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A HIDDEN VOLVELLE IN PETRUS APIANUS' *ASTRONOMICUM CAESAREUM*

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Abstract: We analyse a volvelle hidden under the top disks of one of the volvelles in Petrus Apianus' *Astronomicum Caesareum*. It turns out that this volvelle, completed with an overlay disk with the ecliptic, can be used to compute the rising and setting signs in the zodiac given the latitude of a locality, the longitude of the Sun, and the hour of the day. It is based on a standard stereographic projection normally used for astrolabes but the volvelle instead projects a set of curves for different local horizons. This paper gives an analysis of the volvelle and an explanation of its use and working, and also makes some speculations on its background.

Keywords: Astronomicum Caesareum, volvelle, instrument, stereographic projection, sunrise, sunset.

1 INTRODUCTION

The magnificent work *Astronomicum Caesareum* (Apianus, 1540a) was published in 1540 by Petrus Apianus[1] and dedicated to the Holy Roman Emperor Charles V. Apianus worked as a Professor of Astronomy and Court Mathematician of Charles V in the university town of Ingolstadt in the south of Germany where he also set up a private printing shop. The book, which required about eight years to produce, is often said to be one of the most beautiful books in the world, but unfortunately it was published only three years before Nicolaus Copernicus' *De Revolutionibus Orbium Coelestium*, which would make the Ptolemaic geocentric world of the work obsolete.

The book contains more than thirty volvelles, or as Petrus Apianus called them, 'instruments', all with a background base (*mater*) to give the impression of an octagonal hanging astrolabe, some of them then having up to seven circular rotary disks stacked on top of the mater and rotating around different axes.[2] The volvelles would be used to compute astronomical quantities like planetary longitudes, latitudes and eclipse circumstances and also some astrological matter. In the accompanying Latin text, the workings of the volvelles are explained using examples related to Charles V and his brother Ferdinand II of Aragorn. Petrus Apianus also published a manual for his book in German for the laity (Apianus, 1540b) and in a recent commentary paper the mathematical theory behind these volvelles is explained (Gislén, 2018).

In 1967 the German company Edition Leipzig published a facsimile edition of the book: 750 numbered copies of which 200 were hand-coloured after the original in the State Library in Munich. Unfortunately, there were some errors in the facsimiles in the assignments of the disks to several of the volvelles as has been pointed out by Owen Gingerich (1971). One of these errors had the result of revealing a so far unanalysed volvelle by Petrus Apianus.[3] The volvelle G5, using Gingerich's (1997) notation, is a volvelle for determining the times of oppositions, conjunctions or eclipses of the Moon. It should have two rotary disks on top of the mater but these two disks were instead put on top of the volvelle for the Moon's longitude (FII) and in turn the disks of this volvelle were put on the volvelle for finding the equation of time (C). This caused the exposed mater of G5 to reveal an unexpected and intriguing pattern of lines that would normally be hidden from view due to the two covering disks (see Figures 1a and 1b). The Leipzig facsimile publishers used the original copy of *Astronomicum Caesareum* that once belonged to Tycho Brahe and which is now possessed by the Forschungs- und Landesbibliothek Gotha in Erfurt, Germany. It is clear that this original copy contained the hidden volvelle which was then included in the facsimiles by the copying procedure. The original copy at the University Library in Leiden also contains the hidden volvelle (Griffioen, 2022) (see Figure 2), and it seems very probable that it also appears in the other originals.

The line pattern on the volvelle and the ratio of the radii of the concentric rings strongly suggest that a stereographic projection has been used.

2 THE STEREOGRAPHIC PROJECTION

The stereographic projection is a method for mapping the celestial sphere into a two-dimensional plane with origins in antiquity as far back as the Greek astronomer Hipparchus BCE 180. In medieval times it was used for the construction of planispheric astrolabes (North, 1974), and in some cases also for the layout of the clock dials of medieval astronomical clocks (Gislén, 2020).

