The Astronomer's Palace: an Instrument for the Observation of the Sky

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Abstract
As a result of the improvement in observational astronomy in the seventeenth century, particularly with the advent of the telescope, astronomical observatories started to be built to house the instruments for the observation of the heavens. With Tycho Brahe's Uraniborg as precedent in the XVI century, the astronomical observatories of the XVII century were mainly institutional buildings with a political agenda. In contrast, the project for an *Astronomical Palace* by Juan Caramuel de Lobkowitz (1678-9), was neither a building to contain instruments, nor did it follow an institutional program. In Caramuel's project, the building serves as an instrument for the observation and measurement of the celestial movements, integrating the instruments traditionally housed in the building and the building itself into a single structure. The present paper will look at the *Astronomical Palace* as an instance of architecture as an instrument to inquire into the natural world.

[**Keywords**: Tycho Brahe, Juan Caramuel, astronomical observatory, scientific revolution, Early Modernity architecture, architectural theory]

As a result of the improvement in observational astronomy in the seventeenth century, particularly with the advent of the telescope, astronomical observatories started to be built to house the instruments for the observation of the heavens. With Tycho Brahe's Uraniborg as precedent in the XVI century, the astronomical observatories of the XVII century were mainly institutional buildings with political agenda, where the observations and experiments that took place in them was secondary to the role of the building as means to assert the empowerment of the monarchy[i]. In contrast, the project for an *Astronomical Palace* by Juan Caramuel de Lobkowitz, first published in the treatise *""Architectura Civil Recta y Obliqua"*[ii] in 1678-9, was neither a building to contain instruments, nor did it follow an institutional program. In Caramuel's project, the building serves as an instrument for the observation and measurement of the celestial movements, integrating the instruments traditionally housed in the building and the building itself into a single structure. The present paper will look at the project of the *Astronomical Palace* as a way to unveil the possible motives that Caramuel had in the use of architecture as an instrument to inquire into the natural world. In order to do that, we will look first at the biography of Juan Caramuel de Lobkowitz, then a description of the project for the *Astronomical Palace* will follow, afterwards the paper will examine the influence of Tycho Brahe's "*Astronomia Instaurata Mechanica*"[iii] in the conception of the project, and finally, it will consider how the author overcame the limitation that he saw in observational astronomy, by proposing a building as an instrument for observation, where not only its size but also its conception would warrant truthful knowledge.

Juan Caramuel de Lobkowitz (1606–1682)

Juan Caramuel was born in Madrid in 1606[iv], son of an engineer from Luxemburg and a noble Bohemian woman from the Lobkowitz house. His parents moved to Spain where his father served the court of the Hapsburg. Caramuel was raised in a polyglot home and his endowment with languages allowed him to master over 20 languages in his adulthood. His first teacher was his father, who as an engineer impressed on the young Caramuel the love for mathematics and astronomy that together with his passion for language were going to shape his thought. Caramuel first attended the Jesuit school in Madrid and at the age of nine he entered the University of Alcala de Henares where he studied Humanities and philosophy. At the age of nineteen Caramuel joined the Cistercian order and after traveling for some years in Spain, seeking to deepen his theological education, Caramuel left Spain for the Spanish Netherlands where he attended the University of Louvain and received his Doctorate in 1638.

Caramuel's ecclesiastic career started in 1644 when he became Abbot of Disidodenberg in the Lower Palatinate[v], this appointment inaugurated the years he spent in the Southern regions of the Empire. In 1647 he moved to Prague as Abbot of the Benedictine Monastery of Montserrat where he stayed until 1655, and finally to Italy where he spent the last part of his life. Caramuel spent the last nine years of his life as Bishop of Vigevano in Lombardy, where he died in 1682 leaving a legacy of over two-hundred books and manuscripts. His archive is presently kept at the archdiocese of that city, in the rear of the Cathedral whose facade is the only built work by Caramuel that

Fig. 1. Juan Caramuel de Lobkowitz , *Plate XXXVIII*, 1678-9, Architectura Civil Recta y Obliqua" Vol. III.

has lasted until our days[vi].

