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## Nicephoros Gregoras: the greatest Byzantine astronomer

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In the whole of Greece, no eminent astronomers appeared after the great Claudius Ptolemy (second century AD). For ten centuries after Ptolemy we can distinguish only one astronomer: Nicephoros Gregoras (1295–1360). The monk Nicephoros Gregoras is discussed together with his teacher, Theodoros Metochites, one of the most significant scholars of Byzantium. The literary work of Gregoras is especially important, while Byzantine astronomy owes indisputable progress to him. Gregoras was the first to propose, in 1324, a correction to the calculation of the date of Easter, and to the Julian calendar similar to that adopted later, in 1582, by Pope Gregory XIII. This proposition and, more obviously, his dispute with St Gregory Palamas created problems in the relationship between Gregoras and the Church, leading to the desecration of his corpse by a fanatical crowd.

*Keywords:* Byzantine astronomy; History of astronomy; Nicephoros Gregoras; Roman history; Andronicus II

### 1. Introduction: the first years in the life of Nicephoros Gregoras

Nicephoros Gregoras (1295–1360) was born in Heracleia of Pontus, where he obtained a basic education. Having lost his parents at the age of ten, he was raised by his uncle John (1249–1328), Bishop of Heracleia, on the Black Sea (Pontus), where the eminent Pythagorean philosopher Heraclite of Pontus had been born many centuries earlier.

John educated Gregoras and introduced him to the ancient Greek writers, especially to Plato (see p. 58 of [1]). At the age of 20, Gregoras was sent by his uncle to Constantinople to continue his studies there; Patriarch John XIII ‘the Sweet’ (1315–1328) taught him Aristotelian logic. At about the same time, Gregoras met the most eminent Platonist philosopher and Great Logothetes (a kind of Prime Minister) of the Byzantine Empire, namely Theodoros Metochites (1260–1332), who is considered to be the greatest forerunner of the humanitarian Renaissance of the fifteenth century. Metochites taught Gregoras philosophy, astronomy and mathematics. At the beginning, Metochites was reluctant in his teaching, until he was sure that his student

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Figure 1. The Emperor Andronicus II Palaeologus.

was a suitable receptor for this knowledge (see p. 58 of [1]). Gregoras proved to be worthy of his teacher, 'having no other superior, neither in the East nor in the West' [2], and to share a common interest with Metochites, namely politics.

Despite his young age, Gregoras soon excelled because of his progress in both study and research. Thus, in 1320, Metochites presented his superb student to the enlightened Emperor Andronicus II Palaeologus (1282–1328) (figure 1), who the young student praised in a speech. Because of his abilities and his intelligence, Gregoras won the trust of Emperor Andronicus II, who offered him the eminent position of the Chartularius of the Great Church of Christ when Gregoras was only 27 years old. Gregoras did not accept it, stressing that it was premature because of his age; however, he took over duties as an ambassador of and as a consultant to the Emperor. Indeed, he was assigned various diplomatic missions, e.g. in 1327 to Stefan Urosh III of Dečani, King of the Serbs, whose second wife was Maria Palaeologina, the granddaughter of the brother of Andronicus (figures 2 and 3).



Figure 2. Dinar of the Serbian king Stefan Uroš III Dečanski from the collection of Dimitrijević [3]. The Cyrillic inscription is in Serbian and says STEFAN UROSH THE THIRD.



Figure 3. Dinar of the Emperor of Serbs and Greeks Dušan from the collection of Dimitrijević [3]. On this so-called ‘coronation dinar’, issued after the coronation of Stefan Dušan as the Emperor of Serbs and Greeks (Imperator Rascianorum et Romaiorum or Βασιλεὺς καὶ αυτοκράτωρ Σερβίας καὶ Ρωμανίας) on 16 April 1346 in Skoplje, one can see two angels putting the imperial crown (stema) on his head. The Cyrillic inscription says S[TE]F[AN] C[A]R—STEFAN THE EMPEROR.

