

Astronomy and calendar reform at the curia of Pope Clement VI: a new source

C. PHILIPP E. NOTHAFT

All Souls College, Oxford

philipp.nothaft@all-souls.ox.ac.uk

Summary

The article introduces a previously unknown fourteenth-century treatise on *computus* and calendrical astronomy entitled *Expositio kalendarii novi*, whose author proposed elaborate solutions to the technical flaws inherent in the calendar used by the Roman Church. An analysis of verbal parallels to other contemporary works on the same topic makes it possible to establish that the *Expositio* was produced in the context of a calendar reform initiative led by Pope Clement VI in 1344/45 and that this anonymous text is probably identical to a ‘great and laborious work’ on the calendar that the monk Johannes de Termis prepared for the pope around this time. Its author strove to make an original contribution by extracting new astronomical parameters from both ancient and contemporary data, which made him arrive at an estimate of the length of the tropical year that was independent of the then-current Alfonsine Tables. With its suggestion to remove eleven days from the Julian calendar and to correct the calendar through modified leap-year rhythms and periodically adjusted sequences of lunar epacts, the proposal enshrined in the *Expositio* exhibits some remarkable similarities to the Gregorian reform of the calendar promulgated in 1582. Although its influence on the latter must remain a matter of speculation, the newly discovered text sheds a revealing light on the history of medieval calendar reform debates and on the mathematical sciences practiced at the Avignon court of Clement VI.

1. Introduction

One of the thousands of obscure and unstudied manuscripts in the collections of the Vatican Library is Ottobonianus latinus 842, a parchment codex of 71 leaves formerly in the possession of Giovanni Angelo von Altemps (d. 1620) and Pietro Ottoboni (Pope Alexander VIII, d. 1691).¹ It contains only a single text, which the heading on the first page identifies as an *Expositio kalendarii novi*. This brief title was later extended by a different hand, which inserted the words *et correctio veteris* in black ink above the rubricated original heading. The completed heading reads: *Expositio kalendarii novi et correctio veteris edita anno domini 1340*, that is, ‘An Exposition of the new calendar and correction of the old one issued in the year of the Lord 1340’.² This is unlikely to be the date of our extant copy, however, which was written in a Gothic cursive script familiar from fifteenth-century French scribes (see Figure 1).

As the title already suggests, the *Expositio* was intended as a contribution to a centuries-long discussion surrounding the errors of the ecclesiastical calendar and the reform of Easter reckoning, which, as far as the Roman Catholic Church is concerned, came to a conclusion with the Gregorian calendar reform of 1582.³ Scholars have long been aware than

¹ José Ruyschaert, Adriana Marucchi, and Albinia C. de la Mare, *I codici latini datati della Biblioteca Apostolica Vaticana*, vol. 1, *Nei fondi Archivio S. Pietro, Barberini, Boncompagni, Borghese, Borgia, Capponi, Chigi, Ferrajoli, Ottoboni* (Vatican City: Biblioteca Apostolica Vaticana, 1997), p. 139 (no. 315 and tav. IX).

² The incipit of the text proper is ‘Quoniam cuiusque solempnitatis certa dies in anno solari aut lunari...’ I shall cite the work as *Expositio*, followed by book and chapter numbers, followed by the folio-number in parentheses. A full list of chapter headings is provided in the Appendix to this article.

³ For an overview, see Ferdinand Kaltenbrunner, ‘Die Vorgeschichte der gregorianischen Kalenderreform’, *Sitzungsberichte der philosophisch-historischen Classe der kaiserlichen Akademie der Wissenschaften* [Vienna], 82 (1876), 289–414; John North, ‘The Western Calendar—“Intolerabilis, Horribilis, et Derisibilis”’: Four

an earlier attempt to bring about such a reform had been undertaken in 1344/45 at the curia of Pope Clement VI, who invited the advice of expert astronomers on how to restore the ecclesiastical method of lunar reckoning to its proper order.⁴ Contrary to the claim made in the manuscript heading, the *Expositio calendarii novi* can be shown to have been written several years after 1340, at the exact time of the papal reform effort. An observation of the autumn equinox made in 1344 and cited early on in the text strongly suggests that the work was not completed before 14 September that year (see p. **Error! Bookmark not defined.** below), while a later passage unambiguously identifies the present year as 1345 CE.⁵ This happens to be the very same year in which the astronomers Jean (Jehan) des Murs and Firmin de Beauval addressed an *Epistola super reformatione antiqui kalendarii* to Clement VI.⁶ Compared to this *Epistola* and its attached treatise on how to reform the calendar, the work in Ottobonianus latinus 842 is a vastly more comprehensive contribution to the topic, which comes divided into two books and a total of 54 chapters (listed in the Appendix below).

Centuries of Discontent’, in *Gregorian Reform of the Calendar*, ed. George V. Coyne, Michael A. Hoskin, and Olaf Pedersen (Vatican City: Specola Vaticana, 1983), pp. 75–113. A more comprehensive account will be provided in C. P. E. Nothaft, *Scandalous Error: Calendar Reform and Calendrical Astronomy in Medieval Europe* (Oxford: Oxford University Press, forthcoming).

⁴ See most recently C. P. E. Nothaft, ‘Science at the Papal Palace: Clement VI and the Calendar Reform Project of 1344/45’, *Viator*, 46, no. 2 (2015), 277–302.

⁵ *Expositio* I.10 (fol. 11v): ‘...imprecisionem anni excludere ex qua ab incarnatione usque in presens, hoc est in annum millesimum CCC^m XLV^m, iam undecim dies cum horis quinque collecti sunt’.

⁶ See the two editions by Christine Gack-Scheidig, *Johannes de Muris: Epistola super reformatione antiqui kalendarii; Ein Beitrag zur Kalenderreform im 14. Jahrhundert* (Hannover: Hahn, 1995), and Chris Schabel, ‘John of Murs and Firmin of Beauval’s Letter and Treatise on Calendar Reform for Clement VI’, *Cahiers de l’Institut du Moyen-Âge Grec et Latin*, 66 (1996), 187–215. In what follows, I shall use the shorthand ‘Jean/Firmin, *Epistola*’ to refer both to the letter and the attached quadripartite treatise.

Many of these chapters branch out into more general aspects of time reckoning, astronomy, and even astrology, as exemplified by extended sections dealing with the qualities and causes of the four seasons (I.20–21), the signs of the zodiac (I.26–29), or the critical days (II.8–9).

The first part of the present article will ignore this additional material and instead focus on those astronomical passages that were immediately relevant to the critique and suggested correction of the ecclesiastical calendar. My main goal will be to highlight various innovative or unusual elements in the author's approach to his topic, but also to indicate how some of his core ideas exhibit striking similarities to the Gregorian reform undertaken 240 years later. In the second part of the article, I will turn to some very conspicuous verbal and conceptual parallels between the *Expositio* and two other contemporary works on the same topic, which were both connected to Pope Clement VI's reform initiative. The mentioned parallels clearly reveal that the *Expositio* stems from the same context, making it a valuable source on the details and modalities of the discussions that took place at the Avignon court of Clement VI in 1344/45. As I will argue below, the *Expositio* is likely to have been an earlier work by the Dominican-turned-Benedictine monk Johannes de Termis, who has until now only been known for the *Tractatus de tempore celebrationis paschalis* he addressed to Pope Innocent VI in 1354. If this is correct, his name must be placed next to Jean des Murs, Pierre d'Ailly, and Nicholas of Cusa for being one of the most important voices in the calendar-reform debate of the late Middle Ages.

2. Calendrical astronomy in the *Expositio kalendarii novi*

The 'calendar problem', as it presented itself to the learned observer in the mid-fourteenth century, was rooted in the requirement to fix the dates of the mobile feast days in the Church year in accordance with astronomical criteria, which dictated that Easter had to be the first Sunday after the first full moon to fall on or after the vernal equinox. The vernal equinox

itself was supposed to be located on 21 March, while the full moon was conventionally equated to the 14th day of a calendrical lunar month or lunation, with the consequence that Easter Sunday itself could occupy any date between the 15th and the 21st day, thus paralleling the Jewish feast of unleavened bread on 15–21 Nisan. In principle, the criteria just outlined necessitated a calendar system capable of (a) perpetually maintaining the vernal equinox on its conventional date and (b) reliably identifying the starting date of the first lunar month in spring on a year-to-year basis. Neither of these functions was accurately performed by the medieval ecclesiastical calendar, which comprised two separate components, one solar and one lunar. The solar component was represented by the Julian calendar, whose average year length of $365\frac{1}{4}$ days was brought about by the intercalation of a 366th day (a so-called bissextile day) in every fourth year. Although convenient to use, this rule implied a solar year that was approximately 11 minutes in excess compared to the average interval between two vernal equinoxes, which over the past millennium has remained close to 365.2424d or *c.* 365d 5h 49m 3s. The result of this overestimation was a slow regression of the dates of the equinoxes and solstices in the Julian calendar, which by the year 1345 had landed the vernal equinox on 12 March, nine days ahead of the equinoctial limit assumed by computists (Easter reckoners). The other prong of the calendrical problem was inherent in the 19-year lunar cycle the Church used to predict the *terminus paschalis*, that is, the notional 14th day of the Moon before Easter. This cycle, which had been introduced by the Church of Alexandria in late antiquity, rested on the assumption that 235 lunations were exactly equal to 19 years in the Julian calendar. The implied average lunation of $365\frac{1}{4} \times 19 \div 235 = 29.530851$ d exceeded the length of the mean synodic month (*c.* 29.530589d) by some 23 seconds. After $308\frac{1}{2}$ years, this excess reaches a complete day, explaining why observed discrepancies between calendrical new moon dates and the actual conjunctions of Sun and Moon could reach up to four days by the middle of the fourteenth century.

