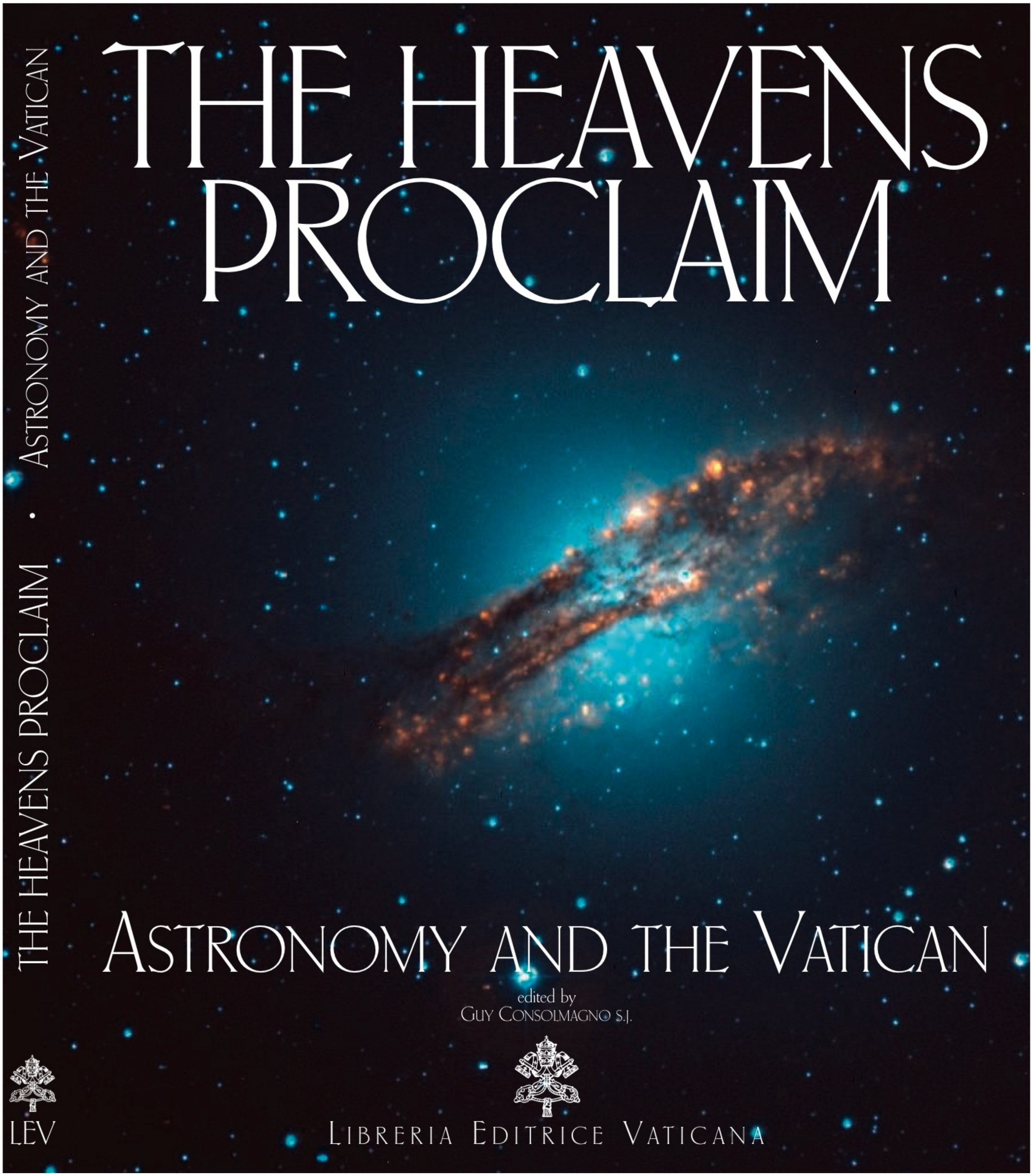
THE HEAVENS PROCLAIM • ASTRONOMY AND THE VATICAN
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ASTRONOMY AND THE VATICAN
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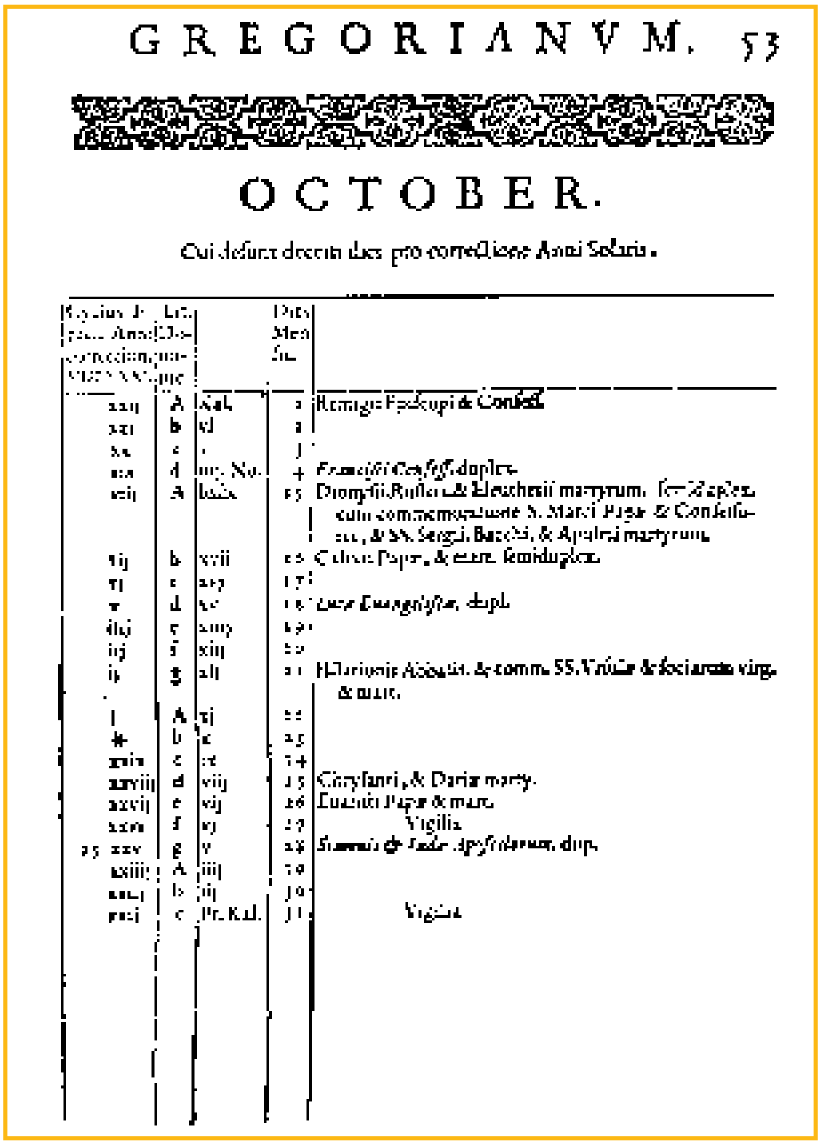
Astronomy, Calendars, and Religion

