Synchronising the Hours: A fifteenth-century wooden volvelle from the Basilica of San Zeno, Verona*

This text, S. M. Griffin, 'Synchronising the Hours: A fifteenth-century wooden volvelle from the Basilica of San Zeno, Verona,' was submitted to the Journal of the Warburg and Courtauld Institutes (JWCI) in December 2017. The paper was formally accepted for publication by the JWCI on 3 February, 2018. It is anticipated that a final version of the paper will be published in volume. 81 (2018) of the JWCI, on completion of the JWCI's editorial and production procedures.

The San Zeno Wheel (fig. 1, hereon referred to as 'the Wheel') is a virtually unstudied and unique fifteenth-century horological device. Yet certain features correspond to contemporary manuscript volvelles and to the liturgical calendars of larger horological devices. The results of an interpretation of the Wheel are twofold: they elucidate the object itself and illustrate groundbreaking implications for medieval horology and the history of time more broadly. Following a description of the Wheel this article will first decipher its relation to fourteenth- and fifteenth-century time-reckoning instruments, notably astronomical clocks, to establish that it is the oldest liturgical calendar disk to survive. The Wheel is therefore an invaluable testament to the original appearance of the earliest astronomical clocks.

Second, a reconstruction of how the Wheel was used in its original setting, and in relation to other *horologia* at San Zeno in Verona, will provide a unique case study regarding how multiple time systems were synchronised in the reckoning of the liturgy following the invention of the mechanical clock. This analysis will lead one to question how the dispensation of mechanical *horologia* in monastic settings affected the perception of time, and is thus not only significant to historical horology but to medieval temporality across disciplines. This study demonstrates how

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San Zeno Wheel

the individual visual analysis of horological instruments problematizes the previous literature concerning time reckoning, in which the impact of the mechanical clock's invention and the historiography of the hour has been simplified to the extent of distortion.

Despite the significance of the object to the history of science, the San Zeno Wheel is remarkably little known. Only one short article (from exactly one century ago) has been published on the Wheel. This includes an attribution of the date and place of its construction, as well as a transcription of the liturgical calendar followed by an explanation of the astronomical content.¹ The lack of attention otherwise given to the Wheel is not the result of neglect but of physical inaccessibility, as it was hidden in a private collection from the late-eighteenth to the early twenty-first century. For at least part of this time, and probably all of it, the Wheel remained in the Cartolari family collection (the exact date of its departure is uncertain).² After four years of drifting between auction houses and galleries in London and New York (2010-14), it was purchased by the La Jolla Map Museum in San Diego.³

The San Zeno Wheel

¹A. Avena and G. V. Callegari, 'Un calendario ecclesiastico veronese del secolo XV^o', *Madonna Verona*, XI (I), 1917, pp. 1-33. Antonio Avena transcribed the calendar and Guido Valerio Callegari explained the Wheel's astronomical content. The Wheel attracted the attention of a specialist in the medieval art of Verona, Caterina Gemma Brenzoni. Following her untimely death in 2015, her dissertation on the restoration of the apse of San Zeno was published posthumously the following year. She discussed the Wheel in relation to her new findings on the painted clock in the apse of the basilica of San Zeno, which will be significant to the discussion below. C. Gemma Brenzoni, *Ricerche inedite d'archivio e lettura storico artistica della decorazione dell'abside della basilica di San Zeno*, Verona 2016, pp. 117-19. Gemma Brenzoni was consulted for the catalogue entry for Daniel Crouch Rare Books, in which she is cited in conversation repeatedly. See 'A unique late Medieval/early Renaissance volvelle astronomical calendar', *Daniel Crouch Rare Books: Catalogue VI*, ed. D. Crouch, E. Napoleone and N. Trimming, London 2014, pp. 12-25 (20-21). From this it would seem that she continued to work on the Wheel past what is included in her published dissertation.

² The Wheel was in the Cartolari collection when Avena and Callegari wrote their article. It is thought that it entered the collection after San Zeno was plundered by Napoleonic troops in 1797, during which 3 of the predella panels of Andrea Mantegna's San Zeno altarpiece (c. 1457-60) were stolen. For more on its tie to the collection, see *Daniel Crouch Rare Books* (as in n. 1), pp. 23-24.

³ The Wheel was sold by Sotheby's (July 6, 2010) before it was sold by Daniel Crouch Rare Books (London) in 2014, then exhibited at Sam Fogg's 'Wonders of the Medieval World' exhibition at the Richard L. Feigen & Co. Gallery in New York (22 January - 17 March 2014), and subsequently bought by the La Jolla Map Museum (San Diego). The Wheel travelled to New York in December 2017 to be displayed at the exhibition 'Now and Forever: The Art of Medieval Time' at the Morgan Library. See 'Lot 27', *Sotheby's*, <http://www.sothebys.com/cn/auctions/ecatalogue/lot.27.html/2010/western-manuscripts-and-miniatures-110240>; *Daniel Crouch Rare Books* (as in n. 1); 'No. 11', *Wonders of the Medieval World: an exhibition of paintings, sculptures and works of art*, London 2014; 'The San Zeno Astrolabe', *Map & Atlas Museum of La Jolla*, <http://mamlj.org/maps/san-zeno-astrolabe>; and 'Now and Forever: The Art of Medieval Time', *The Morgan Library and Museum*, www.themorgan.org/exhibitions/now-and-forever.

The object is a large volvelle consisting of three movable disks that turn on a central axis. The disks are made of pine covered in vellum, giving the impression of a huge manuscript sheet. The diameter of the main disk is 1280 mm, indicating that it was designed to be used by more than one viewer at a time. The only source on the Wheel from its construction until the twentieth century was written by the local antiquarian, Giovanni Battista Giuseppe Biancolini (1697-1780). He recorded its location and possible date in 1757:

A curious calendar is tucked into the wall of the loggia which leads from the dormitory of San Zeno monastery to the choir and the sacristy of the church [the East side of the Cloister]. This calendar is very beautiful, large, and accurate, written on paper on a circular panel that it is possible to rotate for the convenience of readers, placed there about 1455 for use of the monks of San Zeno.⁴

The entry goes on to describe the saints included in the calendar, proving that Biancolini was looking at same object and confirming that the Wheel was in the Basilica of San Zeno in 1757. The calendar entries give a plethora of information about where and when it was constructed. The highest grade (*duplex maius*) of feasts celebrate Benedict (founder of the Benedictine Order) and Zeno; the next highest (*duplex minus*) celebrate the Octave of Benedict and Crescentianus, a bishop of Verona; the next highest (*semiduplex*) celebrate Proculus (bishop of Verona), Peter Martyr (born in Verona), Lupicinus (bishop of Verona), Anthony Abbot (the 'father of all monks'), and Lucillus (another bishop of Verona).⁵ The calendar was undoubtedly made in correspondence to the liturgy of San Zeno.

It is not clear whence the date of 1455 was derived: perhaps from a subsequently lost dedication or inscription accompanying the Wheel. The visual analysis of Caterina Gemma Brenzoni is consistent with Biancolini's date. She argued the closest stylistic parallels of the zodiac figures to be the works of Lombard painters working in the middle of the fifteenth century, and cites the following examples: Maestro Paroto's *Madonna and Child with Saints* and the Crucifixion polyptych

⁴ Translation from *Daniel Crouch Rare Books* (as in n. 1), pp. 22-23. Original text: 'Curioso Calendario si sta rannicchiato nella parete della Loggia che dal Dormitorio del Monistero Zenoniano conduce al Coro e alla Sagristia di quella Chiesa. Codesto Calendario è molto bello, ampio ed esatto, scritto sopra carta su di una tavola sferica che si può girare attorno per comodo de' leggittori, e vi fu posto del 1455. per uso degl'istessi Monaci di San Zenone...' in G. Biancolini, *Dei vescovi e governatori di Verona*, Verona 1757, p. 22.

⁵ These are listed with their dates in *Daniel Crouch Rare Books* (as in n. 1), p. 22. Avena noted that the entry for Lucipino is added in a later hand. See Avena and Callegari (as in n. 1), p. 28.

in the Bagatti Valsecchi Museum, Milan; the *Tarrochi* cards from the workshop of Bonifacio Bembo (Pinacoteca di Brera, Milan); and the frescoes in the chapel of Queen Theodolinda (Monza Cathedral) executed by Ambrogio and Gregorio Zavattari in 1444.⁶ This line of interpretation is valuable to an understanding of the Wheel's commission and further work remains to be done.⁷

The Wheel could not have been made much later than Biancolini's proposed date, as it does not include two significant feast dates in the Italian liturgy: the Transfiguration, instituted by Callixtus III in 1457, and the feast of Saint Bonaventure, who was canonised in 1482.⁸ The calendar was probably made before these were introduced. An earlier date has been suggested, based upon the absence of Bernardino of Siena (May 20), who died in 1444 and was canonised in 1450 after which liturgical calendars quickly adopted the feast.⁹ The handwriting of the calendar entries (excluding some evidently later additions) and the style of the zodiac miniatures, which imply an origin date in first half of the fifteenth century, also support an earlier date.¹⁰ The following discussion of the approximate date of the apse clock in the basilica corroborates the above suggestions of an early to mid-fifteenth century date for the Wheel.

Whilst this article is intended, in part, to generate more attention to the Wheel amongst specialists of Italian painting, who will doubtless have much to say on the illuminations, this discussion is less concerned with identifying the artist who painted it and more with its function and place within the social and material culture of time reckoning in Verona. Such an interpretation first demands an understanding of its content.

⁶ See *Daniel Crouch Rare Books* (as in n. 1), pp. 20-21. For the contextualisation of the Wheel with the apse frescos of San Zeno, see Gemma Brenzoni (as in n. 1), pp. 117-19.

⁷ A study of these figures in relation to the manuscripts of the San Zeno library should prove an excellent starting point. See A. Parolotto, *La biblioteca del monastero di San Zeno in Verona (1318-1770)*, Verona 2002.

⁸ Avena and Callegari (as in n. 1), p. 29.

⁹ *Daniel Crouch Rare Books* (as in n. 1), p. 24.

¹⁰ Avena and Callegari (as in n. 1), pp. 26-27.