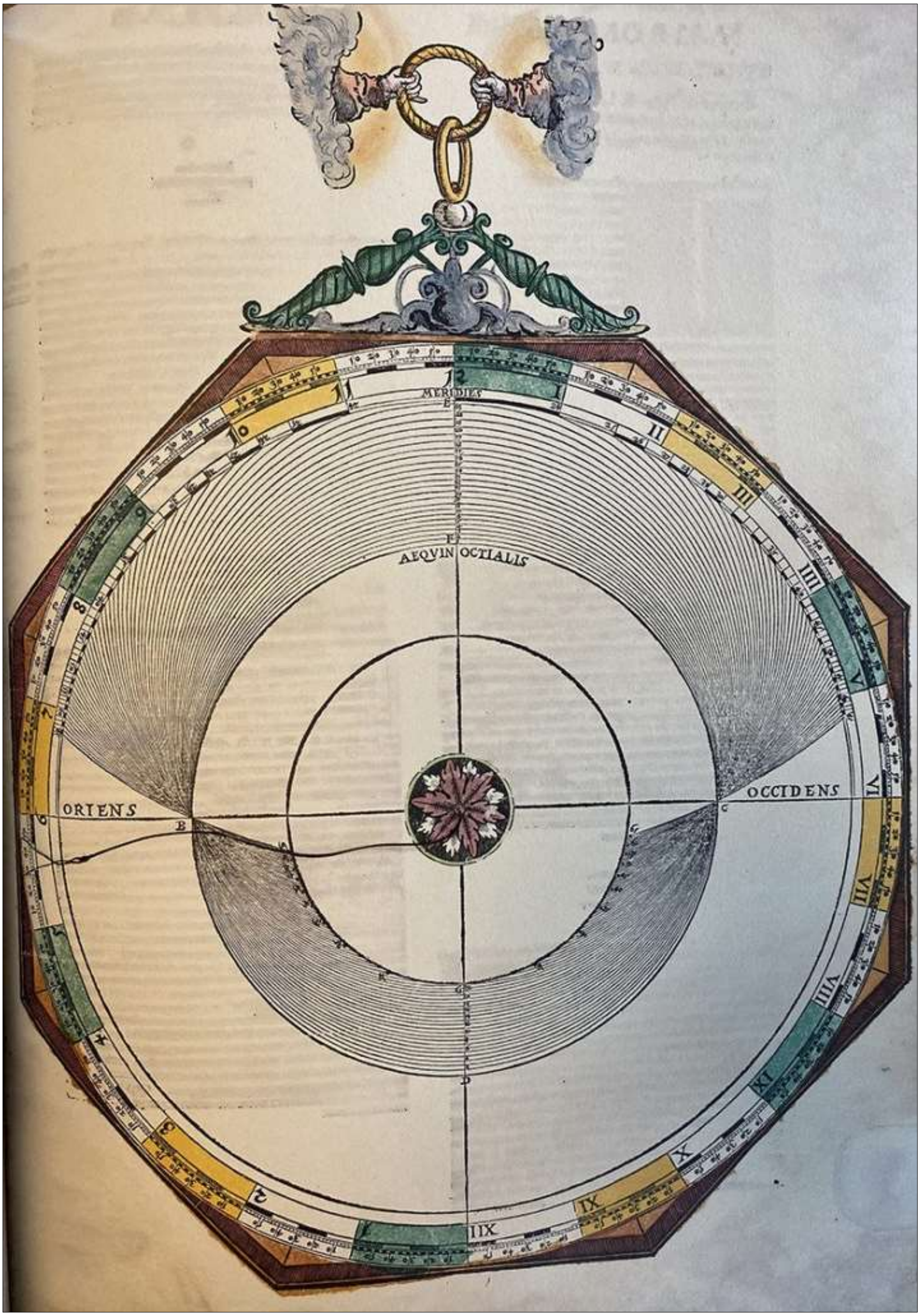

Figure 1a: The hidden volvelle of facsimile #369 (courtesy: Bas Griffioen).