• Fr. Juan CASANOVAS S.J. •



The Hebrew Calendar

The first and most practical reason why people in antiquity studied the stars and planets, and their relative motions, was to construct a reliable calendar.

A calendar counts days in units of weeks, months, and years. The challenge of making any calendar comes from the fact that the lunar month does not have an exact number of days; and likewise, the year has neither an exact number of days nor an exact number of months. The differences, fractions of a day and fractions of a month within a year, accumulate over the years and it eventually becomes necessary to add or subtract days in order to keep the calendar in harmony with the annual sequence of the seasons. This operation is called *interpolation*. A good calendar is a set of simple and clear rules in order to know when to interpolate a day or even a lunar month when needed.

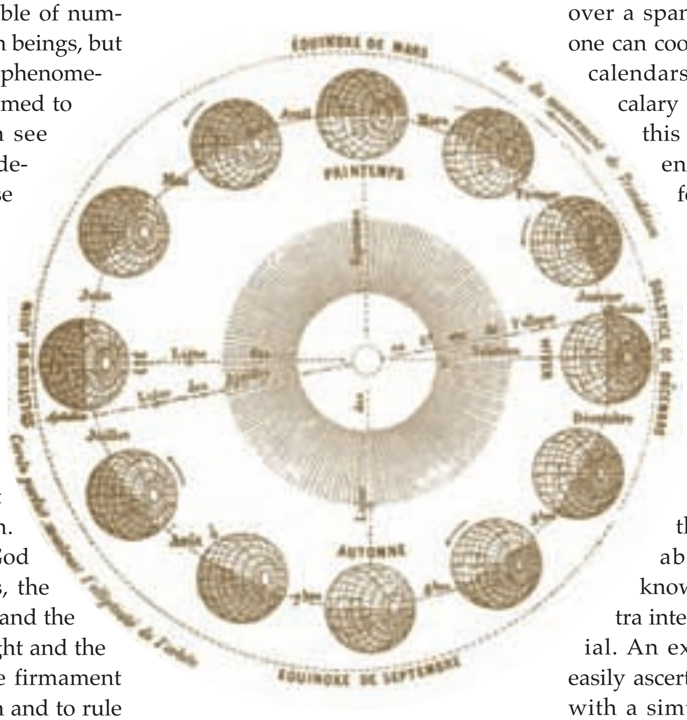
The familiar seven-day week probably originated in Babylon, predating written history; one theory suggests it was a way of counting the days

Left *The calendar for the month of October 1582 from Christoph Clavius' book explaining the reformed Gregorian calendar. In order to bring the calendar in line with the seasons, the days between October 4 and October 15 were skipped that year.*

between market days. The month was originally based on the phases of the Moon; knowing when the Moon would be full (and thus light the night-time sky) was especially important for hunters or anyone living near tidal waters (the highest tides being associated with new and full Moons). The year was most important in agricultural societies, where knowledge of planting and harvesting times was needed.

For the ancient Hebrews, the calendar was not merely a table of numbers put together by human beings, but it was founded on celestial phenomena whose origins were deemed to come from God. You can see this in the way the Bible describes the ultimate purpose of the Creator in making celestial objects: in Genesis (1:14-18) we are told that "God said, let there be lights in the firmament of heaven to distinguish the day from the night; let them serve to indicate the seasons, the days, and the years, and let them illuminate the Earth. And so it came to pass; God made the two great lights, the larger light to rule the day and the smaller light to rule the night and the stars. God put them in the firmament of heaven to light the Earth and to rule day and night and to separate the light from the darkness." Likewise, we find in Psalm 103 v 19, "To indicate the seasons you have made the Moon." Thus the original Hebrew calendar was controlled by celestial phenomena, phenomena that everyone could easily see.

