

MEDIEVAL ASTRONOMICAL CLOCKS IN THE BALTIC REGION AND THE MYSTERIOUS GOLDEN NUMBERS IN GDANSK

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Abstract: Large medieval clocks were built in a number of Hanseatic towns in the Baltic region from the end of the fourteenth century to the middle of the fifteenth century. Several factors contributed to their building: there was a need for public display of time in the rapidly growing medieval towns, the technique of constructing mechanical clocks became available with the invention of the verge escapement in Italy in the second half of the of the thirteenth century, and wealthy Hanseatic towns had the means to pay for their construction. The layout of the clock dial and calendar disk of a number of these clocks in the region is studied. There are two main types of clocks, an older one for clocks constructed around the beginning of the fourteenth century, and a second one for clocks constructed around the middle and end of this century. The older clocks are characterised by having a dial with a stereographic projection of the sky not used in the later clocks. Most clocks also have a calendar disk to display specific information about the days of the year like Sunday letters, golden numbers, and calendar date. The only original calendar disk extant is the one on the Saint Mary cathedral in Gdansk giving times of the mean New Moons for the years 1463 to 1538. The times indicate an origin in the Alfonsine Tables modified for the longitude of Nuremberg in Germany.

Keywords: Baltic region, astronomical clock, stereographic mapping, Sunday letter, golden number, Alfonsine Tables

1 INTRODUCTION

The construction of large astronomical clocks in several towns in the Baltic region began at the end of the fourteenth century and continued during the fifteenth century (Schukowski, 2006). There are two main reasons for this. Firstly, the art of constructing mechanical clocks was improved by the invention in Europe of the verge escapement (Cipolla, 2003; Mogensen, 2008) in the thirteenth century and resulted in the construction of large public tower clocks in European town squares, cathedrals, and monasteries in a movement starting in southern Europe in the middle of the fourteenth century and spreading to France, England,¹ to northern Germany and the Baltic region. An early example of such early clocks was the elaborate early astronomical clock in Strasbourg built in 1352 (Ungerer, 1949; Wählin, 1923: 26), but now destroyed. The accuracy of these first clocks was not impressive, they could be fast or slow by up to one hour a day and had to be corrected, sometimes twice a day (Cipolla, 2003), and it was consequently thought unnecessary to provide them with a minute hand. In spite of this, clocks with verge escapement were used in Europe until the seventeenth century when they were replaced by more accurate clocks with pendulum escapements and seconds precision.

Secondly, the clocks were a matter of money and prestige. The clocks were a kind of status symbol meant to display the affluence of the cities. Growing from a few North German towns in the late 1100s there was the

Hanseatic League, a commercial and defensive confederation of merchant guilds (Hammel-Kiesow, 2008). Merchant circles established the League to protect the guilds' economic interests and diplomatic privileges in their affiliated cities and countries, as well as their trade routes. The Hanseatic cities had their own legal system and operated their own armies for mutual protection and aid, and controlled most of the trade in the Baltic. They had offices in Bruges (Flanders), Bergen (Norway), London and many other major towns in Europe.

Figure 1 shows the extent of the Hanseatic League around 1400. The League became a powerful institution, for instance in 1368, the allied towns sacked Copenhagen and Helsingborg, forcing the Danish King Valdemar VI to grant the League 15% of the profits of the Danish trade. The towns in the Baltic region that were members of the League became very rich and could afford the great expense that was involved in the construction of large astronomical clocks, although not all Hanseatic towns could afford them.

In this paper I will study the physical layout of extant medieval astronomical clocks in towns in the Baltic region: Wismar, Rostock and Stralsund (in Germany), Gdansk/Danzig (Poland), the monastery of Doberan (Germany), and Lund (Sweden). The first four towns were important and wealthy Hanseatic towns on the coast of the southern Baltic. The Doberan Abbey, 15 kilometers west of Rostock, was an economic centre that became very wealthy. Lund, although not a Hanseatic town, was at the time



Figure 1: The extent of the Hanseatic League around 1400 is shown in green (after Andree, 1886: Plate 28)

the Archdiocese of Scandinavia and an important ecclesial power in the Baltic region. Figure 2 shows a map of the locations of these towns marked in red.

There is very little known about the builders of these clocks in the Baltic region. It is probable that the very similar clocks in Doberan, Stralsund, and Lund were built by Nikolaus Lilienfeld from Rostock of whom it is only known that he was a 'horologer' (Schukowski, 2008). The clocks in Gdansk and Rostock also exhibit great similarities and were built by Hans Düringer from Nuremberg, of whom only is known his year of death, which was 1477 (ibid.).