Content of the Wheel

Proceeding from the outer margin towards the centre, the outermost set of information constitutes a fixed saints' calendar.¹¹ This includes:

1. Date: in both Arabic numerals in black ink and Roman numerals (and according to the Roman calendar system of *kalends, ides, nones*) in red.
2. Dominical letters: a-g repeated, which correspond to the days of the week. Also known as the Sunday letters, they begin with 'a' on January 1 each year.
3. Saints' days with their liturgical gradings, many of which are particular to San Zeno. In some cases they are followed by fixed dates of astrological and liturgical significance (such as the equinoxes and solstices) and Roman numerals used to calculate the movable feasts dates (such as *Septuagesima* and Easter, mostly in black but some in red to emphasise the most significant feasts. This is the origin of our modern use of the term 'red-letter days' to signify major events.)¹²
4. Golden number (where relevant), which specifically indicates the place of the year in the nineteen-year Paschal cycle, and is therefore used to calculate the date of Easter.
5. Potential dates of Easter: There are therefore only entries from March 21 to April 25 (a-u in black and a-q in red).

Within this liturgical calendar are sets of astronomical data. First are the degrees of each sign of the zodiac (represented in Arabic numerals from one to thirty in red) which align with the zodiac symbol nearer the centre of the calendar. Second are the sidereal months: the time it takes for the moon to orbit the earth (represented with the letters a to z in black). The following six columns, which will later become central to this analysis, concern the timing of each day. The duration in hours and minutes (in Arabic numerals) is given for half the night (dusk to midnight), the full night (dusk to sunrise) and the full night plus half the day (dusk to noon). These timings would constantly change as the days became longer and shorter within the yearly cycle. This was essential to the timing of the liturgy, which was not measured by our system of modern hours, i.e. two sets of twelve hours starting from midnight and noon, but reckoned from natural cues such as dusk and dawn. Since the first substantial study of the history of the hour, Gustav Bilfinger's *Die mittelalterlichen Hören und die modernen Stunden* of 1892, its historiography has

¹¹ This description of the calendar's data is indebted to earlier accounts, the most recent of which is found in the Daniel Crouch catalogue, which is seemingly translated from Callegari's description in Italian. See *Daniel Crouch Rare Books* (as in n. 1), pp. 18-19; Avena and Callegari (as in n. 1), pp. 30-33.

¹² R. Wieck, *The Medieval Calendar: Locating Time in the Middle Ages*, New York 2017, pp. 2-3.

presented the mechanical clock as the harbinger for the deployment of the modern hours and the end of liturgical time measurement. Yet as will be explored below it has recently been suggested that ecclesiastical time reckoning co-existed with the fixed hours.¹³

Further towards the centre are miniatures of the signs of the zodiac. Each has two vellum labels pasted onto it (some are missing), upon which are written the name of the sign and the word *Bonum*, *Indifferens* or *Malum*. It has been proposed that they indicate the appropriateness of that time for bloodletting, which correlate to theories in astrological-medical texts that were widely circulated at this time, such as those of Pietro d'Abano (c. 1257- 1316), professor of medicine at the University of Padua.¹⁴ On the second wooden disk is a scale of the age of the moon in a peculiar system, which deserves its own study and will not be addressed here.¹⁵ On the uppermost disk is a painted starry sky with a circular hole showing the phase of the moon, which, by partially revealing the appropriate shape on the disk below, waxes and wanes as it is rotated using the small wooden peg.

This lunar volvelle functions in the same way as those found in manuscript and print culture from the late-fourteenth century.¹⁶ In the majority of such volvelles, the base disk is a solar calendar, and the smaller disk a lunar calendar. The disks must be movable as the solar and lunar

¹³ G. Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders*, tr. T. Dunlap, Chicago 1996. Dohrn-van Rossum was not the first to argue this. Giuseppe Brusa noted that Galvano Fiamma, the Milanese chronicler and friar who recorded the installation of the clocks of Sant'Eustorgio (1306/09) and the campanile of San Gottardo in Corte (1336), did not seem surprised that the latter clock recorded the 'equal' hours. Brusa therefore suggested that Fiamma was previously aware of the system. G. Brusa, 'Early Mechanical Horology in Italy (The first Dingwall-Beloe lecture delivered at the British Museum on the 1st November, 1989)', *Antiquarian Horology Society*, 1990, pp. 485-513 (488-89). John North also believed the equal hours to be used earlier than previously thought. J. North, *Richard of Wallingford: An Edition of His Writings*, Oxford 1976, p. 339.

¹⁴ *Daniel Crouch Rare Books* (as in n. 1), p. 20.

¹⁵ This column is split into the rows labelled 'L' (*lune*), 'H' (*horae*), 'M' (*minutae*) and 'E' (*etas*). The age of the moon (in Arabic numerals 1-30) are given alternately below L and E (*etas lune*) and the hours and minutes rise from 0:0 to 12:0, and back to 0:0 in increments of 8 minutes. I would like to thank Stephen Johnston for his discussion on this component of the Wheel.

¹⁶ The earliest volvelle is in fact recorded in the *Ars generalis* of Ramon Lull in 1306. Unlike the astronomical volvelles considered, Ramon Lull made many volvelles for the purpose of theological reasoning. J. Helfand, *Reinventing the Wheel*, New York 2002, p.

19. For more on Lull and his use of volvelles more generally, see A. Bonner, *Selected Works of Ramón Lull (1232-1316)*, I, Princeton 1985. Barely any volvelles are extant from the early or mid-14th century, so they are often seen to be a phenomenon of the late-14th century onwards. For an introduction to lunar volvelles, primarily in printed books, see N. Kanas, *Star Maps: History, Artistry and Cartography*, New York 2012, pp. 234-41. On volvelles more broadly, see S. G. Lindberg, 'Mobiles in Books: Volvelles, Inserts, Pyramids, Divinations, and Children's Games', tr. W. S. Mitchell, *The Private Library*, II (II), 1979, pp. 49-82; and S. Karr, 'Constructions both Sacred and Profane: Serpents, Angels, and Pointing Fingers in Renaissance Books with Moving Parts', *The Yale University Gazette*, LXXVIII (III/IV), 2004, pp. 101-27. The latter study is more concerned with the use of volvelles for memorisation and interpretation opposed to astronomical calculation.

cycles move at a different pace yet must be aligned to calculate the date of Easter. The larger scale of the Zeno Wheel invites further possibilities, as it allows more astronomical and liturgical data to be inserted.

From its data alone, one can deduce that the Wheel essentially functioned as a time-keeping device which allowed the user to track the saints' days and relevant liturgy, calculate the movable feasts by aligning the lunar and solar calendars by the turning of the volvelle, and compute the time of day from the hours of daylight.¹⁷ It hence contains much of the information one would find in *computus* manuscripts from the Carolingian era onwards, yet as each description of the object has lauded, the San Zeno Wheel is a truly unique object, the only one of its type to exist. It is not the case, however, that no other such object existed in the Middle Ages.

Studies of other surviving time-keeping devices, or medieval descriptions thereof, show that large circular liturgical calendars and lunar volvelles were constructed, and even relatively common, during the fourteenth to sixteenth centuries as components of astronomical clocks.¹⁸ The lunar volvelles of astronomical clocks will be considered briefly below, but this interpretation will focus mainly on the base disk, including the liturgical calendar and hours of daylight.

Unfortunately, only one medieval calendar disk from an astronomical clock exists from before the sixteenth century, with the result that scholars have been left to piece together their conclusions from later replacement calendars and textual descriptions.¹⁹ It should therefore be

¹⁷ One should note that its categorisation as an astrolabe is incorrect as it cannot map the stars.

¹⁸ H. King, *Geared to the Stars: The Evolution of Planetariums, Orreries, and Astronomical Clocks*, Toronto 1978, p. 44. For a useful survey of astronomical clocks, including those with lunar volvelles, see A. Ungerer, *Les horloges astronomiques et monumentales les plus remarquables de l'antiquité jusqu'à nos jours*, Strasbourg 1931.

¹⁹ Another pre-16th century calendar disk survives in a triptych made in Germany in 1461 (Nuremberg, *Germanisches Nationalmuseum*, WI58) which also contains a volvelle complete with a liturgical calendar. It is not included in this study as certain features infer that it was functionally dissimilar from the Wheel; the calendar is surrounded by astronomical diagrams and texts and, as shown by the diagram on the outside of the triptych's doors, it is highly likely to have been kept closed. Although this calendar is not as relevant to the focuses of this study, it would be significant to a broader study of the calendars of this period. See 'Astronomischer Kalender', *Objektkatalog der Sammlungen des Germanischen Nationalmuseums*, <http://objektkatalog.gnm.de/objekt/WI58>; and *500 Jahre Regiomontanus, 500 Jahre Astronomie. Ausstellung der Stadt Nürnberg und des Kuratoriums "Der Mensch und der Weltraum e.V." in Zusammenarbeit mit dem Germanischen Nationalmuseum Nürnberg* [exhib. cat.], ed. A. Urschlechter et al., Nuremberg 1976, no. 42, p. 88. For a recent example of a text being used to gauge the appearance of a non-extant clock, see Günther Oestmann's treatment of the Strasbourg clock. This will inform a discussion of the Strasbourg model

emphasised that the San Zeno Wheel is the oldest extant calendar of a medieval horological device, and as will be shown below, the only known Italian calendar disk to have survived. The comprehension of this invaluable object has important ramifications to the discourse of historical horology, first, by supporting many of the conclusions concerning early astronomical clocks which have until now remained speculative, and second, by offering new insights as to the variety of *horologia* that existed in the Middle Ages.

Beyond its similarity to contemporary *horologia*, a consideration of its singularity will focus on its place within the Benedictine monastery of San Zeno during the fifteenth century. An interpretation of the content of the base disk of the volvelle in relation to the other *horologia* at San Zeno suggests that it would have been made to complement another time-reckoning device in the basilica. This refutes an outdated yet often discussed narrative of the invention of the mechanical clock which grossly oversimplifies how the introduction of the mechanical clock into ecclesiastical space in the fourteenth and fifteenth centuries affected the reckoning of liturgical routine. This will be discussed in relation to the twentieth-century sociological studies of medieval time, such as the essays in Jacques Le Goff's *Time, Work and Culture*, which have been treated as definitive contrary to his intention. Before this can be considered, one must turn to the wider material context of fifteenth-century horology, to the surviving objects most similar to the Wheel: the early astronomical clocks of Western Europe.