The actual length of a lunar month – the time over which the Moon cycles through all of its phases – is twenty nine and a half days (29.53085 days according to the presently accepted value). The Hebrews defined their year to consist of twelve months of alternating 29 and 30 days' length. The problem is that such a *lunar year* has only 354 days, and so it is about 11 days too short compared to a *solar year* that follows the seasons. But farmers needed to keep track of the seasons, to regulate agricultural activities such as sowing and harvesting crops. In any calendar designed to follow both the Moon and the Sun (a *lunisolar* calendar), therefore, it is necessary to introduce an extra, *intercalary* month every two or three years.



Above *The annual movement of the Earth around the Sun and the production of the seasons, as illustrated in C. Flammarion's book* Astronomie Populaire *published in Paris in 1880.*

In 432 BC, the Greek mathematician Meton noticed that 19 solar years adds up to almost exactly 235 lunar months; the difference is only a couple of hours, slipping by only about a day over a span of about 300 years. Thus one can coordinate the lunar and solar calendars by inserting seven intercalary (or *embolistic*) months over this 19 year pattern. It is easy enough to construct a table for each year of the Metonic cycle, giving the day in which there is a new Moon. As the cycle repeats, you would have an almost perpetual calendar. Meton devised such a rule for when to insert these extra months.

But the ancient Hebrews were not aware of the metonic system. In the absence of a precise rule, knowing when to insert an extra intercalary month was not trivial. An expert in astronomy could easily ascertain the position of the Sun with a simple gnomon (you can observe the changing length of the shadow of the Sun as projected by a vertical pole or an obelisk) but it seems that in practice the Sanhedrin, the assembly of elders who regulated Jewish life, were not particularly systematic in their working out the progress of the farmers' seasons. Thus there was a certain uncertainty as to when they would declare the first Moon (or month) of the year; intercalary months were inserted whenever it was deemed opportune. They found it easier to keep track of the years according to particular events that occurred within a year, rather than counting from a precisely determined beginning of the year.

The year always began on the first day of a lunar month. Usually, the first month of the year was set to coincide with springtime (in some places it was set to begin with autumn, but it's the same idea as far as this discussion is concerned). The lunar month always began with the New Moon. The day of the New Moon, the *Neomenia*, was a holiday with certain prescribed sacrifices at the Temple (cf. Nm 28: 11-15).

Finding the beginning of the month was not always easy. Aside from problem of bad weather hiding the Moon, it is impossible to actually observe a New Moon itself since it occurs when that body is in conjunction with the Sun, and so is hidden by the Sun's brilliance. You can only see the thin crescent of the Moon on the day after it is new, and even that is not easy. Even today, Muslims must look directly for the first visible crescent of the New Moon in order to regulate their religious calendar; they use direct observations to keep track of the beginnings of the months and to work out their year.

For determining the date of Passover, the Hebrews followed the Mosaic rule set down in Exodus (12: 1-8), Numbers (28: 16) and Leviticus (23: 5): "On the first month, on the 14th day, at the setting of the Sun, shall occur the Passover of the Lord." The fourteenth night of the first month equates to the first Full Moon of the year, since the Full Moon always occurs 14 days after New Moon.

Note that, by this definition, the celebration of Passover was not to them a "moveable feast" but it was fixed as being on the same day of the same month every year: the day of the first Full Moon of the year. But the choice of which month was the first month of the year was proclaimed on the authority of the Sanhedrin, as noted above, who might or might not decide that it was necessary in a given year to add an intercalary month. Thus it was quite possible that they could get it wrong, given the difficulties noted above and the possible inexperience of those making the decision.

Once the New Moon was directly observed by the Sanhedrin, there followed a solemn proclamation, accompanied by the sound of trumpets, sacrifices in the Temple, and the sending forth of messengers to the other cities throughout the country. If bad weather prevented any direct observations they would proceed using calculations based on the observations made in the previous month. The same procedure was used for the proclamation of the beginning of the year.

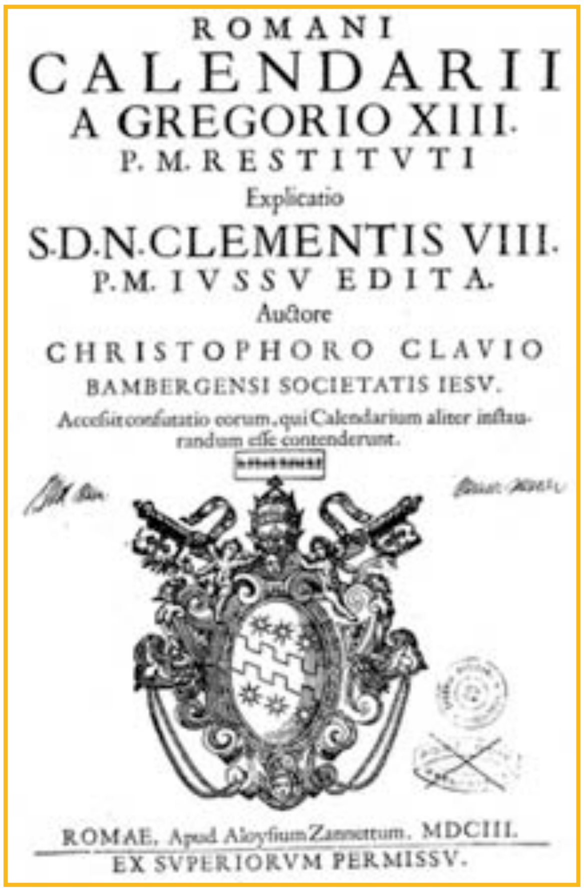
After the destruction of Jerusalem in AD 70 and the subsequent Diaspora of the Jewish people, it was no longer possible to maintain this system; there was no longer a Temple authority that could announce the beginning of the month or the year. Instead, finally, they decided to adapt the Metonic Cycle of 19 years to calculate a calendar, which therefore was no longer based on the direct observation of the Moon. At least in this way the whole Jewish community of the Diaspora could celebrate Passover on the same day.