There were two types of clocks, an older type, Type I and a younger one, Type II. Figure 3 shows typical clocks of the two types: on the left is the older type, the clock in the Cathedral of Lund (Sweden) and to the right is the younger clock in the Church of Saint Mary, Rostock (Germany). At the top there is a clock dial, and at the bottom a calendar disk. The Lund clock has in the middle a set of automata that at special times performs a procession of the three Holy Kings before Virgin Mary. The clock in Rostock has a similar set of automata above the clock dial. The Rostock clock was then the largest clock in Europe with a total

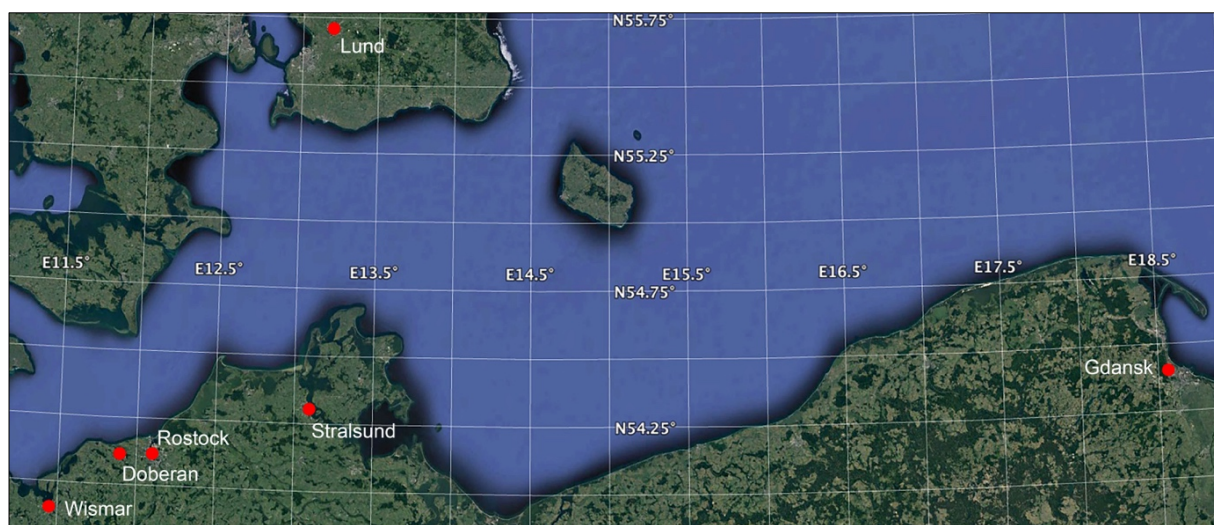


Figure 2: Location of medieval clocks in the Baltic region (after Google Earth; map modifications: Lars Gislén)

