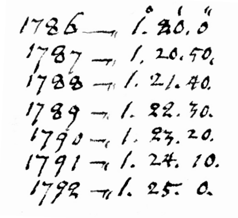
MARGINAL NOTES ► on precession in the Senex chart.



Astronomical cartography

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The full title of a zodiac chart that was published in 1718 by the British cartographer John Senex is *Zodiacus stellatus fixas omnes hactenus cognitas, ad quas lunae appulsus ullibi terrarum telescopio observari poterunt, complexus*; in English: "Zodiac chart of all known fixed stars to which the Moon's approach can be observed by telescope somewhere on Earth". In its time, this chart had a good reputation and was frequently used by both astronomers and navigators. One copy of the Senex chart is preserved in the archive of Pehr Wilhelm Wargentin, for many years the Academy's astronomer and permanent secretary.

The chart was produced as three large printed sheets, with three narrow charts on each. Some of the preserved copies have been coloured, but it was normally used in its original form. To make handling them at the telescope easier, the charts could, as in this case, be cut out and bound together to make an atlas with nine sheets. The charts are constructed with a cylindrical projection and cover an area of eight degrees on each side of the ecliptic. Senex had taken the information, i.e. the positions of all the stars, from an unofficial copy of John Flamsteed's star catalogue (posthumously printed in 1725), so the atlas was of the highest astronomical standard.

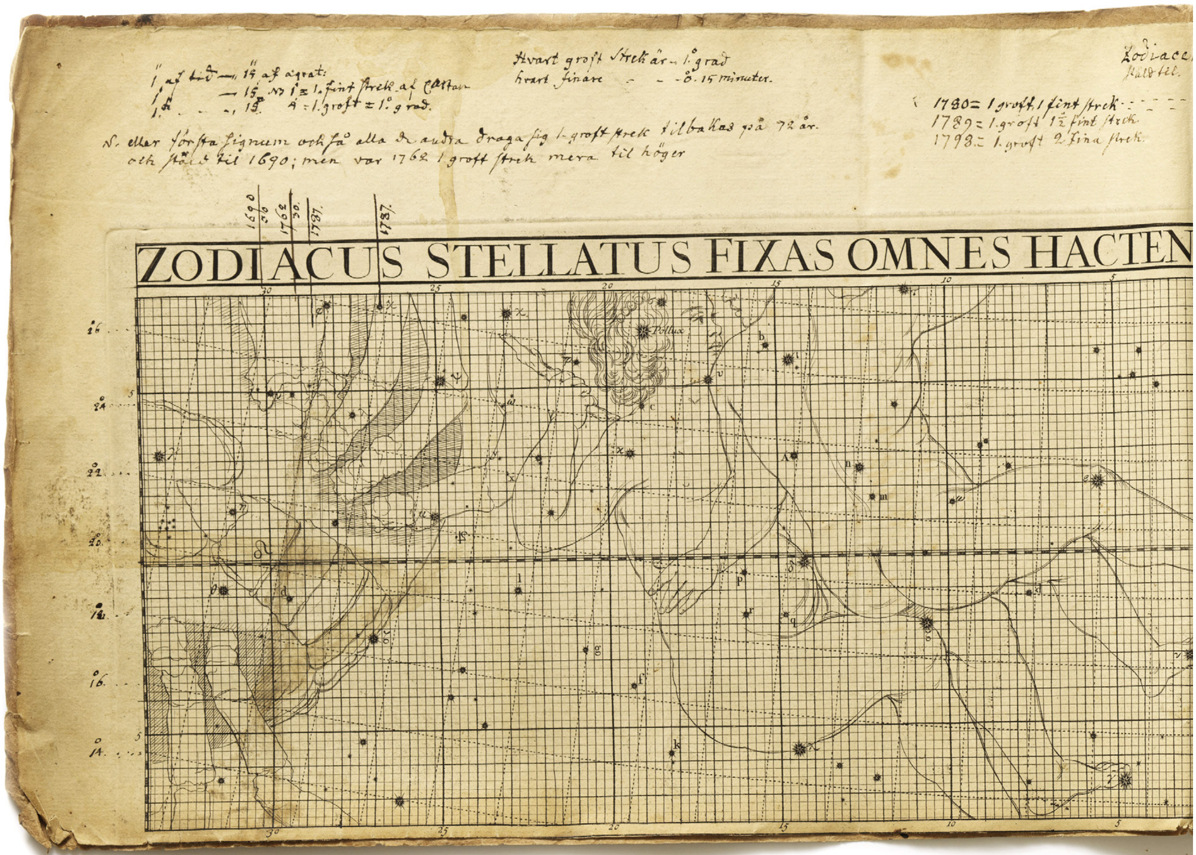
But why a chart that only covers a narrow band across the heavens? The answer says something about 18th-century astronomy. Apart from comets, all the objects that were then of interest to astronomers – the Sun, Moon and planets – moved in this area. The Sun's path across the heavens defines the ecliptic; the planets deviate a few degrees here or there, but in principle follow the same course and, if it weren't for the Moon that moves somewhat further away, the chart could have been even narrower. Of course, this is due to the solar system being disc-shaped; we therefore see all the planets close to the same great circle in the heavens: the ecliptic.