Above *"The first apparition of the crescent moon was announced to the people by the high priest and proclaimed at the sound of the trumpets..." This rather fanciful illustration is taken from p. 137 of C. Flammarion's* Astronomie Populaire.

The Christian Calendar and the Council of Nicea

At first the early Christians followed the Jews in computing the day of Passover, but soon they parted ways, delaying the celebration of Easter to the day immediately after the Sabbath — Sunday — following Passover. This feast had a different significance for the Christians: not the liberation from the slavery of Egypt, but the promise of the Resurrection (which had occurred on a Sunday) and the liberation from sin. But, like the Jews, the various Christian churches were located far from one another and not always in good communication; they each found it necessary to work out for themselves the date for the celebration of Easter. This was a challenge to Christian unity ultimately confronted by the Council of Nicea, which met in AD 325, an important date in the Christian Calendar.

By that time the calendar of Julius Caesar was in use throughout the Roman Empire. In this calendar you no longer needed to determine when you should insert a month or not, in order to keep the first month in spring; the lunar months of 29 or 30 days were replaced by 12 months that were merely intervals of time set, by convention, to 30 or 31 days. Of course, the lunar months were gone forever in the Roman calendar. The advantage of this system lay in the fact that the Julian year was very well harmonized with the seasons and the motions of the Sun. Given the universal use of this calendar, the Council fixed the equinox of the Julian calendar at the time of the council, and then interpreted the text of the Old Testament defining Passover (and thus Easter) in the following mode: one would celebrate Easter on the Sunday that followed the first full Moon after the 21st of March. If the full Moon itself fell on a Sunday, Easter would be celebrated on the following Sunday. This was to avoid the confusion of the Christian Easter with the Hebrew Passover. Notice that, by this definition, the calendar no longer depended on an authority who would solemnly announce a date for Passover every year, with all its attendant arbitrariness or uncertainty. Now each Church, even those most distant, could calculate for itself when Easter would be celebrated.


ROMANI
CALENDARII
A GREGORIO XIII.
P. M. RESTITVTI
Explicatio
S.D.N. CLEMENTIS VIII.
P.M. IVSSV EDITA.
Auctore
CHRISTOPHORO CLAVIO
BAMBERGENSI SOCIETATIS IESV.
Accessit confutatio eorum, qui Calendarium aliter instaurandum esse contenderunt.
ROMAE, Apud Aloysium Zannettum. MDCIII.
EX SVPERIORVM PERMISSV.

Above *After Pope Gregory XIII approved the proposed reform of the calendar, the Jesuit priest Christoph Clavius wrote a book explaining the reasoning behind the reform, and how it would work. Shown here is the cover page of a copy from the library of the Vatican Observatory in Castel Gandolfo.*

Note that the Council could have defined Easter in terms of a direct observation of the full Moon; but instead, they preferred to work out the day of the full Moon independently of direct observation, because it would not always be possible to do make such observations given the particular meteorological conditions. Instead, they relied on the Metonic cycle described above.

The fathers of the Council of Nicea were aware of the fact that the position of the date of Easter was merely a mathematical interpretation of the cited texts of the Old Testament. It was left to the Church of Alexandria, a city that had a strong astronomical tradition, the job of preparing a more specific scheme for computing the date of Easter. The system finally adopted for determining the date of the New Moon was worked out some 200 years later by Dionysius Exiguus, a monk who lived in Rome in the first half of the 6th century. In the process, he introduced the concept and numbering of the "Anno Domini" years now in common use.

Dionysius constructed a table that allowed one to read off the date of the New Moon for each month of every Julian year in the 19 year Metonic cycle; this table was repeated every 19 years. The first cycle was said to commence with the year AD 1. A *Golden Number* was defined as the value that indicated where the current year sat in the Metonic cycle.

Thus, to compute the date of Easter of any given year, one first determined the Golden Number of the year; then, in Dionysius' table of New Moons, one looked for the first New Moon after March 21. The Paschal Moon, the Full Moon, would occur 13 days later, that is, on the 14th day of the lunar month. The date of Easter would be the Sunday after this Full Moon unless this Full Moon fell on a Sunday; in that case, Easter would be celebrated on the following Sunday. (Knowing which day was Sunday for any given month of any given year could also be computed easily with further tables provided by Dionysius. The sequence of the days of the week continued uninterrupted through all of these calendar reforms.)

Thanks to these New Moon tables, the date of Easter could be computed without ambiguity. The Pascal New Moon would occur between 8 March and 5 April, and so the Full Moon could occur from 21 March to 18 April. Given the possibility that 18 April itself might be a Sunday, the dates on which Easter could occur thus ranged from 22 March until 25 April.

Recall that for the ancient Hebrews, Passover was always fixed on the 14th day of the first month of the year, i.e. the day when the Full Moon actually occurs. For them, the date could be determined without needing to use any complicated, approximate tables; anyone can see the Full Moon, which was what was particularly important to them for determining holy days. For the Christian Easter, however, this no longer held; indeed, Easter could occur as much as seven days after the Full Moon.

The Gregorian Reform of the Calendar

Surely the fathers of the Nicene Council realized that they were not leaving us a perfect calendar. They understood that the duration of the Julian solar year was slightly too long, and that the difference would be perceptible within one or two generations, as the error would continue to accumulate. Everyone understood that this "defect" introduced an error of about one day in 133 years if one compared the Julian year of 365 (and a quarter) days and the actual value of the year. It wasn't long before voices were raised demanding a reform of the calendar.