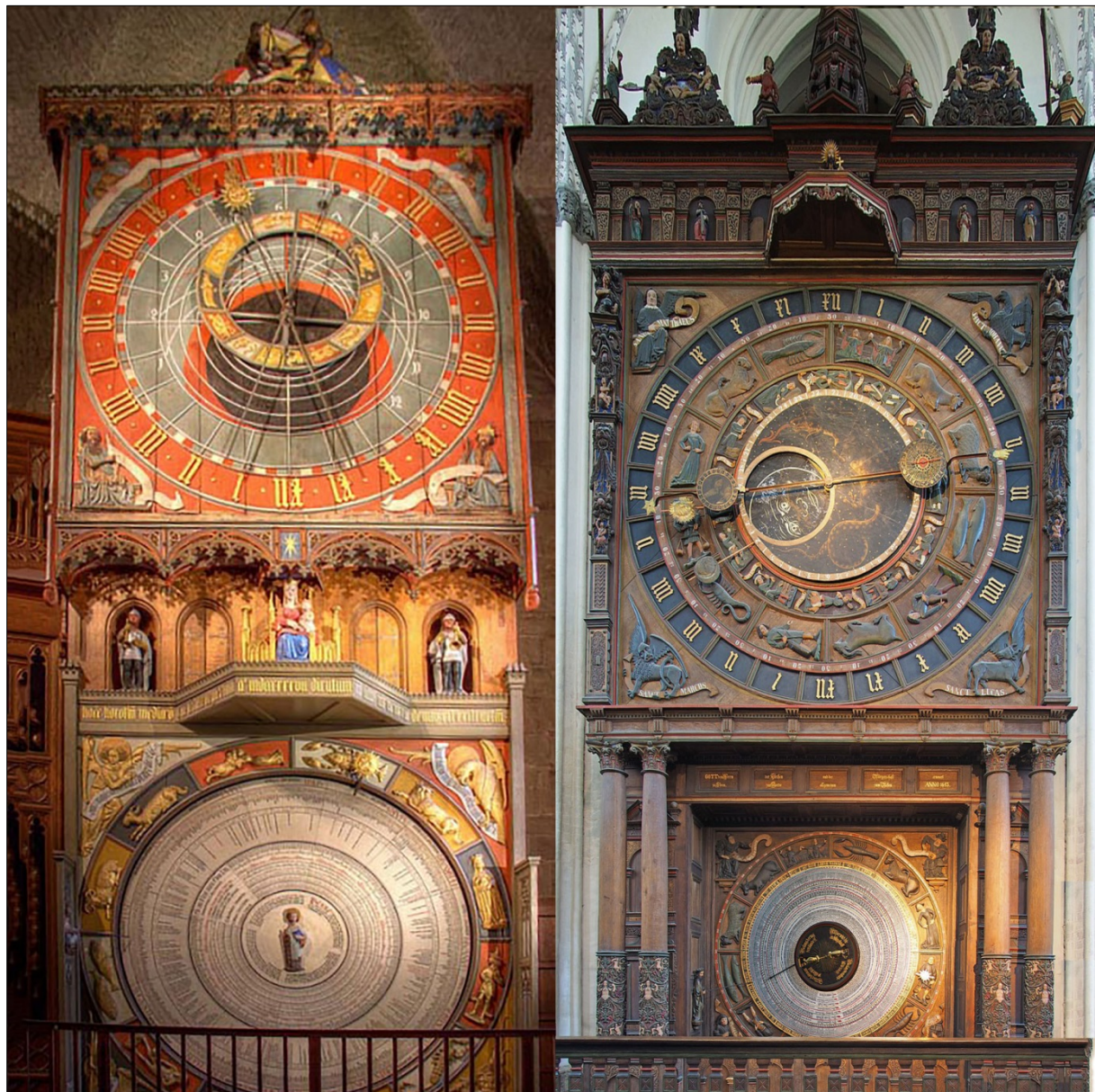


Figure 3. The two clock types. To the left the clock in Lund, to the right the one in Rostock (after Wikipedia).

height of 14 meters.

2 THE CLOCK DIALS

Both types of clocks have a dial divided into 24 hours with a pointer for the display of the Sun and its location in the ecliptic. There is also a pointer showing the position of the Moon relative to the Sun and a display of the phases of the Moon. Both types lacked a minute hand.

2.1 Type I Clock Dial

In this type of clock, the dial shows the celestial sphere mapped onto a plane using a stereographic projection. This kind of mapping, already known in antiquity, was also used to construct the astrolabe, a practical astronomical instrument for the calculation of positions and other data of astronomical objects.

The stereographic projection follows a linear ray from one of the celestial poles via a point on the celestial sphere to hit a horizontal equatorial plane at the mapped point (see Figure 4). A stereographic projection maps all the points on the celestial sphere, except the Pole itself, into points on the horizontal plane. An important property of this projection is that circles on the celestial sphere are mapped into circles on the plane and that angles between lines on the sphere are preserved in the mapping. For an astrolabe, the South Celestial Pole was used as the origin for the projection ray, for the astronomical clocks in most cases the North Celestial Pole was used.

Figure 5 illustrates the stereographic projections of parallel circles (right) and the local horizon (left). The angle between the zenith and

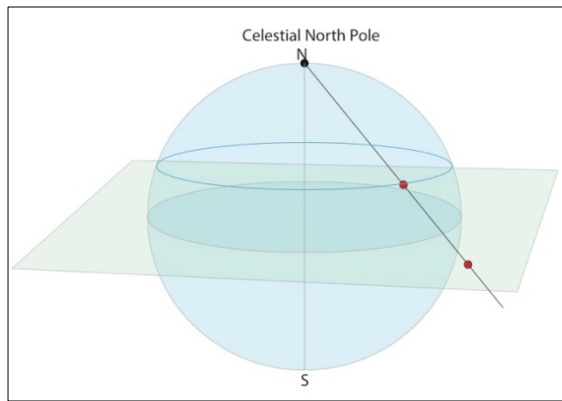


Figure 4: Stereographic projection principle (diagram: Lars Gislén).

and the celestial north pole is the 90° complement of the latitude of the site of the clock. The local horizon of the site will be mapped as an off-centre circle in the plane. The ecliptic will be mapped into an off-centre circle with a diameter that is the sum of the radii of the

Tropics of Cancer and Capricorn, touching the former from the inside and the latter from the outside (see Figure 5 left).

As an example of the clock dial of a Type I clock, Figure 6 shows the dial of the clock in the Cathedral of Lund together with a computer-generated stereographical mapping for the latitude of Lund.