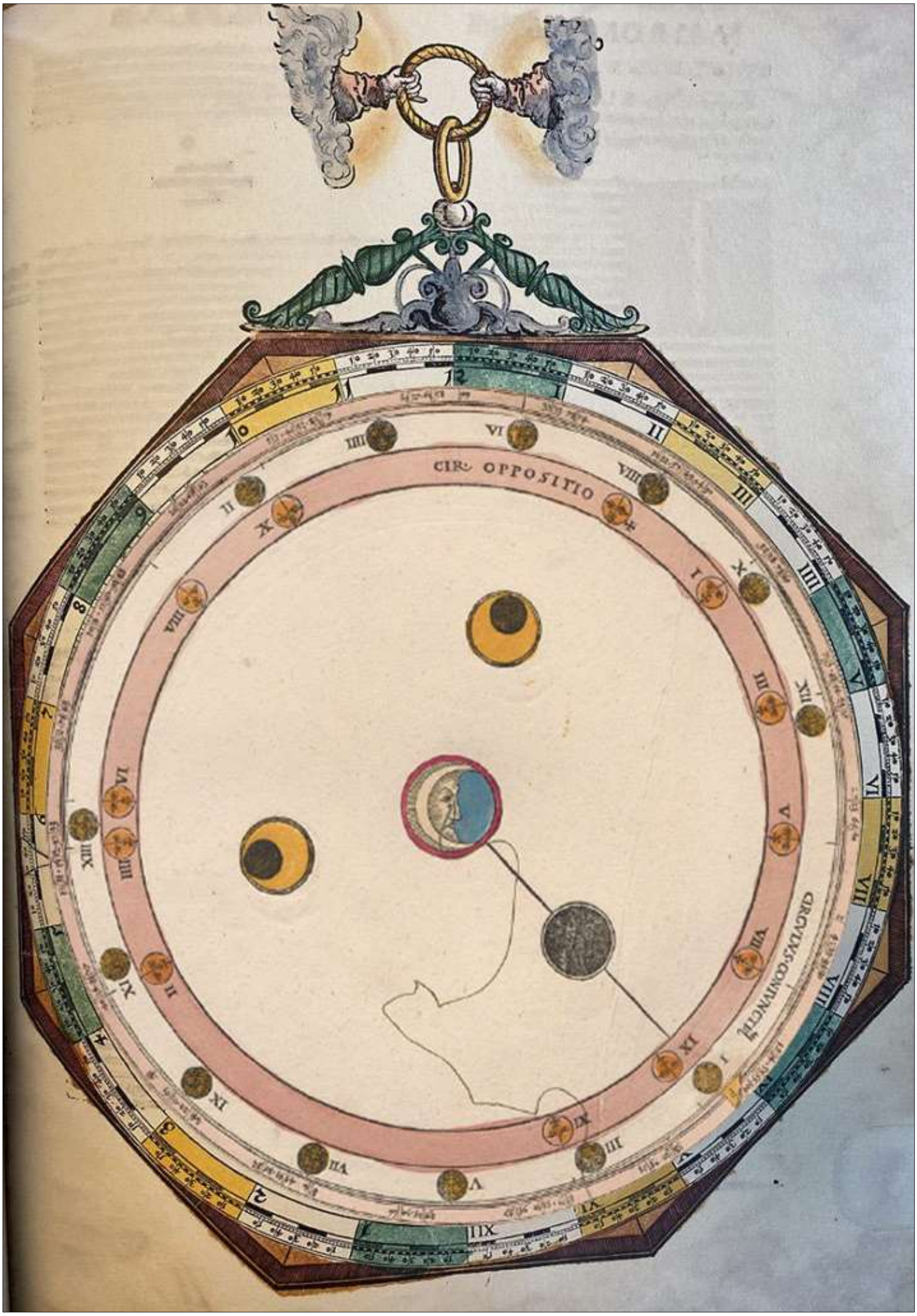

Figure 1b: The same volvelle with the two covering rotary disks (photograph: Lars Gislén).

Figure 2: The hidden volvelle in the Leiden original (Leiden University Libraries, Thysia 1625).

The projection follows a linear ray from one of the Celestial Poles to a point P on the celestial sphere. The ray hits the equatorial plane at the mapped point P' (see Figure 3a). In the projection used for the volvelle, the Celestial Pole chosen is the South Pole which is standard for the stereographic projection used for astrolabes. The projection maps all the points of the celestial sphere, one-to-one, except the Pole itself, into points on the equatorial plane. An important property of the projection is that circles on the celestial sphere are mapped into circles on the equatorial plane and that angles between curves on the celestial sphere are preserved in the mapping. Figure 3b illustrates the stereographic projection of parallel circles on the celestial sphere. They are mapped into circles in the equatorial plane, concentric with the centre of the celestial sphere. Each parallel circle is associated with its declination, the angle between a line from the centre of the celestial sphere to a point on the parallel circle and the equatorial plane and marked by δ in Figure 3b. Declinations are positive for parallel circles toward the North Celestial Pole, otherwise negative. Figure 3c shows the mapping of a local horizon where the angle between the zenith and the North Celestial Pole is the 90° complement of the latitude (co-latitude) of the locality, marked by ϕ in Figure 3c. The local horizon will be mapped as an off-centre circle in the equatorial plane.