By the Middle Ages, calendars used to indicate the "true" or astronomical day of the equinox, which was the entrance of the Sun onto the first point of Aries, and the "official" equinox, which was always kept on the 21st of March. By the 1500s this difference had already grown to be ten days. But this probably wasn't the only motive for the reform of the calendar. There was also an error of four days in the determination of the New Moon according to the Metonic cycle, which made the determination of Easter no longer in accord with the spirit of the Council of Nicea. The situation was getting out of hand.

First of all, one needed to adopt a value of the year that came much closer to its actual length. When Julius Caesar, following the advice of the astronomer Sosigenes of Alexandria, introduced the year of 365.25 days, it was already known that this length was slightly too long – producing an error of one day in about 133 years. But to make a simple and practical calendar, it was decided to merely intercalate, or insert, one day every four years and leave any further corrections to the distant future. This small difference had accumulated with the passage of time, however, and by the Middle Ages it was evident that the spring equinox no longer coincided with the official equinox of 21 March.

Church councils, particularly those held in Constance (1414-1418) and Trent (1545-1563), requested that the Popes work towards a finding a correction to the calendar. Their delay in doing so, however, was not due to negligence on the part of the Popes, but because no one had yet presented a reform that was valid and simple, unambiguous, and fully in accord with the Council of Nicea.

Pietro Pitati, in a treatise published in Verona in 1560, noted that three times 133 years was practically 400 years. Therefore, he realized, a better approximation could be achieved by dropping three days every 400 years: he suggested keeping the regular year of 365 days with a leap year every fourth year, except for years ending with two zeros. But when such years were divisible by 400, it would stay a leap year. (Thus, while 1896 and 1904 were leap years, 1900 was not; but 2000 was.)

But this was only the first step in reforming the calendar. By then the New Moons in Dionysius' table were already off by 4 days in comparison with actual observed position of the Moon. Pitati studied the lunations with

Opposite *Pope Gregory XIII issued the modern reform of the calendar in 1582.*

the astronomical tables of his time, but he could not come up with any truly practical solution. It was left to Aloysius (Luigi) Lilio (1510-1552), a professor of medicine at the University of Perugia, to give the definitive solution.

Recall that Dionysius's scheme, in which one looked up the new Moon for each Golden Number corresponding to the given year, only allowed one to insert extra months as needed to make the lunar and solar calendars agree. Lilio's idea was to make use of the *epact*, the difference between the lunar and solar year as counted in days, instead of months. This allowed one to adjust the calendar by a day instead of by a whole month. The epact for a given year was defined as the age of the Moon, i.e. the day of the lunar month, on the first day of January of that year. For example, if on this day the Moon was in its 14th day (full Moon), the epact of that year would be "14". Then one could replace the ancient tables of Dionysius with an equivalent table that replaced the Golden Number with the epact. Then, to compute the date of Easter, one proceeded more or less as before; you used the epact of the year as the Golden Number. And as the Metonic cycle drifted away from the actual occurrence of the New Moon, the epact could be adjusted by the number of days needed to bring the calendar back into agreement with observations. This intercalation was called the *equation* (using an old sense of the word) of the epact.

The "equation" rule finally adopted was to reduce the age of the Moon by one day every 300 years, repeating this over eight such 300 year periods, and then make another adjustment of a day after an interval of 400 years. This 2800 year cycle could be repeated indefinitely.

Finally, it was decided to make all these intercalations and corrections occur only in years that end with two zeros. These years are called *centenary* years since they begin the century (or end the century, however you prefer to put it). Thus, on each centenary year one might introduce an equation of one day, if necessary (shifting back the equation of the Moon every 300 or 400 years) to adjust the Lunar year, while at the same time one was making the appropriate correction (leap year or not) to the solar year. The sum of these two corrections served to modify the tables of the epact, which would take the place of the appropriate Golden Number tables.

Aloysius Lilio's proposal, presented after his death to Pope Gregory XIII by his brother Antonio, was immediately accepted. A Calendar Commission was named to prepare a description of the proposal, called the Compendium, and in 1577 it was sent to all the civil authorities of Europe, including universities and academies. After going through all the responses, the calendar commission then prepared the Papal Bull, *Inter Gravissimas*, which in 1582 decreed the adoption of the new calendar.

Arguably, the introduction of the new calendar was in fact more of a correction than a reform. One merely used a slightly more accurate value for the length of the year and likewise a slightly adjusted method for calculating the phases of the Moon. The Julian rule for leap years was only somewhat modified. With Lilio's mechanism of epacts, the Metonic Cycle was preserved as a valid way to calculate Easter in accord with tradition. Finally, for one time only, 10 days were eliminated to move the equinox back to March 21, bringing it back into accord with the official date in use since the Council of Nicea. This was the great merit of the Gregorian reform: with a minimum of adjustment and with clear rules, it preserved the intent of the Council. And because it relied on a Council that had sat before the schism between East and West, it was hoped that this reform could avoid further conflict with the Orthodox Church.

An important member of this commission for the reform of the calendar was Fr. Christoph Clavius SJ, a professor of mathematics at the Roman College, known for his publications in geometry, arithmetic, and astronomy. It is difficult to know for sure his full role in the commission, but it is enough to note that he was the one instructed by the Pope to describe and defend the new calendar. His work, *Explanatio Romani Calendarii* (Rome, 1603), is fundamental and indispensible for anyone studying the reform.