Star charts are primarily used as an aid for orientation in the heavens, making it possible, for example, to identify the constellation in which Jupiter is currently found. Still, a trained astronomer hardly needed this type of information, nor is that how the Senex chart was intended to be used. The zodiac chart was a graphical representation of a large amount of astronomical data, specifically the magnitudes and celestial coordinates for the stars in Flamsteed's catalogue, and it was these data that astronomers needed to access when navigating the heavens.

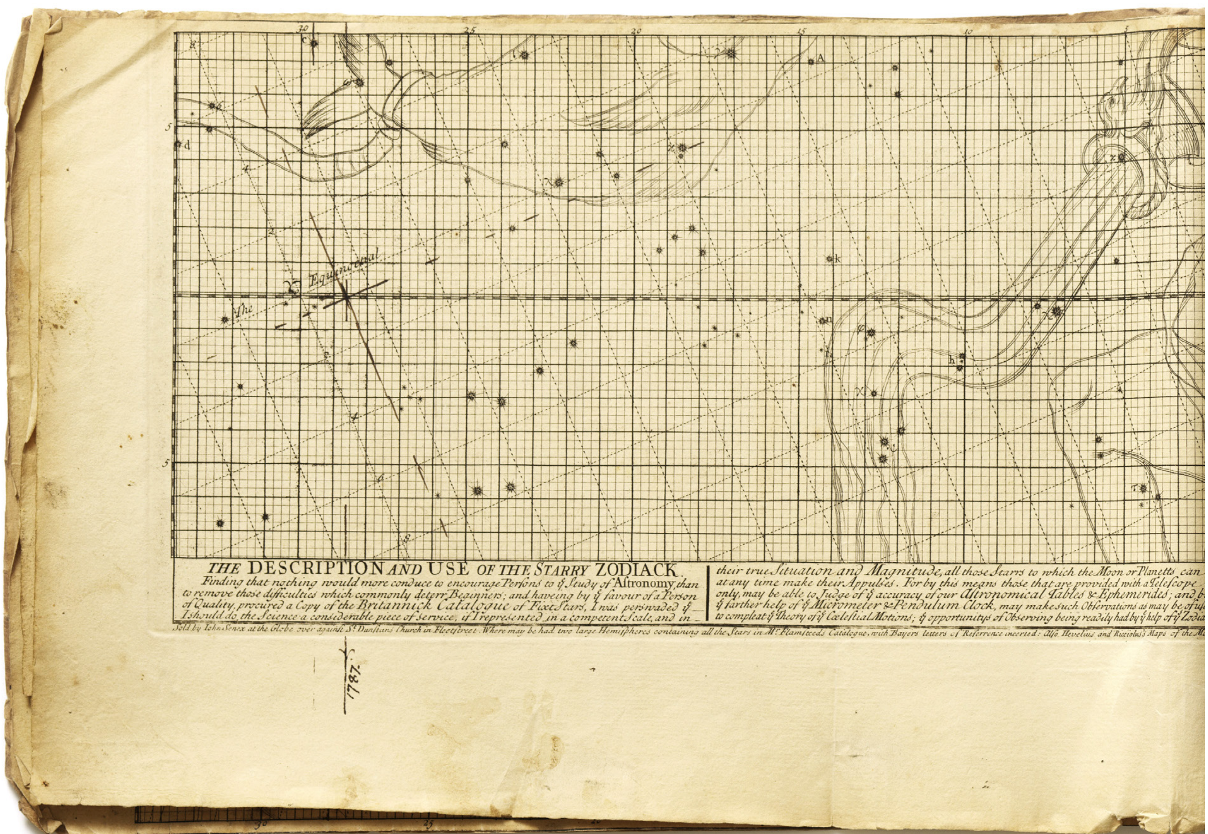
However, this information was not immediately available, something dealt with in the many notes filling the Wargentin chart's margins. Some of these are simply about how the chart should be read – "[t]he angled lines are declinations and right ascensions. The straight are Longit. and Latitudes" – but the majority and the most important ones relate to precession. When reading star positions from the chart, one must consider that because of the gradual shift in the Earth's axis – it makes a full rotation about every 26,000 years – the stars' coordinates thus make the equivalent shift. This means that celestial coordinates are not applicable forever, but are defined in relation to a specific year or, in astronomical terminology, a particular epoch. To deal with this, there are several different handwritten tables in the margin of the chart (one example can be found in the margin of the top map on the next page). The celestial coordinates used by Senex were reduced to epoch 1690, but after 72 years, i.e. 1762, the coordinates had shifted one degree in right ascension. For example, to obtain coordinates for a star that was observed in 1790, one first read the position from the chart and then subtracted 1° 23' 20'' from the value in right ascension. The next question is why these coordinates were needed but, before I answer this, the chart's provenance must be discussed.

