescope*", p 101. Da Capo Press (2004), Cambridge Mass.
27. "Cuando los cristales de roca son de buena agua o claros, y sin manchas, pueden servir para hacer lentes de anteojos. Efectivamente, el padre Buenaventura Suárez, misionero de los indios guaraníes y célebre matemático, los labró muy buenos y hizo algunos anteojos muy claros". Sanchez Labrador, El Paraguay natural (manuscript) vol. 1 page 174, cited in "Glorias", Furlong
28. The Guarani natives had terms for emory and crystal rock. We can read in Sanchez Labrador, El Paraguay natural (manuscript) vol. 1, cited in "José Sanchez Labrador (1717-1798) y la geología del Paraguay natural" Eduardo G. Ottone Correlación Geológica Vol 24 pp 43-54(2008) ISNN 1514-4186 ISNN online 1666-9479.

    In parenthesis we give the paragraph number "*The emory Stone is very hard, known in the Misssions as ytaratá* (550) *used to cut precious stones* (554) *and the amoladera or afilar stone , compact, known as itaayambe* (567) *o itaquí when it is not so compact* (568) *The rock crystal known by the guaranis as itaberá, is very abundant in the missions* (711) *is used in the manufacture of lenses* (742)" "La piedra esmeril piedra muy dura conocida en las misiones como ytaratá "(550)"... usada para labrar piedras preciosas"(554) "... y la piedra amoladera o de afilar , una arenisca fina, compacta, conocida como itaayambe..." (567) o "... itaquí cuando no tan compacta... "(568). "El cristal de roca, conocido como itaberá por los guaranís, es muy abundante en las misiones..." (711) "... usado en la confección de lentes" (742).
29. Voltaire. *Candide Ou L' optimisme, Ch. XIV,– Comment Candide et Cacambo Furent Reçus Chez Les Jésuites du Paraguay.– "Le commandant fit retirer les esclaves nérés et les Paraguains qui servaient à boire dans des gobelets de cristal de roche.*" Art et Poésie Editions 2010. The Commandant sent away the negro slaves and the Paraguayans, who served them with liquors in goblets of rock-crystal.
30. It was in January 1739 that Fathers Procurators Diego Garvia and Jose Rico departed from Buenos Aires carrying with them the manuscripts of Suarez's astronomical work with the purpose of printing them in Europe. In effect they printed them, but they did something more, and much more important in favor of the argentine astronomer savant: they managed to buy several astronomical instruments that he lacked. "Fue en Enero de 1739 que partieron de Buenos Aires Los Padres Procuradores Diego Garvia y José Rico llevando los manuscritos de esta obra astronómica de Suárez para hacerla imprimir en Europa. La imprimieron efectivamente, pero hicieron algo más y mucho más significativo a favor del sabio astrónomo argentino: consiguieron comprar varios aparatos astronómicos de que carecía" Glorias op.cit. p 105.
31. At his arrival to Madrid, Father Rico engaged himself in getting what Suarez desired; but in vain" "Al llegar el Padre Rico a Madrid ocupóse en conseguir lo que Suarez deseaba; pero en vano" Glorias op.cit. p 105.
32. It is worth pointing that Father Rico must have arrived in Madrid not later than the end of 1739, since his departure from Buenos Aires was as stated above (see note 31) in January 1739. Furlong says that upon his arrival he wrote to Father Manuel Campos the Jesuit Procurator in Lisbon asking to find the astronomical instruments. Therefore it is very odd that Campos' reply came in March $7^{Th}$ 1745,that is five years after Father Rico landed in Europe. Glorias op.cit. p 105
33. Glorias op.cit. p 106

34. José Luis Molinari in "Viaje del Padre José Cardiel, del Padre José Quiroga y del Padre Matías Strobel, a las costas Patagónicas" Boletin de la Academia Nacional de Historia XXXIII, Segunda sección (1962) p 536 Bs. As. Argentina.