## 2. Teaching, empiricism and social recognition

Returning from this mission, Gregoras founded the ‘Mone tes Choras’ (‘Monastery of the Country’), a distinguished school where he started to teach philosophy, mathematics and astronomy to large numbers of Byzantine and European students. It seems that he wanted to create an interest in astronomy among his students, and according to Krumbacher [4] he was probably conducting experiments and using diagrams: ‘... and while he was doing astronomy, he was bringing nothing of the science out by the tongue, but instead he was filling the room with spheres, books and diagrams at all times; and foot-stools and floors full showing the wisdom’.

During the same period, Gregoras started to write a large number of his works, which cover various disciplines such as history, theology, philosophy and astronomy, in fact, almost all branches of knowledge in Byzantium. He was the *homo universalis* of his epoch. His work *Ρωμαϊκή Ιστορία* (*Roman History*, i.e. Byzantine history), consisting of 37 volumes, is considered especially important. Its first seven books give a short account of the events from 1204 to 1320, while the rest (30 books) covers extensively the period from 1320 to 1359.

In his philosophical work the influence of his teacher, Metochites, is evident. Gregoras, probably because of his study of mathematics, became a supporter of the Platonic philosophy and an opponent of the Aristotelian philosophy, another element which differentiated the Byzantine scholars from their counterparts in the West. Gregoras followed his teacher in recognizing the value of sceptical philosophy with respect to the inconceivability of the primary truths of the Faith. Nevertheless, the nominalist Gregoras distinguished himself mainly as an astronomer and he continued the astronomical work of Metochites, *Elements of the Astronomical Science*, which in essence is an introduction to Ptolemy's *Syntaxis*. Of great value are the astronomical treatises of Gregoras: 'About the revilers of astronomy', 'Entreaties for