The Liturgical Calendars of Early Astronomical Clocks

Astronomical clocks are compendia of temporal information such as the orbit of the planets, the annual calendar and, in many cases, figural narratives of Christian salvation history, sometimes acted out by automata.²⁰ A select few of the models had calendars organised in the same format as the San Zeno Wheel, with the outer calendar ring of the saints' calendar circumscribing the data necessary to compute the movable calendar, and with a lunar calendar at the centre.

The first invitation to compare such clocks and the Wheel referred to the calendar of the Prague astronomical clock, which was added to the hour dial around 1490.²¹ The Prague calendar is,

below. G. Oestmann, *Die astronomische Uhr des Straßburger Münsters. Funktion und Bedeutung eines Kosmos-Modells des 16. Jahrhunderts*, Stuttgart 1993. The disk that survives from before the 16th century (the Gdańsk calendar) will also be comprehensively treated.

²⁰ E. Truitt, *Medieval Robots: Mechanism, magic, nature and art*, Pennsylvania 2015, p. 37. For a recent list of automata on astronomical clocks from the 14th to 16th centuries with a detailed description of the automata of the Strasbourg clock, see Oestmann (as in n. 19), pp. 21-26. To contextualize the Strasbourg automata in relation to later automata, see K. Maurice and O. Mayr, *The Clockwork Universe: German Clocks and Automata 1550-1650*, Washington 1980, p. 9.

²¹ Gemma Brenzoni (as in n. 1), p. 117.

however, a later replacement, and only contains a saints' calendar. The comparison to astronomical clocks was certainly an important step in deciphering the context of the Zeno Wheel, but there are more illuminating models of comparison. A survey of a select few examples shows that circular liturgical calendars more similar to the Wheel existed, and were even relatively common within horological devices from the fourteenth to sixteenth centuries.

Although astronomical clocks have been the subject of much rigorous attention, their liturgical calendar components have been neglected. This can be explained by the lack of known calendars which survive from the Middle Ages, and because historians of technology have focused instead on the development of the mechanical hour-keeping devices. There are also inherent issues in dating mechanical instruments as their functionality means that the wearing of their components necessitates repair, and their temporal data would have been prone to constant maintenance. This means that any instrument extant from the Middle Ages is almost certainly to have been replaced or altered since its original construction. In choosing comparative sources, one should take care not to be misled by restorations and conservations that have endeavoured to maintain a medieval aesthetic, despite being crafted centuries later.

Many of the best-known astronomical clocks that were first made in the Middle Ages are copies or have been altered gradually over time so that little or none of the original device remains, making a visual analysis based purely on their current state problematic. For example, there is a small group of originally-medieval clocks that currently have liturgical calendars similar to that of the Wheel, in which the saints' calendar circumscribes a system by which to calculate the movable feasts: in Lund (1380, fig. 2) and Rostock (from 1472, fig. 3).²² Due to the inevitable expiration of the movable calendar's content, they must have been modified multiple times. The Rostock clock, for example, only displays at present the data for the years 1885 to 2017, and the Lund clock for the years 1923 to 2123, with the consequence that the central panel will have to be replaced in the forthcoming years – and no doubt has been replaced multiple times since the fifteenth century.

²² A. Götlind, 'Technology and Religion in Medieval Sweden', Ph.D thesis, University of Göteborg 1993, p. 142; *The Astronomical Clock of the St. Marien Kirche in Rostock*, <http://www.astronomischeuhr.de/en/files/vorwort.html>. Note that the calendar of the Prague clock includes the saints' feasts but does not contain further information for the calculation of the movable feasts. It has therefore not been considered in detail here.

There are, however, two extant sources of fourteenth- and fifteenth-century astronomical clocks containing calendar volvelles similar to the San Zeno Wheel: a fifteenth-century calendar that has survived in the astronomical clock of Saint Mary's Church, Gdańsk (fig. 4a, hereon referred to as the Gdańsk clock), made shortly after the Zeno Wheel, and a description of the original clock of the Cathédrale Notre-Dame, Strasbourg (hereafter, the Strasbourg clock) from over a century before.²³

The Astronomical Clocks of Gdańsk and Strasbourg

The similarity between the Wheel and the Gdańsk model, which still contains its original wooden and copper calendar volvelle, has been recognised but not yet explored.²⁴ Constructed between 1464-70 by Hans Düringer, the clock was functional until approximately 1553, when it fell into disrepair and remained this way until it was placed in storage during World War II. It was finally brought out of storage and reconstructed in 1983, with nearly eighty percent of the original clock being re-used. This includes the calendar disk, which still contains the relevant entries for the years 1463- 1538.²⁵ Because the Julian calendar repeats every 532 years, the calendar has in fact been valid since 1995.²⁶

²³ An original liturgical calendar also survives in the circumference of the dial of a clock made in the southern Low Countries at the end of the 15th century, most often referred to as the *kalendervijzerplaat*. Mireille Madou's essay on the date of the dial concludes that it was made around 1500. Holes in the panel and the depiction of clock makers (in the panel associated with Mercury) suggest that it was originally attached to a clock mechanism, which is supported by an X-radiograph of its frame. Matthew Champion argued that it may have also been attached to an indicator of the phases of the moon. Despite having some similar components to the Wheel, the *kalendervijzerplaat* does not have a volvelle and its liturgical calendar is sparse (consisting only of the dominical letters and major saints' days). It therefore does not feature prominently in this study. See M. Smeyers, *Het rad van de tijd: De uur- en kalendervijzerplaat in het Stedelijk Museumto Leuven (ca. 1500)*, Leuven 1997, p. 68; M. Champion, *The Fullness of Time: Temporalities of the Fifteenth-Century Low Countries*, Chicago 2017, p. 34. For the observation about Mercury, Champion cited G. Vandendriessche, 'The Children of the Planets in the Late-Medieval Calendar Clock in the City Museum of Leuven', *Arca Lovaniensis*, XXII, 1993, pp. 45-80; H. Verougstraete, *Frames and supports in 15th- and 16th-century southern Netherlandish painting*, Brussels 2015, pp. 624-25.

²⁴ 'A unique volvelle', *Daniel Crouch Rare Books*, p. 18.

²⁵ The damaged parts that were replaced were the zodiac figures, the 22 other figures and 6 of its engines. The latter were reconstructed according to the 15th-century principles. A. Januszajtis, 'Wiederaufbau- und Erhaltungsprobleme einer Astronomischen Uhr', in *Mittelalterliche astronomische Großuhren: Internationales Symposium in Rostock 25. bis 28. Oktober 2012*, ed. M. Schukowski, U. Jahnke and W. Fehlberg, Leipzig 2014, pp. 341-52 (342-43).

²⁶ Ibid., p. 349. Note that it does not sync with the current liturgical calendar, as Easter is no longer determined by the Julian calendar outside Orthodoxy.

The Gdańsk calendar is a large wooden disk covered in canvas, containing at its centre a smaller copper disk covered in paper.²⁷ Where the lunar volvelle is situated on the Zeno Wheel, the smaller central disk of the Gdańsk model (1.1 metres in diameter) is an extension of the calendar, containing all of the information of the movable calendar. It is covered by a disk with arc-shaped windows that, when turned, reveal the correct information at the appropriate time. Unlike on the Wheel, the Gdańsk lunar volvelle and zodiac ring do not appear inside the calendar, but are instead found in the dial above, with a mechanism that tells the time of day according to the modern hours. The data sets included in the Gdańsk and Zeno calendars are not identical, but both are primarily concerned with the reckoning of the liturgical calendar. Both contain a saints' calendar in addition to the necessary data to calculate the movable calendar (including the dominical letters, date according to the Roman calendar system and golden numbers).²⁸ Although geographically remote from one another and thus differentiated by their content, such as the provincial saint's days, their compositions are similar.

Before knowledge of the Zeno Wheel, the Gdańsk calendar was considered to be the oldest calendar disk from a horological instrument to have survived. Yet there is evidence of the existence of an even earlier liturgical calendar disk situated within an astronomical clock. Despite only surviving in textual description, the Strasbourg clock gives an accurate indication as to how liturgical calendars would have featured within the large horological devices situated within ecclesiastical space during the fourteenth century. Begun in 1352 and erected in 1354 under Jean de Lichtenberg,²⁹ it was replaced around 1572-4 (and has since again been replaced). The only surviving component of the original clock is an automaton cockerel (Musée des Beaux-Arts, Paris), which was re-used on the second clock.³⁰ The description of the first clock by Conrad Dasypodius (1532-1600), the designer of the sixteenth-century clock, has been used to suggest its original appearance.³¹

²⁷ Januszajtis (as in n. 25), p. 346. This is supported by Zimmermann's description from before the clock was brought out of storage. G. Zimmermann, 'Das Kalendarium der Astronomischen Uhr in der Marienkirche zu Danzig', *Mitteilungen des Westpreussischen Geschichtsvereins*, XXXIII (IV), 1934, pp. 75-86 (77).

²⁸ For a detailed description of the Gdańsk calendar's contents, see Januszajtis (as in n. 25), p. 349.

²⁹ G. Schmidt, *Notice historique sur l'horloge astronomique de la Cathédral de Strasbourg*, Strasbourg 1842, p. 4.

³⁰ King (as in n. 18), p. 43.