Better known for his theological writings, Caramuel was also a man of science[vii]. His interest for natural philosophy and astronomy was enhanced during his stay in the Netherlands, and his scientific activity particularly intense before 1644 permeated his work afterwards. During those early years, Caramuel took active part in the main discussions that agitated Europe. As the man of action he was, Caramuel would not be satisfied with a theoretical discussion; he built instruments and performed experiments through which he asserted his positions on the different subjects based on firsthand experience. The results of his experiments and the conclusions he reached, were made public through correspondence or in printed publications and the survival of many of these documents constitute the evidence we have today of his endeavour[viii].

Experiments in the Seventeenth century went hand in hand with the development of new instruments built specifically to aid the investigation. Natural philosophers worked closely with instrument makers in the development of tools, and Caramuel was no exception. Around the year 1643 a thesis put forward by the military engineer Calignon de Peyrens, caused great commotion in the scientific circles of Europe. Peyrens declared the deflection of the vertical line of pendulum. The implication of Peyrens thesis was the impossibility to determine the altitude of the North Pole, fundamental for navigation, or of any other star, which carried important consequences for astronomical observation. Convinced of the importance of proving wrong this theory, Caramuel prepared an experiment in a library in Louvain where a more precise instrument was made, Caramuel and his assistants built a sixteen-foot pendulum[ix]. The precision of the instrument and the care in the setting up of the experiment allowed Caramuel to demonstrate that the vertical line of a pendulum was stable.

Caramuel also built structures to assist in his research into the natural world. In 1635 he built two towers in Bruges and Dunkerke in order to better measure the earth. The correct measurement of the earth's diameter was related to the longitude of the sea, another problem that concerned the learned men of the time. Caramuel's method employed trigonometric parallax, a simple geometrical operation where through triangulation two observers located at two different locations, in this case the towers were seventy-five kilometres apart from each other, would compare their observations of the same celestial body to calculate its distance.

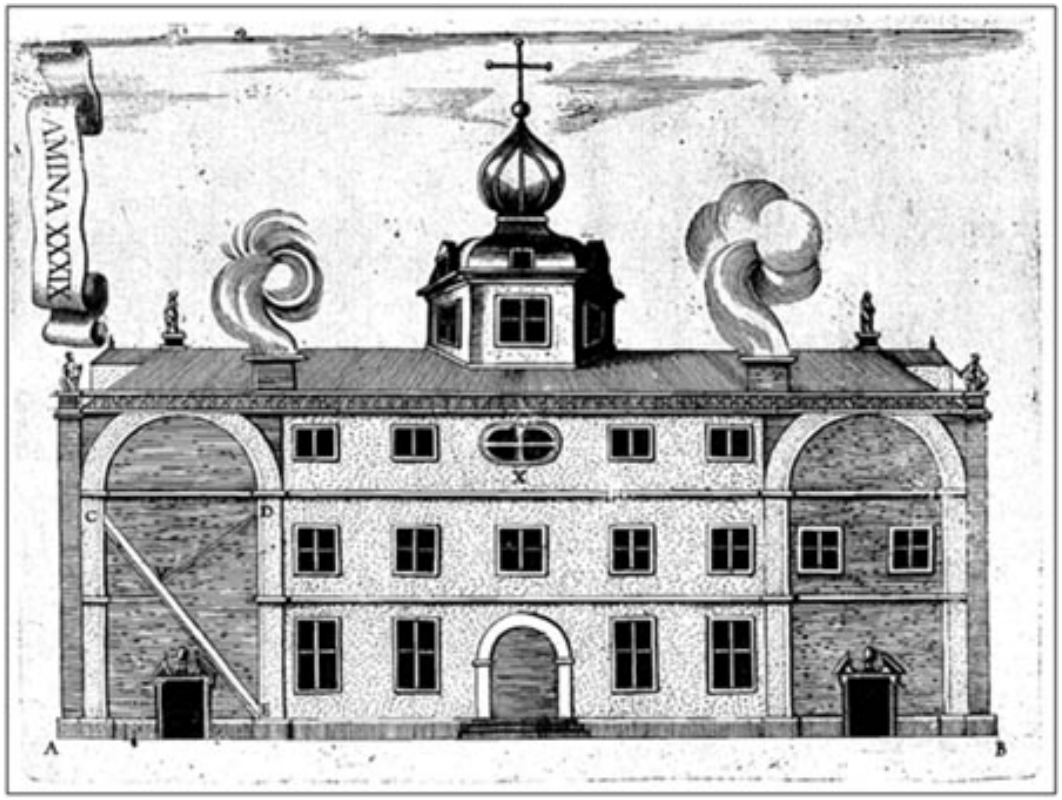


Fig. 2. Juan Caramuel de Lobkowitz , *Plate XXXIX*, 1678-9, "Architectura Civil Recta y Obliqua" Vol. III.

