

ANDERS CELSIUS' CONTRIBUTIONS TO MERIDIAN ARC MEASUREMENTS AND THE ESTABLISHMENT OF AN ASTRONOMICAL OBSERVATORY IN UPPSALA

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Abstract. Astronomy has been on the curriculum of Uppsala University from at least the middle of the 15th century. However, since Uppsala also was the ecclesiastical centre of Sweden, the acceptance of new ideas, such as the Copernican heliocentric system, was slow. At the same time, more peripheral universities in the Swedish empire, including Dorpat/Tartu, enjoyed a larger freedom. It was not until the early 18th century that a 'modern' astronomy emerged in Uppsala. This effort was to a large extent led by Anders Celsius (1701–1744), who was able to establish good international contacts with astronomers in continental Europe. Celsius participated in De Maupertuis' expedition to the far north of Sweden, in order to measure the meridian arc and determine the shape of the Earth. This paper explores how Celsius became involved in De Maupertuis' expedition, and how this effort paved the way to the establishment of a fully equipped astronomical observatory, including an extensive collection of books and instruments, most of which survives up to this day.

Key words: history of astronomy

1. INTRODUCTION

While astronomy in Uppsala has its roots in the 15th century, it was not until the early 18th century that an astronomical observatory was established. This was mainly the result of the efforts by Anders Celsius (1701–1744), who himself could draw on the experiences of his predecessor (and grandfather) Anders Spole (1630–1699). This paper focusses on how both Spole and Celsius were involved in meridian arc measurements, and how this allowed Celsius to firmly establish a centre for astronomy in Uppsala. Important sources for this work have been the earlier works on the history of mathematics and astronomy in Uppsala and Sweden, by Dahlin (1876) and Nordenmark (1959), as well as on a number of biographies. A biography of Spole was written by Nordenmark (1931). Three biographies of Anders Celsius exist; a short memorial speech by Baron von Höpken (1745), an early but excellent biography by Baron von Zach (1806), as well as a very extensive biography by Nordenmark (1936).

2. ASTRONOMY IN UPPSALA IN THE PERIOD 1400–1600

Uppsala university was founded in 1477, and as such it is the oldest university in Northern Europe. Although our present image of the early university is at best fragmented, astronomy appears to have been taught from the very beginning. An extensive set of preserved lecture notes from ~ 1480 , kept by student Olaus Johannis Gutho, show that astronomy teaching at that time consisted of very classical texts, such as Sacrobosco's *Sphaera*. It is unclear whether there were appointed lectures for astronomy – we only know of the visit in 1508 by Petrus 'Astronomus' from the monastery in Vadstena, who lectured in Uppsala on the topic of celestial spheres. However, since the university was primarily a Catholic institute, all teaching slowly ceased after the Lutheran reformation.

A first effort at reestablishment of the university was made in 1566. Again, astronomy appeared on the curriculum, this time through lectures by Olaus Jonae Luth, the first known appointed lecturer in astronomy in Uppsala (1572–1577). A copy of his instruction text on astronomy is preserved in Sweden's Royal Library (republished with extensive notes by H. Sandblad in 1935). Also here, the lectures follow purely classical lines, again firmly relying on Sacrobosco's *Sphaera*. However, after Luth, teaching in astronomy appears to have ceased once more.

A second effort at reestablishment occurred in 1595 – this time a professorship of astronomy (within the discipline of mathematics) was explicitly mentioned in the university's constitution. This 'chair' in astronomy has survived up to today. The first appointed professor was Laurentius Paulinus Gothus, who had spent time at German universities and had come in contact with the works of Copernicus and even discussed the three different world systems (Ptolemaic, Copernican and Tychonic) in his lectures of 1600. While the revolutionary works by Kepler and Galileo were discussed by later professors in astronomy, Uppsala strongly remained a stronghold of geocentrism, mainly because Uppsala also was the ecclesiastical centre of the Swedish empire. It would take a long time before the Copernican system would gain acceptance among Swedish scholars – from an international perspective, one can consider Sweden to be slow in accepting these ideas (see Sandblad 1973). This later played an important role when appointing new professors in astronomy (see below). Therefore, instead of investigating the newest developments in astronomy, the focus of astronomical studies in the early 17th century was on *computus ecclesiasticus*, i.e. preparing calendars and ephemerides.

A major difficulty for Uppsala astronomers in the 17th century must have been the lack of proper instruments. Since no astronomical observatory existed, all instruments were kept in the university library. An inventory of 1678 lists only a basic collection: terrestrial and celestial globes, a quadrant, two astrolabes and a geometric compass (Annerstedt 1894). For *systematic* studies of the heavens, a fixed observatory site was needed. An effort to construct a viewing tower was made in 1657 by Benedictus Hedraeus (professor of astronomy at Uppsala university, 1649–1659). However, he was unsuccessful in securing funding from the university, and his tower was left unfinished.