³¹ T. Ungerer, *L'horloge astronomique de la cathédrale de Strasbourg*, Strasbourg 1922, p. 6. Théodore Ungerer cited 'Wahrhaftige Auslegung des astronomischen Uhrwerks zu Strassburg, beschrieben durch M. Conradum Dasypodium, der solches Astronomische Uhrwerk anfenglich erfunden und angeben', Bibl. no. 39, pp. B4- C1. Note that at least one of the later editions of Ungerer's description contains a misleading misprint in the date of Conrad Dasypodius's text. The 1949 edition states Dasypodius's text was written in 1378 opposed to 1578. Oestmann, the most recent scholar to study the Strasbourg clock(s),

Like the Gdańsk model, the original device amalgamated a rich array of temporal information and figural Christian salvation history. It consisted of a large astrolabe dial, above which there was a portrait of the Virgin and Child. Below this was a circular wooden dial with a liturgical calendar, including a perpetual calendar which indicated the correct date for the current year. Below this was a table indicating the planets and their characteristics which was long believed to have been accompanied by a bloodletting man (*Aderlaßmännchens*) or zodiac man, but the latter detail has since been argued to be a misunderstanding of Dasypodius's text.³² In his study of early astronomical clocks, Henry King deduced that other calendar dials similar to those of the Strasbourg clock were often made of sheet iron, but some (such as Strasbourg's) were made of wood, reinforced behind with thin metal bars and then painted.³³ This is identical to the structure of the disks of the San Zeno Wheel which, as can be seen from its back (fig. 1b), is reinforced with metal bars.³⁴

Digressing momentarily from the large liturgical calendars upon which this study is focused, the Wheel's association with astronomical clocks is reinforced by the similarity of its lunar volvelle to a selection of models extant from the fourteenth and fifteenth centuries. The most similar are the volvelles in the centre of the hour dials of two clocks that were made for cathedral interiors: in Gdańsk (fig. 4b, situated on top of the above-described Gdańsk calendar disk) and in Wells Cathedral (fig. 5), the volvelle of which is believed to have been made around 1400.³⁵ Like the

provided a description of the first clock using Dasypodius's text of 1580: *Cvnradi Dasypodii Warhafftige Außlegung vnd Beschreybung des Astronomischen Vhrwercks zu Straßburg / welches er Anfaenglichs Erfunden vnnd angeben hat. Auch ein Altes Lied vom dem Kampff vn streyt / so entstanden / Zwischen dem Roraffen (welcher vnder der Orglen im Muenster zu Straßburg ist) vnd dem Hanen / so auff der Alten Vhren war / vor 200. Jbaren Gedicht*, Strasbourg 1580. This is a second extended edition of the 1578 print cited by Ungerer. Oestmann (as in n. 19), pp. 17-18 n. 18. The description of the liturgical calendar does not differ from Ungerer's so will not be scrutinised here.

³² Ungerer referred to the system which indicated the relevant year as *un système d'aiguilles*. Ungerer, *L'horloge astronomique de la cathédrale de Strasbourg*, Strasbourg, 1949, p. 11; King (as in n. 18), pp. 43-44; Oestmann called Ungerer's assumption that there was a zodiac or bloodletting man a unsupported and *sehr freien* interpretation. Oestmann (as in n. 19), p. 18.

³³ King (as in n. 18), p. 44.

³⁴ The folios of plainchant pasted onto the back of the Wheel are also worthy of note, but were inaccessible during the author's examination of the Wheel. A conservational analysis will prove useful to show the reason for their application.

³⁵ Based on the study of Robert Pickersgill Howgrave-Graham, the lunar disc (which he referred to as the 'moon plate') is part of the original clock, made around 1394. He based this on the text around the viewing hole of the lunar phases, which he dated to 1400. The text labelling Phoebe (the personification on the moon) on the right, in contrast, is much later (he argued it to be 16th century, perhaps when the numerals of the day and minute dial were changed). R. P. Howgrave-Graham, *Peter Lightfoot- Monk of Glastonbury and the Old Clock at Wells*, Glastonbury 1922, p. 31, p. 36. The stylistic features of the Phoebe painting also appear much later, supporting Howgrave-Graham's suggestion. For more on the Wells clock see 'Well's Cathedral clock', *Science Museum*,

Wheel's volvelle, both turned to reveal the changing phases of a golden moon that occupy most of their revolving disks, which are both painted with stars on a blue background.

Other astronomical clocks, such as the models in Padua (fig. 6, 1434 onwards, see below) and Venice (from 1493), also include lunar volvelles, but theirs are less stylistically similar to the Wheel's than the above two ecclesiastical models. Though the Padua volvelle contains a hole through which the changing lunar phases are viewed, the central dial also contains an *aspectarium*, a diagram that depicts the astrologically significant angles between planets.³⁶ This meant that the moon on the Padua volvelle had to be much smaller. The Venice clock's volvelle does not illustrate the changing phases of the moon by revealing part of an image below the disk, but instead contains a ball which rolls as it is moved. Whilst the geographically closest public clocks in Venice and Padua contain lunar volvelles, the Wheel is more closely related to the volvelles of clocks made for ecclesiastical settings, such as the Gdańsk and Strasbourg models. This supports the proposed argument that the Wheel was made for the interior of the San Zeno complex.

From these examples one can conclude first, and most importantly, that objects very similar to the San Zeno Wheel existed as components of astronomical clocks found in ecclesiastical buildings both before and after its construction. This strongly indicates that many more calendar disks existed and were likely to be situated in churches, but have not survived due to their physical fragility and expiration of their content. The geographical distance between each of these models highlights the regional significance of San Zeno Wheel as the only Italian model with a liturgical calendar to survive from this time, raising the question of what can it tell us about Italian horology. After all, it was in the cities of northern Italy that the use of public clocks and the modern system of hour reckoning originated, and where astronomical clocks were promoted from within multiple circles of power, including the Visconti, the Carrara, the Este

http://www.sciencemuseum.org.uk/objects/time_measurement/1884-77.aspx and T. R. Robinson, 'Wells Cathedral clock overhauled', *The Horological Journal*, CIII, 1961, pp. 214-18.

³⁶ It is difficult to tell, due to lack of extant medieval clocks and their ongoing maintenance, when the *astrarium* began to be depicted on their lunar volvelles. Dr Louise Devoy has conducted a study as to their appearance on scientific instruments, see L. E. Devoy, 'Astrological *aspectaria* on early modern scientific instruments', in *Scientific Instruments and Astrology*, ed. R. Dunn, S. Ackermann and G. Strano, Leiden forthcoming. Ahead of its publication, she has kindly informed the author that the diagram appeared in Latin translations of Al-Qabisi's 'Book of the Introduction to the Craft of Astrology' from 1473 onwards, and that the earliest *aspectaria* she has found on volvelles and instruments were made c. 1490 (including a manuscript volvelle in an astronomical miscellany from 1490/91 (London, British Library, Egerton MS 848, fol. 22r) and a sundial/nocturnal/equinotial dial/compass dial made by Hans Dorn in 1490 (British Museum, Inv. No. 1894,0615.1)). This could suggest that the lunar volvelle of the Padua clock was crafted in the late-15th century or later.

and the pope.³⁷ To find similar models to the Wheel in northern Italy, one must first review the current state of knowledge concerning liturgical calendar disks and Italian astronomical clocks.

The Padua Clock and the 'Italian Dial'

Taking account of Verona's geographical situation, one might first consider the nearby Padua clock, made by Jacopo de'Dondi for Prince Ubertino in 1344. Although the original model was destroyed in 1390, Novello Dondi dall'Orologio began to build a replacement in the fifteenth century which was placed above the archway of the *Palazzo del Capitano*.³⁸ It has been restored and changed many times since, yet it has been suggested that Novello may have only changed the movement, meaning that the current dial could be the fourteenth-century original.³⁹ The Padua clock maintains superficial similarities to the Wheel: an annual calendar in which each day of the year is demarcated, a lunar volvelle (as described above), and a ring of zodiac figures representing the celestial sphere.⁴⁰ In contrast to the Wheel the Padua calendar is not liturgical and is made from more durable materials, as its unsheltered placement meant that it could not be made from wood and vellum. It is also a mechanical object, meaning that the volvelle would be turned by the clock's mechanism, whereas the San Zeno Wheel had to be much closer to the viewer in order that the disks could be turned manually using the small peg attached to the uppermost disk.⁴¹ An examination of the Padua clock demonstrates that whilst there were regional and chronological trends, the calendar component of astronomical clocks is highly dependent on the immediate space in which it is situated. The San Zeno calendar cannot be compared to a public

³⁷ Dohrn-van Rossum (as in n. 13), p. 134.

³⁸ Novello died before its completion, leaving Giovanni dal Cadière to finish the second clock in 1434. Dohrn-van Rossum (as in n. 13), p. 182. 'Dall'Orologio' was a common epithet for clockmakers in the 14th century. Ibid., p. 182 n. 28. Yet as Giuseppe Brusa noted, the reasoning for this epithet after Jacopo de Dondi dall'Orologio is contentious. Brusa argued that Jacopo earned the epithet through the importance of the Padua clock, whereas it is unclear whether his son, Giovanni, was given this epithet due to his relation to Jacopo or because of his impressive work on the *astarium*, an astronomical time-reckoning device. Brusa (as in n. 13), pp. 490-92 n. 23.

³⁹ King (as in n. 18), p. 47; S. A. Bedini, and F. R. Maddison, 'Mechanical Universe: The Astrarium of Giovanni de' Dondi', *Transactions of the American Philosophical Society*, LVI (V), 1966, pp. 1-69 (18). Bedini and Maddison acknowledged that there is currently no certainty concerning the original Padua clock and so a comprehensive analysis of its contemporary documents is necessary.

⁴⁰ King argued that the original Padua clock likely consisted of 2 or more concentric circular-zodiac plates, arranged like a volvelle. See King, *Geared to the Stars*, p. 43. This is supported in Bedini and Maddison (as in n. 39), p. 17.

⁴¹ The study considers the physical accessibility of the Wheel as its use necessitates manual contact. The importance of its accessibility is hence not a question of its legibility or illegibility, which is a growing topic in the study of medieval and renaissance art. In a recent example that relates to medieval time keeping, Tom Nickson discussed the illegibility of inscriptions on bells, arguing it was their presence, not their legibility, that was significant to their use. T. Nickson, 'Texts and Talismans in Medieval Castile', *Art in Translation*, VII (I), 2015, pp. 9-38 (15).

clock such as that of Padua, but instead to one situated in a sheltered, accessible, ecclesiastical setting in which the user could closely engage with it and turn its disks.⁴²

This raises an issue, as no calendars from Italian ecclesiastical clocks survive from the fourteenth or fifteenth centuries. Instead, it is possible to deduce certain trends in their composition and content by combining the documentation (some descriptions but particularly maintenance details) of various astronomical clocks together with their current appearance, in order to gauge which components were most widely used in different contexts and regions. In the case of the aforementioned clocks of Lund and Rostock, for example, the present similarity of their liturgical calendars is less likely to be the result of later alteration but rather because they shared a common original design. From such evidence, King was able to categorise the types of dials of extant and non-extant clocks into three classes: the Italian dial, consisting of two or more concentric plates; the astrolabe dial; and the hybrid dial, in which an astrolabe is the central component of the concentric circles.⁴³ In each of these variants, the calendar would have been featured below the hours dial of the clock. Through a consideration of the calendar component of the select group of horological devices mentioned above in relation to King's analysis of this wider documentation, it is apparent that calendar disks were incorporated in such mechanisms in northern Italy during the fifteenth century.