The scientific activity of Caramuel was less intense in the years following his departure from the Netherlands; nevertheless he remained involved in scientific endeavours at a more theoretical level. While his writings turned toward mathematics as the encompassing science, his preoccupation with astronomy evolved in an interesting way. During the period in which he published the "*Mathesis Audax"* --around 1642-- Caramuel was deeply involved in observations and experiments on natural philosophy, while his writings on astronomy remained at a general level. In that publication, astronomy was included among the other sciences for which Caramuel gave only their fundamental principles **- "***astronomicis... fundamentis"*[x]*.* Thirty-eight years later, his interest in astronomy was focused on observational astronomy. In the "*Mathesis Biceps"*, an encyclopaedic work on the mathematical sciences published in 1670, astronomy was included as "*Astronomia physica"*, revealing a preference for the observation of the sky with the aid of instruments over theoretical discussions and generalities. The "*Mathesis Biceps"* established also the foundations for Caramuel's architectural treatise that will appear published eight years later. When "*Architectura Civil Recta y Obliqua"* was published in 1678-9, astronomy was at the base of his architectural theory, moreover, Caramuel considered architecture an instrument through which man could measure the sky.

An Astronomical Palace

In *"Architectura Civil Recta y Obliqua"* Caramuel consigned his theory of architecture over approximately 600 pages and illustrated it with 159 images. Since the Renaissance, architectural treatises included reconstructions of buildings of the past, whether ideal or based on archaeological evidence, along with buildings proposed by the author, usually temples and palaces. Caramuel's treatise is in some ways concordant with the tradition, even though his originality permeates the selection of projects. These include the Temple of Solomon, the Egyptian pyramids and the Roman temples for Hercules and Vulcan, as some examples of temples from the past. He also includes a proposal for a temple that is an idealized version of the Pantheon. The palaces that Caramuel chose to illustrate in his treatise were those of the princes of the new world, based on the traveler's chronicles that he had available. From his own hand there is only one project: an *Astronomical Palace*.