As he pointed out, there were any number of other possible solutions for the reform of the calendar. For example, one could have left the true equinox at March 11, where it was at that point; or completely simplify the whole question of finding Easter by fixing it to a non-moveable date; or perhaps use astronomical tables to determine the first Full Moon of spring. But these would have been a significant break with the tradition that had followed the text of the Old Testament to determine the date of Passover. It was preferred instead to respect as much as possible the spirit of what had been determined at the Council of Nicea and the longstanding tradition of the Church. Since the true equinox had originally been set at 21 March, that would not be touched in the rule for determining Easter. In addition, one wanted a simple system in which there would be no need for a special understanding of astronomy, in a format that could be easily transported and adapted to distant regions by explorers and missionaries, who would be able to generate the calendar accurately and without ambiguity.

In Chapter IV of his book, Clavius gave additional reasons for adopting this version of the calendar. He maintained that if one were to use the true astronomical value for the New Moon instead of the approximate value according to the Metonic Cycle of 19 years, this would likely just provoke arguments and so put Christian unity (already strained by the Protestant Reformation) further at risk. Using astronomical tables would not help, because of the discrepancies among the diverse tables available at that time. Instead, it seemed more convenient to adopt a calendar that anyone could carry with them and use, rather than relying on experts who were not always in agreement. That was certainly the case in the 16th century.

The new calendar was accepted almost immediately in Catholic countries. There was, however, a great reluctance to adopt it in the Protestant lands, for obvious political and religious reasons. Some Protestant communities in northern Germany chose instead to calculate the dates of the Full Moon in accord with published ephemerides; this recourse to astronomical data, as noted by Clavius, gave them an excuse for evading the Gregorian reform. Only at the beginning of the 18th century was the reform accepted by all of Europe except the Orthodox Christians. (A complete table of the dates of adoption in each country can be found in the *Explanatory Supplement to the Astronomical Ephemeris* prepared by the Royal Observatory in London; or see E. G. Richards, *The Mapping of Time*, Oxford, 1999.)

Above Fr. Christoph Clavius S.J., a professor of mathematics at the Roman College, known for his publications in geometry, arithmetic, and astronomy; he was instructed by the Pope to describe and defend the new calendar.

According to the reform commission, the new calendar was in essence perpetual, in the sense that if one compared the value of the tropical Gregorian year with the value found the Alphonsine table of 365.24255 days, you would find an error of only one day in about 20,000 years. Many people thought that the end of the world would occur long before this day arrived. In any case, they reasoned, it should not be all that hard to make the tiny adjustment of one day necessary after so many years. As it happens, however, comparing the Gregorian year with the modern tropical year, one finds that the difference of one day actually will come much sooner, after 3,000 years.

Still, there is really no point in looking for a way to improve the Gregorian tropical year. Every so often, someone points out that the value of the Gregorian year is in error; but generally what they forget is that the reform commission was well aware that they had not adopted the best and most precise value of the tropical year then available. It was, instead, a value conditioned by the decision to make the interpolation only during centenary years.

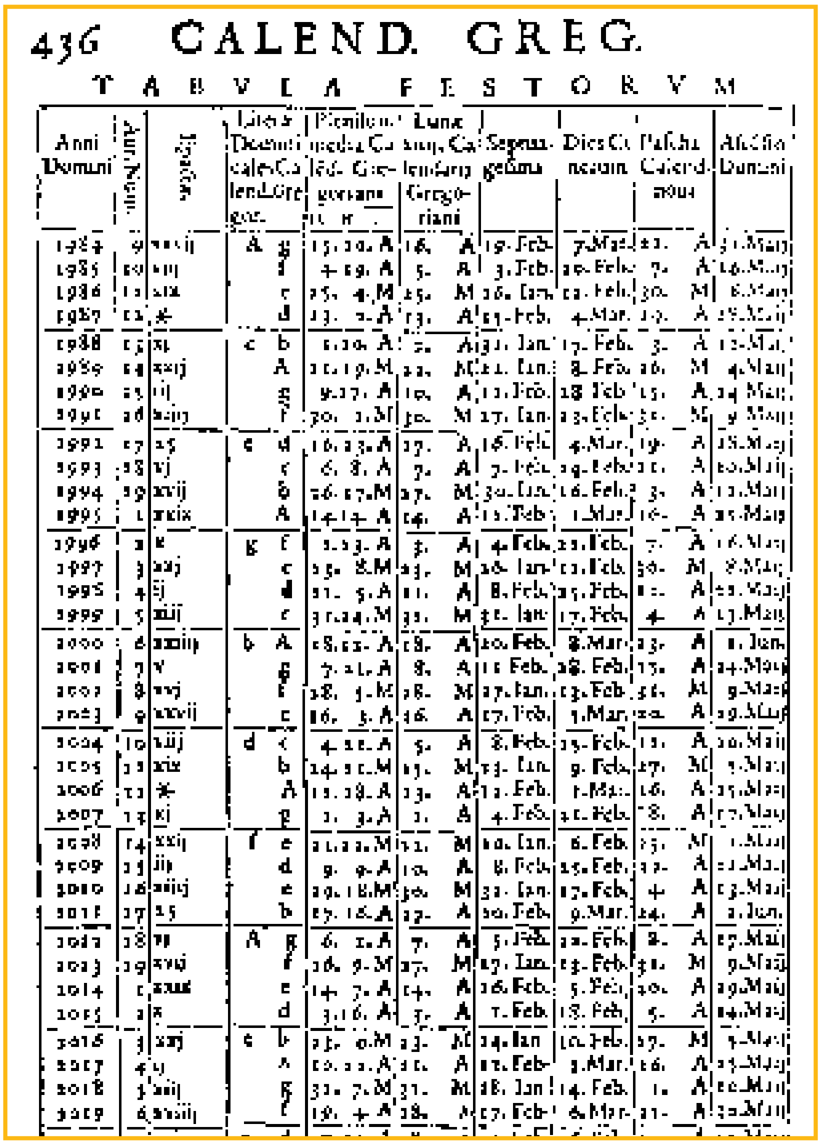
Modern Attempts to Reform the Gregorian Calendar