As stated above, the chart is in Wargentin's archive. It is not impossible that the astronomer was the chart's first owner, but he was not the person who made all the notes. Instead, the handwriting in most of them is that of Anders Hellant, long-time friend of Wargentin and, among other things, deputy district judge and district court judge in Torneå. Hellant, who also signed the chart with his name on the back of one of the sheets, received his astronomical education in Uppsala under Anders Celsius. His local knowledge and great language skills had won him a place on Pierre de Maupertuis' French-Swedish geodesic expedition to Lapland in 1736–37. The skills in

SHEETS FROM THE SENEX CHART. The upper image shows Gemini and Taurus, the lower one shows Aquarius and Capricornus. ►



Hvart groft Strek är 1. grad
hvart finare - - 0. 15 minuter.
1780 = 1 groft 1 fint streck
1789 = 1. groft 1½ fint streck
1798 = 1. groft 2 fina streck
1690
1762
1787.
1787.
ZODIACUS STELLATUS FIXAS OMNES HACTEN
Pollux



THE DESCRIPTION AND USE OF THE STARRY ZODIACK.
Finding that nothing would more conduce to encourage Persons to ye Study of Astronomy, than to remove those difficulties which commonly deterr Beginners; and haveing by ye favour of a Person of Quality, procured a Copy of the Britannick Catalogue of Fixt Stars, I was persuaded ye I should do the Science a considerable piece of service, if I represented in a competent Scale, and in
their true Situation and Magnitude, all those Starrs to which the Moon or Planetts can at any time make their Appulses. For by this means those that are provided with a Telescope only, may be able to Judge of ye accuracy of our Astronomical Tables & Ephemerides; and b ye farther help of ye Micrometer & Pendulum Clock, may make such Observations as may be of us to compleat ye Theory of ye Cœlestial Motions; ye opportunitys of Observing being readily had by ye help of ye Zodia
Sold by John Senex at the Globe over against St. Dunstans Church in Fleetstreet. Where may be had two large Hemispheres containing all the Stars in Mr. Flamsteeds Catalogue, with Bayers letters of Reference incerted: Also Hevelius and Ricciolus's Maps of the M
1787.