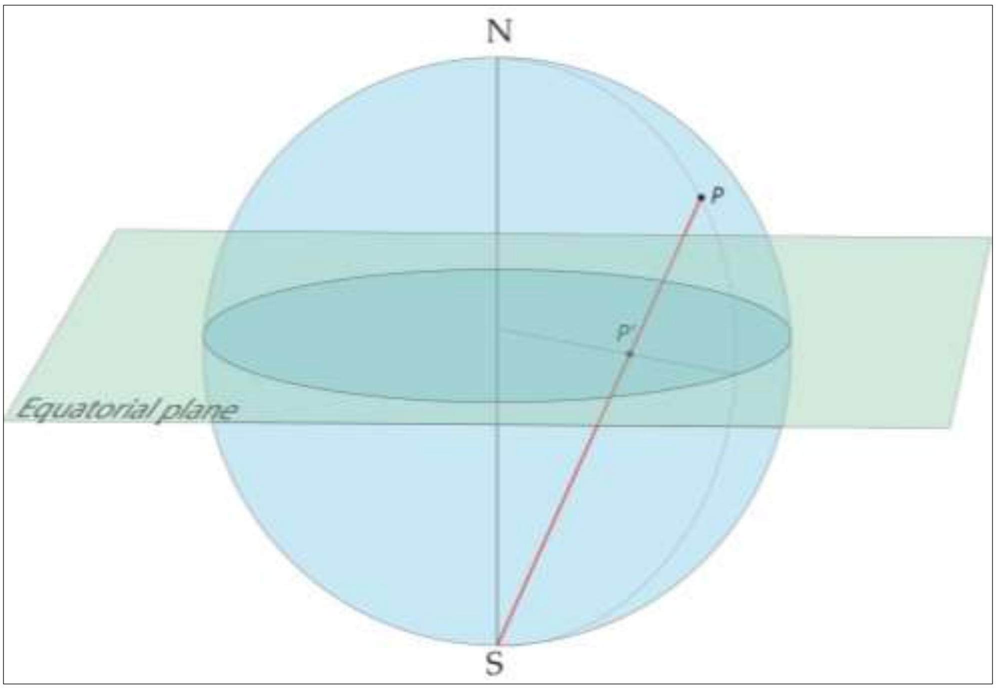

Figure 3a: Principle of stereographic projection (diagram: Lars Gislén).

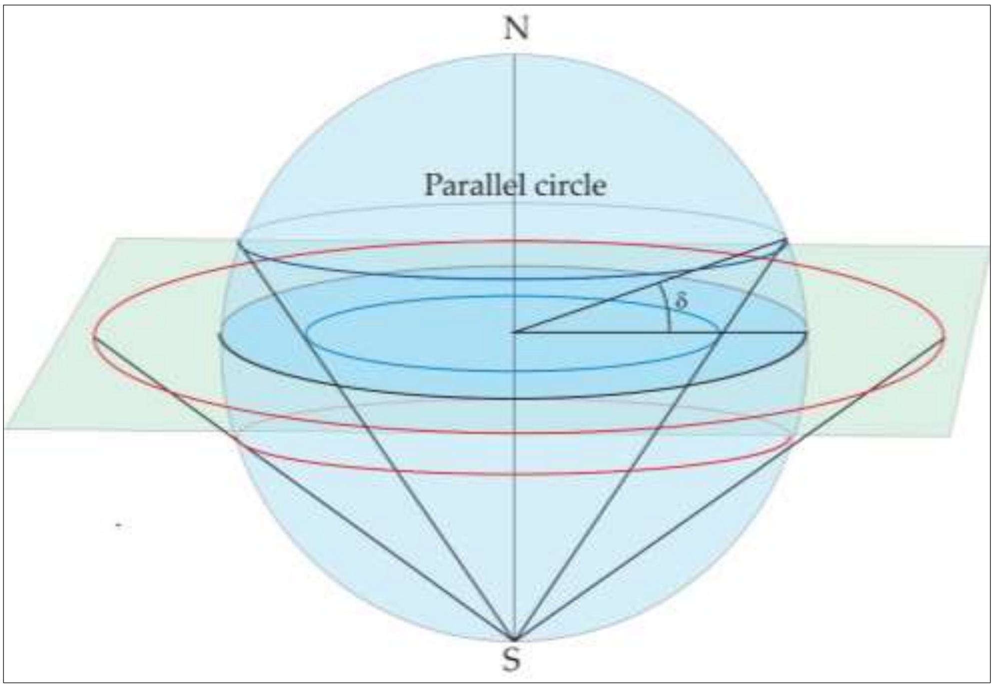

Figure 3b: Projection of parallel circles (diagram: Lars Gislén).