According to King, the Italian concentric dial consisted of two or more plates that combined to make a perpetual calendar, similar to the San Zeno Wheel, which included the disks of the lunar calendar in order that the movable feasts could be calculated. Apart from the Padua clock, none of the Italian models prior to the sixteenth century survives. King suggested the most similar

⁴² For this reason the detailed analysis of other public clocks are excluded from this study. It should be noted that in addition to the Padua clock, components of a couple of Italian public clocks survive from the fifteenth century, most notably those of San Marco's Square in Venice and on the clock tower of the *Palazzo della Ragione* in Mantua. The majority of their current devices, however, are not original. The first clock of San Marco's Square in Venice was commissioned 1493, though various components have been changed since. For a brief overview of the history of the Venice clock, see R. Zamberlan and F. Zamberlan, 'The St. Mark's Clock, Venice', *The Horological Journal*, CXLIII (I), 2001, pp. 11-14. The clock in Mantua was commissioned by Ludovico II Gonzaga (1412-78) in 1473. Bartolomeo Manfredi, the Italian mathematician and astronomer who constructed the clock, asserted that in addition to keeping the time of day, his cosmological clock showed 'the proper time for phlebotomy, for surgery, for making dresses, for tilling the soil, for undertaking journeys and for other things very useful in this world'. See C. Cipolla, *Clocks and Culture, 1300-1700*, London 1967, p. 42; Ungerer, *Les horloges astronomiques* (as in n. 18), p. 360. Rodolfo Signorini's recent study on the Mantua clock has revealed a great deal more about how its appearance changed over time, making it clear that the original clock did not contain a calendar. See Manfredi's description of the original clock in full in R. Signorini, *Il Mirabile Orologio di Mantova e diciannove disegni inediti del 1706*, Mantua 2011, p. 11.

⁴³ King (as in n. 18), p. 44.

extant example to be the above-mentioned Wells clock. Some of these volvelles were roughly 1.5 metres in diameter (slightly larger than the Wheel) and mounted with a ring-gear with 365 teeth on the back plate, so that each night they would turn by one unit (equivalent to one day). Like the Zeno, Gdańsk and Strasbourg calendars, many would have included the golden number, the dates of movable church festivals, and the twelve zodiac symbols.⁴⁴ This indicates that more calendars like those of the above-mentioned models existed in Italy.

The Wheel, however, has distinctive details which carry significant implications for the broader study of early astronomical clocks. By conforming to the description of the 'Italian dial' of the fourteenth and fifteenth centuries, this reinforces the previous evaluations which sought to reconstruct the non-extant models. From this and the non-Italian models detailed, one can deduce that many similar calendars like the San Zeno Wheel existed in Italy. Following this logic, it is reasonable to question whether the Wheel was made to accompany a mechanical clock dial, like the volvelles of early astronomical clocks. To answer this, one must look at how the Wheel fits within the practice of time reckoning at San Zeno: the other *horologia* available there, the spaces in which they were kept, and the communities who would have used them.

The Basilica of San Zeno, Verona

Tied to the burial location of Saint Zeno (c. 300-80), the Basilica of San Zeno lay outside the Roman walls of the city. Its library is often heralded as central to the 'Carolingian renaissance', a period of particular significance in Verona due to the legacy of the ninth-century archdeacon, Pacificus (c. 776-844).⁴⁵ San Zeno's monastic community had always accepted astronomy as a way to understand the Christian cosmos. Zeno himself wrote the baptismal sermon, *Tractatus de duodecim signis* (c. 380), in which he used the zodiac to structure a Christian sermon by assigning a spiritual significance to each sign: for example; Aries was the lamb; Taurus, the little calf; and Gemini, the Old and New Testaments.⁴⁶ The value of astronomical and horological instruments within Verona is later shown in the celebration of Pacificus, who is best known as the inventor

⁴⁴ Ibid., p. 52.

⁴⁵ C. Kleinhenz, *Medieval Italy: An Encyclopaedia*, II, London 2004, p. 1134.

⁴⁶ S. C. McCluskey, *Astronomies and Cultures in Early Medieval Europe*, Cambridge 2000, p. 111. For the original in Latin, see B. Löfstedt, *Zenonis Veronensis tractatus*, Belgium 1971, pp. 105-06. For the most recent study on the sermon, see F. T. Dirani, 'Il Sermone dello Zodiaco di Zeno di Verona (I, 38), "Astrologia Praedicabilis" ed inculturazione', *Angelicum*, LXXXIII, 2006, pp. 533-56. The sermon begins with an established trope of Christian numerology: Christ the Sun who was crowned with 12 rays that correspond to the 12 signs of the zodiac (though sometimes the 12 apostles). Jean Daniélou noted that the theme first arose amongst Jewish Christians influenced by the Hellenistic writings of Philo of Alexandria, who compared the zodiac to the Old Testament patriarchs. See J. Daniélou, 'Les douze apôtres et le zodiaque', *Vigiliae Christianae*, XIII (I), 1959, pp. 14-21 (19).

of the nocturnal, a device that could tell the time at night. None of Pacificus's instruments survive, requiring one to piece together their function from textual descriptions, which indicate an observation tube with crosshairs and an accompanying explanation of how this could be used to interpret the stars. Like the San Zeno Wheel, it could present the time without sunlight and also be used for calendric purposes.⁴⁷

Zeno and Pacificus remained central to Verona's civic identity into the fifteenth century. Zeno appears in more than twenty representations in his basilica (probably more if one were to see the wall paintings hidden beneath those currently visible),⁴⁸ including a prominent position within Mantegna's altarpiece commissioned by Abbot Gregorio Correr (1411-64) in 1456. There are no images of Pacificus in Verona's ecclesiastical buildings, but instead he remained prominent in civic texts, within which his astronomical invention plays a crucial role. Many of these laudatory texts date from the thirteenth to fifteenth centuries, such as the *Historiae imperiales* of Giovanni de Matociis (notary and mansionarium of Verona cathedral, 1311-37), and the *Cantare in Onore di Verona* of Corna da Soncino (late-fifteenth century).⁴⁹ Pacificus's invention was more publicly recognised in his epitaph in Verona cathedral, upon which many of the later texts are based.⁵⁰ The prominence and variety of horological instruments and wall paintings in Verona that will now be discussed are not purely practical tools but part of the rich tapestry of Verona's civic identity.

⁴⁷ Dohrn-van Rossum (as in n. 13), p. 29.

⁴⁸ T. Franco, F. Coden, and P. Brownell, *San Zeno in Verona*, Verona 2014, p. LV.

⁴⁹ See Giovanni de Matociis, *Historiae imperiales*, VI: 'And, as he was the best astrologer, he first discovered in material figures the proof of the sphere of heaven with the circles and their connections, the motion of the sphere and of the fixed stars, the orbits of the planets, and the motions of the planets against the sphere. He put together a nocturnal clock through fine calculation, and he also obtained a daily one according to calculation and degree'. Translation from C. La Rocca, 'A man for all seasons: Pacificus of Verona and the creation of a local Carolingian past, in *The Uses of the Past in the Early Middle Ages*, ed. Y. Hen and M. Innes, Cambridge 2000, pp. 251-79 (257). She provided the original Latin: 'Hic diversis scientiis imbutus in diversis facultatibus libros CCXVIII edidisse describitur et cum esset optimus astrologus argumentum spere celi cum circulis et eorum connexionibus, motum spere et stellarum fixarum orbes planetarum et eorum contra speram motus in figuris materialibus primus invenit. Item horologium noturnum subtili calculatione composuit et diurnum etiam ad rationem et ordinem reportavit', (p. 258 n. 23).

⁵⁰ La Rocca argued that Pacificus's identity and life was completely 'reshaped and reinvented' in the 12th century through the 'medium of written word and the production of forged documents'. See La Rocca (as in n. 49), p. 251. His 12th-century epitaph in Verona cathedral claims, 'No one had seen a nocturnal clock before [his time]. Behold, he discovered a method, and built the first one. He composed a gloss on the Old and New Testaments, he put the best song of the spheres of heaven in the clock, and he composed many other writings which the intelligent man will find'. Translation from *Ibid.*, pp. 254-55.

The *Horologia* of San Zeno

There were certainly many mechanical *horologia* in Verona prior to the Wheel's construction. In 1371, Cansignorio della Scala (Lord of Verona 1359-75) ordered that a clock tower be built in the city,⁵¹ and in 1425, an anonymous engineer who had proven his capabilities through his hydraulic constructions was given the title of clock keeper of Verona.⁵² Through archival research on the nineteenth-century restoration of the basilica, it has been established that there have been multiple clocks at San Zeno: on the tower of the abbey,⁵³ and on the campanile,⁵⁴ each of which were possibly visible from the loggia where the Wheel was kept. The broad categories of public and ecclesiastical clock have already been referred to in a comparison of clocks of Strasbourg, Wells, Gdańsk, Padua and Venice, but one needs to be more specific and differentiate the clocks within their immediate space: from campanile, to cloister, to crossing. There is unfortunately no evidence as to when these clocks were built and they are often not distinguished from one another in the repair records.⁵⁵

Fortunately, a *horologium* that seems to have been constructed at a similar date to the Wheel has survived in the basilica (fig. 7). A square wall painting of a clock face is situated on the left side of the apse and high above the ground (approximately in line with the capitals of the nave's columns). Painted with the numbers one to twenty-four in both Arabic and Roman numerals, it is surrounded by four red cherub figures, one in each corner of a square that is bordered by a blue background with golden stars. At the centre is a blue circle containing a small black circle that is likely to have held a mechanism with a hand indicating the time of day. During the restoration of the apse, a few small ochre fragments and traces of fine vegetal motives were found above the clock quadrant. It has been proposed that these originally made up the

⁵¹ Dohrn-van Rossum (as in n. 13), p. 137.

⁵² Ibid., p. 187.

⁵³ In 1865 and 1866, the majority of San Zeno's expenses were used to repair the clock on the abbatial tower. Gemma Brenzoni cited the following document entries: '19.11.1865 relazione sui restauri dell'orologio dell'abate Beniamino Bussinello (*Incarto riparazioni diverse alla basilica*)'; '20.11.1865 Paragmento di fiorini 41,50 orologiaio per riparazioni orologio della torre abbaziale (*Incarto riparazioni diverse alla basilica*)'; '21.12.1865: lettera dei Filippi con la descrizione "dei lavori eseguiti per orologio"'; '28.11.1866 doc. n. 5490: pagamento all'artista Filippi Gaetani per riparazione "all'orologio della chiesa, lire 41,50"'. See Gemma Brenzoni (as in n. 1), p. 22 n. 23.