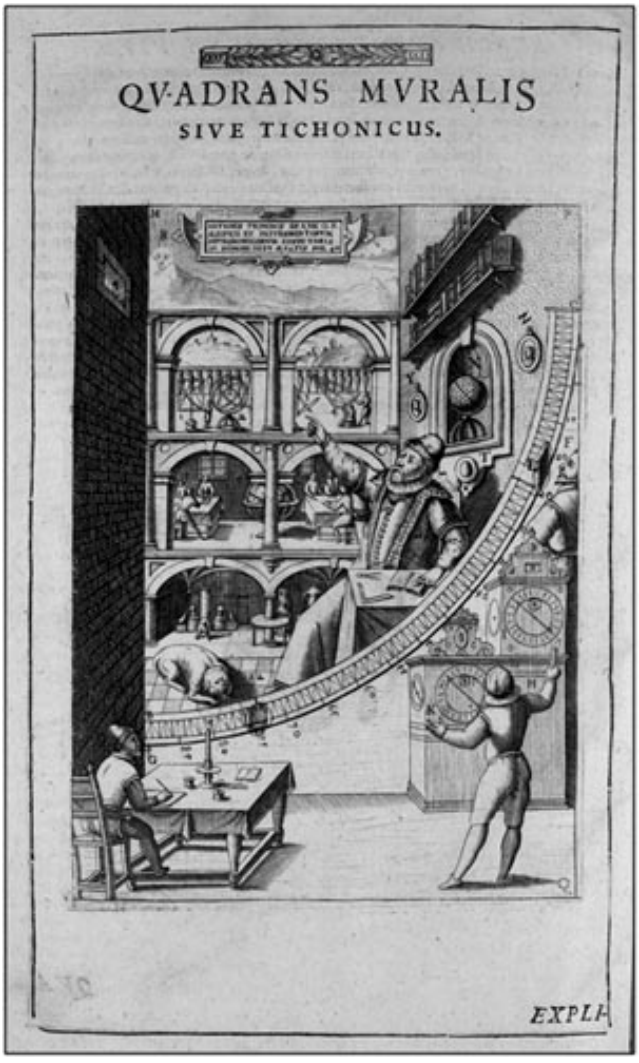
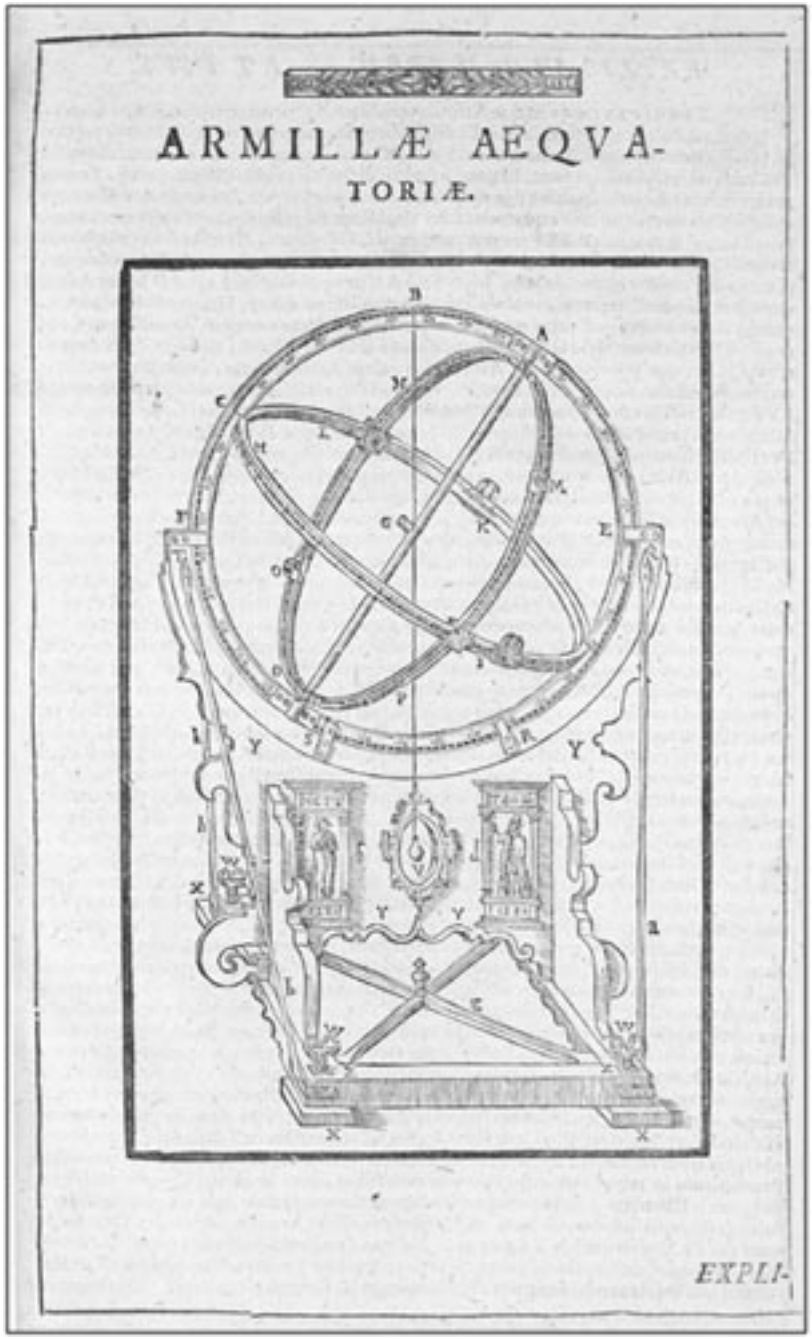


Fig. 3. Tycho Brahe, *Mural Quadrans*, 1598, "Astronomia Instaurata Mechanica". Reproduced from http://www.sil.si.edu/digitalcollections/hst/brahe/sil4-3-33a.htm (accessed August 29, 2010)

The project for the *Astronomical Palace* is described in two pages within *"Architectura Civil Recta y Obliqua"*. In the architectural treatise astronomy appears included in chapter VII of the second volume among *"the arts and sciences that accompany and adorn architecture"*[xi] that included also painting, sculpture, perspective, music, and military architecture[xii]. Caramuel started by explaining to his reader the reasons for including astronomy in an architectural treatise. The author believed that there was a fundamental difference between the work of God and the works of men, however at a less general level, he conceived of *Astronomical Architecture* as a science where astronomy and architecture converged. This new science was concerned with the building of palaces from which the stars could be

observed. Its purpose, he claimed, was to give the architect the knowledge necessary in the construction of appropriate buildings for astronomers. For this reason Caramuel considered *Astonomical Architecture* a discreet form of knowledge for the architect and decided to include it in a text intended for the education of the architect as was his *"Architectura Civil Recta y Obliqua"*[xiii].