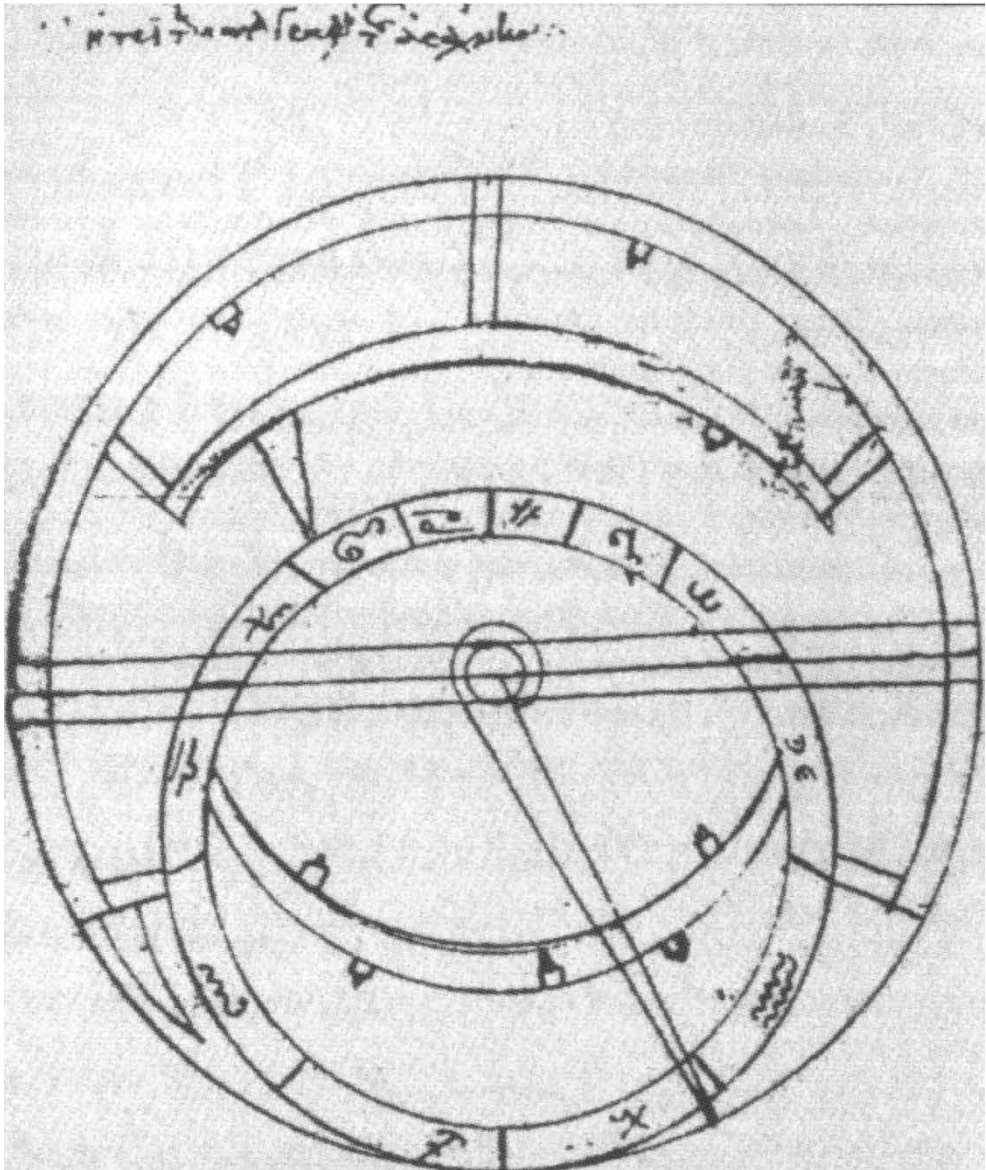


Figure 4. From Codex Vaticanus Gr. 318, sheet 143n: N. Gregoras, 'How an astrolabe should be constructed'; a diagram with the caption 'the third recording of the arachne (grid)'.



Figure 5. From Codex Vaticanus Gr. 318, sheet 146n–147r: N. Gregoras, ‘How an astrolabe should be constructed’.

astronomy’, ‘How an astrolabe should be constructed’ (figures 4 and 5) and others. As an astronomer, he is superior to those who were studying astronomy in his epoch, in both the East and the West.

Later, after the abdication of his protector Andronicus II in 1328, who became a monk with the name of Antonios and died in 1332, Gregoras fell into disfavour, lost his property and retired from the public life. He had served this Emperor faithfully, and his teacher even more so; because of this, Metochites was exiled by the new Emperor Andronicus III. However, in 1330, Gregoras started to fight against the heretic Greek Aristotelian philosopher and monk Barlaam (1290–1348), who, when preaching in southern Italy, was representing the scholastic perception of the Western Church. Gregoras returned to public life in 1331 with a public debate with Barlaam, which he won. After the successful end of his struggle against the heretic monk, Gregoras was restored by the new Emperor Andronicus III (1328–1341) to the Office of the Great Teacher of the Empire. Perhaps the defence by Gregoras of the ruling class helped him both socially and professionally, and most probably this was the reason that Metochites returned from exile in Didymoteichon to Constantinople and remained during the last year of his life in his beloved Mone tes Choras.

However, the most important contribution of Gregoras is the correction to the calculation of the date of Easter and the calendrical reform, which had already been finished in 1324, before his involvement in the Hesychastic controversy.

In 1330 the Patriarch of Constantinople, Isaiah (1323–1332), nominated Gregoras as the head of the delegation of the Orthodox Church in the dialogue for the unification of the Churches, for both his debating ability and his theological knowledge. Gregoras faced the delegates of Pope John XXII (1316–1334) without retreating at all with respect to their claims concerning the Papal Primacy.

Regardless of all this, Gregoras, as we shall see, continued his writing, astronomical and theological work until his death in the year 1360.

### 3. The scientific work of Gregoras

Mathematics was not a priority in the research of Gregoras; only the following are mentioned as his mathematical work:

- (i) 'Commentary on Nicomachus of Gerasa';
- (ii) 'Tackling of a geometrical problem according to Euclid';
- (iii) 'Letter concerning the relation of the squares of two consecutive numbers' [5].