⁵⁴ Restoration of the campanile clock: '10.03.1891 lettera dell'orologiaia'; '8.3.1891 l'abate sull'orologio e sull'abbattimento della casetta attigua al campanile'; '27.01.1892 Paga lire 43 a (Businello Beniamino, abate) Bertasi Giacomo e Marchiori Ludovico (collaudo) attestano che l'orologio del campanile di S. Zeno funziona bene. Paga lire 180 a favore dell'orologiaio Turri Antonio per riparazione radicale'. Ibid., p. 33 n. 45.

⁵⁵ Gemma Brenzoni (as in n. 4), p. 14. For example, the following record from 1861 does not clarify which clock they refer to: '27.11.1861 *sul bisogno di restaurare l'orologio incarto riparazioni diverse alla basilica*'. Gemma Brenzoni (as in n. 1), p. 22 n. 21.

background of a canopy structure above the clock.⁵⁶ Many illuminations survive that depict canopied clocks. An example from a copy of the *Roman de la rose* from the 1420s illustrates that some canopied ecclesiastical wall clocks had bells that were used as an alarm. It is possible that the Zeno apse clock originally had a similar alarm, which chimed the hours.⁵⁷

Following the inadequate restoration of 1930, a recent restoration of the Zeno apse clock inspected the inside of the wall in the hope of finding a trace of the original mechanism.⁵⁸ There was unfortunately no mechanism, but instead a narrow cavity about one metre deep in which was found terracotta, glass, and iron wire that the restorers believe supported an oil container and wick, which would have been used to light the clock compartment. This shows the lengths to which the makers went to ensure that the clock could be read at night.

It has been suggested that the apse clock was almost contemporary to the Wheel. This is supported by a consideration of the construction and painting of the apse, which was built by Giovanni and Nicolò da Ferrara from 1386 to 1398 and therefore provides a *terminus post quem* for the apse painting.⁵⁹ The date of the apse's construction also supports a fifteenth-century date for the painting of the clock.⁶⁰ Another similar clock face survives in part in the wall paintings in the nave of Sant'Anastasia (fig. 8), a church within the medieval ecclesiastical centre of Verona. Only the right-hand semi-circular border of Roman numerals from fourteen to eighteen is visible, but their style and the small circles of colour on the inside of the numerals show they were probably executed by the same painter, if not one painter emulating the other. The date of the Sant'Anastasia clock painting is also undocumented, but its damage during the construction of the Cappella del Rosario (begun 1585) shows it must have been executed before that period. Jacopo de'Dondi (1290-1359) has been speculated to have made both of these frescos, but this is

⁵⁶ Gemma Brenzoni (as in n. 4), pp. 118-19.

⁵⁷ MS Valencia, Biblioteca de la Universidad, 387, fol. 141r. For a description of the scene, see J. V. Fleming, *Roman de la Rose: A Study in Allegory and Iconography*, Princeton 1969, pp. 233-35. The image is briefly discussed in Dohrn-van Rossum (as in n. 13), p. 93. Many illuminations of clocks can be found in 14th- and 15th-century copies of Heinrich de Suso's *Horologium sapientiae*.

⁵⁸ The apse has been subject to multiple occasions of change and restoration in recent history: by the architect Giacomo Franco (1870), the restoration of Alessandro Da Lisca (1930), work on the windows in 2007, and a restoration in 2008. F. Pachera, 'Il restauro dell'abside', in *Andrea Mantegna. La Pala di San Zeno Studio e conservazione*, ed. M. Ciatti and P. Marini, Florence 2009, pp. 65-74 (65-66).

⁵⁹ This is supported by the dating of the fresco above the apse by Martino da Verona, which has been insinuated from the featured coats of arms of Abbots Pietro Paolo Cappelli (1387-99) and Pietro Emilei (1399-1421). See Franco, Coden and Brownell (as in n. 48), nos 208-11.

⁶⁰ Pachera (as in n. 58), pp. 70-71.

highly unlikely, considering Jacopo died before the construction of the apse had even begun.⁶¹ They are both most likely to have been painted in the fifteenth century.

The evidence for the existence of twenty-four hour clock paintings in Tuscany reinforces an early to mid-fifteenth century date for the San Zeno painting. A clock painted by Paolo Uccello (fig. 9, completed in 1443), for instance, has remained above the main door inside the Florence Duomo.⁶² Thanks to its restoration from 1963 to 1968, during which multiple layers of paint were discovered and removed, its original appearance has been restored.⁶³ Like the Zeno clock painting, the central circle is dark blue and the outer circle is divided into twenty-four sectors containing Roman numerals, inside of which is a circle in the centre of each sector. Unlike that in San Zeno, however, the Roman numerals of the Florence clock begin at the bottom and run anticlockwise. The direction of the numbers and the point at which they begin is varied across the surviving clock paintings. In the fragment of the Sant'Anastasia painting, for example, the numbers begin just left of the circle's lowest point.

This is similar to the now-destroyed fifteenth-century clock on the *Torre del Mangia* in the *Piazza del Campo* of Siena. Although the first clock was made in 1360 by Peter of Normandy, it was not until 1424 that it displayed the hour of the day.⁶⁴ The appearance of the clock is recorded in Sano di Pietro's painting of St Bernardino preaching in front of the *Torre* in 1425 (fig. 10, 1445).⁶⁵ This means that the scene depicted in Sano's painting took place only a year or so after the clock had been rendered into that form. The detail is minute, yet it is clear that the clock had a similar

⁶¹ F. Pietropoli, 'La decorazione pittorica nella chiesa di Santa Anastasia', in *La Basilica di Santa Anastasia a Verona: Storia e restauro*, ed. P. Marini et al., Verona 2011, pp. 51-73 (68-69). One could also speculate that the wall painting coincided with Cansignorio della Scalla's commission of a clock, as Sant'Anastasia functioned as the Church of the Scalla Court. See C. Hourihane, *The Grove encyclopaedia of medieval art and architecture*, I, Oxford 2012, p. 509.

⁶² According to the accounts of the Opera del Duomo, Uccello was paid 40 lire on 22 February, 1443 for the clock face. G. Poggi, *Il Duomo di Firenze: Documenti sulla decorazione della chiesa e del campanile tratti dall'archivio dell'opera*, II, Berlin 1909, p. 162. For more concerning the documentation of Uccello's clock, see G. Poggi, 'Paolo Uccello e l'orologio di S. Maria del Fiore', in *Miscellanea di storia dell'arte in onore di Iginio Benvenuto Supino*, Florence 1993, pp. 323-36.

⁶³ The clock face was restored by Dino Dini (lead conservator), Guido Botticelli and Sabino Giovannoni. U. Baldini, 'L'Orologio Dipinto da Paolo Uccello nel Duomo Fiorentino: Nuovi Studi e Precisazioni per la Sua Lettura', in *Gli "Orinoli Meccanici" di Filippo di Ser Brunellesco Lippi: Documenti e Notizie Inedite sull'Arte dell'Orologeria a Firenze/L'Orologio Dipinto da Paolo Uccello nel Duomo Fiorentino: Nuovi Studi e Precisazioni per la Sua Lettura*, Florence 2000, pp. 35-70 (38-39); Brusa (as in n. 13), p. 499.

⁶⁴ A. Lisini and F. Iacometti, *Cronache senesi*, XV (VI), Bologna 1931, p. 591 n. 1; G. Milanesi, *documenti per la storia dell'arte senese*, I, Siena 1854, p. 236.

⁶⁵ For the documentation of the painting's commission see M. Mallory and G. Freuler, 'Sano Di Pietro's Bernardino Altar-piece for the Compagnia Della Vergine in Siena', *Burlington Magazine*, CXXXIII, 1991, pp. 186-92 (187). Bernardino is recorded to have preached in Siena for 50 consecutive days from April 1425. P. Thureau-Dangin, *Saint Bernardine of Siena*, London 1906, p. 78.

configuration to the above examples: a blue centre with a golden star as the hand mechanism, with the Roman numerals I to XIII running clockwise from the bottom of the circle. These examples show not only that other similar examples of twenty-four hour clocks existed in Italy, but that they were rendered in this way during the first half of the fifteenth century.

The Zeno clock face is especially significant to this interpretation of the original function of the Wheel because, as suggested above, the Wheel's similarity to the liturgical calendars of ecclesiastical astronomical clocks indicates that it may have been intended to work in conjunction with a mechanical clock face. In the above-mentioned ecclesiastical astronomical clocks of Gdańsk and Strasbourg, the liturgical calendar with the zodiac is situated below the dial of the hours. This had led to speculation concerning the original placement of the Wheel and whether it could have been placed below the clock in the apse.⁶⁶

This theory is nevertheless problematic. First, if the Wheel were placed directly below the fresco clock, it would still be so high as to be inaccessible to the viewer, both in its legibility and the mobility of the disks. Second, the Zeno apse clock is very different from the dials of the aforementioned astronomical clocks. These were large, three-dimensional machines supported on large wooden platforms, and they expressed much more information, such as that in the zodiac and lunar volvelle, which in our case are instead found in the Wheel. Third, both the Zeno Wheel and apse clock are much smaller than the aforementioned astronomical clocks. The largest Zeno disk measures 1.28 metres, whereas the diameters of the Gdańsk and Strasbourg calendars are respectively 2.76 and 2.8 metres.⁶⁷ This meant that they could include more information than the Wheel. The Gdańsk model, for instance, contains fifteen columns and 3584 information entries. This suggests that the Zeno Wheel was not meant to be a monumental instrument situated within the body of the basilica of San Zeno, but was intended for a more intimate setting.

Whereas the more physically accessible *horologia* on the campanile and in the apse would have been less concerned with the minutiae of the liturgical calendar, the Wheel was hidden from the laity in the cloisters, and evidently intended for the use of the clergy.⁶⁸ According to Biancolini,

⁶⁶ Gemma Brenzoni (as in n. 1), p. 14.

⁶⁷ Januszajtis (as in n. 25), p. 346.