Tycho Brahe was the first one to attempt making a building for the observation of the stars. Caramuel was familiar with Tycho's work. Through the published work "*Astronomia Instaurata Mechanica"*[xiv] of 1580[xv], Caramuel knew of Uraniborg and Stjerneborg. But if Caramuel gave Tycho priority in his treatise, he didn't judge the buildings at Hven worthy of being considered part of *Astronomical Architecture.*

According to Caramuel, the palace at Uraniborg provided a house for Tycho, but it was not more appropriate for the intended observations than any house with big windows and rooms big enough to fit his instruments, therefore Tycho's project according to the Spaniard belonged to the realm of civil architecture. It was the shortcoming of Tycho's building that inspired Caramuel in his proposal for his project for an *Astronomical Palace.*

Fig. 4. Tycho Brahe, *Armillae Aequatoriae*, 1598, "Astronomia Instaurata Mechanica". Reproduced from http://www.sil.si.edu/digitalcollections/hst/brahe/sil4-3-33a.htm (accessed August 29, 2010)

To the two pages of the description correspond two plates, XXXVIII and XXXIX (fig. 1 and 2), that show the east and west facades of the building in that order. As it is normal for a building of the sort, it appears aligned with the meridian line and oriented looking to the four cardinal points. In plate XXXVIII (fig. 1) we see a symmetric building of three storeys with a central volume formed by two exterior stairs and crowned by a hexagonal tower with an onion dome. The main elements of this facade are two quadrants the size of the entire building. The height of the sun, the moon, planets and stars, would be measured when crossing the Meridian in the southern hemisphere using the quadrant to the south (PSR), and when in the northern hemisphere the other quadrant (OTV), located on the opposite side, would be used. Caramuel placed the two staircases (IG and MH) that face each other and protrude from the facade, in order for the astronomer or one of his assistants to reach the edge of the quadrant where the angle measurements would be inscribed. Where these two stairs meet at the top, there is a door that gives access to a room on the second floor. The light of the sun would enter the room through the small orifice (X) on the eastern wall of the room and shine on the opposite wall, making possible to measure the eastern amplitude of the luminaries at each specific moment. The west facade had a similar orifice in order to measure the western amplitude of the sun. This upper room with its walls would serve to measure the solstice, equinoxes and declinations of the sun.

The west facade of the buildings appears in plate XXXIX (fig.2). At the south end of this facade there is a door to a room where the astronomer would measure the right ascension of the stars[xvi]. The facade of the room includes a line that corresponds to the equinoctial (CE) and a polar line (VD) that intersects it perpendicularly. Using these two lines and the help of a dioptra, the astronomer would accomplish his task. The cross at the top of the central dome would also be used as an instrument. To understand how to use it is necessary to imagine that there is a garden outside the building with a path running east-west crossing the main body of the building at the center on both sides. This path would be the tangent of an imaginary circle with its center at the top of the cross. Measuring the height of a star and projecting it to the tangent, the astronomer would be able to calculate its position with great accuracy.

Caramuel refrained from any further description of the building in the treatise, with the promise for a more complete explanation to follow in the Latin translation of the same text. Unfortunately, this explanation together with the promise of a fourth volume for the treatise never materialized[xvii]. Consequently we need to content ourselves with the brief description of the building as it was printed in the original text and the information that we can gather from the plates[xviii].

It seems obvious in the text that the work of Tycho Brahe and his buildings for astronomical observation in the island of Hven were the point of departure for Caramuel's proposal. Caramuel explicitly criticized Brahe's building which he claimed was not any better than a house with rooms and windows big enough to fit instruments inside. Caramuel was familiar with the work of Tycho[xix], particularly his *"Astronomia Instaurata Mechanica"*[xx], where the Danish astronomer presents a description of

Uraniborg and Stellaeburg. Recent scholarship on the project at Hven[xxi] has demonstrated that the description that appears in Tycho's book is if anything scanty. We have evidence that Brahe finding Uraninborg inadequate for the use of the instruments decided to build Stjerneborg, a subterranean structure that warranted stability of the instruments. Nevertheless, Caramuel didn't seem to be aware of the difference in the time of the construction of the two observatories. His criticism was based on the assumption that the observatories at Hven were structures, subterranean or otherwise, where instruments were contained. For Caramuel an astronomical building should be more than a mere depository of instruments, it should be an observational instrument itself.