3. ANDERS SPOLE

The first professor of astronomy in Uppsala with a considerable scientific output beyond *computus ecclesiasticus* was Anders Spole (1630–1699). As a student Anders Spole first spent some time at German universities, before coming to Uppsala,

where he quite successfully studied astronomy. In parallel to his own studies, he also served as an instructor for students with a wealthy background. This provided him with an important basis for his future career. With his fellow students he travelled to the most important centres of astronomy of the time: Holland, England, France and Italy, meeting some of the foremost astronomers, such as van Schooten, Huygens, Hook, Mercator, Riccioli, Jean-Domenique Cassini and Kircher. During his voyage he amassed quite a following of Swedish students with roots in nobility. The message went around that he clearly was an able astronomer, and when in 1666 a new Swedish university was established in Lund, he was called to a professorship there.

Having seen the state of the art of astronomy at leading European universities, Spole immediately started building an observatory (observing tower) on top of his own house in Lund. He also maintained contact with several of the astronomers he met during his voyage. In particular, he travels several times to Uranienborg on the island of Hven, not far from Lund and Copenhagen, where Tycho Brahe used to perform his observations. Among the people he meets on Hven is the French astronomer Jean Picard, who in France performed the first meridian arc measurement with triangulation. Nordenmark (1931, p 420) mentions that one of Spole's students, Nicolaus Lundbergius, in 1674 presented a dissertation on the topic of the shape and size of the earth – and apparently Spole actively worked with Picard on measuring the location of Hven. Clearly, Spole is well-informed of the question of the shape of the Earth, and the important role of meridian arc measurements. However, the dissertation presents the Earth as egg-shaped, following the view of Cassini.

In 1676, the Danes invaded southern Sweden, and Lund was damaged by fire. Spole's books were saved, but the observatory was destroyed and the university was dissolved. Spole, having good connections with nobility and the king himself, chose to actively participate in the war. In 1679, he was (as a reward for his loyalty?) offered the professorship in astronomy in Uppsala, which had become vacant in the same year. The following 20 years were among the most productive of Spole's career.

One of Spole's most promising students was Nils Celsius, son of Magnus Celsius, (professor of mathematics at Uppsala 1668–1679). Under the authority of Anders Spole, Nils Celsius prepared a dissertation where he firmly states that the proper principles of astronomy are empirical observations, and not any doctrine prescribed by theologians or the bible. This implied opening up for heliocentrism, and naturally put both Celsius and Spole on a collision course with the theology-dominated university. The university inhibited the dissertation and Nils Celsius found himself fighting for his career, which later must have played in when a successor to Spole was to be appointed. Despite this incident, the relation between Anders Spole and Nils Celsius was good – Nils Celsius married one of Spole's daughters, Gunilla Spole.

In Uppsala, Spole built an observatory of very similar character as the one in Lund. His own house was equipped with a wooden observing tower, and he purchased instruments, as well as numerous astronomical books. The funding for these projects came from private means – Spole had been richly rewarded for his engagement in the war.

In 1694, the Swedish king Charles XI travelled to the north of Sweden, and observed the midnight Sun in Torneå, which is located a latitude of about 66° N,

which places it just *south* of the arctic circle. Knowing that this was of astronomical significance, the king sent Anders Spole and his mathematical colleague Johan Bilberg to Torneå the following summer in order to perform measurements of this phenomenon (atmospheric refraction). One of the original goals of the mission was also to perform a meridian arc measurement (Nordenmark 1931, p 471). However, Spole and Bilberg did not have the resources for this – they were also not helped by the fact that at such northerly latitudes only a handful of stars are visible during the bright summer months. In a later letter to the Swedish king (Nordenmark 1931, p. 466), Spole repeated his wish to perform a meridian arc measurement closer to Uppsala.

Spole died in 1699, and had himself suggested that Nils Celsius succeed him as professor of astronomy. However, the university instead chose to appoint Per Elvius (incidentally also married to one of Spole's daughter). Elvius himself was succeeded by Nils Celsius in 1718. However, by then Nils Celsius was already 61 years old, and he died in 1724. Celsius was succeeded by Erik Burman, who also died at an early age in 1729.