⁶⁸ This is a question of intellectual accessibility as well as physical. The painted clocks of the San Zeno apse and Sant'Anastasia nave are simple to read and give both Arabic and Roman numerals, whereas those not versed in the calendar and astronomy would not have found much use for the Zeno Wheel.

the Wheel in the eighteenth century hung on the wall of the loggia, between the dormitory and the entrance to the sacristy. The loggia originally sheltered the lavabo, as documented in a plan of the monastery from 1771, where it is described as a large circular basin with a column in the centre that worked as a fountain.⁶⁹ According to the Roman Rite, the brethren would wash their hands here and pray before entering the church: a moment of both physical and spiritual cleansing before the liturgy. If the loggia was the place for liturgical preparation for the monks, the Zeno Wheel would have fulfilled its purpose here as a tool for the liturgy through the correct timing of the prayers.

From an identification of the Wheel's location, function and audience, one can build a picture of its role within the San Zeno complex in the fifteenth century, during which there was a liturgical reform. The details of this reform can even lead one to suggest a potential patron. According to the sixth-century Rule, the monastery's adherence to the liturgical timings was the responsibility of the Abbot.⁷⁰ If a mid-fifteenth century date is accepted for the construction of the Wheel, it was most likely commissioned by Abbot Correr, whose programme of patronage was centred around liturgical renewal.⁷¹ Since much of his documented work involved the choir of San Zeno, in particular the commission of Andrea Mantegna's altarpiece and the construction of new and more comfortable stalls,⁷² it is reasonable to believe that the apse clock would have also been painted under his abbacy.

The Wheel's scale and location show it to be a device that was not intended for the use of the laity in the basilica, but instead for the monastic community in the restricted areas of the San Zeno complex. Even though the Zeno Wheel was not physically attached to the apse clock, this does not necessarily mean that they did not work together. An understanding of the content of the Wheel and how it would have been used by the Benedictine community shows that it has the potential to function in correspondence with a device that counted the hours, such as the apse clock, and also supports its monastic role: to calculate the daily liturgical routine.

⁶⁹ Franco, Coden, and Brownell (as in n. 48), nos 180-81. For an idea of how this would have looked, the lavabo in the loggia of Fossanova, a Cistercian abbey South of Rome, still exists.

⁷⁰ Ibid., pp. 55-56.

⁷¹ Franco, Coden, and Brownell (as in n. 48), pp. LVIII-LIX.

⁷² L. Simeoni, *S. Zeno di Verona: studi con nuovi documenti*, Verona 1909, pp. 70-71. In Correr's will (dated November 29, 1464 in MS Venice, Arch. Stato Venezia, S. Zeno B. 31) he ordered the stalls to be paid for at his expense.

A Benedictine *Horologium*

The inclusion of the major feasts of Saints Zeno and Benedict establishes that it is undoubtedly a calendar for the Benedictine monastic community at San Zeno. Although the claim itself is not novel, it has only thus far been mentioned to verify the Wheel's provenance.⁷³ Its Benedictine identity is not only key to an understanding of the object itself, but also shows it to be an eloquent artefact of monastic time keeping in the later Middle Ages. An understanding of how the Wheel was used is first necessary.

According to the Benedictine Rule, the organisation of the monastic routine depended on two critical systems: first, the movable date of Easter and second, the timing of the Vigils.⁷⁴ The time of liturgical celebrations had to be calculated day by day, and the movable feasts each year. When not simply consulted from a table, Easter was calculated from the *millésime* of the year, the Golden number, and the dominical letter, according to well-known rules. The Wheel demonstrates a specifically monastic function, as it provides the necessary data to carry out both of these calculations.

The liturgical calendar contains all the information crucial to the computation of Easter: the calculated (and not-necessarily correct) date of the Spring Equinox, the golden numbers, and the dominical days. As Easter falls on the Sunday following the calculated full moon (understood to be the fourteenth day of the lunar month and referred to as *luna XIII*) that does not precede the Spring Equinox, the solar (the Earth's rotation around the sun and therefore the year divided into 365 days, as now understood) and lunar calendars must both be taken into consideration. This is aided by the volvelle's ability to find the full moon for specific dates. The column with the letters a-u written next to the potential dates of Easter was most likely to have been used with a table to find the moon's age (by indicating the new moon for every month of the year throughout the nineteen-year cycle).⁷⁵ As it was the custom in medieval monasteries to read aloud calendrical information (normally the date and age of the moon) during the offices, the table would have facilitated the daily monastic routine of San Zeno.⁷⁶

⁷³ Daniel Crouch *Rare Books* (as in n. 1), p. 22.

⁷⁴ Dohrn-van Rossum (as in n.13), pp. 37-38.

⁷⁵ For an illustrated example of this, see B. J. Blackburn and L. Holford-Strevens, *The Oxford Companion to the Year*, Oxford 1999, pp. 758-59.

⁷⁶ At Exeter Cathedral, for example, the moon's age and the date of the following day were read aloud. See J. N. Dalton, ed. *Ordinale Exon. (Exeter Chapter Ms. 3502 Collated with Parker Ms. 93.): With Two Appendices from Trinity College, Cambridge Ms. B.XI.16 and Exeter Chapter Ms. 3625, I*, London 1909, p. 37.

The centrality of Easter to the calculation of the movable feasts, as well as its symbolic significance to the Christian perception of the year, is possibly indicated by what appears to be an illuminated crown of thorns on the top disk of the volvelle, probably in reference to Christ's Crucifixion. The identification of this illumination remains ambiguous. In addition to its symbolic circularity, it could have also been intended to be a liturgical wreath or a reference to the Psalms: 'You crown the year with your bounty', (Psalms 64:12). As shown above in the sermon of Saint Zeno, Christological readings of astronomical content were common in monastic communities, as the calendar year was a mirror of the life of Christ.⁷⁷ The wreath with red ribbon was also used to celebrate liturgical feast days, specifically during Advent from the Early Modern period, by which time it had become an established symbol of the calendar year.⁷⁸ The wreath with ribbon was also a fairly common motif in fifteenth-century northern Italy. It appears in the pattern book (the *Essempio di recammi*) of Giovanni Antonio Tagliente (c. 1465-1528) made in Venice, in which a wood cut depicts a tortoise in the centre of a wreath with ribbons, eating the foliage.⁷⁹

Reckoning the Hours

Most significant to our comprehension of the Wheel's function is its role in the calculation of the time of day, and hence the ordering of the monastic routine of San Zeno. This is complicated by the current lack of understanding concerning the use of the equal and unequal hours in ecclesiastical settings during the fourteenth and fifteenth centuries. From early Christianity, the hours of worship would vary greatly from place to place according to local custom and habit. In the sixth century, the Rule of St Benedict (c. 480- 543) recorded a standard by which the approximate timing of the liturgy was regulated by the canonical hours: Matins, Prime, Terce, Sext, None, Vespers and Compline.⁸⁰ These do not directly correspond to the equal hours, as used today and counted in the clock paintings in San Zeno and Sant'Anastasia, but instead are based on natural cues and thus correspond to the duration of daylight. This system is particularly complex as it constantly adjusts according to seasonal changes. It therefore demanded a

⁷⁷ Stephen McCluskey also suggested this in his *Astronomies and Cultures* (as in n. 46), p. 39.

⁷⁸ For a recent study concerning the wreath, see N. M. Lyon, 'Wreaths of Time: Perceiving the Year in Early Modern Germany (1475-1650)', Ph.D thesis, University of Cincinnati 2015.

⁷⁹ 'Essempio di recammi, page 23 (verso)', *Metropolitan Museum of Art*, <http://www.metmuseum.org/art/collection/search/659449>.

⁸⁰ J. E. Barnett, *Time's Pendulum: The Quest to capture Time-- From Sundials to Atomic Clocks*, New York 1998, p. 46; Blackburn and Holford-Strevens (as in n. 75), p. 633.

procedure of daily reckoning that incorporated the duration between sunrise and sunset and at night, the movement of the stars.

Understanding the initial concurrence of the unequal and equal hours has proved an issue in the historiography of time reckoning, as shown in history of the hour from Bilfinger onwards. The subject enjoyed a resurgence in the flourish of publications concerning the history of technology during the 1950s and 60s, which framed the invention of the clock as a decisive shift to the modern temporal hours (the system by which clocks are set today).⁸¹ This encouraged the binary categorisation of time systems. For example, Le Goff divided 'Church time' and 'Merchant time', stating that 'Merchants and artisans began replacing this Church time with a more accurately measured time useful for profane and secular tasks, clock time'.⁸² What followed was a surge of sociological studies which explored the relationship between the clock and monastic culture, as explored below.

As Gerhard Dohrn-van Rossum has most recently argued, the transition between modes of time keeping was not so sudden and, in fact, a new temporal framework of standardised hours only became prevalent in the late-seventeenth century.⁸³ His re-interpretation of Le Goff's distinct categorisations shows that Le Goff himself was in fact more careful in his approach, and argued that for a long time after the appearance of the mechanical clock, 'a time associated with natural rhythms, agrarian activity, and religious practice remained the primary temporal framework'.⁸⁴ After all, sundials denoting the canonical hours were used long after the fourteenth century.⁸⁵ Le Goff's study was not intended as the definitive text that it became, but instead as an invitation for more thorough research into the modes of time reckoning following the appearance of the mechanical clock.⁸⁶ Only through a case-by-case analysis, such as that of the Zeno Wheel, can one see how the medieval horologist responded to these issues.

⁸¹ Alistair Crombie, for example, argued that, 'The division of the hour into 60 minutes and of the minute into 60 seconds also came into general use in the fourteenth century and was fairly common as early as 1345', A. C. Crombie, *Augustine to Galileo*, 2nd edn, London 1959, p. 219.

⁸² J. Le Goff, *Time, Work & Culture in the Middle Ages*, transl. A. Goldhammer, Chicago 1980, p. 36.

⁸³ See n. 13 above.

⁸⁴ Le Goff (as in n. 82), p. 49.

⁸⁵ The Rule does not mention any particular procedure for determining the time, but the *Regula Magistri* (c. 520, contemporary to the Rule) mentions a *horologium* that should be observed day and night. Accounts from the early Middle Ages give evidence as to a variety of manual tools that this could have been, such as the cock's crow, star gazing, special observation tables, water clocks, shadow tables, sundials and the burning of candles. See Dohrn-van Rossum (as in n. 13), p. 57.

⁸⁶ *Ibid.*, p. 13.