The white concentric circles are the mappings of the parallel circles. The edge of the central red region is the local horizon, the edge of the central black region shows the limit for dusk and dawn when the Sun is assumed to be 10° below the horizon. The red off-centre circle to the left is the ecliptic corresponding to the outer rim of the ecliptic band to the right. The ecliptic band moves with the Sun, the Sun moving slowly anti-clockwise 360° relative to the ecliptic band during one year. The intersection between the solar pointer and the outer rim of the ecliptic band shows the location of the

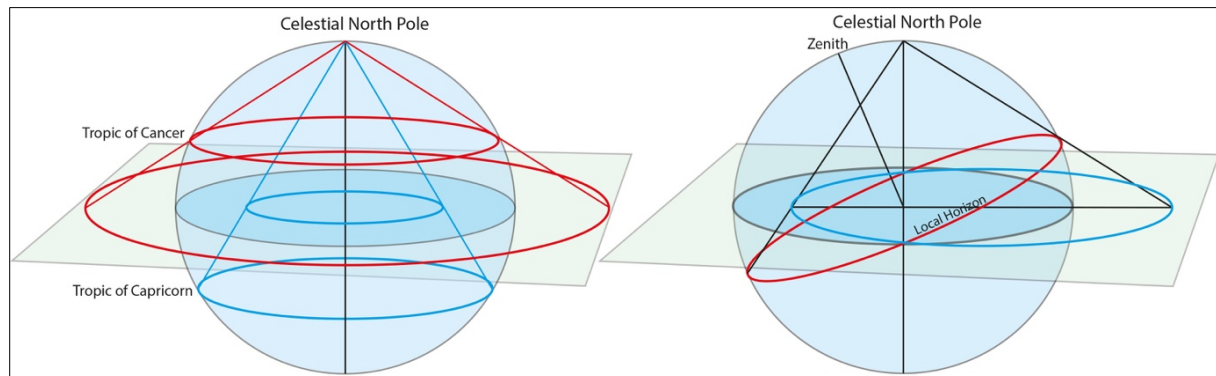


Figure 5: Mapping parallel circles and the local horizon (diagrams: Lars Gislén).

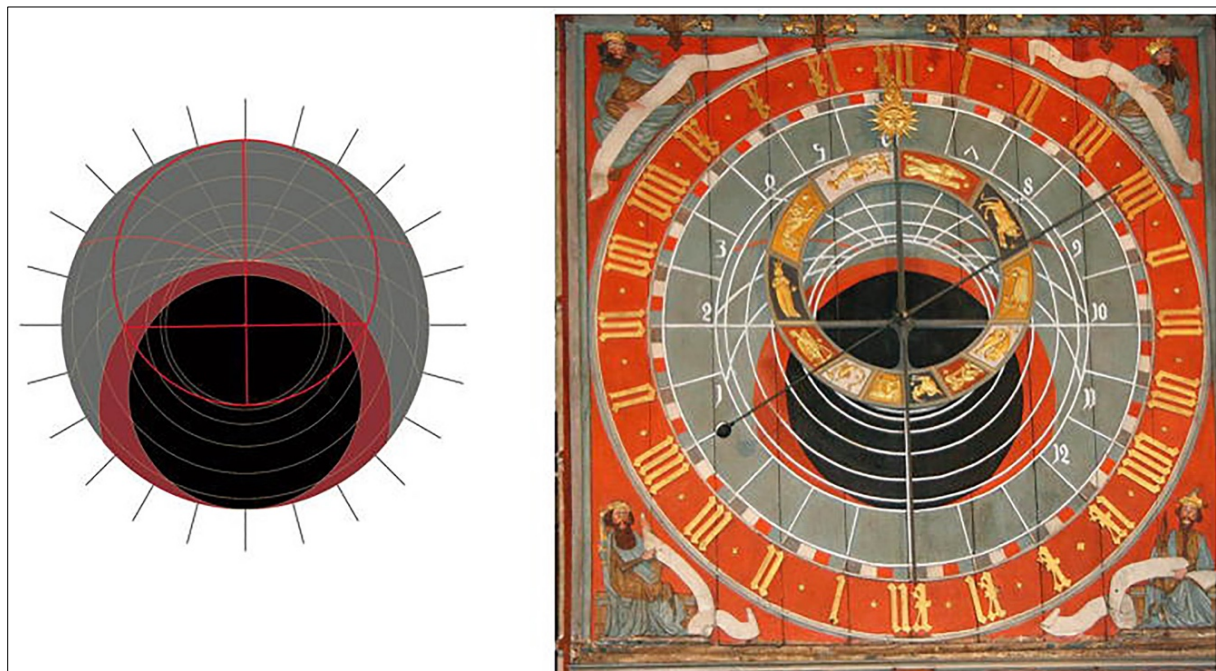


Figure 6: On the left is a computer-generated stereographic dial for the latitude of Lund (diagram: Lars Gislén), and on the right the dial of the clock in Lund.



Figure 7: The Stralsund and Doberan clock dials (Wikipedia).