We move now to the attempts of various societies and nations to come up with a perpetual calendar. The rock on which every such proposal has foundered is that there is not an exact number of weeks in a year. There is always one day extra, two in leap years, that does not belong to any week; and many religious groups absolutely refuse to accept any interruption in the weekly cycle (thus interrupting the celebration of the Lord's Day).

Other proposals have been made to adjust the value of the length of the Gregorian year, which is slightly longer than the true value; but they forget that the day is also variable, as we will show below, and it is not advisable to modify the year to obtain a better match to the fractional number of days in a year, when you don't know exactly what the length of the day itself will be in future times.

At a gathering of the World Council of Churches held in Aleppo in 1997, it was proposed that the Gregorian calendar's rule for the determination of Easter should be eliminated in favor of a more precise calculation, more in keeping with improved astronomical ephemerides. That had already been tried for a while in various Protestant countries, until they eventually decided to adopt the Gregorian calendar; and certainly, the editors of printed calendars today already include the dates of the phases of the Moon based on astronomical almanacs. But while this might seem to be a reasonable idea, in practice it is not so easy or obvious to implement when it comes to determining the date of Easter.

First of all, if you are going to use astronomical tables, you have to choose which longitude you will use for your computations (for example, to determine whether it is Saturday or Sunday when a given Full Moon occurs). Let's say, by mutual agreement, you choose to make your calculations by assuming you are in Jerusalem. Now, while the "spring equinox" for the Gregorian calendar is always fixed at March 21 independent of the actual position of the Earth, it can happen that spring actually starts when it is March 20 or even, some years, March 19 at Jerusalem's longitude. In preparation for the Aleppo conference, the date of Easter was calculated using both the astronomical and Gregorian calendar methods. From the year 2001 through 2100 the astronomical and Gregorian methods disagreed nine times. It is not surprising that there was such a difference, because the use of the Jerusalem longitude influences all the dates of the equinox used in determining which Full Moon is the first Full Moon of spring.



436 CALEND. GREG.

TABVLA FESTORVM

Anni Domini	Aureus numerus	Epactae	Litterae Dominicales Calend. Greg.		Plenilunium medium Calend. Gregoriani	Lunae xiiij Calendarij Gregoriani		Septuagesima	Dies Cinerum	Pascha Calend. nouu		Ascensio Domini
1984	9	xxvij	A	g	15. 10. A	16.	A	19. Feb.	7. Mar.	22.	A	31. Maij
1985	10	viij		f	4. 19. A	5.	A	3. Feb.	20. Feb.	7.	A	16. Maij
1986	11	xix		e	25. 4. M	25.	M	26. Ian.	12. Feb.	30.	M	8. Maij
1987	12	*		d	13. 2. A	13.	A	15. Feb.	4. Mar.	19.	A	28. Maij
1988	13	xi	c	b	1. 10. A	2.	A	31. Ian.	17. Feb.	3.	A	12. Maij
1989	14	xxij		A	21. 19. M	22.	M	22. Ian.	8. Feb.	26.	M	4. Maij
1990	15	iij		g	9. 17. A	10.	A	11. Feb.	28. Feb.	15.	A	24. Maij
1991	16	xiiij		f	30. 1. M	30.	M	27. Ian.	13. Feb.	31.	M	9. Maij
1992	17	25	e	d	16. 23. A	17.	A	16. Feb.	4. Mar.	19.	A	28. Maij
1993	18	vj		c	6. 8. A	7.	A	7. Feb.	24. Feb.	11.	A	20. Maij
1994	19	xvij		b	26. 17. M	27.	M	30. Ian.	16. Feb.	3.	A	12. Maij
1995	1	xxix		A	14. 14. A	14.	A	12. Feb.	1. Mar.	16.	A	25. Maij
1996	2	x	g	f	3. 3. A	3.	A	4. Feb.	21. Feb.	7.	A	16. Maij
1997	3	xxij		e	23. 8. M	23.	M	26. Ian.	12. Feb.	30.	M	8. Maij
1998	4	iij		d	11. 5. A	11.	A	8. Feb.	25. Feb.	12.	A	21. Maij
1999	5	xiiij		c	31. 14. M	31.	M	31. Ian.	17. Feb.	4.	A	13. Maij
2000	6	xxv	b	A	18. 23. A	18.	A	20. Feb.	8. Mar.	23.	A	1. Iun.
2001	7	vj		g	7. 21. A	8.	A	11. Feb.	28. Feb.	15.	A	24. Maij
2002	8	xvij		f	28. 5. M	28.	M	27. Ian.	13. Feb.	31.	M	9. Maij
2003	9	xxviij		e	16. 5. A	16.	A	17. Feb.	5. Mar.	20.	A	29. Maij
2004	10	viij	d	c	4. 12. A	5.	A	8. Feb.	25. Feb.	11.	A	20. Maij
2005	11	xix		b	24. 20. M	25.	M	23. Ian.	9. Feb.	27.	M	5. Maij
2006	12	*		A	12. 18. A	13.	A	12. Feb.	1. Mar.	16.	A	25. Maij
2007	13	xi		g	2. 3. A	2.	A	4. Feb.	21. Feb.	8.	A	17. Maij
2008	14	xxij	f	e	21. 12. M	21.	M	20. Ian.	6. Feb.	23.	M	1. Maij
2009	15	iij		d	9. 9. A	10.	A	8. Feb.	25. Feb.	12.	A	21. Maij
2010	16	xiiij		c	29. 18. M	30.	M	31. Ian.	17. Feb.	4.	A	13. Maij
2011	17	25		b	17. 16. A	17.	A	20. Feb.	9. Mar.	24.	A	2. Iun.
2012	18	vj	A	g	6. 1. A	7.	A	5. Feb.	22. Feb.	8.	A	17. Maij
2013	19	xvij		f	26. 9. M	27.	M	27. Ian.	13. Feb.	31.	M	9. Maij
2014	1	xxix		e	14. 7. A	14.	A	16. Feb.	5. Mar.	20.	A	29. Maij
2015	2	x		d	3. 16. A	3.	A	1. Feb.	18. Feb.	5.	A	14. Maij
2016	3	xxj	c	b	23. 0. M	23.	M	24. Ian.	10. Feb.	27.	M	5. Maij
2017	4	ij		A	10. 22. A	11.	A	12. Feb.	1. Mar.	16.	A	25. Maij
2018	5	xiij		g	31. 7. M	31.	M	28. Ian.	14. Feb.	1.	A	10. Maij
2019	6	xxiiij		f	19. 4. A	18.	A	17. Feb.	6. Mar.	21.	A	30. Maij