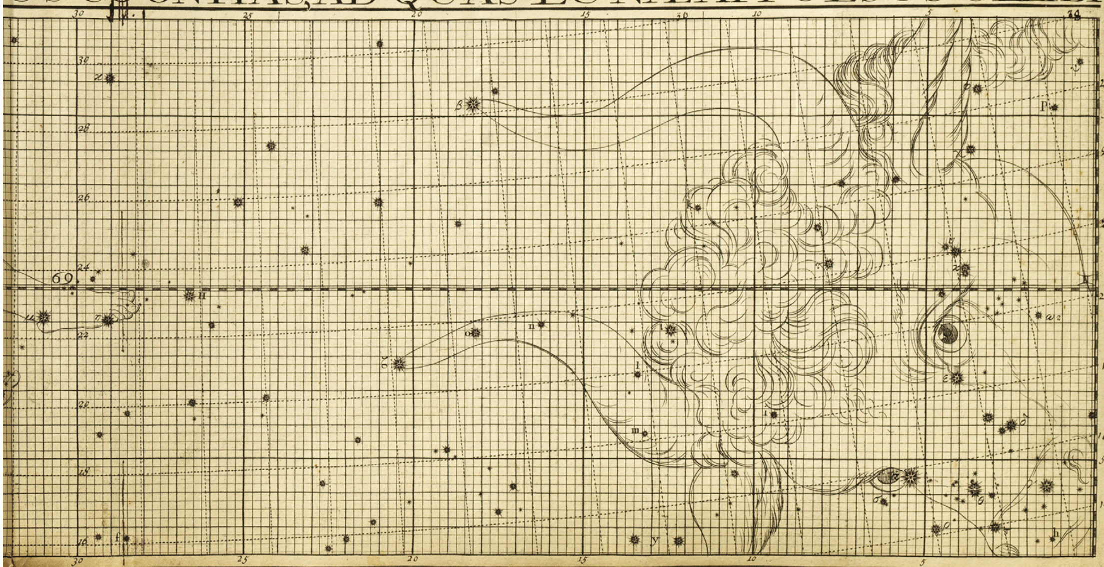
(års begynnelse)
n – 1690: 1 grad subtr: för 72 år: och 15 minut: för 18 år

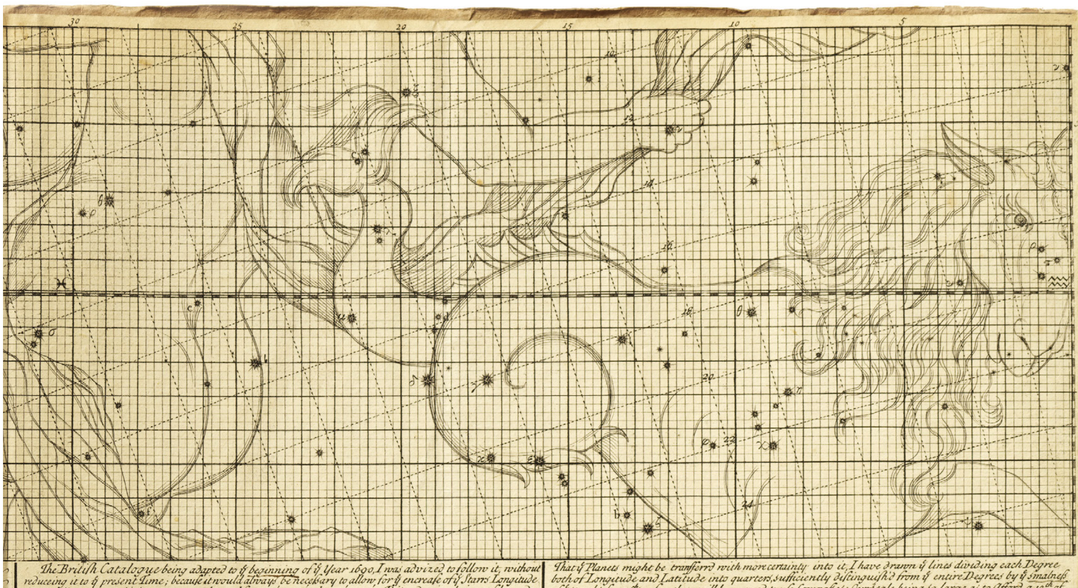
1762 – 1. grad.	1: år – 0: 50.	1786 – 1. 20. 0	1793 – 1. 25. 50	D på en dag – 0. 13. 10. 33.	♄ – 0. 2. 1
1780 – 1. 15. 0	2 – 1. 40.	1787 – 1. 20. 50.	1794 – 1. 26. 40.	3. dag – 1. 9. 31. 45.	♃ – 0. 4. 59.
1782 – 1. 16. 40.	3 – 2. 30.	1788 – 1. 21. 40.	1795 – 1. 27. 30.		♂ – 0. 31. 27.
1783. 1. 17. 30.	4 – 3. 20	1789 – 1. 22. 30.	1796 – 1. 28. 20.		o. ☉ – 0. 59. 8.
1784 – 1. 18. 20	5 – 4. 10	1790 – 1. 23. 20.	1797 – 1. 29. 10		♀ – 1. 36. 8.
1785 – 1. 19. 10.	6 – 5. 0.	1791 – 1. 24. 10.	1798 – 1. 30. 0 = 1½ streck:		☿ – 4. 5. 33.
1786 – 1. 20. 0.	12 – 10. 0	1792 – 1. 25. 0.			
	24 – 20. 0				
	36 – 30. 0.				
	72 – 1. 0. 0				

Planeten hyfunne 0. 1. 30 dage på et år — 4. 5. 0.