The more the calendar grew out of sync with the phases of the Moon and the more the vernal equinox regressed towards the beginning of the year, the more frequently the Church could be accused of celebrating Easter, Lent, Pentecost, and all the other mobile feasts on incorrect days. Medieval computists and astronomers had already begun to discuss this problem in earnest in the twelfth century, but it was not until the 1340s that the reform of the calendar and the restoration of Easter reckoning to its proper order became a project actively pursued within the leading ranks of the Latin Church. By this time, the technical-astronomical basis for analysing the problem had switched to the Alfonsine Tables, named after their patron King Alfonso X of Castile and León (1252–1284), which had quickly established themselves as the standard set of computational tables after their introduction in Paris around 1320. Their influence is evident in the *Epistola* that Jean des Murs and Firmin de Beauval addressed to Pope Clement VI in 1345, since according to this text the equinoxes and solstices regress at a rate of 1 day every 134 years. This estimate ultimately depends on the Alfonsine tables for the Sun's mean motion in tropical longitude, which show a daily rate of progress of $0;59,8,19,37,19,13,56^{\circ}/d$, amounting to 360° after approximately 365d 5h 49m 16s or $365\frac{1}{4} - \frac{1}{134}$ days.⁷ Jean and Firmin could not exclude that the tropical year was subject to fluctuations over time, but on the whole they were confident that this Alfonsine parameter yielded a good enough estimate for the time being, especially since the tables that contained it

⁷ Emmanuel Poulle, *Les Tables Alphonsines avec les canons de Jean de Saxe: édition, traduction et commentaire* (Paris: Éditions du CNRS, 1984), p. 134. On the background, see José Chabás and Bernard R. Goldstein, *The Alfonsine Tables of Toledo* (Dordrecht: Kluwer, 2003).

had received confirmation from ‘many sensory experiences [that were had] in Paris and elsewhere’.⁸

Among the most noteworthy aspects of the *Expositio kalendarii novi* is the way in which its author tacitly undermined the Alfonsine consensus that had already formed in his time. Far from simply relying on any existing set of tables, he dedicated the opening portion of his treatise (Book I, chapter 2) to extracting the length of the tropical year from historical and contemporary evidence.⁹ A starting point was provided by two ancient observations of the date and time of the autumn equinox, both of them recorded in Ptolemy’s *Almagest*:

26/27 September 147 BCE, midnight (*Almagest* 3.1)

25 September 132 CE, 2 pm (*Almagest* 3.7).¹⁰

Our author came up with more precise times by extracting the corresponding entry of the Sun into the sign of Libra from Ptolemy’s own mean motion tables (times counted from noon of the previous day):

26 September 147 BCE, 12:05h

25 September 132 CE, 01:50h.¹¹

In a next step, he chose to obtain the midpoint between these two dates by halving the interval between them:

⁸ Jean/Firmin, *Epistola* (1.3), ed. Schabel (n. 6), p. 198: ‘Ita quod secundum tabulas Alfoncii, quas credimus in proposito ceteris veriores, et per multas sensibiles experientias Parisius et alibi magis consueverunt approbari, in singulis 134 annis fit elongatio predicta ad quantitatem unius diei’.

⁹ See *Expositio* I.2 (fols. 1r–4r), which the following paragraphs will attempt to summarize.

¹⁰ See Ptolemy, *Almagest*, trans. G. J. Toomer (Princeton, NJ: Princeton University Press, 1998 [1st edn 1984]), pp. 138, 168, and *Almagestum Cl. Ptolemei*, trans. Gerard of Cremona (Venice: Lichtenstein, 1515), fols. 28r, 34r.

¹¹ Recalculation with Raymond Mercier’s programme *Deviations* (<http://raymondm.co.uk>) shows true equinox times that fall only one minute later (12:06h and 01:51h).

$$278y^{12} 68d 13:45h \div 2 = 139y 34d 06:52:30h$$

If subtracted from the equinox Ptolemy had observed in 132 CE, this number led back to a autumn equinox on 25 September 8 BCE, at 18:57h. It is interesting to see that the author expressly treated this date and time as an average between the two observations attributed to Hipparchus and Ptolemy, which was supposed to help balance out any minor errors the two astronomers might have committed on account of imperfections in the instruments they used. He proceeded to compare the inferred autumn equinox of 8 BCE with the one the Alfonsine Tables signalled for 15 September 1289 CE, at 01:22h. Mindful of the difference in longitude between Ptolemy's Alexandrian meridian and the Toledan meridian presupposed in the Alfonsine Tables, he concluded that the interval between the two timestamps, which was 1296y 313d 06:25h, had to be increased by another 01:31h (equivalent to 22;45°). An additional step was to home in on the Sun's mean, as opposed to true, longitude at these equinoxes, which the Alfonsine Tables showed to have been 0;7;43° lower in 8 BCE (182;2,15°) than in 1289 CE (182;9,58°) as a result of the changing position of the solar apogee. At a daily rate of solar motion of 0;59,8°, this difference of 0;7;43° was equivalent to almost exactly 03:08h in time. Subtracting it reduced the interval in question to 473,353d 06:25h + 01:31h – 03:08h = 473,353d 04:48h, which happened to be exactly equivalent to 1296 years of 365d 5h 48m:

$$365d 5h 48m \times 1296 = 473,353d 04:48h.$$

The author showed himself confident that this result for the mean tropical year could be confirmed by one of his own observations, which he alleged to have made in Paris in 1344 CE. In order to be able to compare his own 'observed' time, which was 09:11h on 14 September, to the Alfonsine equinox of 15 September 1289 CE, at 01:22h, the author lowered

¹² Here and elsewhere in this article, 'y' = year(s) refers to Egyptian years of 365d each.

the interval by 00:49h (00:48h for the longitude difference between Toledo and Paris + 00:01h to correct for the motion of the solar apogee), making him arrive at 20,088d 07:49h – 00:49h = 20,088d 07:00h. This once again amounted to an average annual revolution of 365d 5h 48m (= 20,088d 07:00h ÷ 55).¹³

The way in which the author managed to have the *Almagest*, the Alfonsine Tables, and contemporary observation all bear witness in support of one and the same value for the mean tropical year is certainly curious and raises suspicions about his *modus operandi*. Thus, his value for the Sun's mean longitude at the time of the autumn equinox of 8 BCE is best explained by his use of the Alfonsine Tables, which placed the equinox on 25 September at 15:56h (Alexandrian meridian) and hence three hours earlier than the time he had inferred from the data in the *Almagest*.¹⁴ Even then, the correct result for the corresponding mean longitude would have been 182;3,3° rather than the 182;2,15° stated in the text, which may indicate that he lowered the result on purpose to obtain the desired correction of –03:08h for the total interval between 8 BCE and 1289 CE. The likelihood that he strategically selected

¹³ *Expositio* I.2 (fol. 3v): ‘Nobis, denique, qui idem quoque equinoctium in fine revolutionis quinquagesime quinte post, quanto subtilius pro modulo nostri fuit possibile, inquisivimus super Parisius, visum fuit post dictum tempus ad meridiem Tholeti numeratum per dies viginti milia octoginta octo cum horis, septem et quadraginta novem minutis, quam videlicet summam diminutam primo uno minuto, propter motum augium, ac deinde quadraginta octo, propter distanciam regionum, cum super quinquaginta quinque revolutiones diviserimus, invenimus illud quod de ea unicuique revolutioni pertinuit esse idem quod prius’.

¹⁴ The Alfonsine Tables are clearly more likely to have been his source than the *Almagest*, which would have given the solar mean longitude for 25 September 8 BCE, 18:57h, as 182;10,18°. The Alfonsine Tables, as simulated in *Deviations* (n. 11), show that a solar mean longitude of 182;2,15° was already reached at 15:36h after noon. The Alfonsine true equinox occurred *c.* 20 minutes later, at 15:56h. The mean longitude at the equinox of 1289 CE (15 September, 01:23h, Toledan meridian) was almost exactly 182;9,59° and at any rate very close to the 182;9,58° stated in the text.

both the data that led to this interval and the time of the equinox of 1344 CE seems particularly strong if the prior history of his result is taken into account. As it happens, a solar year of 365d 5h 48m or $365\frac{1}{4} - \frac{1}{120}$ days had been a staple of computistical literature since at least the thirteenth century, as seen from Alexandre de Villedieu's widespread *Massa compoti* or the less famous *Computus lunaris* written in 1254 by Bòno da Lucca, which became the main source for Book VIII in Guillaume Durand's *Rationale divinatorum officiorum* (1286).¹⁵ Computists who endorsed this value often justified it by referring to the long-standing notion that the conception and birth of Jesus Christ (25 March/25 December) as well as the conception and birth of John the Baptist (24 September/24 June) had coincided with the then-current dates of the equinoxes and solstices. Based on the alleged fact that the equinoxes and solstices in c. 1200 CE had already been found 10 days earlier, they argued that the average year in the Julian calendar was 12 minutes too long, causing the dates to shift at a rate of 1 day every 120 years.¹⁶ What makes the *Expositio* of 1345 unusual is the author's resolve to support the year length of the computists not with pseudo-historical arguments about birth dates, but with actual astronomical data. The Alfonsine Tables are in this context still appealed to as a source for solar longitudes close to the time of their starting epoch (1252), but not for the overall length of the tropical year. This suggests that the author regarded these tables as reliable for the time at which they had been constructed, but not for

¹⁵ See Walter Émile van Wijk, ed., *Le Nombre d'Or: étude de chronologie technique suivie du texte de la Massa compoti d'Alexandre de Villedieu* (The Hague: Nijhoff, 1936), pp. 58–59; Bòno da Lucca, *Computus lunaris*, ed. Gino Arrighi (Lucca: S. Marco, 1991), p. 8; Guillaume Durand, *Rationale divinatorum officiorum* (VIII.3.25), ed. A. Davril and T. M. Thibodeau, *Corpus Christianorum Continuatio Mediaevalis 140B* (Turnhout: Brepols, 2000), p. 140; *Computus ecclesiasticus*, ed. in Jennifer Moreton, 'John of Sacrobosco and the Calendar', *Viator*, 25 (1994), 229–44, at pp. 243–44. Further examples will be discussed in Chapter IV.1 of Nothaft, *Scandalous Error* (n. 3)

¹⁶ See already Kaltenbrunner, 'Die Vorgeschichte' (n. 3), pp. 293–97.

more remote periods, precisely because the *Alphunsiste* had failed to use the correct year length.¹⁷

Later sections of the *Expositio*'s first book expressed a considerable degree of confidence in the computists' estimate for the tropical year, which in our author's opinion was not compromised by the fact that astronomers in bygone centuries had come up with significantly different values. He was well aware that sceptics might utilize this fact to level one of two different arguments against him. One insisted that, just like present-day astronomers had improved upon earlier ones, future astronomers might find a value even closer to the truth than any of the ones presently accepted, thus turning the correction of the Julian calendar into a business fraught with uncertainty and the danger of failure. The other took the ancient astronomers at their word, arguing that the length of the year had evidently decreased between the observations made in the second century by Ptolemy (who upheld a tropical year of $365\frac{1}{4} - \frac{1}{300}$ days) and in the ninth century by al-Battānī (whose tropical year was $365\frac{1}{4} - \frac{1}{106}$ days), but grown again in more recent times, explaining the larger value accepted by King Alfonso and his advisers ($365\frac{1}{4} - \frac{1}{134}$ days). If this trend continued for long enough to allow the tropical year to exceed $365\frac{1}{4}$ days, it was even imaginable that the equinoxes and solstices, far from continuously moving towards the beginning of the year, might eventually return to their former resting places.¹⁸ Our author briefly rehearsed these arguments in

¹⁷ See the remark in *Expositio* I.2 (fol. 3r): 'Quod quidem fuit in anno ab incarnatione millesimo ducentesimo octogesimo nono et a nativitate regis Alphunsi tricesimo septimo, a quo non longe ipsi Alphunsiste verificasse noscuntur'. For a more outspoken contemporary critique of the Alfonsine Tables, see the work discussed in C. P. E. Nothaft, 'Critical Analysis of the Alfonsine Tables in the Fourteenth Century: The Parisian *Expositio tabularum Alfonsii* of 1347', *Journal for the History of Astronomy*, 46 (2015), 76–98.

¹⁸ This argument was pioneered in the twelfth century by the author of the *Compotus Petri* of 1171, MS Paris, Bibliothèque Mazarine, 3642, fols. 13r–47r, at fols. 18va–20ra. See also Magister Cunestabulus, *Computus* (c.