However, he also left important and pioneering work in astronomy, consisting of the following:

- (i) 'How an astrolabe should be constructed';
- (ii) 'How the grid in the astrolabe should be constructed';
- (iii) 'On the inscription of the astrolabe on a plane';
- (iv) 'Entreaties for astronomy';
- (v) 'About the revilers of astronomy';
- (vi) 'An exposition of the calculations of solar eclipses according to Ptolemy';
- (vii) 'The corrected Easter calculation';
- (viii) 'On the Universe';
- (ix) 'Annotation and completion of Ptolemy's harmonics';
- (x) 'System of the World'.

### 4. Comments on the astronomical work of Gregoras

#### 4.1 *Astrolabe and eclipse calculations*

The astrolabe is an instrument used in the determination of the altitudes of the stars (angular heights above the horizon). Gregoras wrote about its construction and its theoretical background after he consulted the related works of Claudius Ptolemy, Synesios of Kyrene, Ammonius and John Philoponos.

In his work 'How an astrolabe should be constructed', Gregoras showed some originality in the construction of his astrolabe in comparison with the astrolabes constructed by other astronomers. It seems that the instrument that he called an 'astrolabe' was not a device to determine observationally just the altitudes of the stars. Gregoras succeeded in constructing a kind of planisphere, whose function was based on stereographic projection. On it were traced parallel and meridional circles, for a given latitude  $\phi$ , while many bright stars were recorded, as well as the zodiacal circle. With this instrument the observer could find the positions of the stars at a given moment with the best possible accuracy or could solve various other astronomical problems [2]. Gregoras knew, beyond doubt, that Hipparchus was the first to study the planisphere problem; however, the instrument used by Hipparchus was adopted with many modifications by Gregoras [6].

Moreover, Gregoras had read, as noted earlier, the imperfect and rather theoretical works on the topic by Ptolemy (AD 108–178 or 180), Synesios of Kyrene (fourth century AD), Ammonius and John Philoponos (fifth and sixth centuries AD). So it seems that, after he studied



the problem in depth, he achieved a breakthrough [7]. The existence of such an astronomical instrument could explain his ability to calculate the solar and lunar eclipses.

We note that the treatise of Gregoras, ‘An exposition of the calculations of solar eclipses according to Ptolemy’, is most significant. In a preserved manuscript there is a table of solar eclipses. Indeed, after the publication of his ‘Annotation and completion of Ptolemy’s harmonics’, Gregoras occupied himself with the calculation of solar and lunar eclipses; he calculated *de novo* the most significant eclipses since AD 448, when Theodosius II was Emperor [8] (figures 4 and 5), and he predicted many eclipses that occurred in his lifetime, as reported by many of his contemporary scholars (see p. 83 of [7]).

Finally, Gregoras made calculations for the total solar eclipse of 16 July 1330 [5], and for another two lunar eclipses earlier that year. He mentions these three eclipses in a letter that he wrote to his friend George Pepagomenos in 1329 (see p. 83 of [7]): ‘On this coming 13th of indiction there will be two eclipses of the moon and one of the sun; that is, on the evening of the 5th of January before midnight will be a lunar eclipse less than total, i.e. 11 digits, and one similar to that after three [probably a typographic error] months, i.e. on June 30th at about the 8th hour of the night; and on [always according to the Julian calendar] July 30th at about the 12th hour of the day there will be a total eclipse of the sun. And of the occurrence of these I think you should be aware.’ We see that Gregoras defines with precision and certainty the eclipses of the following year. Bréhier [8] wrote: ‘Among all of his astronomical works there are two that reveal a true progress: the predictions of the eclipses and the plan for the calendar reform.’ On the contrary, Guiland (see p. 279 of [7]) believed that ‘the characterization of Gregoras as a savant is a result not of his eclipse calculations, but of his research on the astrolabe and the calculation of the date of the Easter’.