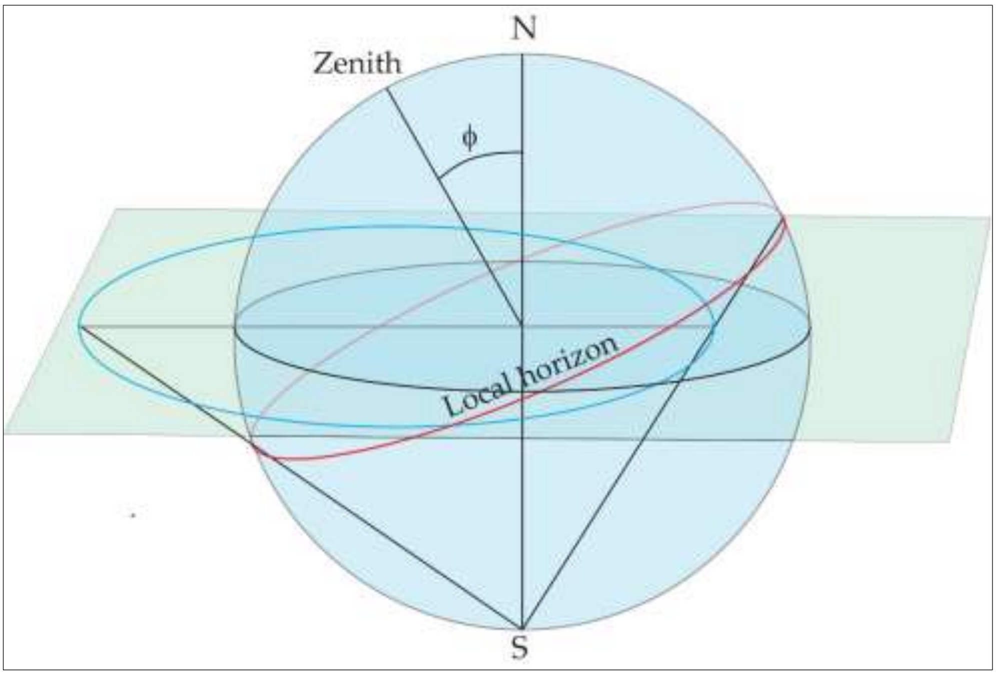

Figure 3c: Stereographic projection of the local horizon (diagram: Lars Gislén).

The Sun will, except for the very small daily change in declination, move around a fixed parallel circle during a specific day. At the equinoxes, the solar parallel circle and its projection lie in the equatorial plane and the declination of the Sun is zero. As the year progresses from the vernal equinox, about 21 March, the parallel circle of the Sun will move toward the North Celestial Pole and the declination of the Sun will increase until it reaches the Tropic of Cancer at the summer solstice about 21 June when the declination of the Sun is approximately 23½˚. The Sun will then return toward the equatorial plane, reaching it on the autumn equinox around 21 September. The Sun will then move toward the South Celestial Pole with negative declinations, reaching the parallel circle of the Tropic of Capricorn on the winter solstice about 21 December when its declination is –23½˚ and will then again return toward the equatorial plane. During the year the Sun will travel along a great circle on the celestial sphere, the ecliptic relative to the fixed stars. This circle will be projected as an off-centre circle, tangent to the concentric projections of the tropics.