Expositio I.9, but found them both wanting. In response to the first, he insisted that an adequate fixing of the equinoxes and solstices did not necessarily require a perfect measure of the tropical year. Indeed, it sufficed to have a value that came close enough to the truth to make the remaining drift of dates imperceptible or barely perceptible over longer periods of time—a condition his own estimate of 365d 5h 48m promised to fulfil.¹⁹

He showed himself equally unimpressed by the idea that the length of the tropical year might undergo significant shrinkage or growth over time, pointing out that such changes could be accounted for only in one of three ways: (a) by having the Sun move non-uniformly on its deferent, (b) by having it move uniformly on a large epicycle, or (c) by having the sphere of the fixed stars undergo the non-linear back-and-forth motion known as ‘access and recess’ (*motus accessus et recessus*), which had the effect of continuously displacing the equinoctial points in relation to the Sun’s sidereal course.²⁰ The epicycle theory was easily

36), ed. Alfred Lohr, *Corpus Christianorum Continuatio Mediaevalis* 272 (Turnhout: Brepols, 2015), pp. 109–10.

¹⁹ *Expositio* I.9 (fol. 10r–v): ‘Sed ista non cogunt, quia cum aliquid dicatur immobile, vel quia simpliciter non movetur vel quia si movetur hoc est lente et tarde. Sicut ad compositionem kalandarii non fuit neccesarium solsticia et equinoctia sic immobilitare quod simpliciter non moverentur, nec per consequens habere quantitatem anni sic verissimam et precisam quod verior precisioreve haberi non posset, ita illud non est neccesarium ad eius correccionem, sed suffecit correctiori quod vel si moveantur solsticia ipsa et equinoctia post suam correccionem quod hoc sit tardissime, ut sic sua correctio vel ad semper vel usque in tempore longissima absque omni mutacione sensibili valeat perdurare, et quod cum hoc de remedio opportuno provideat, si forte post tempore longissima aliqua mutacio sensibilis occurat’.

²⁰ On the access and recess-theory in the context of the old Toledan Tables, see Raymond Mercier, ‘Accession and Recession: Reconstruction of the Parameters’, in *From Baghdad to Barcelona*, ed. Josep Casulleras and Julio Samsó, vol. 1 (Barcelona: Instituto ‘Millás Vallicrosa’ de Historia de la Ciencia Arabe, 1996), pp. 299–347. See now also C. P. E. Nothaft, ‘Criticism of Trepidation Models and Advocacy of Uniform Precession in Medieval Latin Astronomy’, *Archive for History of Exact Sciences* (forthcoming).

discarded given the lack of support from famous astronomers, not to mention the unobserved changes in apparent disk-size and solar parallax such a model would have necessarily implied. Against the assumption of non-uniform motion, it could be objected that this should have manifested itself in changes to the length of the synodic lunar month, which could be expected to decrease in length as the Sun slowed down and was hence more easily overtaken by the Moon. The historical record instead showed that Hipparchus and Ptolemy accepted a greater value for the synodic month than al-Battānī or Alfonso, even though the solar year in their time was supposedly longer.²¹ This was a clever demur, but not one that could also be applied to the theory of access and recess, since the motion of the sphere of the fixed stars was supposed to affect the spheres of Sun and Moon in equal measure. For our author, there was nevertheless no hope for this theory, which he noted had been endorsed by neither Hipparchus nor Ptolemy nor al-Battānī nor Alfonso. ‘And since these were the greatest astronomers [...] it would be fatuous for anyone else to assume it’. Arguments from authority aside, he believed that the equinoxes and solstices now already fell 18 days earlier than when the Roman calendar was first created, which made the prospect that they were ever going to swing the other way seem less than likely.²²

²¹ *Expositio* I.9 (fols. 10v–11r). The length of the synodic month according to Hipparchus and Ptolemy was 29;31,50,8,20d, whereas the Alfonsine Tables have an implicit 29;31,50,7,37,27,8,25d. Al-Battānī’s value was in fact the same as the one found in the *Almagest*, but perhaps our author here thought of the average month in the lunar calendar used by Arabic astronomers, which was only 29;31,50d. See on the background Bernard R. Goldstein, ‘Ancient and Medieval Values for the Mean Synodic Month’, *Journal for the History of Astronomy*, 34 (2003), 65–74.

²² *Expositio* I.9 (fol. 11r): ‘Non propter primum tamen, quia nec Abrachim nec Ptholomeus nec Abbathegni nec Alphonsus posuerunt unquam solem movere illo motu. Unde cum isti fuerunt maximi astronomi et de maioribus qui fuerunt a creatione mundi nec hoc posuerunt, fatuus esset qui poneret. Tum eciam, quia cum ipsa solsticia et equinoctia loca in kalendario sibi data tempore quo fuit factum ipsum kalendarium iam per decem et octo dies

Even if the access and recess model was rejected, however, the question remained why more ancient astronomers had found the solar year to be longer than later ones. The author responded to this question by asserting that the original definition of the year, as used by Hipparchus and Ptolemy, had corresponded to the Sun's period of return to its apogee (i.e., the anomalistic year), which happened to be exactly $365\frac{1}{4}$ days. Hipparchus accepted precisely this value, whereas Ptolemy was later surprised to find a shorter interval from comparing observed equinoxes, leading him to subtract 4 minutes and a few fractions from the length of the year.

Al-Battānī, however, and Alfonso, when they perceived the motion of the apogees and [decided to] count the motion of the Sun from the [vernal equinox] put down the length of the year in a more precise fashion. One of them, namely al-Battānī, [accepted] beyond a complete number of days 5 hours, 47 minutes together with a few fractions, whereas the other, namely Alfonso, [accepted] 49 minutes, again with a few fractions. Others, however, as is the case with nearly all computists, held the middle ground between these two and accepted exactly 48 minutes, which length of the year is endorsed by experienced astronomers and [regarded] as the most precise of them all and found [to be so] by reliable experiences.²³

anticipaverunt nec adhuc apparet quod aliquo modo incipiant redire, quinimmo eque velociter continue anticipando procedunt sicut unquam fecerunt, probabiliter potest argui quod numquam redibunt'. The passage implies that the calendar was created at a time when winter solstice still fell on 1 January, which is an anachronistic claim found in various thirteenth-century *computus* texts. See, e.g., Bòno da Lucca, *Computus lunaris*, ed. Arrighi (n. 15), p. 8, and the *Computus* of Peter of Berne, MS Oxford, Bodleian Library, Can. Misc. 71, fols. 5r–14v, at fols. 5v–6r. It also crops up in Jean/Firmin, *Epistola* (1.2), ed. Schabel (n. 6), p. 198.

²³ *Expositio* I.10 (fol. 12r): 'Abbathegni vero et Alphunsus motum augium percipientes motumque ipsius solis a capite Arietis fixi numerantes posuerunt quantitatem anni magis precisam. Unus quidem, videlicet Abbathegni, ultra dies integras <quinque> [Ms.: atque] horas, XLVII minutorum, cum quibusdam fractionibus, alter vero,

In unpacking these remarks, it is worth starting with the author's assertion that Hipparchus believed the solar year to last $365\frac{1}{4}$ days exactly. This is not a statement supported by the *Almagest*, although it can be found in Robert Grosseteste's *Compotus correctorius* (c. 1225–30), who in turn probably relied on the *Almagestum parvum*, a summary of the first six books of Ptolemy's work created c. 1200. Both sources agree on Hipparchus's value as well as on the one they assign to al-Battānī, which Grosseteste expresses as $365\frac{1}{4} - \frac{1}{100}$ days and the *Almagestum parvum* as $365;14,24d = 365d\ 5h\ 45m\ 36s$.²⁴ Al-Battānī's astronomical work contained the same claim about Hipparchus, whereas the actual tropical year proposed in it was $365;14,26d = 365d\ 5h\ 46m\ 24s = 365\frac{1}{4} - \frac{3.4}{360} \approx 365\frac{1}{4} - \frac{1}{106}$ days.²⁵ Both values conflict with our author's claim that al-Battānī's year exceeded $365d\ 5h\ 47m$. There is, however, at least one contemporary text that fits all of the *Expositio*'s pronouncements about past and present estimates for the tropical year. It is the aforementioned *Epistola* by Jean des Murs and Firmin de Beauval, which contains a table listing the following four values:

Hipparchus: 365d 6h

Ptolemy: 365d 5h 55m 12s

scilicet Alphunsus, XLIX minutorum similiter cum quibusdam fractionibus. Alii autem, scilicet compotiste fere omnes, medium inter duos ultimos tenentes posuerunt XLVIII minutorum precise, que anni quantitas et ab expertis astronomis approbatur et magis precisa inter omnes et per certas experientias invenitur'.

²⁴ Robert Grosseteste, *Compotus correctorius* (c. 1), ed. in Robert Steele, *Opera hactenus inedita Rogeri Baconi*, vol. 6, *Compotus Fratris Rogeri* (Oxford: Clarendon Press, 1926), pp. 212–67, at p. 215; *Almagestum parvum* (III.1), MS Paris, Bibliothèque nationale de France, lat. 16657, fol. 96v. On the *Almagestum parvum*, see Henry Zepeda, 'Euclidization in the *Almagestum parvum*', *Early Science and Medicine*, 20 (2015), 48–76.

²⁵ al-Battānī, *De motu stellarum* (c. 27, 52), trans. Plato of Tivoli (Nuremberg: Petreius, 1537), fols. 26v, 27v, 80v.

al-Battānī: 365d 5h 47m 9s

Alfonso: 365d 5h 49m 16d.²⁶

The accompanying text expresses al-Battānī's year differently, claiming that he lowered the length of the Julian year by $\frac{1}{112}$ of a day ($365\frac{1}{4} - \frac{1}{112}$ days = 365d 5h 47m 8.57s). This passage was in fact excerpted from an astronomical work known as *Patefit*, which Jean des Murs had already composed between 1329 and 1332.²⁷ While Jean, for reasons outlined below, cannot have been the author responsible for the *Expositio*, it is not unlikely that he served as its source in this particular instance. As seen, both texts agreed in attributing to Hipparchus a solar year identical to the Julian $365\frac{1}{4}$ days. The *Expositio*'s author treated this estimate as an accurate one as far as the anomalistic year was concerned, stating in a later passage (I.17) that this view received support from both 'the experience of the moderns and the authority of those who composed the Alfonsine Tables'.²⁸ His rationale for writing this way becomes apparent from a closer look at the Alfonsine Tables, which have the 'apogees and fixed stars' move at a rate of 0;0,0,4,20,41,17,12°/d against a mean daily solar motion in tropical longitude of 0;59,8,19,37,19,13,56°/d.²⁹ Implicit in these two values is a joint sidereal and anomalistic motion of 0;59,8,19,37,19,13,56°/d – 0;0,0,4,20,41,17,12°/d = 0;59,8,15,16,37,56,44°/d, which is virtually the same as the mean solar motion according to the Julian calendar (0;59,8,15,16,37,56,48°/d). Another way of putting it is to say that according to the Alfonsine Tables the apogees and fixed stars take 49,000 years to go full

²⁶ Jean/Firmin, *Epistola* (1.1), ed. Schabel (n. 6), p. 197.

²⁷ See the textual comparison between *Patefit* and *Epistola* in C. P. E. Nothaft, 'John of Murs and the Treatise *Autores kalendarii* (1317): A Problem of Authorship', *Sudhoffs Archiv*, 99 (2015), 209–29, at pp. 220–21.