In conclusion, Gregoras is the greatest astronomer in Byzantine history. He calculated all the solar eclipses of the millennium up to the thirteenth century and he predicted future eclipses of both the Sun and the Moon. He constructed a prototype astrolabe (also, he wrote, as stated above, a book on the subject), while he studied in depth the calendar question and the determination of the date of celebrating Easter.

#### 4.2 *The plan for the reform of the Easter calculation and of the calendar*

In his effort to find a method for the accurate determination of the date of the Easter, Gregoras proposed a reform of the Julian calendar. This is probably his major insight, although he was not fortunate enough to see it implemented.

The date of Easter was determined from the first full moon after the vernal (spring) equinox. Gregoras realized that the vernal equinox was calculated with an accumulating systematic error (because the tropical year was in reality shorter than was believed then), and this error was transferred in the calculation of the first vernal full moon and finally in the date of Easter. From his most important work, *Roman History* [2], as printed in *Patrologiae Graecae* [9] (figures 6 and 7), we obtain valuable information about the calendar reform that he proposed. Gregoras observed the difference accumulated between the Julian calendar and the vernal equinox. Moreover, he ascertained the shortcomings of the Julian calendar regarding the duration of the tropical year; in his *Roman History* (book 8, chapter 13), he noted: ‘because to the 365 days-and-nights we add a whole quarter of a day-and-night, while we should not’. Proceeding quantitatively, he determined the error in the calculation of the date of Easter more than 250 years before the calendrical reform of Pope Gregory XIII, and he made a plan to correct both the paschal canon and the calendar.

The problem of the correction of the calculation of the date of Easter was probably one of the main activities of Gregoras for a large period of time. His work on the astrolabe was