Sun in the sky. The numbered curved lines on the right in Figure 6 show the so-called temporal hours that divide the bright part of the day into twelve equal parts. These were used in the beginning of the fifteenth century when the Sun was still the main time reference. In later clocks only the division of the day and night into 24 equal hours was used—equinoctial hours—an adaptation to time now being determined by mechanical clocks. The clock dial shows both kinds of time: the older temporal time and the newer equinoctial time. In Figure 6, the dial to the right shows noon time at the summer solstice when the Sun is just leaving the zodiac sign of Gemini and entering Cancer. Also shown is the Moon pointer on the border between Libra and Scorpio. At the end of the Moon pointer is a half-silvered ball that by its rotation shows the phase of the Moon. From the dial it is possible to determine the time of sunrise and sunset for a given position of the Sun in the ecliptic and also to find approximately the same quantities for the Moon if the ecliptic latitude of the Moon is neglected. The average townsman would not have been expected to comprehend all the available astronomical information. The Lund clock is dated to 1423 and was renovated and reconstructed in 1923 after having been neglected for several hundred years (Wählin, 1923). By then, only the clock dial and some wheels from the clock-work remained.

Figure 7 shows the old type of clock dials of the still extant but not working astronomical clocks in Stralsund (1394) and Doberan (1398). The clock in Doberan lacks the ecliptic ring and the pointers. All the towns with astronomical clocks in the Baltic region originally had clocks

of this type but they were destroyed or replaced by newer clocks later on. In Lübeck the old clock was replaced in 1561, only to be destroyed by fire in 1942. The clock of this older type in Marienkirche in Wismar, Germany (Figure 8) was destroyed in 1945.

2.2 Type II Clock Dial

The dials in Figure 9 are characteristic of the younger clocks, the clocks in Gdansk and Rostock, which were constructed by Hans Düringer (d. 1477) in 1464 and 1472, respectively. They are comparatively modern recreations of the original dials.

In these dials there is no stereographic mapping and the temporal hours have disappeared in preference for the equinoctial hours. The Moon's phase is shown in a circular aper-

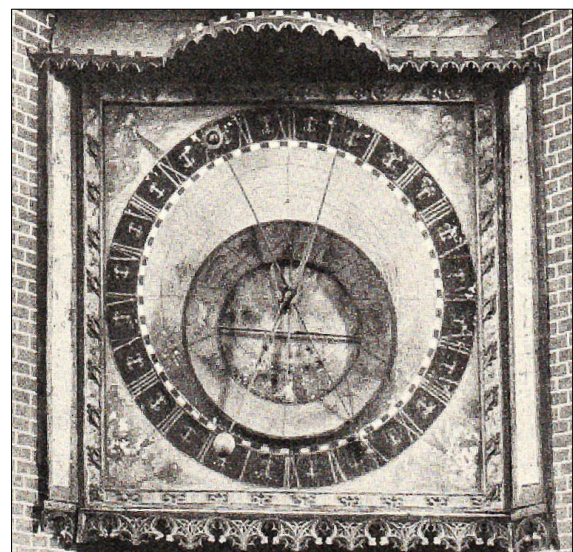


Figure 8: The clock dial of the clock in Wismar (after Wählin, 1923: 24).



Figure 9: The Gdansk and Rostock clock dials (Wikipedia).

ture. The Sun's and the Moon's position in the ecliptic is shown by a Sun and a Moon image, respectively. In the Gdansk dial the time of the day is shown by a separate pointer.

3 THE CALENDAR DISKS

The calendar disks show the days of the year as 365 radial slots, one for each day of the year. Each day slot carries information for that day. The original calendar disks of the clocks in Doberan and Stralsund perished long ago. The calendar disk of the clock in Rostock has been periodically updated, the latest update was in 2018 and now contains no original data. The original calendar disk of the Lund clock was lost and a new one made when the clock was reconstructed in 1923. The new calendar disk was modelled after consulting several calendar disks of other ancient astronomical clocks in Europe.² The calendar disk of the clock in Gdansk is the only original one extant and will be analysed below.

4 THE GDANSK CALENDAR DISK

4.1 Sunday Letters and Golden Numbers

All calendar disks display Sunday or dominical letters. The days of the year, starting with the first of January are labelled by a repeating sequence of the seven letters A, B C, D, E, F, G. The last day, 31 December, will then be labelled A. Each year will be associated with one of these letters and the days marked with this letter will be Sundays. Leap years will have two Sunday letters, one to be used before 28 February, the other to be used after that day of the year. The year 2019, for example, has Sunday letter F, 2020 being a leap year has

Sunday letters E and D, 2021 has Sunday letter C, the Sunday letter stepping backwards in the sequence for each subsequent year.

The golden number, *numerus aureus*, is a number from 1 to 19, associated with each year. There is a simple rule to calculate the golden number for a given year: divide the year by 19, keep the remainder and add 1.

The golden number for the year 2020 is then 7. The golden number is used to find the dates of the New Moons of a year. The background for the golden numbers is the fact that 19 mean solar years are almost exactly equal to 235 synodic months or lunations something that has been known by astronomers for thousands of years. Using mean Julian years of 365.25 days and mean synodic lunar months of 29.53059 days we have $365.25 \times 19 = 6,939.75$ days and $29.53059 \times 235 = 6,939.68865$ days.