²⁸ *Expositio* I.17 (fol. 22v): '...quod quidem fieri in 365 diebus cum 4^a precise et modernorum experientia et compositorum tabularum Alfonsi auctoritas convincit'.

²⁹ Poulle, *Les Tables Alphonsines* (n. 7), pp. 133–34.

circle, during which period the Sun completes 49,001 full revolutions relative to the vernal equinox, such that the Alfonsine mean tropical year ends up being equivalent to $49,000/49,001 \times 365\frac{1}{4}$ days = $365.242546d \approx 365\frac{1}{4} - \frac{1}{134}$ days. The author responsible for the *Expositio* of 1345 sought to maintain this schematic solar theory, even though his endorsement of the opinion of the computists, who gauged the tropical year at 365d 5h 48m or $365\frac{1}{4} - \frac{1}{120}$ days, forced him to declare that the Sun's apogee moved in a cycle that took 44,000 (rather than 49,000) years to complete.³⁰ This claim was obviously motivated by the fact that $365d\ 5h\ 48m = 44,000/44,001 \times 365\frac{1}{4}$ days.

A notorious feature of the Alfonsine Tables was that they added to the aforementioned (linear) motion of the apogees and fixed stars a non-linear or periodic term designated as the 'access and recess of the eighth sphere', which worked analogously to the older Toledan model of the same name.³¹ In principle, any inclusion of this theory should have gone hand in hand with accepting a variable length of the tropical year, which spoke in favour of tabulating sidereal rather than tropical longitudes. The makers of the Alfonsine Tables in their Latin form nevertheless chose a tropical reference frame, thus implying that the mean tropical solar motion remained fixed at the aforementioned rate of $0;59,8,19,37,19,13,56^{\circ}/d$. Even so, the access and recess still influenced the motion of the solar apogee, which was assumed to move along with the sphere of the fixed stars. The

³⁰ *Expositio* I.14 (fol. 15r-v).

³¹ Poulle, *Les Tables Alphonsines* (n. 7), p. 132. See the extended discussions of the Alfonsine precession model in Jerzy Dobrzycki, 'The Theory of Precession in Medieval Astronomy', in idem, *Selected Papers on Medieval and Renaissance Astronomy*, ed. Jarosław Włodarczyk and Richard L. Kremer (Warsaw: Instytut Historii Nauki PAN, 2010), pp. 15–60, at pp. 34–40, Julio Samsó, 'Algunas notas sobre el modelo solar y la teoría de la precesión de los equinoccios en la obra astronómica de Alfonso X', *Dynamis*, 4 (1984), pp. 81–114, at pp. 87–102; Chabás and Goldstein, *The Alfonsine Tables* (n. 7), pp. 256–66.

resulting slow change in the solar equation was non-uniform, which effectively meant that the length of the true tropical year in the Alfonsine Tables was subject to minor fluctuations, even as the mean length remained fixed at $c. 365\frac{1}{4} - \frac{1}{134}$ days. Although the *Expositio* never directly acknowledges the existence of the access and recess-component, the author nevertheless clearly recognized that, as a consequence of the Alfonsine model, the true vernal equinox could not be fixed on a single date, citing ‘its circular motion’ as the underlying cause.³² This insight on his part also explains why he chose to eliminate the motion of the apogee from the historical data he compared at the beginning of his treatise (see p. 8), basing his analysis of the calendar problem entirely on the mean motion of the Sun, which he took to be $360^\circ \div 365\text{d } 5\text{h } 48\text{m} = 0;59,8,20,8,4,36^\circ/\text{d}$.³³ He for the very same reason found it preferable to work with mean rather than true equinoxes and solstices, which had the added benefit of confirming the traditional view that Jesus Christ had been conceived on the day of the vernal equinox (see p. 10 above). Taking as his starting point the true autumn equinox of 8 BCE, the author established mean dates for AD 1, the assumed year of the incarnation, which were each spaced by an interval of $365\text{d } 5\text{h } 48\text{m} \div 4 = 91\text{d } 7\text{h } 27\text{m}$:

Vernal equinox: 25 March, 13:49h

Summer solstice: 24 June, 21:16h

Autumn equinox: 24 September, 04:43h

Winter solstice: 24 December, noon.³⁴

³² *Expositio* I.16 (fol. 18v): ‘...quod esset reducendum aliquando ac stabiliendum, non verum equinoctium, quid eo quod propter motum eius circularem predictum immobilitari non possit, sed magis medium, quod immobilitari possit...’.

³³ *Expositio* I.30 (fol. 39v).

³⁴ See *Expositio* I.14 (fols. 15v–16r), where the stated times are slightly less precise.

If the mean tropical year was 365d 5h 48m and hence 12 minutes shorter than the average year in the Julian calendar, the dates and times of these four cardinal points were bound to move towards the beginning of the year at the exact rate of 1 day every 120 years, with the result that the mean vernal equinox of the present day could no longer be found on 25 March, but on 14 March. This was 8 days earlier than the currently accepted lower limit for the date of Easter Sunday, meaning that the Church ended up celebrating in the wrong month whenever the 14th day of the lunar month fell between 14 March and 22 March. The question that remained to be pondered was whether or not the Church should try to remove this blemish by making changes to the existing calendar. Our author examined the arguments for and against a reform in 13 lengthy chapters (I.5–17), coming down in favour of a thoroughgoing correction that restored the mean equinoxes and solstices to the dates they had supposedly occupied at the time of Christ's incarnation. Since the regression over the past *c.* 1340 years had been slightly more than 11 days, the necessary adjustment could be achieved within a single year by subtracting a day from each month except February. Confident that he had the adequate knowledge at his disposal, he further concluded that the equinoxes and solstices could be perpetually fixed in the calendar by omitting the bissextile day once every 120 years, that is, in every 30th intercalation cycle.³⁵

Next to the correction of the Julian calendar, an astronomically sound computation of Easter naturally also required an accurate method of locating the beginning of the first lunation of spring, which according to the established rule was supposed have its 14th day fall no earlier than the date of the vernal equinox. By the fourteenth century it had become customary to count lunar ages in the Julian calendar with the help of the so-called Golden Number, which could take on any number from I to XIX to mark the year of the 19-year

³⁵ See especially *Expositio* I.3, 5, 10, 15, 18–19 (fols. 4r–5r, 11v, 16v–17v, 22v–26r).

cycle in which the date in question received the *primacio* or calendrical new moon. Two tasks presented themselves to the prospective reformer of this scheme: one was to move the calendrical *primaciones* to earlier dates in order to have them coincide as closely as possible with the actual mean conjunctions of Sun and Moon, which had started to differ from those displayed in the calendar by up to four days. The other was to modify the existing 19-year cycle so as to prevent this error from newly occurring in the future. A prerequisite for the latter task was to determine the actual length of the mean synodic month, which was evidently shorter than the calendar's equation of 235 months with $19 \times 365\frac{1}{4} = 6939\frac{3}{4}$ days demanded. Followers of the Alfonsine Tables would have been able to extract from them a daily elongation between Sun and Moon of $13;10,35,1,15,11,4,35^\circ/d - 0;59,8,19,37,19,13,56^\circ/d = 12;11,26,41,37,51,50,39^\circ/d$, which could in turn be translated into a mean synodic month of $\frac{1}{12;11,26,41,37,51,50,39^\circ/d} \times 360^\circ = 29;31,50,7,37,27,8,25d \approx 29d 12;44,3,2,59h$.³⁶

As in the case of the mean tropical year, the author of the *Expositio* decided to go his own way and extract the length of the mean synodic month from a series of comparisons involving both ancient and contemporary observations.³⁷ Of the three individual calculations he detailed at the beginning of Book II, one involved a lunar eclipse Ptolemy recorded as having occurred on 5 April 125 CE, with a mid-point 08:05h after noon.³⁸ The author used the solar and lunar equations to infer that the corresponding mean opposition of Sun and

³⁶ See Poulle, *Les Tables Alphonsines* (n. 7), pp. 134–35. A simplified version of the Alfonsine value was evidently on the minds of Jean des Murs and Firmin de Beauval when they gave the length of the lunar year as 354d 8h 48m 36s (= $12 \times 29d 12h 44m 3s$). See their *Epistola* (2.1), ed. Schabel (n. 6), p. 200.

³⁷ See *Expositio* II.1 (fols. 52v–54v), which the following discussion summarizes while reducing all chronological information to dates in the Julian calendar.

³⁸ Ptolemy, *Almagest* (4.9), trans. Toomer (n. 10), pp. 206–7; *Almagestum Cl. Ptolemei* (n. 10), fol. 44r–v.

Moon would have arrived 05:52h later, on 6 April at 13:57h. For reasons that are not entirely obvious, he chose to compare this to a mean opposition that lay halfway between the eclipse of 125 CE and an earlier one seen in April of 491 BCE. According to Ptolemy's tables, this opposition had been reached on 14 October 184 BCE, at 17:52h. The interval between the two dates was 307y 249d 20:05h, covering 3803 successive lunations. One of these lunations hence comprised:

$$307y\ 249d\ 20:05h \div 3803 = 29d\ 12;44,3,2,41,52\dots h.$$

The author, for his part, claimed the correct result to be 29d 12;44,3,2,1h and went on to offer further confirmation for this length by using the interval between the mean opposition of 125 CE and the mean opposition of 1 October 1289 CE as predicted by the Alfonsine Tables. The latter occurred at 15:33h (rounded from 15:32:25h) for the meridian of Paris or at 16:16h, if adjusted to Ptolemy's Alexandrian meridian (+10;45° or 00:43h), pointing to a mean synodic month of

$$1165y\ 104d\ 02:19h \div 14,403 = 29d\ 12;44,3,1,42,43\dots h.$$

Next in line was the partial lunar eclipse the author claimed to have observed in Paris on 26 January 1339 CE, at 06:24h after midnight, or 18:24h from the previous noon. From the lunar and solar equations valid for this point in time, he concluded that the corresponding mean syzygy had already occurred 10:59h earlier, which points to 07:23h from noon on 25 January. Both the true and mean time stated here happen to be identical to the times predicted by the Alfonsine Tables, which strongly suggests that the author fixed the eclipse's mid-point by computational means. He gave the interval between the mean opposition of 25 January 1339 CE and the mean opposition of 1 October 1289 CE (15:32:25h) as 49y 128d 15:51h, which implied an average lunation of

$$49y\ 128d\ 15:51h \div 610 = 29d\ 12;44,3,2,57\dots h.$$

This is a close match with the Alfonsine value for the mean synodic month, which should come as no surprise in light of the author's evident reliance on the Alfonsine Tables for both of the syzygies compared in this example. It does little to explain, however, why the author instead adopted the aforementioned 29d 12;44,3,2,1h. Conceivably, it entered his argument as the result of a scribal error for 29d 12;44,3,2,41h, which is the correct value for the average lunation between the oppositions of 184 BCE and 125 CE.³⁹ Whatever its true rationale, the stated result made it possible to gauge the accuracy of the traditional 19-year cycle, which turned out to overstate the length of 235 consecutive synodic months by 1;28,7,6,5h (= $235 \times 29\text{d } 12;44,3,2,1\text{h} - 19 \times 365\text{d } 6\text{h}$).⁴⁰ Yet this was not true for the situation in the *Expositio*'s proposed new calendar, which was supposed to halt the calendrical regression by subtracting a day every 120 years. Since the rate of this regression was more than two times as swift as that of the new and full Moons (*c.* 1d/310y), it was clear that a simple implementation of the proposed plan would have grossly overcompensated for the error inherent in the Golden Numbers, causing the new Moons to further recede from the dates assigned to them, only this time in the opposite direction. Accepting as before a mean tropical year of 365d 5h 48m, the new calendar turned out to underestimate the combined length of 235 synodic months by $235 \times 29\text{d } 12;44,3,2,1\text{h} - 19 \times 365\text{d } 5;48\text{h} = 2;19,52,53,55\text{h}$. For this discrepancy to amount to a complete day, it took $\frac{1}{2;19,52,53,55\text{h}} \times 24 = 10.294417$ cycles or approximately $195\frac{1}{2}$ years. The author carried his analysis even further, realizing that it was going to take almost exactly 304 19-year cycles or 5776 years for the error to reach the size of a complete synodic month,

since $\frac{1}{2;19,52,53,55\text{h}} \times 24 \times 29\text{d } 12;44,3,2,1\text{h} = 304.000221$.⁴¹

³⁹ I would like to thank one of the anonymous referees for pointing this possibility out to me.