4. ANDERS CELSIUS

In 1702 Uppsala was hit hard by a large fire, destroying about three quarters of the town, including Spole's observatory. His library, however, survived. There were some quick initiatives to rebuild the astronomical observatory, but given the large scale of destruction, it was a difficult time for the university to fund such projects. In addition, Spole's successors, albeit able astronomers, lacked strong connections with leading European astronomers. All this led to a certain stagnation of astronomical research in Uppsala. The university was well aware of this, and when the professorship in astronomy became vacant again in 1729, it was important to choose the right person among the candidates.

The most promising student of the time was Anders Celsius (1701–1744), the son of Nils Celsius, and grandson of both Anders Spole and Magnus Celsius, all former professors in Uppsala. In 1728, Anders Celsius acted as a substitute lecturer in mathematics while the professor in mathematics, Samuel Klingenstierna, was travelling abroad. Directly after Burman's death, Celsius also continued Burman's lectures in astronomy. In addition, Celsius had inherited a sizeable collection of books and instruments from his ancestors. Celsius also expressed his willingness to travel to a number of major European centres of astronomy, not unlike the voyage conducted by Anders Spole. Anders Celsius was the obvious choice, and was appointed professor in 1730.

After Klingenstierna's return to Uppsala in 1732, Anders Celsius travelled to Berlin, where he bought an astronomical quadrant. He then continued to Nuremberg, Wittemberg, Venice, Padua, Bologna and Rome. During this part of the voyage, Celsius performed many observations with his quadrant, and measured the direction of several meridians. However, it was not until late 1734 that Celsius travelled to Paris, one of the true astronomical centres of its day. His initial contact in Paris was De l'Isle, with whom he in later life would work to design his own temperature scale.

While in Paris, Celsius presented some of his astronomical observations to the Académie des Sciences, where he established contact with Pierre de Maupertuis. The Académie des Sciences was at that time investigating whether the shape of the Earth is prolate or oblate, with Jacques Cassini and Pierre de Maupertuis

representing the two different points of view. The Académie had decided to send two expeditions to measure the length of one degree of meridian arc, one to the equator, and one to very northern latitudes, although the exact destination of the latter was at that point still under debate. However, it did not take much time to decide that the northern expedition be sent to northern Sweden.

The exact role that Celsius played in this decision may be difficult to determine. However, Celsius must have been well aware of the collaboration of his grandfather Spole with Jean Picard, and Spole's later expedition to Torneå in the north of Sweden. It was also recently (1732) that Carolus Linnaeus travelled through the same area with the purpose of collecting botanical specimens, a trip that Celsius was made aware of through a letter of Linnaeus from 1733. At this point it is interesting to quote Celsius biography by Baron von Zach, who was extremely well connected to most leading astronomers of the late 18th century, and of which many must have known Celsius, De Maupertuis and others around them personally. Von Zach (1806, p 110) writes:

“Versicherungen sehr glaubwürdiger Männer machen es wahrscheinlich, dass er es war, der damals Maupertuis die erste Idee zu der in Lappland ausgeführten Gradmessung gab [...] Das jene Idee zuerst dem Celsius angehört hat, wird uns so wahrscheinlicher wenn man bedenkt, dass Maupertuis als ein damals sehr junger Mann, der mit praktischen Operationen gar wenig bekannt war [...]”

Clearly, Celsius' arrival could not have been more timely. De Maupertuis was to head the northern expedition, and having a Swedish professor with experience of measuring angles and meridians on his team would simplify things immensely. Celsius was asked to commission a zenith sector from Graham in London, one of the best instrument makers of the time. In April 1736 he then travelled to Dunkerque, where he joined the French expedition to Sweden.

The expedition to northern Sweden has been discussed extensively in earlier literature. Detailed notes of the expedition were written both by De Maupertuis (1738) himself, as well as by Regnaud Outhier (1744), a priest who was specifically asked by the Académie des Sciences to join the expedition as its correspondent. A more modern summary was published by Tobé (1986). In summary, the expedition travelled to Torneå in the summer of 1736, where they first measured a network of triangles along the north-south oriented Torne river. Then, during winter, the difference in latitude was established from observations with the zenith sector in the northern and southern end of the network. A baseline was determined on the frozen bed of the Torne river using wooden rods. The expedition members returned to Paris in the late summer of 1737, where De Maupertuis presented his results in support for an oblate earth to the Académie des Sciences.

From a historical perspective, it is interesting to take a closer look at Celsius' contribution to this expedition. His participation had profound effects on the future of astronomy in Uppsala, especially since it generated intense and amicable contacts with some of the leading astronomers across Europe. However, Celsius is not mentioned very often in the publications by De Maupertuis and Outhier, and some have even taken this as an indication that Celsius' contributions was minor (see Todhunter 1873, p. 93). However, the expedition was primarily a French expedition, and it was important for both De Maupertuis and Outhier to show it as such. However, quoting from De Maupertuis (1738, pages XXII and 6):

“La plupart de ces observations sont dûes à la vigilance de M. le Monnier & de M. Celsius, qui dans un pays où le Ciel se refuse beaucoup aux observations, étoient continuellement attentifs à n’en laisser échapper aucune de celles qui étoient possibles.”