Despite the criticism towards the buildings at Hven, the work of the Danish astronomer can be considered the most important influence in Caramuel's own project. If Caramuel was opposed to his building, he clearly admired the instruments that Tycho had devised. The biggest achievement of Brahe was the accuracy of his observations, granted by the accuracy of his instruments, which because of their size and craftsmanship were very precise. With Caramuel's familiarity with instruments, he knew that bigger instruments granted greater accuracy. The instruments of the astronomer grew gradually in Caramuel's project, the building became an oversized instrument where the astronomer would take his measurements, and finally it grew to the point it encompassed the whole building. Caramuel imagined a building that with its walls, windows, dome and garden paths, etc, would itself measure the movement and position of the heavenly bodies.

Caramuel's building is several instruments at the time, all based on the work of Brahe. The easiest ones to identify are the mural quadrants on the east facade. These giant quadrants are similar to the one that appeared in *"Astronomia Instaurata Mechanica"* under the name *Mvral Qvadrans* (fig. 3). Built on a wall, the mural quadrant has an arc with a radius of two meters, and is perpendicular to another tall wall with a small aperture through which the celestial object's altitude is measured. Caramuel decided to make a quadrant as big as a the total height of the building, that overall was three storeys high, resulting in a quadrant of at least three times the size the one Tycho Brahe built. When looking at the similarities between the plates of *"Astronomia Instaurata Mechanica"* and Caramuel's own plate, one can see how Tycho's plate must have served as inspiration for the *Astronomical Palace.* In the background of the plate, Uraniborg is shown with three storeys and the quadrant is shown of the wall in the foreground. As he shows in Plate XXXVIII, Caramuel collapsed the literal and figural distance between building and instrument, and made the quadrant part of the building.

The two other instruments that are incorporated into the building are also derived from traditional instruments for astronomical observation. The south end of the west facade was used to measure the ascension of the stars, something traditionally achieved with the use of an armillary sphere. In Tycho's plates this instrument appeared under the name of Equatorial Sphere (fig. 4). In Caramuel's plate the line CE corresponds to the one representing the equator and DV a meridian line. In other words, Caramuel

imagined an armillary sphere that was as big as a room, where the astronomer would be able to go inside to make his calculations. Caramuel's imagination was not restrained by the size of his building. The last instrument that he envisioned encompassed the whole building. Caramuel imagined a circle with its center at the tip of the cross atop the dome tangential to the garden path. In his imagination, the astronomer would stand in the garden and imagine a circle. By transferring the position of the star from the circle to the tangent, the astronomer would be able to calculate its height in the sky.

Given Caramuel's interest in instruments and assuming that the project was conceived between the years 1635 and 1678[xxii], it is intriguing that Caramuel never mentioned the telescope in the description of the *Astronomical Palace.* We know with certainty not only that Caramuel was aware of the work of Galileo but also that Caramuel aided his observations with the used of the telescope[xxiii]. His intentional exclusion of the instrument is in fact the most important clue that we have to understand Caramuel's project. The telescope had become the emblem of observational astronomy[xxiv] carrying with it a heretic anathema. Most of the Catholic savants of the Seventeenth Century, including Caramuel, held an anti-Galilean position and claimed that telescopic observations were unreliable. On the other hand Tycho represented the position of the Church, and it is obvious that Caramuel by choosing the instruments of the latter stated his position in the discussion. Caramuel's intention to associate his project with Tycho Brahe's is also evident in the name of his project. The term castle that Tycho had used for his buildings, *Castle of Urania* (Uraniborg) and the *Castle of the stars* (Stjerneborg), while it implies a fortification it also has a domestic connotation. In the case of the buildings at Hven, located on an arid and desolated island where, according to Caramuel, nobody would want to live[xxv], the construction of a fortified structure was necessary. Caramuel certainly foresaw a much better site for his project where there was no need of a defensive structure, yet he preserved the domestic aspect of the term. He imagined a palace, a house for an important person, in this case the astronomer. By choosing to build a palace instead of a castle, Caramuel preserved the domestic aspect of the building yet the defensive connotation was replaced by splendour.