⁴⁰ *Expositio* II.6 (fol. 58v).

⁴¹ *Expositio* II.2 (fols. 54v–55r).

His method for dealing with this problem, as described in *Expositio* II.3–6 (fols. 55r–60v), was comprised of several different components. An essential first step was to scrap the old Golden Number in favour of new Moon letters from A to T (*littere primacionum radicalium*), which were supposed to reflect the actual dates of mean conjunction in the 19-year cycle that began in the year of Christ’s incarnation. Eager to heighten the precision of his new lunar calendar, the author proposed to add to these letters the number of hours before or after noon, keeping them up to date by subtracting some rounded version of the required 1;28,7,6,5h per 19-year cycle. This was not enough, however, since users also had to know how to adjust for the overcompensation generated by the Julian calendar’s altered intercalation pattern, which on occasions required them to move the calendrical new moons to the following date. In order to simplify this task, the author proposed to synchronize these interventions with the omissions of the bissextile day once every 120 years, using a system of *claves primacionum* to guide prospective users. At the beginning of the newly reformed calendar, the *clavis* was still 0, indicating that the conjunctions of Sun and Moon fell just on the dates occupied by the new letters inscribed into the calendar. With each subsequent interval of 120 or 240 years, the *clavis* was supposed to increase by one unit, with the result indicating the number of days by which the actual conjunctions had moved away from the locations marked by the *radices*. The planned steps for an increase of the *clavis* were laid down in a separate *Tabula clavium primacionum lune*, from which it can be seen that the *clavis* was meant to return to 0 after 5760 years (Figure 2).⁴² This was still 16 years short of the aforementioned period of 5776 years the new lunar calendar needed to return to its original state. For extremely long periods of use, it hence became expedient to eventually increase the final step in the table by 120 years and return the *clavis* to 0 only after 5880

⁴² See *Expositio* II.4 (fol. 56r).

years. Since $5776 - 5760 = 16$ and $120 = 16 \times 7.5$, this extension had to be deployed sometimes after 7 and sometimes after 8 iterations of this cycle, as the author himself was careful to point out.⁴³

There are a number of additional complications and nuances in the proposed method, not all of which can be addressed here. What is worth underlining, however, is the author's decision to have the *littere primacionum radicalium* represent the conjunctions of the first 19 years of the Christian era and to calculate the growth of the *clavis* from 1 CE. For present times (1200–1440 CE), the *clavis* was hence already 7, calling for a forward shift of all calendrical new Moons by 7 days. If the dates of the conventional Golden Numbers were retained, but the Julian calendar reformed by subtracting 11 days, the sum total of these interventions would have been a current set of new moons that fell $11 - 7 = 4$ days earlier than in the conventional ecclesiastical calendar, which agrees well with the size of the error the latter had incurred since antiquity. As an alternative approach to Golden Numbers or lunar letters, the author presented a cruder scheme based on lunar 'epacts' and 'regulars', which was reminiscent of, though not identical to, the techniques used by medieval computists to find the lunar age on the first day of each Julian month. In the case of the *Expositio*, the regulars were a list of twelve new moon dates valid for the year 1 CE, whereas the epact represented the number of days that had to be added in order to adjust these to subsequent years of the 19-year cycle. For the first 120 years after the incarnation, the series of epacts would have been 0, 19, 8, 27, 16, 5, 24, 13, 2, 21, 10, 28, 17, 6, 25, 14, 3, 22, and 11, yet these numbers were bound to grow with each increase of the *clavis primacionum* after 120 or 240 years. The author reacted to this by drawing up a separate table in which he

⁴³ *Expositio* II.3 (fol. 55v): 'Ex qua quidem superfluitate, si de octonis revolucionibus in septenas et de septenis in octonas unus ciclus centivigenalis colligatur [...] omnia perpetuo sine quocumque deffectum continuabuntur'.

mapped out the appropriate sequence of epacts for each of the 30 different values the *clavis* could take (Figure 3).⁴⁴

Although a detailed analysis of the lunar calendar proposed in the *Expositio* exceeds the limits of the present discussion, it would be negligent not to point out some of the parallels that exist between this proposal and the actual reform of the ecclesiastical calendar achieved in 1582, when Pope Gregory XIII issued the bull *Inter gravissimas*.⁴⁵ Similar to the ‘new calendar’ outlined in 1345, the Gregorian calendar was created by excising several days from a given year in the calendar, although here the plan was to remove 10 consecutive days from 1582 in order to restore the vernal equinox to its approximate position at the time of the Council of Nicaea (the *Expositio*, by contrast, targeted the time of Christ’s incarnation and intended to subtract 11 days by curtailing as many months). In order to keep the equinox on its new date (assumed to be 21 March), the Gregorian calendar interrupts its leap-year rhythm three times over the course of 400 years, thus generating an implied solar year of $365\frac{97}{400}$ days or $365\frac{1}{4} - \frac{1}{133.333\dots}$ days. Whenever such an interruption occurs, the calendar’s new moons must be transposed forward by one day to keep the correction of the solar calendar from interfering with the lunar count, a step which is also known as the Gregorian calendar’s ‘solar equation’. Yet the 19-year cycle, too, is in need of correction, which is achieved by a shift in the opposite direction—the so-called ‘lunar equation’—scheduled to take place 8 times in 2500 years. Significantly, both of these ‘equations’ are confined to centennial years, i.e., to years of the Christian era evenly divisible by 100, in direct analogy to the way the *Expositio* planned to limit the suppression of leap days and the increase of the *clavis primacionum* to years that

⁴⁴ *Expositio* II.5 (fols. 58r).

⁴⁵ See, in general, August Ziggelaar, ‘The Papal Bull of 1582 Promulgating a Reform of the Calendar’, in *Gregorian Reform of the Calendar*, ed. George V. Coyne, Michael A. Hoskin, and Olaf Pedersen (Vatican City: Specola Vaticana, 1983), pp. 201–39.

were multiples of 120. Even more striking is the fact that the original proposal for the Gregorian calendar, as represented in the *Compendium novae rationis restituendi kalendarium* of 1577, came with a table of epacts that was structurally very similar to the one in the *Expositio* (see Figure 4).⁴⁶ Like the table envisioned in 1345, the one in the *Compendium* listed 30 different epactal sequences, a new one of which had to be selected every 100 to 300 years in accordance with the interplay between the solar and lunar equations. Although the so-called Lilian epact—named after its inventor Luigi Lilio (or Giglio, 1510–1574/76)—was a somewhat different device from the one envisioned in 1345,⁴⁷ it is probably no exaggeration to say that, out of all the calendar reform schemes proposed during the Middle Ages, the one laid down in the *Expositio kalendarii novi* came closest to the scheme eventually realized in 1582.

3. Authorship and context

As seen from the foregoing discussion, the anonymous *Expositio* is a text replete with original, or at any rate rather unusual, ideas pertaining to calendar improvement and its astronomical underpinnings. Of the various opinions expressed in it, however, none was as potentially controversial as the author's insistence on omitting 11 days from the Julian

⁴⁶ *Compendium novae rationis restituendi kalendarium* (1577), ed. in Egidio Mezzi and Francesco Vizza, *Luigi Lilio: medico astronomo e matematico di Cirò* (Reggio Calabria: Laruffa Editore, 2010), p. 215. The *Compendium* was reprinted in Christopher Clavius, *Romani kalendarii a Gregorio XIII. P.M. restituti explicatio* (Rome: Zannetti, 1603), pp. 3–12.

⁴⁷ The intricacies of the Lilian-Gregorian epact system are discussed in more detail in Mezzi and Vizza, *Luigi Lilio* (n. 46), pp. 130–49. See also Heiner Lichtenberg, 'Das anpassbar zyklische, solilunare Zeitählungssystem des gregorianischen Kalenders: Ein wissenschaftliches Meisterwerk der späten Renaissance', *Mathematische Semesterberichte*, 50 (2003), 45–76; Reinhold Bien, 'Viète's Controversy with Clavius over the Truly Gregorian Calendar', *Archive for History of Exact Sciences*, 61 (2007), 39–66.

calendar in order to restore the mean equinoxes and solstices to the positions they had occupied in the year of Christ's incarnation. That this side of his proposal provoked outspoken dissent can be confirmed thanks to the known existence of an anonymous treatise beginning *Ad correctionem calendarii...* (hereafter shortened to *Ad corr.*), which discusses arguments for and against a reform of the calendar in the manner of a scholastic disputation. It has come down to us as part of an anthology of four fourteenth-century works on calendar reform, which survives only in two sixteenth-century copies in Vienna.⁴⁸ The texts contained in it are as follows:

- (1) *Autores kalendarii...*, written in 1317 and attributed in both manuscripts to Jean des Murs⁴⁹
- (2) *Ad correctionem calendarii*⁵⁰
- (3) Jean des Murs and Firmin de Beauval, *Epistola super reformatione antiqui calendarii*, presented in 1345 to Pope Clement VI.⁵¹
- (4) Johannes de T(h)ermis, *Tractatus de tempore celebrationis paschalis*, presented in 1354 to Pope Innocent VI.⁵²

⁴⁸ See MS Vienna, Österreichische Nationalbibliothek, 5292, fols. 199r–242v, which was the exemplar for MS Vienna, Österreichische Nationalbibliothek, 5273, fols. 91r–138v. In what follows, I shall reference these codices as MS A and MS B respectively.

⁴⁹ Edited in C. P. E. Nothaft, 'The Chronological Treatise *Autores Kalendarii* of 1317, Attributed to John of Murs: Text and Introduction', *Cahiers de l'Institut du Moyen-Âge Grec et Latin*, 82 (2013), 1–89, with further discussion in Nothaft, 'John of Murs' (n. 27).

⁵⁰ Edited in Chris Schabel, '*Ad correctionem calendarii...* The Background to Clement VI's Initiative? Text and Introduction', *Cahiers de l'Institut du Moyen-Âge Grec et Latin*, 68 (1998), 13–34.

⁵¹ See n. 6 above.

⁵² This treatise remains unpublished. See MS A, fols. 231r–42v = MS B, fols. 122v–38v.