The Wheel's method for daily reckoning demonstrates that such hour systems were not inevitably opposed, but could be synchronised. Whereas mechanical clocks would have been helpful in quantifying the time of day, the Wheel would have been used to calculate more accurately the times of the liturgical day. This did not solely depend on a numerical measurement of the time, but also on the distance from sunrise and sunset as the feasts of the liturgical day commenced at sunset of the modern calendar day preceding the date of the feast. The six columns of Arabic numerals inside the liturgical calendar of the Wheel are dedicated to the duration of daylight and darkness (in hours and minutes) for each day. The columns split each day into four segments by stating the duration of the half night,⁸⁷ full night,⁸⁸ and full night plus half day in hours and minutes.⁸⁹ This system considered natural cues whilst recording their durations according to the measurement of the equal hours.

This allows one to deduce two features of its use. First, it is highly likely that these durations were used to reckon liturgical timings by measuring them from sunset. For example, Vigils was held as close as possible to midnight, but would also be timed so that the monks could get enough sleep as possible before Matins at the break of dawn,⁹⁰ a particular challenge during the short summer nights.⁹¹ There are also many examples of less ubiquitous timings that conformed to this division of the day into quarters. The *Angelus* bell, for example, originally signalled the time for the *Ave Maria* prayer at sunset, for a morning prayer which was added in the fourteenth century, and for an additional noon prayer introduced in the fifteenth century.⁹² These points of the day each correspond to those given in our Wheel, yet as these timings were community specific one cannot be certain as to their relation before knowing the Rites particular to San Zeno.

⁸⁷ Time from dusk till midnight. This varies from the maximum number of hours of darkness during the Winter solstice (7 hours 45 minutes on December 13-16), to the minimum number of hours on the Summer Solstice (4 hours 15 minutes on June 13-18).

⁸⁸ Time from dusk till dawn, and therefore the double of the previous columns: 15 hours 30 minutes on December 13-16, to a minimum of 8 hours 30 minutes on June 13-18.

⁸⁹ Time from dusk till noon, therefore the previous 2 columns combined. Maximum 19 hours 45 minutes on December 13-16, to a minimum of 16 hours 15 minutes on June 13-18.

⁹⁰ The day offices took their names from the original times according to unequal roman hours: Prime, Terce, Sext and None. See Dohrn-van Rossum (as in n. 13), p. 36.

⁹¹ Ibid., p. 38

⁹² Dohrn-van Rossum (as in n. 13), p. 204.

Second, it seems that these tables were intended to complement a twenty-four hour clock, such as that in the apse of the basilica. Unlike our current system that measures the hours from midnight (and midday), they were often counted from sunset. This system is often referred to as the 'Italian hours' as they were re-introduced (having originally been used in Antiquity and falling out of use) in Italy during the Middle Ages.⁹³ This meant that they had to be adjusted according to the time of year, and to do so would require consultation of tables, such as those in the Wheel. There is documentation (but no surviving apparatus) that the 'Grand Clock' in Nuremberg (used from 1374) worked in a similar way by using tables that divided the day into day hours and night hours, depending on the month.⁹⁴ The reliance on its hour reckoning to daylight meant tables had to be used.

The Wheel's data could therefore be used with the clock in the apse (or perhaps those on the abbey tower or campanile) to count when it was midnight, sunrise and midday, the first of which could not be reckoned by observing the position of the sun. This mode of time reckoning does not show a sudden change from one time system to another, but demonstrates a synchronised method that relied on natural cues and used the equal hours as its unit of measurement.

Monastic Time after the Mechanical Clock

The Zeno Wheel is significant in its corroboration of the most recent study of monastic hour reckoning by Dohrn-van Rossum, in which he contended that the time-telling methods following the invention of the mechanical clock attempted to 'avoid a complete break with the accustomed system of unequal hours'.⁹⁵ He challenged the conclusions of sociologists who regularly cited the significance of monastic life to the historiography of modern industrial society. Lewis Mumford argued that 'The application of quantitative methods of thought to the study of nature had its first manifestation in the regular measurement of time; and the new mechanical conception of time arose in part out of the routine of the monastery'.⁹⁶ Herbert Enoch Hallam described the 'spirit of the clock' to be 'wholly Benedictine', and Eviatar Zerubavel identified

⁹³ The 'Italian hours' were used by Jews and Greeks in Antiquity, then re-introduced in the Middle Ages in Italy before spreading to parts of Germany and Bohemia. G. Bilfinger, *Die Mittelalterlichen Horen*, Stuttgart 1892, p. 189. Exactly when they were re-introduced is still debated now.

⁹⁴ Our modern version of the clock was referred to as the 'small' or 'half clock' and was rarely used due its total abstraction from natural time. Dohrn-van Rossum (as in n. 13), pp. 114-15. Dohrn-van Rossum cited C. T. Gemeiner, *Regensburgische Chronik*, II, Regensburg 1971, p. 181.

⁹⁵ Dohrn-van Rossum (as in n. 13), p. 113.

⁹⁶ L. Mumford, *Technics and Civilization*, New York 1934, p. 12.

Benedictine monasteries as prime examples of 'clockwork communities' that were the 'original models for all modern Western schedules'.⁹⁷ Within this historiography, the mechanical clock became a symbol of the strict scheduling of Benedictine routine.

Dohrn-van Rossum argued that these (more often sociological) arguments were biased by their framework, which was centred on a historical understanding of modern mechanisation.

Mumford's study was thus 'seduced by a machine metaphor that has taken on a life of its own'.⁹⁸

Zerubavel, although less extreme than Mumford in his allusion to industrialism, still worked on the assumption that a regular monastic time signal existed in Benedictine communities.⁹⁹

Dohrn-van Rossum attributed the above conclusions to a misunderstanding of the *horologia*, as Mumford, Hallam and Zerubavel all failed to distinguish between alarm devices, mechanical clocks and striking clocks.¹⁰⁰ Even so, the idea of 'clockwork' Benedictines is in fact paradoxical as the hours would constantly change according to the seasons and were hence not governed automatically, but read from natural cues. The reliance on such cues meant that indications of the equal hours were not always necessary, and the duration of offices was often measured by liturgical durations. In summary:

Talk of 'iron discipline' or the machine-like or clockwork rhythm of monastic life, even in a purely metaphorical sense, is misleading, because it suggests a time giver (a machine or clock) external to natural rhythms and the daily round of human life. In actual fact, life according to the Rule was bound in a very high degree to natural time givers, daylight and the seasons, and was by no means marked by ascetic resistance to the natural environment.¹⁰¹

Computistical calculation and the observation of natural cues remained a regular component of the Benedictine routine, demonstrating the complexity of timing the liturgy in the fourteenth and fifteenth centuries following the widespread use of the mechanical clock. This clarifies the reason

⁹⁷ He went on to contend that the rhyme *Frère Jacques* demonstrates how the notion of temporal regularity is perceived to be synonymous with monasticism. E. Zerubavel, *Hidden Rhythms: Schedules and Calendars in Social Life*, Chicago 1981, pp. 31-32.

⁹⁸ Dohrn-van Rossum (as in n. 13), p. 33.

⁹⁹ Zerubavel made it clear, in fact, that one does not need to 'go as far as to claim, like Mumford, that the clock "is a key-machine of the modern industrial age"'. Zerubavel (as in n. 97), p. 38.

¹⁰⁰ Ibid., p. 35.

¹⁰¹ Dohrn-van Rossum cited H. E. Hallam, 'The Medieval Social Picture', in *Feudalism, Capitalism and Beyond*, ed. E. Kamenka and R. S. Neale, London 1975, pp. 29-49, and Zerubavel (as in n. 97), pp. 31-69.

for the multiple *horologia* used in San Zeno during the fifteenth century and the role of the Wheel within this.

Concluding Remarks

The intention of this article has been to elucidate the San Zeno Wheel and how it can inform our present understanding of medieval time keeping. It is indeed a unique survival of great importance to the history of science and technology, in particular as an indicator of how calendrical components of ecclesiastical *horologia* originally appeared. Its function has significant implications for the sociological literature concerning the history of time keeping, as the Wheel emphasises the diversity of instruments that catered to various ecclesiastical spaces and needs, reflective of the multiple time systems simultaneously in use following the appearance of the mechanical clock. This paper is just the beginning of this conversation, and there is still much to be said about the Wheel. The identification of the sources of the astronomical data, how the age of the moon on the middle disk of the volvelle works, the illuminators of the Wheel and a conservational study of its structure and damage are all highly likely to reveal further insights regarding its construction and use.

More broadly speaking, the Wheel is a key to our understanding of the material history of the calendar, a valuable subject that has remained understudied. During the fourteenth and fifteenth centuries, the temporal information initially collected in *computus* manuscripts began to be rendered as cosmological machines. The calendar broke free from its listed format in manuscript codices to be found in scrolls, almanacs, atlases, volvelles, and printed books, before being transformed into three-dimensional devices, such as disks within astronomical clocks, rings around globes and even volvelles within triptychs.¹⁰² The Wheel is situated within this blurring of

¹⁰² At this time, the synthesis of the astronomical learning and the liturgical calendar was of particular importance between northern Europe and northern Italy, as shown in the books of Regiomontanus (1436-76, a student of Georg von Peurbach, also known as Johannes Müller), who visited Veneto from Vienna to lecture in Padua. Regiomontanus produced the *Calendarium*, in which he applied novel scientific methods of astronomical observation and calculation to the lunar calendar. In the copies of the *Calendarium*, published in numerous editions from 1474 to 1499, volvelles and other paper instruments were often situated in the back of the codices. Regiomontanus's presence in Italy is well documented. He travelled to Rome with Cardinal Bessarion in September 1461, where he stayed until 1467 before moving to Hungary for a professorship in mathematics and the University of Pressburg (modern Bratislava). D. A. King and G. Turner, 'The Astrolabe presented by Regiomontanus to Cardinal Bessarion in 1462', *Nuncius*, IX (I), 1994, pp. 165–206 (167-68). Regiomontanus was then invited to visit Pope Sixtus IV in Rome in 1475 in order to advise on the future revision of the calendar, but arrived in 1476 shortly after the pope died. P. Nothaft, *Dating the Passion: The Life of Jesus and the Emergence of Scientific Chronology (200-1600)*, Leiden 2012, p. 223. With regard to a calendar volvelle in a triptych, see n. 19 above. This calendar would be particularly pertinent in a study of the migration of calendar types between northern Italy and northern Europe in this period.

forms. It is not quite a manuscript calendar. It is not quite an astronomical clock. Yet its individual analysis reveals a wealth of new information concerning both groups by confronting the previous assumptions concerning medieval time reckoning. This demands that researchers return to the object-based interpretation of individual instruments, and that historians of visual culture take a prominent role in the re-evaluation of the history of time.