There is however a deeper implication of the exclusion of the telescope in Caramuel's building. By omitting the emblem of astronomical observation, Caramuel tacitly stated that the observations that would be achieved with the use of his building were of a higher order. For Caramuel, as for many of his contemporaries, scientific observation by means of instruments was not sufficient to achieve true knowledge. The instruments of the astronomer facilitated his task, but were not enough to achieve real knowledge. Caramuel believed that human vision was limited not only because of the physiology of the eye, but also by the spiritual condition of the viewer. Consequently, instruments could overcome the limitations of the eye, but God's grace was necessary when seeking true knowledge. When in the "*Mathesis Bicep"* Caramuel discussed Calignon's experiment mentioned above, an erroneous conclusion was explained as the result of an experiment conceived under original sin[xxvi]. According to Caramuel, not only was the craftsmanship of the pendulum defective, moreover, Calignon was deceived into believing that there was deflection in the vertical line of the pendulum,

because his soul was in sin. In order to overcome the limitation of observational instruments, Caramuel decided to include one last instrument in his project: two concave mirrors. These mirrors are not inside the building but above it, held by two angels (see fig. 1). The two angels use the mirrors to gather the sun's rays and direct them to the building, making possible the measurement of the position of the sun inside the building. Yet, besides their obvious purpose, there is more.

Caramuel was not an amateur astronomer and his appreciation for Tycho Brahe's advancement in the field of observational astronomy was the point of departure for designing his project. Using the plates on Tycho's treatise as inspiration he imagined a building where its different elements, walls and windows, were transformed into oversized viewing devices. Caramuel increased the size of Tycho's instruments to the point that they became an inhabitable structure from within which man could measure the sky. Nevertheless, bigger and better instruments didn't warrant truthful knowledge of the world. For Caramuel, the observation of the natural world and the knowledge derived from it, didn't take place at a physical level only, but also at a spiritual one. Therefore the improvement of the instruments that the scientist used in his investigation of the world wouldn't be enough to achieve full knowledge if unaided by God's will. In the *Astronomical Palace* Caramuel provided a building that works as an instrument because of its size helped the human eye in its measurement of the sky, but only with the help of the angels he assured that Divine Grace (God's true Light) was delivered to the astronomer to assure the truthfulness of his observations.

Notes

[i] In the case of the Royal Observatory in Paris, the two hexagonal rooms provided for the observations were adjacent to the main building and as a result, instruments had to be moved from one room to the other in order to record the complete movement of a star in a day. Similarly, the Royal Observatory in Greenwich was built on the existing foundation of a destroyed building and because of this the building was oriented thirteen degrees from true north, making it unsuitable for observations.

[ii] Juan Caramuel de Lobkowitz, *Architectura Civil Recta Y Obliqua, Considerada Y Dibuxada En El Templo De Jerusalem... Promovida Á Suma Perfeccion En El Templo Y Palacio De S. Lorenço Cerca Del Escurial Que Inventó... El Rey D. Philippe Ii (1678).* (Vigevano: Camilo Conrado, 1678-9).

[iii] Tycho Brahe, *Astronomiae Instauratae Mechanica*, trans. and Bengt Strömgren Elis Strömgren Hans Ræder (Copenhagen: I Kommission hos Ejnar Munksgaard, 1598).

[iv] For a complete biography of Caramuel see D. Pastine, *Juan Caramuel : Probabilismo Ed Enciclopedia* (Firenze: La Nuova Italia, 1975). and J. Velarde Lombraña, *Juan Caramuel. Vida Y Obra* (Oviedo: Pentalfa, 1989).

[v] See J. Fernandez-Santos, "Juan Caramuel's Journey from Flanders to the Palatinate: A Travel Diary Presented to Fabio Chigi in 1644," *Juan Caramuel Lobkowitz : The Last Scholastic Polymath* (Prague: Filosofia, 2008).

[vi] It seems that while Caramuel was in Prague he renovated the monastery and church at Emmaus. However the great destruction during WWII has razed all evidence of his work. Still standing is only the interior of the refractory and a small room next to it.