The remainder of this section will offer textual evidence to show that *Ad corr.* was written specifically to address and counter the arguments the *Expositio* had made in favour of reforming the Julian calendar. That both texts originated in the context of Pope Clement VI's reform initiative of 1344/45 will become clear from their ties to item (3) on the above list, as Jean des Murs and Firmin de Beauval included tacit quotations from them in their *Epistola*. As for item (4), it will be argued below that the monk Johannes de Termis not only borrowed material from the *Expositio novi kalendarii* for his *Tractatus* of 1354, but that he is a very probable candidate for having been its anonymous author. This identification provides further grounds for accepting that the work was originally produced in Avignon at the behest of Clement VI.

Let us begin with *Ad corr.*, which is the only one of the four texts included in the Viennese anthology to come without any ascription of authorship. The two clearest hints as to its date and place of origin to have been discovered thus far are a reference to the year from the incarnation '1345, or 44, or 43' (*1345, seu 44, seu 43*)⁵³ and the fact that a longer passage from this text reappears in the *Epistola* penned by Jean des Murs and Firmin de Beauval in 1345, which creates the impression that the *Ad corr.* originated in the context of Clement VI's calendar reform project.⁵⁴ According to a hypothesis formulated by Joël Plassard and later endorsed by Emmanuel Poulle, *Ad corr.* was an earlier work by Jean des Murs and Firmin de Beauval, who submitted it to the pope as a preliminary report to what was to become their *Epistola*.⁵⁵ Convincing objections to this idea were first raised by Chris

⁵³ *Ad corr.* 7, ed. Schabel (n. 50), p. 24.

⁵⁴ See *Ad corr.* 1a, ed. Schabel (n. 50), p. 26; Jean/Firmin, *Epistola* (1.4), ed. Schabel (n. 6), pp. 199–200.

⁵⁵ Joël Plassard, 'Projets de réforme du calendrier à Paris au début du XIV^e siècle: textes édités et commentés', *École Nationale des Chartes: Positions des thèses*, (1975), 175–181, at p. 178. Poulle went even further and suggested that the surviving text of *Ad corr.* was originally part of a larger work, which dealt with lunar

Schabel, who published the text's *editio princeps* in 1998 and used this opportunity to point out manifold divergences between the viewpoints taken in *Ad corr.* and those expressed in the *Epistola* of 1345 as well as significant stylistic differences between the two works.⁵⁶

Although its discovery does not completely settle the question of authorship, the *Expositio* helps us form a much more precise understanding of the purpose for which *Ad corr.* was written. The key is in its abrupt opening statement:

Three ways to correct the calendar have been found, the first of which is that the solstices and equinoxes are brought back to the state in which they were at the time of the incarnation and that they are fastened there, and that afterwards those things that pertain to the Moon are corrected.⁵⁷

This is very recognizably a summary of the proposal put forward in the *Expositio kalendarii novi*, from which the author of *Ad corr.* turns out to have recycled several extended passages. These excerpts make up most of the first part of the treatise, which amounts to a list of ten arguments in favour of fixing the dates of the equinoxes and solstices and restoring them to their ancient locations by removing days from the calendar. The second and third part of *Ad corr.* juxtapose this list with various reasons why the Julian calendar should not be tinkered with at all and with a series of specific counters to the arguments made in the first part. *Ad*

reckoning in addition to the correction of the Julian calendar. Emmanuel Poulle, 'Les astronomes parisiens au XIV^e siècle et l'astronomie alphonsine', in *Histoire littéraire de la France*, vol. 43.1 (Paris: Boccard, 2005), pp. 1–54, at pp. 32–33. *Ad corr.* was already linked to Jean des Murs by Kaltenbrunner, 'Die Vorgeschichte' (n. 3), p. 322.

⁵⁶ Schabel, '*Ad correctionem kalendarii...*' (n. 50), pp. 15–18.

⁵⁷ *Ibid.*, p. 20: 'Ad correctionem kalendarii invente sunt tres vie, quarum prima est quod solsticia et equinoctia ad statum in quo erant tempore incarnationis reducuntur et quod ibidem figantur, ac postmodum corrigantur ea que pertinent ad lunam'.

corr. can, with other words, be viewed as a conscious reaction towards or critique of the reform plan sketched in the *Expositio*. To illuminate the dependency of one text on the other, it is worth turning to a specific example. What follows is a passage from *Expositio* I.6 (fol. 5r), which reappears in slightly modified form at the start of *Ad corr.*⁵⁸ The overlap between the two texts is marked with italics:

<p><i>Expositio</i> I.6 (fol. 5r):</p> <p>At quidem <i>quod solsticia et equinoctia debeant figi</i> potest ex ipsa fixione quatinus debetur paschalibus <i>sic probari</i>. Nam <i>preceptum de paschate tali tempore anni celebrando communiter est tam nobis quam Iudeis. Hoc apparet quia cum inter nos et Iudeos quantum ad propositum non sit differentia nisi in hoc quod nos facimus pascha verum et ipsi figurativum, omnia alia debent nobis et ipsis esse communia, illis dumtaxat exceptis de quibus ecclesia aliter ordinavit, sicut de die.</i></p>	<p><i>Ad corr.</i> 1:</p> <p>Et <i>quod solsticia et equinoctia debeant figi sic probatur: Quia preceptum de Paschate celebrando tali tempore anni vel tali commune est tam nobis quam Iudeis. Hoc apparet, quia, cum inter nos et Iudeos non sit differentia nisi in hoc quod nos celebramus Pasca verum et ipsi celebrant Pasca figurativum, omnia alia debent esse nobis et ipsis communia, illis dumtaxat exceptis de quibus ordinavit ecclesia, sicut de die, etc.</i></p>
---	---

Expositio I.6 greatly expands on the point just made, reminding readers that ‘the holy and venerable Roman Church decided that we and the Jews may never come together in celebrating the Pasch on the same day’, which is then followed by six reasons for this

⁵⁸ *Ad corr.* 1, ed. Schabel (n. 50), p. 20.

particular ordinance.⁵⁹ The compiler of *Ad corr.* omitted all of this material with the exception of a sentence from the very end of the same chapter, which involves a quotation from Exodus 34:18.⁶⁰ For the remaining sentences of *Ad corr.*'s first paragraph, he drew inspiration from an earlier chapter in the *Expositio* (I.4), as can be seen from the textual comparison below. As before, words transferred from the *Expositio* into *Ad corr.* are marked using italics.

<p><i>Expositio</i> I.4 (fol. 4v):</p> <p>Et posset <i>contingere</i> <i>processu temporis</i> quod nativitas Iohannis in hieme et nativitas Christi in estate celebrantur, quod absurdum valde videretur. [...] De Pascha eciam, quod secundum sacram scripturam [...] tempore vernali celebrari debet, posset <i>contingere per anticipationem equinoctii quod celebraretur tempore autumpnali et quod Marcius et Aprilis, qui sunt menses vernaes, efficerentur primo estivales, postea autumpnales.</i></p>	<p><i>Ad corr.</i> 1:</p> <p>Sed istud <i>processu temporis</i> non poterit continuari nisi figatur equinoctium vernale; quinymo poterit <i>contingere per anticipationem ipsius equinoctii quod ipsum Pasca celebrabitur tempore autumnali, et quod illi menses, puta Marcius et Aprilis, qui modo sunt vernaes, efficientur post estivales et postea autumnales.</i></p>
---	--

⁵⁹ *Expositio* I.6 (fol. 5r-v): 'Statuit siquidem sancta ac reverenda Romana ecclesia quod nos et Iudei numquam in eodem die concurrere debeamus in celebracione paschali et hoc rationabiliter propter multa'.

⁶⁰ *Ad corr.* 1, ed. Schabel (n. 50), p. 20: 'Sed Iudei per preceptum tenentur facere Pasca tempore vernali, iuxta illud Exodi 34: 'Septem diebus vesceris azimis sicut precepi tibi in tempore mensium novorum. Mense enim verni temporis egressus es de Egypto'. Ergo et nos *tempore vernali debemus Pasca celebrare*'. The same passage, with the exception of the italicized portion, appears in *Expositio* I.6 (fol. 6v).

The borrowings from the *Expositio* are not confined to the paragraphs just discussed, but pervade the entire first part of *Ad corr.* as seen from the following chapter concordance, which notes instances of close verbal parallels between the two texts:

<i>Ad corr.</i>	<i>Expositio</i>
1	I.4, 6 (fol. 4v, 5r)
1.1	I.8 (fols. 8v–9r)
1.2	I.12 (fol. 14r)
1.3	I.9 (fols. 9v–10r)
2	I.12 (fol. 13r)
2.1	I.12 (fol. 13r–v)
3	I.13 (fol. 14r–v)
3.1	--
3.2	I.16 (fol. 20r)
4	I.12 (fol. 13v)
4.1	I.11 (fol. 12r–v)
5	I.13 (fol. 14r)
6	I.4, 8 (fols. 4v, 8v)
7	I.17 (fols. 20v–21r) ⁶¹
8	I.17–18 (fols. 21v–23r)
9	--
10	I.17 (fol. 22r)

⁶¹ This passage contains a reference to the ‘anni ab incarnatione 1344, aut 1345, vel 1346’ (fol. 20v), which *Ad corr.* changes to ‘1345, seu 44, seu 43’ (see n. 53 above).

The demonstrable dependency of *Ad corr.* on the *Expositio* provides us with valuable evidence that the latter treatise, too, was written in the context of Clement VI's reform initiative.⁶² Further confirmation for this hypothesis comes from the *Epistola* that Jean des Murs and Firmin de Beauval submitted to the pope in 1345. Of the four chapters or 'treatises' attached to this *Epistola*, the first is devoted to the correction of the solar year, even though Jean and Firmin make it very clear that this was not part of their official remit, which had been restricted from the outset to repairing the Golden Number.⁶³ Their and the pope's decision not to go any further had at the very least been reinforced by the arguments the author *Ad corr.* had previously levelled against the *Expositio*. This much can be inferred from the *Epistola*'s section 'On the advantages and disadvantages [that arise] from a correction of the solar calendar' (*De utilitatibus aut inconvenientibus ex correctione kalendarii solis*), which begins by admitting that 'to certain people it seems that its correction is useful to the Church'. Of the two arguments in favour of a correction the authors attribute to this party, the first echoes a passage in the *Expositio kalendarii novi*, as seen from the following comparison.

⁶² It may be worth mentioning that the author includes a reference to the Jubilee year Clement VI had decreed for 1350. *Expositio* I.15 (fol. 17r): '...usque ad annum prime celebracionis anni Iubilei secundum spiritualem intentionem prout ipsum celebrari post instituit sanctissimus pater ac dominus summus pontifex Clemens sextus supputantur excludendo annum illum anni numero 1349'.

⁶³ Jean/Firmin, *Epistola* (1.3), ed. Schabel (n. 6), p. 199: 'Sed quia correctio kalendarii lune magis est necessaria quam correctio kalendarii solis, ut videbitur infra, et vocati sumus solum ad correctionem kalendarii lune, propter hoc de labore predicto non immerito voluimus supersedere'. The correction of the Golden Number is indeed the only task mentioned in the letters Clement VI sent to the two astronomers on 25 September 1344. See Eugène Déprez, *Clément VI (1342-1352): lettres closes, patentes et curiales*, vol. 1.2 (Paris: Boccard, 1925), p. 209 (no. 1134), as quoted in Nothaft, 'Science' (n. 4), p. 277.