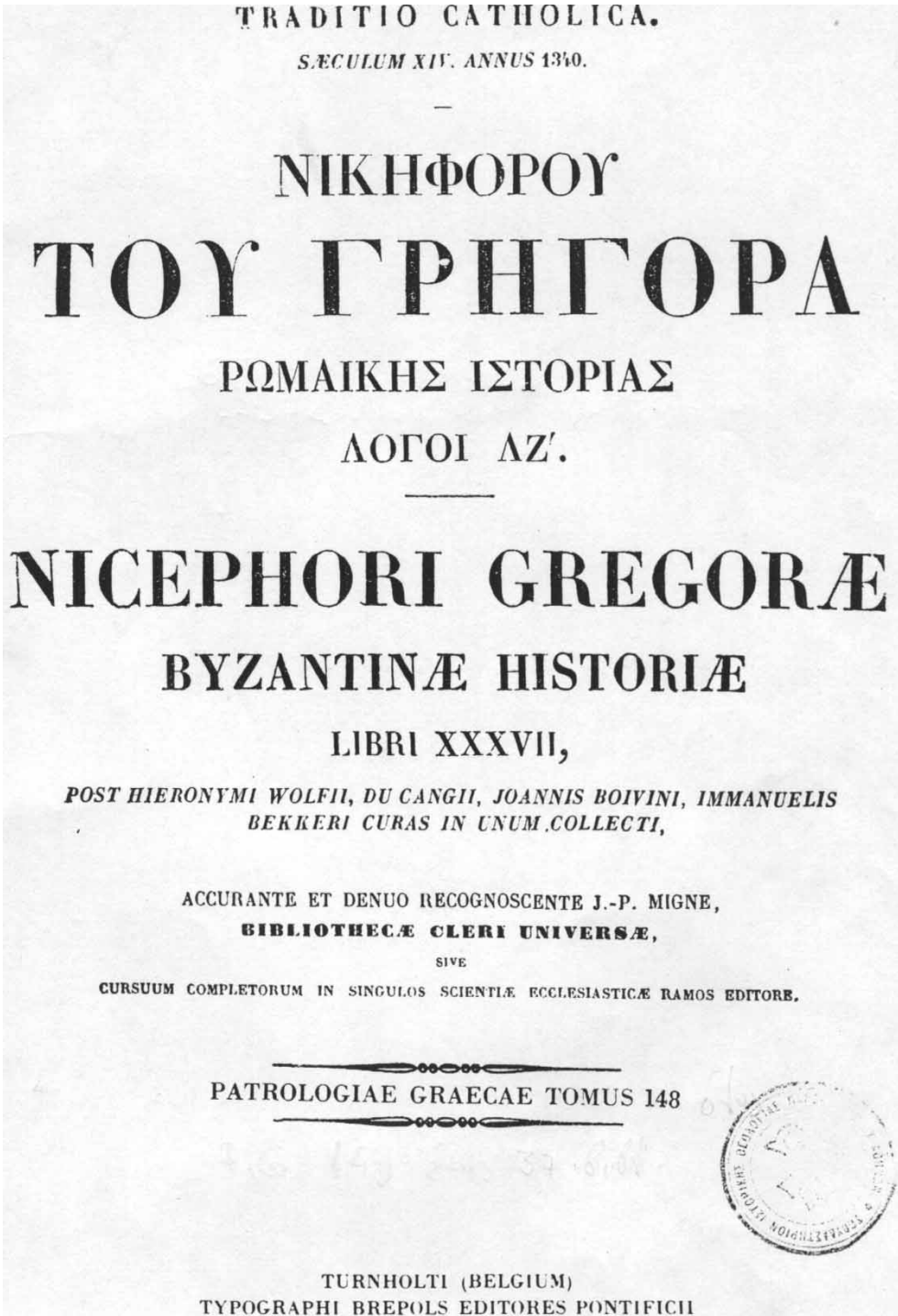


Figure 6. The front page of the *Roman History (Byzantinae Historiae)* by Gregoras.



related to this calculation. As a good astronomer, he realized that the duration of the tropical year, which was then taken to be equal to exactly 365.25 days, was smaller than that, and based on this he prepared a plan to correct the calendar. He wrote in his *Roman History* (see p. 364 of [10]): ‘But I do not think it opportune to pass also unmentioned what during this year happened to be said about the Easter. And we said that we should first research with accuracy the vernal equinox. Because this is the reason of this whole issue, as we will say later on; then the following full moon after the equinox; and we call full moon the time when the hemisphere of the moon facing us is fully illuminated. And this can take place when the moon has completed its 14th day (and slightly more than that) since it coincided with the sun at the same degree of the zodiacal sphere, when one vertical passes from both. So because the Easter of the nomics [the Judaic Easter] precedes our own, and is in turn preceded by the full moon after the equinox, this should be studied first.’

He then examined historically the problem of the equinox calculation and of the accurate calculation of the tropical year’s duration and stated (see p. 367 of [10]): ‘The tiny fraction of the day in so many years is now becoming very obvious.’ On the same page he also mentioned that this error remained uncorrected, and on the next page he wrote (see p. 368 of [10]): ‘Having now the people of our own Church to set the start of the Easter observance as close as possible to the 20th of March, while those setting it on March 22nd are not doing the correct thing . . . it is therefore obvious that, because of the precession of the equinoxes, the dates of the full moon also precessed.’

Gregoras submitted this plan for further discussion to a group of Byzantine scholars, the so-called ‘Logical Panegyris’, which discussed the various scientific issues. He referred to this event in a letter he wrote to his teacher Joseph, entitled ‘To Mr Joseph the philosopher about the Easter. A proof that an error was made many years ago and that there is need to make its correction’ [11]. In that letter he wrote, among other points: ‘Because when I met with the majority of our savants, being together, during the  $\pi\rho\omicron\tau\rho\iota\tau\alpha$  festival, I was making clear to them the problem of the Easter error’.