[vii] Velarde Lombrana has dedicated the first chapter of his book *Juan Caramuel: Vida y Obra* to the involvement of Caramuel in the development of modern science. I have used his biography as a main source of information on Caramuel's scientific activity.

[viii] It is not the intention of the present paper to present a full account of the scientific activity of Caramuel. The reader can refer to the bibliography for a complete list of Caramuel's scientific publications before 1644.

[ix] Velarde Lombrana.

[x] Juan Caramuel de Lobkowitz, *Mathesis Audax Rationalem, Naturalem, Supernaturalem, Divinamque Sapientiam Arithmeticis, Geometricis, Catoptricis, Staticis, Dioptricis, Astronomicis, Musicis, Chronicis, Et Architectonicis Fundamentis Su Bstruens Exponensque* (Lovanii: A. Bouvet, 1642).

[xi] Tratado VII, "De algunas Artes y Ciencias, que acompañan y adornan a la Architectura". Vol. II, Treat. VII, art. VI, p. 64

[xii] The chapter also includes chapters that deal with solid cubes and a table where the rays of different polygons are consigned.

[xiii] In this point Caramuel claims to follow Vitruvius in including the many faculties that an architect must know.

xiv Brahe, Astronomiae Instauratae Mechanica.

xv Caramuel may have seen the edition of 1580 and he includes the page numbers of the images that illustrate the building. However, Caramuel doesn't mention the name of the book and says that the images are part of Tycho's first volume of his "cartas". The word "cartas" in Spanish could be used for correspondence or astronomical tables. Even if Tycho printed some of his letters at Hven and he might have included the engravings of the building, we can assume that Caramuel is referring to the Astronomia Instaurata since he is saying that those images that he has seen are part of the first volume of a published work.

[xvi] Right ascension is one of two coordinates of a point on the celestial sphere. It is a line that goes north-south and corresponds to terrestrial latitude. See http://www.astronomynotes.com/nakedeye/s6.htm#anim

[xvii] Between the year of the publication of the architectural treatise and Caramuel's death in 1682, the monk's vision deteriorated rapidly and this might be an explanation for the unfulfillment of the task. Caramuel was already blind of one eye in 1680 and completely blind the next year, and even if this didn't impede his work, he had to rely on copyists to write his books, including the Latin version of *"Architectura Civil Recta y Obliqua".*

[xviii] The Latin volume, "*Templum Salomonis Rectam et Obliquam Architecturam"* seems to be only a translation of the original text without any additional plates or chapters that expand the information given in the Spanish text. Even though I have located one copy of the "***Templum Salomonis…"*** at the Biblioteca del Seminario Vescovile di Vigevano, I have not compared the two texts to verify if there is further information on the project in the Latin text as indicated in the edition of 1678.

[xix] It is possible that Caramuel owned or had access to the edition of 1598 of *"Astronomia Instaurata Mechanica"*, since in *"Architectura Civil Recta y Obliqua" he* quoted this edition of Brahe's book.

[xx] Brahe, *Astronomiae Instauratae Mechanica*.

[xxi] On the work of Tycho Brahe and the construction of his observatories see J R Christianson, *On Tycho's Island : Tycho Brahe, Science, and Culture in the Sixteenth Century* (Cambridge, U.K. ; New York: Cambridge University Press, 2003). and Mosley Adam, *Bearing the Heavens : Tycho Brahe and the Astronomical Community of the Late Sixteenth Century* (Cambridge: Cambridge Univ. Press, 2007).

[xxii] The dating of the projects is also problematic. In the dedication of the volume of the plates to Don John of Austria, Caramuel tells us that the plates of the treatise preceded the text and that they were produced over a period of forty-three years. The lack of signature from the engraver makes it impossible to determine when the plates of the *Astronomical Palace* were made and we need to content ourselves with the big range between 1635 when he started plates and the publication in 1678-9.

[xxiii] Caramuel described his observation with the use of a telescope on a letter sent to Antonio Maria Schirlaeus de Rheita included in the *Mathesis Biceps*. See Velarde Lombrana p 74.

[xxiv] W. B. Ashworth, "Divine Reflections and Profane Refractions: Images of a Scientific Impasse in Seventeenth-Century Italy," *Gianlorenzo Bernini: New Aspects of His Art and Thought* (London: University Park, 1985).

[xxv] A.C.R.Y.O, Vol. II, Treat. VII, art. VI, p 65.

[xxvi] See Velarde Lambraña p. 69.

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