When the projection of the ecliptic on the equatorial plane crosses the projected local horizon circle, the crossing point of the ecliptic will be in the local horizon and will be either the ascendant, rising sign, or descendant, setting sign, of the zodiac. This is the principle used for this volvelle. The big central part of the volvelle displays the equatorial plane. There is a smaller concentric circle at the centre which is the projection of the Tropic of Cancer and a larger concentric circle for the equator marked AEQVINOCTIALIS. The periphery of the central part of the volvelle corresponds to the projection of the Tropic of Capricorn. The points ORIENS (East) and OCCIDENS (West) on the volvelle relate to sunrise and sunset. There are a number of dense circles corresponding to projected local horizons for co-latitudes (0° to 65° or latitudes from 25° to 90° with one degree steps) presumably intended to cover most locations in the then known civilized world. I made a computer simulation plotting these latitude circles (see Figure 4). Placed on top of the volvelle there is an almost perfect fit illustrating the high quality of Petrus Apianus' work.

3 THE USE OF THE VOLVELLE

Fortunately, the working of the instrument is explained in another book by Apianus (1524b: 25–26; Van Ortroy, 1902: #21). It shows not only pictures with the same but less dense stereo-graphic pattern as for the instrument in *Astronomicum Caesareum* but also gives a complete instruction for its use. It turns out that the instrument was used to find the ascendant and descendant given the location of the Sun, the hour of the day, and a geographical latitude. Figure 5 shows that volvelle. The off-centre ecliptic can be rotated around the centre of the volvelle. The working of the volvelle is best illustrated by an example where we use the setting of the instrument in the figure. We assume that the geographical latitude is 40° N.

The user stretches thread from the centre of the instrument to the hour of the day, in this

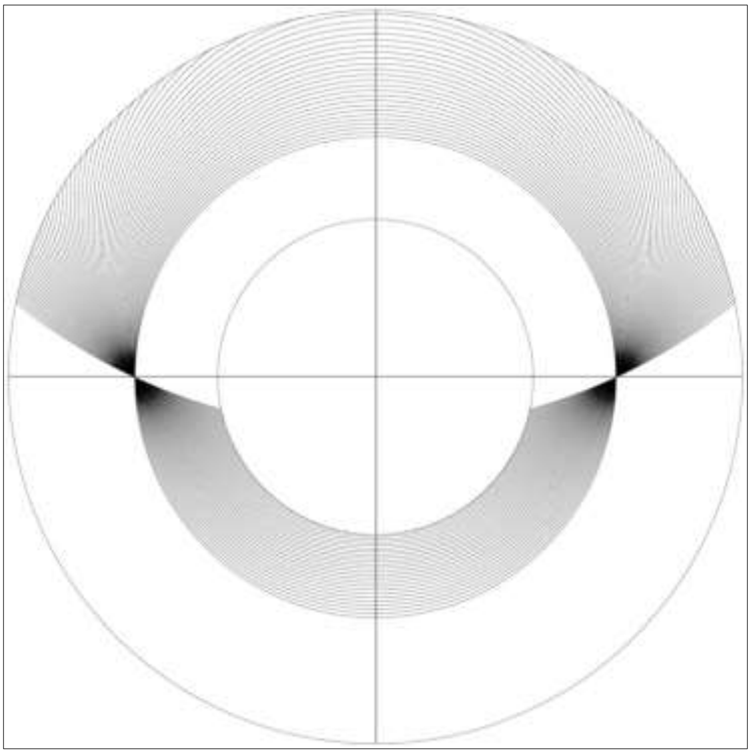

Figure 4: Computer simulation of the central part of the volvelle (diagram: Lars Gislén).