<p><i>Expositio</i> I.10 (fol. 11v)</p> <p>Item <i>precisum utilius est et honestius impreciso, sed kalendarium post correctionem</i> erit magis <i>precisum</i> quam nunc sit, ergo erit <i>utilius</i>, ergo erit <i>utile</i> ipsum corrigere.</p>	<p><i>Epistola</i> (1.4)⁶⁴</p> <p>Videtur autem quibusdam quod correctio eius sit ecclesie utilis. Primo, quia <i>precisum honestius et utilius est impreciso; sed kalendarium</i> quo utimur est imprecisum, et per sui <i>correctionem</i> ad precisionem reduceretur; ergo etc.</p>
---	---

As a counterweight to the *Expositio*'s enthusiasm for a thoroughly restored calendar, the two astronomers inserted into their work a lengthy passage from *Ad corr.* that evoked the problematic political, economic, and legal consequences of removing days from the calendar, claiming that this might cause seditions and lead secular rulers to obstruct the reform.⁶⁵ Since *Ad corr.* does not repeat the just-cited passage from *Expositio* I.10, it would appear that Jean des Murs and Firmin de Beauval had independent access to both of these works, which had been completed in the same year as their *Epistola* and may have been made available to them after their arrival in Avignon. What all of this clearly implies is that the circle of Clement VI's calendrical advisers must have included more individuals than the two French astronomers he had invited in September 1344. Positive evidence for this notion is indeed provided by the monk Johannes de Termis, whose name appears with this particular spelling in a formal supplication addressed to Clement's successor Pope Innocent VI on 30 August 1353. The text reveals Johannes to have originally been a member of the Dominican order with some reputation as a skilled astronomer, whom Clement VI summoned to Avignon 'for the reparation of the calendar' (*pro reparatione Kalendarii*). Following this papal mandate,

⁶⁴ Jean/Firmin, *Epistola* (1.4), ed. Schabel (n. 6), p. 199.

⁶⁵ See n. 54 above.

Johannes spent two years at the curia, tirelessly writing on a ‘great and laborious work’ (*opus magnum et laboriosum*) at his own expense, after which the pope transferred him to the Benedictine monastery of San Salvador da Torre (Galicia), so he could fully concentrate on the work’s perfection.⁶⁶ Another claim this supplication makes about Johannes—who hoped that Innocent VI would grant him a benefice Clement had promised him shortly before his death—is that he spent some of the intervening years studying theology in Paris, which is noteworthy in light of the abovementioned references to this city in the *Expositio*. Next to the author’s ‘observations’ of the lunar eclipse of 1339 and the autumn equinox of 1344, which were both said to have taken place on the Parisian meridian, there is a reference to the Sun’s noon altitude at the vernal equinox as observed at the latitude of Paris (here implied to be 48;50°).⁶⁷

The suspicion that the monk’s ‘great and laborious work’ was none other than the *Expositio* preserved in Ottobonianus latinus 842 receives a great deal of additional weight from the *Tractatus de tempore celebrationis paschalis* Johannes de Termis addressed to Innocent VI in 1354, one year after the supplication.⁶⁸ At first glance this unpublished work, which survives only as part of the aforementioned dossier of fourteenth-century texts, would seem to have very little in common with the *Expositio* written nine years earlier. In contrast to the close attention to astronomical detail that prevails in the latter work, the *Tractatus* tends to bypass most calendrical technicalities in favour of an attentive focus on the

⁶⁶ The supplication is printed in Ursmer Berlière, ‘La réforme du calendrier sous Clément VI’, *Revue Bénédictine*, 25 (1908), 240–41, at p. 241. See the previous discussion of Johannes de Termis’s involvement in Nothaft, ‘Science’ (n. 4), pp. 291–96, which must be revised in light of the findings presented in the present article.

⁶⁷ *Expositio* I.31 (fol. 41r).

⁶⁸ See n. 52 above.

theological and exegetical background to the Easter date, in particular as it emerges from St Augustine's response to Januarius.⁶⁹ Upon closer inspection, however, it is precisely this extended discussion of the historical-theological significance of the Easter date that resonates in more than just tangential ways with some of the material contained in the *Expositio*. One major example comes from *Expositio* I.7, which presents three lengthy blocks of quotations from the aforementioned Augustinian letter in support of three interlocking criteria for the date of Easter, viz. that it must take place in (a) the first lunar month of spring, (b) the third week of this month, (c) and between the 14th and the 21st day of the Moon. All of these quotations reoccur at the start of Johannes de Termis's *Tractatus*, most of them in identical fashion, reproducing not just Augustine's words but also the interjections and modifications we find in the *Expositio*.⁷⁰ In the following extract, which is taken from the second block of quotations, the italicized parts indicate wording identical to Augustine's letter, whereas the Roman lettering represents modified or extraneous wording specific to the *Expositio* and/or the *Tractatus*.

<p><i>Expositio</i> I.7 (fols. 7v–8r):</p> <p><i>Quia vero in toto tempore seculi [...] in prophetico enigmatē. Hoc ergo et in lunari numero figuratur cum a tertia lune ebdomada pascha celebratur, id est dominico die, que a quartadecima luna</i></p>	<p>Johannes de Termis:⁷⁴</p> <p><i>Quia vero in toto tempore seculi [...] in prophetico enigmatē. Hoc etiam et in lunari numero figuratur cum a tertia lune ebdomada pascha celebratur, hoc est die dominico que a 14^a luna occurrerit usque in 21. Hec Augustinus et adhuc: Est illic,</i></p>
---	---

⁶⁹ Augustine of Hippo, *Epistulae* (55), ed. Kl. D. Daur, Corpus Christianorum Series Latina 31 (Turnhout: Brepols, 2004), pp. 234–65.

⁷⁰ Compare *Expositio* I.7 (fols. 7r–8v) with the *Tractatus* in MS A, fols. 231v–32v = MS B, fols. 123v–125r.

⁷⁴ MS A, fol. 232r = MS B, fol. 124r.

<p><i>occurrerit usque in vicesimam primam.</i>⁷¹ Et statim post: <i>Est illic, inquit, et aliud sacramentum.</i>⁷² Nam <i>manifest<ta>um est et cuivis advertenti facile cognitum lumen lune ab ea parte que terram respicit non augeri nisi a soli recedendo, neque minui nisi ad solem post dimidium mensem ex alio semicirculo propinquando ab ea vero parte que superius eminet.</i>⁷³ Econtrario ipsum non crescere nisi propinquando ad solem neque decrescere nisi recedendo a sole, quia quo magis luna ipsa sive propinquando ad solem sive recedendo ab ipso in altera sui medietate claruit eo minus in medietate cooposita illustrat.</p>	<p>inquit, <i>et aliud sacramentum.</i> Nam <i>manifestatum est cuivis advertenti lumen lune ab ea parte que terram respicit non augeri nisi a soli recedendo, neque minui nisi ad solem</i> post dimidium mensem ex alio semicirculo iterum <i>propinquando</i> ab ea vero parte que superius eminet. Econtrario ipsum non crescere nisi propinquando ad solem neque decrescere nisi recedendo a sole quia quo magis luna ipsa sive propinquando ad solem sive ab eo recedendo in una sui medietate claruit eo minus medietate altera illustrat.</p>
---	---

This trend towards repeating biblical and patristic quotations as well as some original phrases from the *Expositio* is also visible elsewhere in the *Tractatus*, especially in the final section where Johannes de Termis lists five reasons why the Church postpones Easter Sunday by a week if it would fall on the 14th of the Moon. Substantial parts of this section repeat the

⁷¹ Augustine, *Epistulae* (55.5), ed. Daur (n. 69), p. 238, ll. 95–103

⁷² Ibid. (55.6), p. 238, l. 104.

⁷³ Ibid. (55.7), p. 240, ll. 146–49.

wording of *Expositio* I.6, where six such arguments are provided.⁷⁵ Was the *Tractatus* of 1354 a case of Johannes de Termis revisiting ideas he had first put down in the more voluminous *Expositio* of 1345? The likelihood of this scenario appears strong, especially in light of a remark Johannes makes in the *Tractatus*'s prologue, where he admits to having 'extracted' (*extraxi*) the present treatise, or parts thereof, from an earlier work written at the behest of Clement VI.⁷⁶ In discussing the errors that affected the ecclesiastical calendar, he shared the *Expositio*'s preference for mean solar longitudes, claiming—in unison with the earlier work—that the vernal equinox at the time of Christ's birth had been on 25 March, but had moved to 22 March by the time the Council of Nicaea introduced the currently valid rules for Easter reckoning. In present times, this reference point resided on 14 March, but Johannes de Termis did not take the *Expositio*'s approach of calling for a removal of 11 days from the calendar. Instead, he followed the more conservative stance recommended in *Ad corr.*, calling for an adjustment of the Easter limits to the changed astronomical situation. From now on, the earliest *terminus* for the lunation of Easter should be placed on the final day of February, so as to allow Easter to fall anywhere between 14 March and 17 April.⁷⁷

The contrast to the *Expositio* is striking, but nothing prevents us from seeing this divergence as part of an evolution in Johannes de Termis's way of thinking, which was

⁷⁵ See *Expositio* I.6 (fols. 5v–6v), and MS A, fols. 241r–42v = MS B, fols. 136v–38v. Arguments 2–6 in the *Expositio* correspond to nos. 1, 2, 4, 3, 5 (in this order) in the *Tractatus*.

⁷⁶ MS A, fol. 231v = MS B, fol. 123r–v: 'Opusculum quodam tempore et de mandato [...] beati Clementis [...] quandoque consiliorum ac canonum et sanctorum autoritatibus, quandoque etiam illorum qui et nunc et primum de siderum motibus astrologizati sunt experiētiis certis, innixus totaliter studui pertractare, ex quo quidem ad finem ut vestre sanctitatis sublimitas una cum sanctissimo dominorum cardinalium collegio infra scriptis et aliquantulum iam supratactis [...] erroribus remedium apponere dignetur oportunum sequens negotio vestre sanctitatis examini extraxi presentandum'.

⁷⁷ MS A, fols. 238r–40r = MS B, fols. 132r–35r.

probably influenced by the criticism the original proposal had received in 1345. What survived, at any rate, was his commitment to a mean tropical year of $365\frac{1}{4} - \frac{1}{120}$ days,⁷⁸ although the *Tractatus* made no effort to justify this choice as had been done at length in the *Expositio*. In a similar vein, the treatise of 1354 failed to assert any concrete plans for the correction of the calendar's lunar cycle, which had occupied most of Book II of the *Expositio*. Whereas the latter work had argued for a synodic month of 29d 12;44,3,2,1h, the *Tractatus* mentioned a length of 29d 12;44,3,1h, yet this may be no more than the result of a mistake.⁷⁹ A point of consensus in both works is their assessment of Ptolemy, who to Johannes the Termis was the undisputed 'leader and founder of the science of astronomy' (*scientie astrorum princeps et fundator*).⁸⁰

4. Concluding remarks

On balance, the hypothesis that Johannes de Termis authored the *Expositio kalendarii novi* in 1344/45 before revisiting the subject with his *Tractatus* of 1354 is the most plausible that one can deduce from the material at hand. Even if we accept, however, that Clement VI's circle of advisers extended further than the recorded names of Jean des Murs, Firmin de Beauval, and Johannes de Termis, and that some unknown fourth author was behind the *Expositio*, the discovery of this work sheds a great amount of new light on the calendrical side of fourteenth-century astronomy while considerably expanding our ability to reconstruct the history of the papal reform initiative of 1344/45. It is now clear that the first salvo in the

⁷⁸ MS A, fol. 238v = MS B, fol. 133r.