This means that, on average, New Moons will repeat on the same date every 19 years, the Metonic cycle named after the Greek astronomer Meton (fifth century BCE), but the cycle was in use much earlier in the Babylonian and Hebrew calendars. There will be a variation of about one day plus or minus for the true Moons because the Moon's orbit is not a perfect circle and also because the solar year being every fourth year a leap year. Thus, we can for each year mark the days with a New Moon with the golden number of that year and we will have an approximate repeating 19-year calendar of New Moons.

Golden numbers in combination with Sunday letters were very important for the Christian Church as tools for determining the date of



Figure 10: The calendar disk of the Gdansk clock. (Wikipedia)

Easter Sunday, which occurs on the first Sunday after the first (ecclesial) full moon on or after 21 March. In both the Lund and the Gdansk calendar disks the day slots have both Sunday letters and golden numbers. Unfortunately, a few of the golden numbers on the Lund disk are in error due to scribal errors writing the Roman numbers in the reconstruction in 1923. The Gdansk disk shows not only the golden numbers of the days but also the mean times of the respective New Moons (see Figures 10 and 11).

The outermost rim of the Gdansk calendar disk shows the Sunday letters. The next band inwards gives the calendar date in the quite complicated Roman calendar. Then follow four bands of numbers, each covering a 19-year interval: 1462–1481, 1482–1500, 1501–1519 and 1520–1538. In each of these intervals the golden number of the first year is 1. Figure 11 shows a detail of part of the two inner bands for the month of January.

Each band first shows the golden number written as a Roman numeral. Then follows the hour of the mean New Moon and finally the minute, also in Roman numerals. As is explain-

ed by text on the disk both in Latin and in German, the times are counted as 24 hours starting from noon. For 2 January, the slot with Sunday letter “b” in the middle of Figure 11, the golden number is viii = 8 corresponding to the year 1470 and the time is ii li = 2:51. Further down in the same band (not shown in the Figure) we find again, on 31 January, the



Figure 11: Detail of the calendar disk (Wikipedia).

golden number 8 associated with the time 16:35. The difference between these times, 31 January 16:35 – 2 January 2:51 = 29 days 12 hours and 44 minutes, precisely the length of the mean synodic month.

The calculation of these numbers would require an enormous amount of work. Each 19-year interval has 235 lunations, in total the four 19-year bands require $235 \times 4 = 940$ calculated New Moon times. Table 1 shows in the respective second columns these numbers for the month of January for the four bands and read from the disk. A few numbers cannot be read and are marked by question marks and there are two obvious printing errors that have been corrected (marked in red). The left-most column (G) is the golden number. Column D gives the disk times, AT the times according to the Alfonsine Tables, and D-AT the time difference.

4.2 The Origin of the Times

The most widespread astronomical canon at the time was the Alfonsine Tables. These tables were produced by a team of Jewish, Christian, and Muslim scholars, sponsored by King Alfonso X of Castile (1221–1284) and were based on earlier Islamic works and observations as well as contemporary observations made by astronomers in Toledo. The Tables did not exist in printed form at the time of the construction of the clock in Gdansk (the first printed edition appeared in 1483—see Alfonso and Leon, 1483), but they existed in manuscript form in several versions and were the standard astronomical reference of the time.

There were also quite a few derivations of the Alfonsine tables, adapted for different long-

itudes, the most famous being *Tabulae Eclipsium* (Peurbach, 1514) by George Peurbach (1423–1461) for the longitude of Vienna but with all of these derivations still using the parameters of the Moon from the Alfonsine tables. Again, these modified tables existed in printed form only after the time of the construction of the Gdansk clock. A comparison of the times on the Gdansk disk and times calculated from the Alfonsine Tables (AT) is shown in Table 1.

A 19-year interval can have either 6,939 or 6,940 days as there can be four or five leap days in 19 years. This causes the time series for the respective intervals to be displaced relative to one another.

The time differences between the times on the disk and the times calculated from the Alfonsine Tables ($D - AT$) are almost constant, the average being 1 hour 17 minutes. This represents a longitude correction to the Alfonsine tables that, remembering that 15° of longitude corresponds to one hour of time, amounts to a longitude difference of about $19^\circ 15'$. The 1483 edition of the Alfonsine table also contains a list of longitudes and latitudes of known locations. The Alfonsine Tables were computed for the longitude of Toledo, Spain. The prime meridian of longitude in the Tables was, as already established by Marinus of Tyre, Ptolemy's predecessor, *Fortunatae Insulae*, the Isles of the Blessed. These were semi-legendary islands in the Atlantic located near the Canary Islands although the precise location is debated (Russo, 2013; de Grijs, 2017) although this is not important for the argument here. Adopting this as prime meridian meant that all locations in the known world at that time were situated east of the prime meridian,

Table 1: A comparison between disk times and the Alfonsine Table times for January.