35. Archivo General de la Nación: Buenos Aires, División Colonia. Jesuitas, 1745. Quoted in Molinari p 537

36. Furlong informs that father Rico arrived in July 1745, bringing with him two telescopes of 12 and 24 palmos. That is 8 and 16 feet. Glorias p 106

37. Furlong informs that Quiroga arrived in 1745, bringing with him two telescopes of 8 and 16 feet. Guillermo Furlong "*Los Jesuitas y la Cultura Rioplatense*" Impresores Urta y Curbelo, Montevideo (1933) in Chapter IX "Matemáticos y Astrónomos" p. 59.

38. In 1749 Quiroga occupied the Chair of Mathematics (which included astronomy) at the University of Cordova where he might possibly had made good use of the "mathematical instruments". Furlong, ibid in Chapter IX "Matemáticos y Astrónomos" p. 60.

39. Determining the latitude was trivial, since the earliest years of the 18th century by using a backstaff or a quadrant. The observer would measure the angle between the horizon and a star (the Sun during the day), or (in the northern hemisphere) Polaris at night. John P. Budlong "*Sky and Sextant: practical Celestial navigation"* (1978) supra note 10 at p. 12.

40. For years island of Hierro's meridian in the Canaries was accepted as the prime meridian. Ptolomeus (200-300) believed that Isla del Hierro was the farthest west island of the known world so ancient geographers drew the prime meridian on this site. However there was a time that Toledo, then capital of Castille, was considered as the prime meridian since the influential Alphonsine tables were written under King Alphonse of Castille. Paris also claimed the right after establishing the Observatorie de Paris in 1671. Countries assisting to the International Washington convention of 1885 finally settled their disputes for meridian in Greenwich.

41. Michael Florent van Langren was a cosmographer and mathematician to the king of Spain in Brussels. He competed for the prize offered by the Spanish crown to find the solution to the problem of longitude. Van Langren's idea was to utilize the phases of the moon instead of its eclipses. See "*Jesuit Science and the republic of Letters"*, edited by Mordechai Feingold. Page 339, note 46. MIT press Cambridge Mass.2002 ISBN: 0-262-06234-8

42. Laurence Bovis and James Lequeux Cassini, "*Roemer and The velocity of Light*". *Journal of Astronomical History and Heritage*, 11(2) 97-105(2008)

43. See "*The work of Lagrange in celestial mechanics*", by Curtis Wilson, in "*Planetary astronomy from the Renaissance to the rise of astrophysics*", Part B, ed. Taton and Wilson, Cambridge U.P.,1989

44. P.W. Wargentin "*Tabulae procalculandis eclipsibus satellitum Jovis*", in Acta societatis Regiae Scientiarum Upsaliensis pro 1741 (1746)

45. P.W. Wargentin "*Series Observatorium primi satellitis Jovis, ex quibus theoria motuum ejusdem satellitis est deducta*" in Acta societatis Regiae Scientiarum Upsaliensis pro 1742 (1748) Series 1, 3: 1-32

46. Io is the innermost of the four moons of Jupiter discovered by Galileo in January 1610. Rømer and Cassini refer to it as the "first satellite of Jupiter".

47. It is understandable why it took Suarez several years to make 147 records of Jupiter's satellites. For example Io orbits Jupiter once every 42 hours, and the plane of its orbit is very close to the plane of Jupiter's orbit around the sun. This means that it passes much of each orbit invisible, in the shadow of Jupiter. From the Earth, it is not possible to view both the immersion and the emergence for the same eclipse of Io, because one or the other will be occulted by Jupiter itself. At opposition both the immersion and the emergence would be hidden by Jupiter. For about four months after the opposition of Jupiter, it is possible to view emergences of Io while for about four months before opposition, it is possible to view immersions of Io into Jupiter's shadow. For about five or six months of the year, around the point of conjuntion it is impossible to observe the eclipses of Io at all because Jupiter is too close (in the sky) to the sun. Even during the periods before and after opposition, not all of the eclipses of Io can be observed from a given location on the Earth's surface: some eclipses will occur during the daytime for a given location, while other eclipses will occur while Jupiter is below the horizon hidden by the Earth itself.