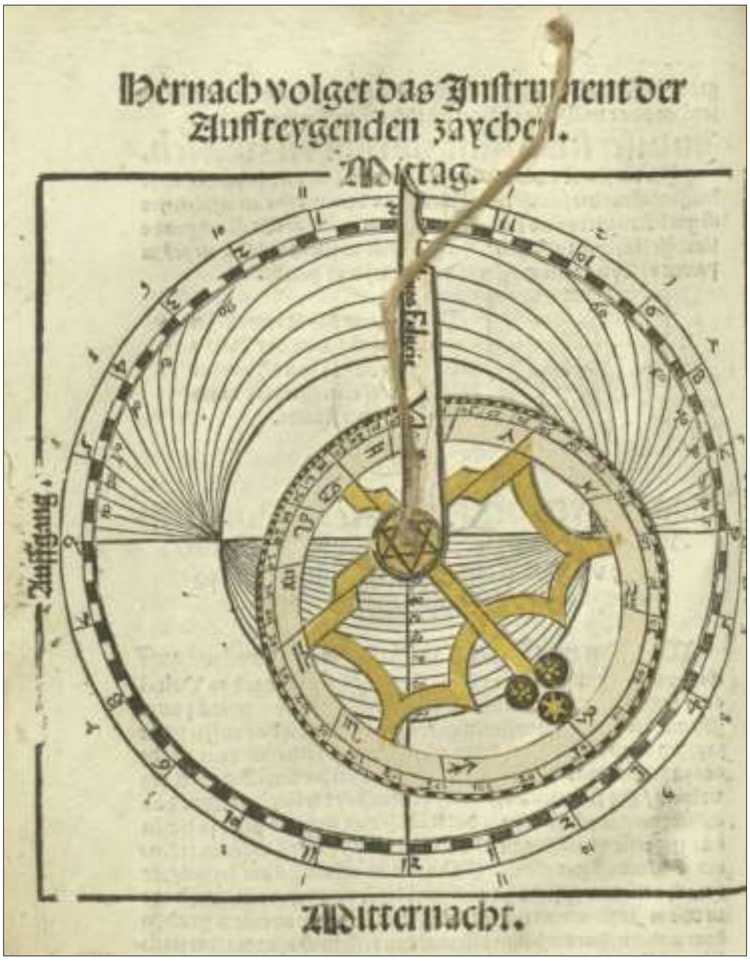

Figure 5: The volvelle in [Apianus, 1524], Yale University Library.

case 12 AM. The ecliptic is rotated until the longitude of the Sun, here Taurus 23°, is below the thread. The instrument is now set. Next, the user looks for where the ecliptic circle crosses the projected horizon circle that corresponds to the chosen latitude with the ascendant to the left and the descendant in the right part of the volvelle. In the example there will be such crossings for Leo 29° which is the ascendant and diametrically opposite the descendant Aquarius 29°. A modern calculation gives Leo 28.7° for the ascendant.

4 DISCUSSION

In order to operate the volvelle the user will need three quantities: the latitude of the location, the longitude of the Sun, and the hour of the day. The geographical latitude could be given simply in the form of a table like the one found in many versions of contemporary Alfonsine Tables. The longitude of the Sun could be calculated by a volvelle already present in *Astronomicum Caesareum*. The concepts of ascendant and descendant were mainly used by horoscope makers. To calculate their longitudes by hand is quite complicated and the volvelle would greatly simplify their work.

As a matter of saving work, Apianus reused some of the printing blocks for his volvelles. For example, eleven of the thirty-two volvelles have an identical zodiac mater. The volvelle G5 has a different mater where the peripheral time scale is divided into 24 hours, hours 1–12 written with Arabic numbers on the left side and with Roman numbers on the right side. For this volvelle Apianus could reuse a printing block with the same peripheral hour scale that he already had at hand but with the wrong central part. That part would anyhow be hidden by the two top disks and the procedure would save him the time, work, and cost of making a separate printing block. Considering the amount of computational and artistic work invested in the hidden volvelle it seems very probable that the volvelle was originally planned to be part of *Astronomicum Caesareum* but that for some reason it was deleted for the final edition. The early plan could also have included a latitude table. In fact, a similar stereographic pattern was reused in several editions of Apianus' *Cosmographicus Liber* (Apianus, 1524a), but there again hidden under a movable disk displaying a map of the world. In many extant editions the covering disks have been lost.

5 NOTES

1. Petrus Apianus (1495–1552) is also known as Peter Apian, Peter Bennewitz and Peter Bienewitz. In this paper I will only refer to him as Petrus Apianus.
2. Not all of the instruments in *Astronomicum Caesareum* have rotating disks. Although the word ‘volvelle’ suggests a rotating disk I have here used it as a generic term.
3. This hidden volvelle is certainly the one observed but not further investigated by Owen Gingerich (1994*:* 294): “For example, underneath one of the moving parts is an entirely irrelevant base of an astrolabe, the fossil of a plan that was undoubtedly abandoned ...”

6 ACKNOWLEDGEMENTS

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Lars retired in 1983, and since then his interests have focused on medieval European astronomy and on the astronomy and calendars of China, India and Southeast Asia. He has published more than 20 research papers in this field. He has also made public several spreadsheet tools implementing a number of astronomical models from Ptolemy to Kepler as well as computer tools for the calendars of India and Southeast Asia. He is a member of the IAU.