1463–1481					1482–1500				1501–1519				1520–1538			
G	Day	D	AT	D-AT	Day	D	AT	D-AT	Day	D	AT	D-AT	Day	D	AT	D-AT
8	2	02:51	01:35	1:16	1	19:25	18:07	1:18	2	11:56	10:39	1:17	2	04:28	03:11	1:17
16	3	15:32	14:16	1:16	3	08:07	06:48	1:19	4	00:37	23:20	1:17	3	17:10	15:52	1:18
5	5	11:41	10:25	1:16	5	04:13	02:57	1:16	4	20:47	19:29	1:18	5	13:19	12:01	1:18
13	7	00:23	23:06	1:17	6	16:56	15:38	1:18	6	09:28	08:10	1:18	7	02:05	00:42	1:23
2	8	20:32	19:16	1:16	8	13:03	11:48	1:15	8	05:35	4:19	1:16	7	22:08	20:51	1:17
10	10	09:14	07:57	1:17	10	01:46	00:29	1:17	9	18:18	17:00	1:18	9	10:50	09:32	1:18
18	11	21:??	20:38	–	11	14:27	13:10	1:17	11	06:58	05:42	1:16	10	23:31	22:13	1:18
7	12	18:03	16:47	1:16	12	10:33	09:19	1:14	13	03:07	01:51	1:16	12	19:39	18:23	1:16
15	14	6:44	05:28	1:16	14	23:16	22:00	1:16	14	15:45	14:32	1:13	14	08:21	07:04	1:17
4	16	02:53	01:37	1:16	15	19:25	18:09	1:16	16	11:56	10:41	1:15	16	04:30	03:13	1:17
12	17	15:34	14:18	1:16	17	08:07	06:50	1:17	18	00:40	23:22	1:18	17	17:10	15:54	1:16
1	19	11:44	10:27	1:17	19	04:15	02:59	1:16	18	20:48	19:31	1:17	19	13:18	12:03	1:15
9	21	00:23	23:08	1:15	20	16:58	15:40	1:18	20	09:32	08:12	1:20	21	2:05	00:44	1:21
17	22	13:06	11:49	1:17	22	05:39	04:21	1:18	21	22:10	20:53	1:17	22	14:42	13:25	1:17
6	24	09:14	07:58	1:16	24	01:45	00:30	1:15	23	18:18	17:02	1:16	23	10:40	09:34	1:16
14	25	21:46	20:39	1:17	25	14:28	13:11	1:17	25	07:00	05:43	1:17	24	23:33	22:15	1:18
3	26	18:06	16:48	1:18	27	10:35	09:20	1:15	27	03:08	01:52	1:16	26	19:41	18:24	1:17
11	28	06:46	05:29	1:17	28	23:18	22:01	1:17	28	15:51	14:33	1:18	28	08:22	07:05	1:17
19	29	19:27	18:10	1:17	30	11:59	10:42	1:17	30	04:30	03:14	1:16	29	21:??	19:46	–
	31	15:35	14:19	1:16	31	08:10	06:51	1:19	2/1	00:40	23:23	1:17	31	17:12	15:55	1:17

avoiding negative numbers for their longitudes. In this system Toledo has a longitude of $11^{\circ} 0'$. Thus, the location longitude of the numbers on the disk is $11^{\circ} 0' + 19^{\circ} 15' = 30^{\circ} 15'$. Examining the location table in the Alfonsine Tables (Table 2), we find three potential targets: Prun-suiga (Braunschweig/Brunswick), Nurenberga (Nürnberg/Nuremberg), Ulma (Ulm) in Germany and two towns in Italy (Novaria and Mediolan-us).

Neglecting the Italian towns, we are left with Brunswick, Nuremberg and Ulm. Of these Nuremberg is the most probable alternative. Nuremberg was the unofficial capital of the Holy Roman Empire. It had a long tradition of science, particularly astronomy, and calendar-and clock-making (Cippola, 2003), it was the site of one of the first printing presses, and perhaps most important, it was the native town of the clockmaker, Hans Düringer. A speculation is that there already existed a pre-calculated list of times for the mean conjunctions of the Moon and the Sun, the New Moons, for the longitude of Nuremberg. Saving himself a lot of work, Hans Düringer would use this list for the construction of the calendar disk of the astronomical clock in Gdansk. A true correction to the longitude of Gdansk would have added about another half hour to the mean New Moon times. Presumably, no one would notice this as the true New Moon could deviate about one day from this time.