☉ och ☽ Diameter = ½ grad = 2 fina strek.

US COGNITAS, AD QUAS LUNÆ APPULSUS ULLIBI





The British Catalogue being adapted to y^e beginning of y^e Year 1690, I was advized to follow it, without reduceing it to y^e present Time; because it would always be necessary to allow for y^e encrease of y^e Starrs Longitude in succeding Years, and it is no more work to substract 30 or 40 than 10 or 20: This reduction being easily made, by substracting 15 min: for every 18 Years lapsed since 1690, from y^e Place of y^e Moon or Planet found in the Ephemerides, when you would compare them with y^e Starrs places in the Zodiack.

That y^e Planets might be transferr'd with more certainty into it, I have drawn y^e lines dividing each Degree both of Longitude and Latitude into quarters, sufficiently distinguish'd from y^e entire Degrees by y^e smalness of y^e stroaks, for w^{ch} reason there will be no need to use Compasses: Our Scale being so large as to Afford a 10^{th} of an Inch to each quarter of a Degree. Thus for Example, if you desire to see how y^e 3 Superiour Planets are situated among y^e fixt Starrs y^e 1^{st} of Aprill 1718, Wee find by y^e Ephemerides of M^r G. Parker (which are computed from Astrono-

…on; and M^r Whistons Solar System with the Paths of the Comets &c.

1. N. Ställd efter British Catalogue til 1690. års begynnelse.
2. N. 15 minuter för hwart 18 år subtractio = 5' på 6 år.
0. 30 för 36. år
1. 0. för 72 år = 1762:
1. 15 för +18 — = 1780. etc.

☽ Diameter på denna Zodiac

1. minut på 1,2 år = 14 månar ifrån stiernans Longitude subtrah:
2 — 2,4
3 — 3,6 eller Planetens eller månans, Come-
4 — 4,8 tens, får man des ställe på Chartan.
5 — 6,0

En grad på denna Zodiac är ungefär fyratiyonde delen af en Engelsk tum: och då är Angelska foten delad i 12 tum;
15 minuter, el. ¼ grad, är en tjonde del af en Engelsk tum.
2½ grad eller
10 linier på denna scala är ungefär en Engelsk tum, efter 12 tum på foten
det är 5 el. 20 linier på scalan är 2 tum Engelska.
och som denna delning brukas för Engelsk decimal tum: a 12 tum på en fot.

geodesy he obtained there were put to use by Sweden's Border Commission at the end of the 1740s, when Hellant was commissioned to measure the locations of various places in Tornedalen. After these efforts, other duties called and thereafter he dedicated himself to astronomy as a kind of amateur. It was at this later stage that Hellant acquired the chart. If we return for a moment to the above table, we can see that the annual tabulation of the precession starts in 1780, which was probably the year Hellant began using it.

How the chart then came to be in Wargentin's archive is unclear, but we know that in his twilight years Hellant bequeathed his books and astronomical notes to the Academy of Sciences. The "12 heavenly charts" that the estate inventory mentions were probably included. Hellant died in 1789, six years after Wargentin, and the Senex chart was presumably moved to Stockholm when his estate was settled.

Hellant's notes fill five whole boxes in the archive. His handwriting is fairly difficult to read and I have only succeeded in finding a few, undated, references to the zodiac chart. None of these say anything about how it was used. Nor is there anything in any of his published works that can shed light on the matter.

To find examples, we must instead turn to his colleague in Stockholm. It is obvious from Wargentin's observation journal that he used the chart frequently, particularly in the 1750s. Of course, it is possible that he had his own copy, but he could also have been the chart's first owner and then given it to Hellant. We know that Hellant's home, including his astronomical equipment, was destroyed in a fire in 1762, and that at a later stage Wargentin helped him to recreate his observatory. A preserved inventory from 1775 shows that Hellant had borrowed a telescope and other equipment from Wargentin, and perhaps he also received the map at this time.