“[...] M. Celsius célèbre Professeur d’Astronomie à Upsal, qui a assisté à toutes nos opérations, [...] on verroit que l’ouvrage que nous entreprenions, tout difficile qu’il peut paroître, étoit facile à exécuter avec eux.”

It is clear from the above quotes that Celsius was actively involved in the measurements. Celsius was also awarded a pension by the French king of 1000 livres per year, which is exactly on the same level as other members of the expedition. Furthermore, De Maupertuis reveals in his letters to his former teacher Bernoulli¹ that he keeps Celsius (and Le Monnier) in high esteem:

“[...] nous avons encor deux Astronomes de Profession M.^{rs} Monnier et Celsius, qui, je crois, ne cedent à personne du monde pour l’observation; et je n’ai pas trouvé que ceux qui avoient moins fait qu’eux, leur principal objet des pratiques de l’Astronomie, se soient trop écartez de ce que ces M.^{rs} trouvoient dans chaque observation.”

Celsius himself was also deeply engaged in the question of the shape of the Earth. In 1736, while still in Pello, just north of Torneå, Celsius published a small (Swedish) monograph indicating the importance of knowing the shape of the Earth, *‘Ett bref till N.N. om jordens figur’*. Also later, after the De Maupertuis’ publication of their results supporting an oblate Earth, Celsius actively took part in the international debate, firmly taking position against Cassini and his followers, who (relatively unfounded) accused the northern expedition of errors and mistakes, and putting the credibility of the results in question. Celsius’ monograph from 1738 *‘De Observationibus Pro Figura Telluris Determinanda’* systematically rebuts these allegations. In addition Celsius published in 1739 an article on the thermal expansion of wooden rods, *‘Om Trästångers utvidgande i kiöld’*, finding that this leaves the conclusions of the northern expedition unchanged.

Celsius’ participation in the expedition of De Maupertuis gave him national and international recognition. Once he, after more than 5 years of travelling, returned to his teaching duties in Uppsala, he immediately started to work for the construction of an astronomical observatory. The basis of his instrument collection consisted of the instruments he acquired during his voyage through Europe. He also received as a gift from his French colleagues a small quadrant that was used during the expedition. In order to bring his instrument collection up to ‘modern’ standards, he ordered a zenith sector and pendulum clock from Graham (and Bradley) in London, who earlier prepared the zenith sector used during the expedition, as well as a transit instrument from Ekström in Stockholm. The university also helped Celsius by releasing funds for acquiring a suitable building in the centre of Uppsala, and converting it to an astronomical observatory. In 1741, Celsius relocated his astronomical observations to the newly finished observatory.

¹ Letter from de Maupertuis to Johann I Bernoulli, dated 8 September 1737, transcription available from the library of the University of Basel:
<http://www.ub.unibas.ch/bernoulli/index.php/Briefinventar>

Celsius now became a well-established professor in astronomy, with a university-owned state-of-the-art observatory². He continued working on a number of fundamental questions, such as the timing of eclipses of the moons of Jupiter in order to address the problem of longitude, constructing a temperature scale, variations in the Earth's magnetic field, and the observations of comets. Much of this research was conducted in collaboration with his contacts in Paris. For example, he frequently exchanged letters with De l'Isle, and Le Monnier. His relation with de Maupertuis also seems to have been good. Although no letters survive from after 1738, de Maupertuis sent dedicated copies of his books to Celsius in 1741.

Unfortunately, Celsius only worked a few years in his new observatory. He died in 1744, at an age of only 43 years. However, he provided Uppsala with a stable base for astronomy, something that his predecessors had failed to accomplish. This was for a major part possible through Celsius' (accidental?) participation in De Maupertuis' meridian arc expedition. Celsius' dedicated assistant, Olof Hjorter, continued Celsius' observations as *Observator Regius*. He also inherited Celsius' extensive library, many books of which can be traced back to Anders Spole, and some to even earlier times. Hjorter made the astronomical observatory in Uppsala completely independent of personal investments by donating this excellent library to the observatory in 1746, a collection that survives up to today.

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² However, after Celsius' death, it would become clear that the foundation of the observatory was unstable, and therefore not suitable for astronomical observations. Also, Uppsala cathedral renders a major part of the southern sky inaccessible. A new observatory located outside the city centre was inaugurated in 1853.