5 CONCLUDING REMARKS

The medieval astronomical clocks in the Baltic region were remarkably sophisticated mechanical instruments and represented the state-of-the-art clock-making at the time and were intended for public display. Several of them have, in addition to the astronomical function, elaborate mechanical automata and organs that perform at special hours of the day. They were extremely expensive and could only be afforded by the most affluent towns in the Baltic region that were part of the Hanseatic League. These clocks were inspired by earlier clocks in southern Europe made technically possible by the invention of the verge escapement. They represent a fundamental change in the measurement and concept of time, from continuous devices like water clocks, sand glasses, and sundials to a discrete partition of time based on oscillatory movement. The earliest clocks displayed temporal hours, an indication that the Sun was still considered the fundamental time-keeper. In later clocks these hours were replaced by equinoctial hours as more convenient for mechanical clocks. It is a little surprising to find that the mean New Moon times on the calendar disk of the clock in Gdansk, derived from the Alfonsine Tables, are not the correct ones for the longitude of Gdansk but instead for the longitude of the clock-maker, Hans Düringer's hometown Nuremberg.

Table 2: An excerpt from the location table in the Alfonsine Tables.

Tabula latitudinis et longitudinis ciuitatū ab oriente babitaro.					
Nomina	Longi- tudo		Nomina	Longi- tudo	
Forinſe inſule	g	m		g	m
Manna	3	0	Mons pellulan?	26	0
Compoſtellum	5	0	Colonia agrippina	26	50
Lyfbona	5	0	Maguntia	26	35
Lepra	8	0	Traiectum	27	20
Lordaba	9	0	Conſtantia	27	50
Lile inſula	10	0	Argentina	27	20
Coletum ●	11	0	Chartago	27	0
Hibernia inſula	11	20	Delbronna	28	0
Ytta	10	0	Hallis	28	20
Maiorica	13	30	Ediua	28	0
Ceſar auguſta	13	50	Herbipolis	29	20
Tanab	15	30	Piſaurū	29	0
Straniū	15	30	Genua	29	0
Alcor	16	0	Lunir	29	0
Burdigala	17	20	● Prunſuiga	30	20
Oxonium	17	20	● Nurenberga	30	20
Labaria	18	0	● Ulma	30	20
Rhotomagus	19	35	● Novaria	30	15
Coloſa	19	35	● Mediolanū	30	20
Amenia	20	0	Laurinū	30	50
Scoria	21	20	Erfordia	31	20
Prugis	21	20	Ingelſtadiū	31	20
Burgem	21	0	Ratiſbona	31	50
Ciuitas regni magog	22	0	Cremona	31	0

6 NOTES

1. A very early example of an elaborate astronomical clock is the one described in 1327 by the English monk Richard of Wallingford (1292–1336) in *Tractatus Horologii Astronomici* (see North, 1976; 2005; Lehr, 1981: 300).
2. For technical reasons the reconstructed calendar disk was made to have 366 day slots, the slot for 29 February being skipped over in common years (Wählin, 1923: 148).

7 ACKNOWLEDGEMENT

I am grateful for comments and suggestions from Dr J.C. Eade.

8 REFERENCES

- Alfonso, King of Castile, and Leon, J. 1483. *Alfontij regis castellę illustrissimi Cęlestiu[m] motu[m] tabule ...* Venice, Erhard Ratdolt.
- Andree, R., 1886. *Professor G. Droysens Allgemeiner Historischer Handatlas in sechsundneunzig Karten, mit erläuterndem Text*. Bielefeld Velhagen & Klasing.
- Cipolla, C.M., 2003. *Clocks and Culture 1300–1700*. New York, WW Norton & Co.
- de Grijns, R., 2017. *Time and Time Again: Determination of Longitude at Sea in the 17th Century*. Bristol, Institute of Physics.
- Hammel-Kiesow, R., 2008. *Die Hanse*. München, C.H. Beck.
- Lehr, A., 1981. *De Geschiedenis van het Astronomisch Kunstuurwerk*. Den Haag, Martinus Nijhoff.
- Mogensen, L. (ed.), 2008a. *Det Underbara Uret i Lund*. Lund, Historiska Media.
- Mogensen, L., 2008b. *Så fungerar uret*. In Mogensen, 2008a, 63–81.
- North, J., (ed.), 1976. *Richard of Wallingford: An Edition of His Writings*. Oxford, Oxford University Press.
- North, J., 2005. *God's Clockmaker. Richard of Wallingford and the Invention of Time*. London, Hambledon.
- Peurbach, G., 1514. *Tabulae Eclipsium: Tabula Primi mobilis Joannis de Montereio*. Vienna, Maximiliano Caes.
- Russo, L., 2013. *L'America Dimenticata. I Rapporti tra le Civiltà e un Errore di Tolomeo*. Milano, Mondadori Università.
- Schukowski, M., 2006. *Wunderuhren in Kirchen*. Helms, Thomas.
- Schukowski, M., 2008. *Astronomiska ur i Hansetidsens kyrkor*. In Mogensen, 2008a, 123–127.
- Ungerer, A., and Th., 1949. *L'horloge Astronomique de la Cathedral de Strasbourg*. Strasbourg, F.-X. Le Roux et Cie.
- Wählin, T., 1923. *Horologium Mirabile Lundense, Det Astronomiska Uret i Lunds Domkyrka*. Lund, C.W.K. Gleerup.



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