In addition, while the Gregorian calendar uses a simple, easy-to-use arithmetic based on whole numbers, with the proposed change you would have to use fractional ephemeris values that are constantly varying. Normally this would not make any difference between the Easter determined by the Gregorian and the "astronomical" calendar, but if it should happen that the Full Moon occurs a few minutes before or after midnight (in Jerusalem) this could lead to problems. Fortunately this wouldn't occur very often, but it cannot be ruled out: there would be uncertain cases if you wanted to make any long-term calculations for the date of Easter.

The reason for this situation is that lunations are calculated with what is called "Terrestrial Dynamic Time" (which is found, in practice, with "atomic clocks": very precise clocks based on various properties of atoms). But the lunations that are needed for the liturgical computation of Easter are calculated in "Universal Time" which is obtained simply by counting the number of days, i.e. the number of rotations of the Earth about its axis. Well, the difference ΔT between these two times is slightly variable in an unpredictable way, which changes over time, due to the fact that the rotation of the Earth about its axis is not uniform. Even if we could calculate in Terrestrial Dynamic Time the precise position of the Sun and the Moon for some far future time, that would not be the position that would be used by a calendar, which is measured in Universal Time. Therefore it would not be possible to prepare a table of Easter dates for the distant future, but only for an interval of years for which the unknown ΔT is not critical; in other words, so long as we don't have the situation —very rare, to be sure — when the New Moon occurs within the error of the ΔT of the ephemeris. Naturally this influences only the calculation of Easter for the far distant future, but it would be necessary to create an authority to decide what to do in such special circumstances.

The Gregorian rule for the calculation of Easter is in practice very simple and proceeds automatically without needing any authority that would have to make decisions in uncertain cases, since there are no such cases. After three thousand years there will be the need to eliminate one day in the year because, for reasons of simplicity as we have described, the Gregorian year is still a little too long. The beginning of a millennium can provide a perfect opportunity to correct the year and at the same time make an adjustment of a whole number of days in the equation of the New Moon, in a way analogous to the fundamental rule of the Gregorian reform of the calendar.

The introduction of a more "scientific" determination of the spring Full Moon does not affect a fundamental problem of the date of Easter: when should it occur when the choice lies at the extremes of the season, and one must choose either 22 March or, say, 25 April? In other words, should Easter be celebrated at the beginning or spring or in roughly the middle of the season? This oscillation of the date of Easter carries with it the dates of all the other moveable feasts, such as the beginning of Lent, the feast of Pentecost, and the Sundays of Ordinary Time during the year. Of course, fixing Easter independently of the Full Moon, for example at the last Sunday of March or the first Sunday of April, would reduce this oscillation to less than one week. But obviously this would run contrary to the spirit of the Council of Nicea.

On the whole, it would not seem to be a good idea to introduce changes into the calendar unless they have been well thought-out and are likely to be enduring. If nothing else, such changes would lead to great confusion in historical chronology. Above all, whatever the modifications of the rules of the calendar, the date of Easter in particular has a fundamental importance for Christians, who would want to act in accord with all the other Christians to avoid further divisions and confusion. One can well ask if the increase in precision that would come with the introduction of using lunar positions calculated with a modern ephemeris would be justified, if it otherwise did not follow either the Old Testament or the traditional practice of Christians. In any case, one should not forget that the principle intent that guided the Council of Nicea was not so much astronomical precision as the unity of all Christians in the celebration of Easter.

Left *The power of the Gregorian Reform is that one can calculate dates indefinitely into the future. This table, taken from Clavius' book on the Gregorian Reform, lists the dates of moveable feasts like Easter (Pascha Calend. noui – Easter, New calendar – second column from the right) calculated more than four hundred years into the future...*

Fr. Juan CASANOVAS s.j. *(Spain) is a solar astronomer and historian of astronomy.*
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