48. *"... las inmersiones y emersiones de los quatro Satelites de Jupiter, que observé por espacio de treze años en el pueblo de San Cosme, y llegaron a ciento quarenta y siete,... despache a Europa al P. Nicasio Grammatici de la Compañía de Jesus... "* Suarez B. Introducción "Lunario de un Siglo" Editor F. da Silva, Lisbon 1748

49. See M. Asúa op.cit

50. The Dictionary of Scientific Biography, Gillispie, Charles, ed., New York, 1970-1980, in the Article on Wargentin, says "*Among his contemporaries Wargentin was considered the outstanding expert in his field, and his tables of Jupiter's moons remained authoritative until the improvement of mathematical analysis made possible exact theoretical solutions of the problems. And his empiricism, even when compared with modern theory must be considered surprisingly reliable*." The same Dictionary, in the Article on Laplace states that "*Wargentin's tables needed only a small correction*"

51. " *...y vine en conocimiento de la verdadera longitud del Meridiano de San Cosme, que es de 321 grados, y 45, minutos numerados desde la isla Ferro en Canarias*" Suarez B. Introducción "Lunario de un Siglo" Editor F. da Silva, Lisbon 1748

52. Quiroga finished the map in 1749 and this was published in 1753 by Franceschelli in Rome. "*Mapa de las Misiones de la Compañía de Jesús en los ríos Paraná y Uruguay conforme a las más modernas observaciones de latitud y longuitud hechas en los pueblos de dichas Misiones de ambos ríos, realizado por el padre Joseph Quiroga, de la misma Compañía de Jesús de la Provincia del Paraguay en el año 1749*". He used Suarez's longitudes. See page 136 of Glorias.

53. Allen, P., 1947. "*The Royal Society and Latin America as reflected in the Philosophical Transactions 1665-1730*". *Isis*, 37: 132-138.

54. Journal Book XIV 553-554 (Jan 18, 1730/31), page 393 Royal Society, London. Quoted in Raymond Phineas Stearns "*Science in the British Colonies of America*" University of Illinois Press 1970, p 766.

55. Journal Book XX, page 267 Quoted in R.P. Stearns ibid.

56. Reported May 5, 1748. Journal Book XX p 508. The account treated on the River Plate area. Quoted in Raymond Phineas Stearns "*Science in the British Colonies of America*" University of Illinois Press 1970,

57. Journal Book XX, page 79 Royal Society, London. Quoted in Raymond Phineas Stearns "*Science in the British Colonies of America*" University of Illinois Press 1970, p 766.

58. *Letter: Buenaventura Suarez to Mattheo Sarayva with observations on astronomical subjects*; 17 Apr. 1744. *Spanish.* ff. 171-177b. ROYAL SOCIETY PAPERS. Vol. VII (ff. 268).

59. Journal Book XX, p 300 (june 25, 1747)

60. Suarez's orbituary in the 1750 Littera Annua. Cited in Furlong Glorias p. 139

61. Miguel de Azúa. "*The publication of Astronomical Observations of Buenaventura Suarez SJ (1679-1750) in European scientific journals*" *Journal of Astronomical History and Heritage* **7**(2): 81-84 (2004) cf Section 4. The Portuguese Connection.

62. J.H. Lieske, "*A Collection of Galilean Satellite Eclipse Observations, 1652-1983: Part I*", *Astronomy and Astrophysics*, vol. *154* (1986), pp. 61-76

63. J.H. Lieske, "*A Collection of Galilean Satellite Eclipse Observations, 1652-1983: Part II*", *Astronomy and Astrophysics Supplement Series*, vol. **63** (1986), pp. 143-202.