As the Academy's astronomer, Wargentin was a dedicated observational astronomer, as testified to by meticulously kept observation journals. Through them, one can follow astronomical work at the observatory. The Senex chart particularly appears in the notes in the early 1750s. At that time Wargentin was, like Hellant and most of the world's astronomers, occupied with the question of longitude. How could a location's geographical coordinates be determined with the greatest possible precision? Latitude was comparatively straightforward and could be easily calculated using a series of measurements of the Sun's or a star's height above the horizon. Longitude was considerably more complicated. Before the modern chronometer finally solved the problem, longitude was determined by several geographically separated observers clocking a well-defined astronomical event – the difference in longitude followed by the difference in the local time of the event.

For example: on 12 March 1752, Wargentin's observations started at lunchtime, when he observed the Sun's transit through the meridian (which, per definition, occurs at noon local solar time). He found that the clock in the "room" was 4 minutes and 35 seconds wrong, and that the clock in the "chamber" was only out by 16 seconds. Once the clocks were adjusted, he was ready for the night's exercises. First, he observed the Moon's transit through the meridian and measured its diameter to 32.45 minutes. Then he continued to follow the Moon:

> [T]he following night *arctissmus transitus lunae* [very close transit of the Moon] was observed, past the star f geminorum, that Senexe's schema has placed under longit. 19° 1/3 in Cancer, with 3° 1/4 southerly latitude. The moon's *re vera* [real] North or upper edge touched this star so closely that it was by barely a hair's breadth that she was not occulted, and I waited for many minutes to see that there would not be an occultation from this, but she was always visible, though at the end so weakly when she was below the lit area of the Moon, that she could be seen with the greatest effort and then completely in under the moon's light: So that if I had not known this was a star, I had surely believed her to be a small raised mountain top on the moon itself, like one that was right beside her. The actual Conjunction appeared to be when the clock in the chamber showed 11.57'.30'' at passage, correct time 11.57.26.

So, this is an example of how the chart was used. At the telescope and using "Senexe's schema", Wargentin unequivocally states which star is involved – f Geminorum, or HD 59686 in modern terminology. While the telescope and clock were essential for following and determining the time of the events, the chart was necessary for locating them in the heavens and thus making the observation mobile. If any other astronomer were to determine the time of the same transit, it would be possible to calculate the difference in longitude between the observatories.

This example also explains why the title of the Senex chart talks of "known fixed stars to which the Moon's approach can be observed by telescope". As the Moon regularly occults (eclipses) or, as in this case, passes various fixed stars, it offers a continual array of very distinct astronomical occurrences which, when correctly handled, allow astronomers to order our world. This naturally required a certain amount of international organisation. For example, in 1751 both Wargentin and Hellant had aided the French astronomer Nicolas Louis de la Caille, when he organised a project with astronomers from Sweden, France and South Africa, among others, who observed the Moon's passage in order to position various towns on the map. However, this project had been completed by the time Wargentin made his observation of the grazing occultation and, from what I can determine, it has not made an impression in the annals of science.

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The history of star maps, including Senex's zodiac chart, is discussed in Nick Kanas' *Star Maps: History, Artistry, and Cartography* (Chichester, 2007). Biographies of Wargentin and Hellant are found in Nils Nordenmark's *Pehr Wilhelm Wargentin: Kungl. Vetenskapsakademiens sekreterare och astronom 1749–1783* (Uppsala, 1939) and Erik Tobé's *Anders Hellant: En krönika om sjuttonhundratalets märkligaste tornedaling* (Luleå, 1991) and an essay in Sten Lindroth's *Fru lusta och fru dygd: Studier och porträtt* (Stockholm, 1957). The history of geodesy is depicted in detail in Sven Widmalm's *Mellan kartan och verkligheten: Geodesi och kartläggning, 1695–1860* (Uppsala, 1990). All the named archived papers are housed at the Center for History of Science, the Royal Swedish Academy of Sciences, Stockholm: the relevant copy of the Senex chart is preserved in Pehr Wilhelm Wargentin's archive; the inventory of Hellant's estate is in Anders Hellant's archive (papers regarding Hellant's bequest of his estate to the Royal Swedish Academy of Sciences); Wargentin's inventory "Följande instrumenter finnas på Observatorium i Stockholm, Kongl. Vetenskaps Akademien tillhöriga" in Sekreteraren's archive (documents regarding the Academy's observatory); "Pehr Wilhelm Wargentins astronomiska observationer 1749–1756" in Pehr Wilhelm Wargentin's archive; and finally the discussion of La Caille's project in *Kungl. Vetenskapsakademiens dagböcker för åren 1742–1751*, 26 January 1751, Section 12.