⁷⁹ MS A, fol. 238r = MS B, fol. 132r: '...cum tamen earum unaqueque 29 dies veraciter continere et horas 12 et 44 minuta cum 3 secundis et uno tertio experimentaliter deprehendatur'.

⁸⁰ *Expositio* I.1 (fol. 1r): '...ut ait ille prudentissimus scientie astrorum princeps et fundator, Ptholomeus'. MS A, fol. 238r = MS B, fol. 132r: '...Ptolomeus, qui scilicet scientie astrorum princeps extitit et fundator'.

debate was fired by the author of the *Expositio*, who wanted to see a restoration of the ecclesiastical calendar to its putative state at the time of Christ's incarnation. Unusually for such discussions, he based his reform proposal on the mean date of the vernal equinox, adopting a measure of the solar year known from previous computistical texts ($365\frac{1}{4} - \frac{1}{120}$ days). His plans for keeping the lunar calendar in sync with the Moon resembles the system later chosen for the Gregorian calendar, in that adjustments to the Julian intercalation cycle were supposed to be regularly counteracted with changes to the sequence of lunar epacts. Evidence that Gregorian reformers, in particular Luigi Lilio, were familiar with this fourteenth-century precedent is lacking, but even if the schemes were elaborated independently, the *Expositio* remains a valuable reminder that some key elements that characterize the contemporary civil and ecclesiastical calendar were already thinkable, and indeed expressed in writing, 250 years prior to their implementation.

Although astronomically sound, the proposal made in the *Expositio* required some drastic interference with the Julian calendar and its leap-year rhythm. Bissextile days were to be suspended once every 120 years and a single year was going to have 11 days subtracted from it. Contemporary observers found this idea extreme and impractical, as seen from the manifold objections raised against it in the anonymous work *Ad correctionem calendarii...*, which may have been commissioned by Clement VI, but was almost certainly intended as a memo to the pope. The two astronomers he had invited to the curia in the autumn of 1344, Jean des Murs and Firmin de Beauval, were aware of the arguments involved and, in the treatise they submitted in 1345, duly confined themselves to proposing several schemes of how the lunar component of the ecclesiastical calendar might be reformed. Since the need to balance the lunar against the solar calendar had fallen away, the measures proposed in the *Epistola super reformationem kalendarii* were on the whole of a simpler nature than those expounded in the *Expositio* or in the Gregorian *Compendium novae rationis restituendi*

kalendarium of 1577. Even so, Clement's advisers found no fully satisfactory answer to the calendrical regression of the vernal equinox, which would have dictated moving the range of permissible Easter dates from 22 March–25 April down to 13 March–14 April.⁸¹ The same impasse is visible in the *Tractatus de tempore celebrationis paschalis* Johannes de Termis sent to Pope Innocent VI in 1354, evidently in the hope of reigniting the discussion. Despite the fact that parts of his *Tractatus* recycled the *Expositio*, Johannes de Termis carefully avoided any reference to the original proposal of omitting 11 days, which shows that he was mindful of the criticism the latter work had attracted a decade earlier. In place of the original plan, he suggested a conservative reform that left the Julian calendar untouched, but moved the Easter limits closer to the beginning of March to respect the mean equinox's current location on 14 March. He thus chose to ignore the objections the earlier text had raised against a solution of this type. Against those who believed it licit to have the boundary-dates for Easter move along with the equinoxes and solstices, the *Expositio* responded with a determined *istud non valet*.

Firstly, because we would need to make this advancement of boundary-dates several times and we would always be in doubt as to when and by how much it would need to happen, and thus certitude as to whether Easter happens correctly or not would be had only very rarely or by very few people. Secondly, because all feasts of the whole year could take place successively now in Lent [*Quadragesima*], now at the time of Easter, and thus one would have to make so many alterations and such frequent ones in the breviaries that there would not be an end to these alterations. Thirdly, because the

⁸¹ See Jean/Firmin, *Epistola* (4), ed. Schabel (n. 6), pp. 209–10, and Nothaft, 'Science' (n. 4), pp. 296–99.

coincidence of mobile and immobile feast days would disturb the divine service to no small extent.⁸²

The necessity of maintaining the feasts of the liturgical year in their accustomed order and sequence goes some way towards explaining why the Gregorian reform of the calendar, as decreed 1582, resembled the one depicted in the *Expositio* more closely than the alternative proposals made in its wake.

⁸² *Expositio* I.9 (fols. 9v–10r): ‘Sed istud non valet, primo quia oporteret talem anterioracionem terminorum frequenter facere et essemus semper in dubio quanta fieri deberet et quando, et ita utrum pascha bene fieret vel non bene rarissime et a valde paucis haberetur certitudo. Secundo quia omnia festa tocius anni possent esse successive modo in Quadragesima, modo in tempore paschali, et ita oporteret facere tot mutaciones et tociens in breviariis quod mutacionum illarum non esset finis. Tercio quia propter concursum festorum mobilium et immobilium non modicum turbaretur divinum servicium’. The passage is repeated nearly verbatim in *Ad corr.* 1.3, ed. Schabel (n. 50), p. 21.

Appendix: List of Chapters in the *Expositio kalendarii novi*

Liber primus

1. De anno solari
2. Quot modis dicatur annus
3. Quod non oportet in quolibet quaternario fieri bissextum
4. De inconvenientibus que sequuntur ex observacione antiqui kalendarii
5. Quomodo antiquum kalendarium sit corrigendum
6. Ratio prima ad probandum quod premissum est in capitulo precedenti
7. Confirmacio predictorum ex dictis beati Augustini ubi prius allegabatur
8. Concludit ex premissis propositum
9. Responsio ad premissa et probacio solucionis et confirmacio propositi
10. Conveniencia corrigendi antiquum kalendarium, utilitas et possibilitas
11. Responsio ad rationes illorum qui tenent quod sine scandalo non potest fieri
huiusmodi correctio
12. Racio secunda principalis ad probandum propositum
13. Tercia ratio principalis ad ostendendum propositum
14. Confirmacio predictorum per dicta astronomorum et beati Augustini
15. Regula pro inveniando equinoctium in omni tempore
16. Responsio ad quamdam tacitam obiectionem
17. Quod reductio et fixio solstitiorum et equinoctiorum debet fieri ad tempus Christi.
18. Quid sit annus solaris vulgaris et bissextilis, quid bissextus et unde oriatur et ubi
sit locus eius
19. Quod cum ciclo solari sunt necessari 2 alii cicli, scilicet cyclus centivigenalis et
cyclus ciclorum centivigenalium

20. Divisio anni in 4 tempora, scilicet in ver, estatem, autumpnum et hyemem et eorum qualitatibus
21. Quare ver et autumpnus habent oppositas qualitates cum tamen sol in utroque eque distet a nobis et quare tempora per accidens varientur
22. De duplici solsticio et equinoctio et qualiter habent fieri
23. De inequalitate dierum artificialium et qualiter debent intelligi
24. De causa inequalitatis predictae, de Ieiuniis quatuor temporum et de adventu
25. Quod in anno sunt tantum 12 menses, quare sic vocentur et tot habeant dies et non plures
26. De signis et eorum nominibus et quare per animalia designentur, cur signa vocentur et quare sunt tot, neque plura, neque pauciora
27. De qualitatibus signorum et eorum proprietatibus
28. Racio positi ordinis in signis et quare dicuntur masculina et feminina, diurna et nocturna
29. Quomodo disponuntur signa in celo et qualiter se habent ad ortum et occasum
30. Quantum movetur sol in die naturali
31. Qua die cuiuslibet mensis sol intrat quodlibet signum; invencio gradus solis qualibet die et hora eiusdem diei declinacionisque solis et altitudinis meridiano
32. Divisio anni per dies, dierum per artificialem et naturalem, artificialis et naturalis per quadras et quid sit horum unumquodque vel cuius qualitatis
33. De diversis dierum appellacionibus
34. De dierum denominatione a planetis necnon et planetarum condicionibus
35. De dierum appellacionibus per Romanos inductis, de kalendis scilicet, ydibus atque nonis

36. Quid sit ebdomada et septimana et unde dicantur, quibus litteris dominica et alie ferie designentur
37. De regulari feriali vel solari
38. Quid sit concurrens et unde oriatur et quod in eius ciclo septenarius poni non debet
39. Quid sit indictio et unde ortum habuit et ubi incepit ciclus eius
40. Qualiter alio modo inveniuntur littera dominicalis et concurrens ciclo ciclorum centivigenalium
41. De diebus Egiptiacis

Liber secundus

1. Quid sit phisica lunacio et cuius quantitatis
2. Quid sit annus lunaris et quotis constet lunacionibus
3. De clavibus primacionum et primacionibus radicalibus
4. De compositione tabule clavium primacionum et eius usu
5. De regularibus lunaribus et epactis
6. De compositione contratabule kalendarii perpetue ad sciendum horas distancie coniunctionis a primacione et eius usu
7. Quid sit annus lunaris communis et quid sit mensis lunaris, quot modis et unde dicatur
8. Divisio mensis lunaris per quadras et de diebus creticis ac periodicis
9. De tribus periodis universalibus et diebus creticis intercidentibus
10. Quid sit annus embolismalis et quot sunt anni embolismales in ciclo 19^{li}; de lunacionibus paschalibus regularibus et irregularibus

11. Quod Christus passus fuit tercio nonas Aprilis et non octavo kalendis, ut dicitur communiter
12. Quod inter nativitatem et passionem Christi non fuerunt nisi 31 anni integri cum tribus mensibus et 10 diebus
13. Quid sit terminus et clavis terminorum, quomodo formentur et quis [!] sit eorum usus

List of Figure captions:

Figure 1: Beginning of the *Expositio kalendarii novi*, MS Vat. Ott. lat. 842, fol. 1r.

Reproduced by permission of Biblioteca Apostolica Vaticana, with all rights reserved.

Figure 2: *Tabula clavium primacionum lune*, MS Vat. Ott. lat. 842, fol. 56r. Reproduced by permission of Biblioteca Apostolica Vaticana, with all rights reserved.

Figure 3: *Tabula epactarum*, MS Table of Vat. Ott. lat. 842, fol. 58r. Reproduced by permission of Biblioteca Apostolica Vaticana, with all rights reserved.

Figure 4: Luigi Lilio's table of epacts, in: Christopher Clavius, *Romani kalendarii a Gregorio XIII. P.M. restituti explicatio S.D.N. Clementis VIII. P.M. iussu edita* (Rome: Zannetti, 1603), p. 9. Oxford, All Souls College Library, 2: Sr.41.a.3. Reproduced by permission of the Warden and Fellows of All Souls College, Oxford.