Gregoras was trying to persuade the relevant authorities to correct the calculation of the date of Easter; so after the ‘Logical Panegyris’ he tried to persuade the head of the Empire. In 1324, he submitted his correction plan to the Emperor Andronicus II Palaeologus (1282–1328) and he explained it in his address. The logical arguments of Gregoras persuaded Andronicus and the Patriarch with the bishops of the Holy Synod that the suggestions of the great astronomer were correct. However, they did not make the calendrical reform since they feared that it might cause confusion to the uneducated public and division in the Church. Gregoras wrote on this in his *Roman History* (see pp. 372–373 of [10]): ‘. . . the King understood the proof and he became in favour. . . . Because he promptly showed his intention to impose the correction immediately; but in order not to appear more as a cause of confusion to the ignorant ones and induce division to the Church, he left this issue to rest in silence, completely inactive.’

Isaac Argyros (1300–1375), a student of Gregoras, added [2] (see pp. 372–373 of [10]): ‘Who [i.e. Gregoras], having made it obvious to everyone, even in front of the King himself and his senate, and of the scholars of the Church, was praised by all; and all of them had judged as reasonable to celebrate the Easter from then on, according to the correction of the new canon, having succeeded in changing their minds to the truth of his words.’

Valuable information on the Byzantine astronomers and on the attempts to change the calendar has been given by the late Professor of Astronomy at the University of Athens, Demetrios Kotsakis (1909–1986), in his book *Astronomy and Mathematics in the Byzantine Era* [12]. In this study he noted: ‘Unfortunately, the change did not happen in 1324 but in 1578 by Pope Gregory XIII. If it had been imposed in the first occasion, then it would be probably called also the Gregorian calendar, but in honour of Nicephoros Gregoras.’ Indeed, the glory would then belong to this important Byzantine astronomer, who had pointed out the

imperfection of the Julian calendar two and a half centuries before Pope Gregory XIII and had submitted a detailed plan for its correction.

### 4.3 *Astrology*

Gregoras, following his teacher Metochites, was an opponent of astrology. On the other hand, he believed that the stars and especially the Moon had a certain influence on humans, probably since the influence of the Moon on the creation of the tides was known to him [8]. Of course, his predictions of the lunar eclipses did not prevent him from attacking star foretellers. In a 1329 letter, according to Guiland (see p. 77 of [7]) he wrote [2]: ‘At least that needs perhaps also some foretelling and I don’t have anything to say. Because they talk about destructions and transfers of towns, trees and mountains by all the winds being moved together. . . . But that passed over me. For they set as cause of the battle of the winds the meeting of Saturn and Mars under one zodiacal sign, and before them some solar eclipse. Thus, if these could appear as a lie when preceding the following events, they should appear even more so in this case. Because not only currently Saturn and Mars are not under one sign, but not even for two consecutive years could one hope they will be. For Mars has already left since quite a while Saturn at the fifteenth degree of Leo, and is now travelling through the claws of Scorpion, and the solar eclipse neither throughout this whole summer, nor during the following autumn will be seen, even if all hens cackle together. But let you consider as teachers of them both time and the accurate sense of truth; because nothing else is so indisputable for scientific proof, as is experience and perception.’

According to the late Professor of Astronomy, Kotsakis [2], special attention is deserved by the final sentences of the previous passage written by Gregoras: ‘But let you consider . . . as is experience and perception’. ‘Because in this way he stresses the great importance and value of the experience and the perception for the accurate scientific research. Experiment and observation are, as we know, the two basic methods for the research of the Nature, which, together with the mathematical reasoning, are the only means of systematic scientific study of the natural world. The work and attitude of Gregoras in this area of knowledge are, indeed, very pioneering.’

Gregoras also mentions a heretical sect of astrological nature and Persian origins, which existed in Trapezous (Trebizon) between 1328 and 1341. These heretics promulgated that, when a solar eclipse occurs during a conjunction of Saturn and Mars, then there ‘will be jumbling of winds and destructions of towns and motions of mountains’. Gregoras [13] countered these beliefs as ‘being by their nature certainly sick, and erratic resoundings of a broken lyre’.

### 4.4 *Collection of manuscripts*

It seems that the time that Gregoras contributed to the rescue of both ancient and medieval texts is significant. He collaborated on the restoration of manuscripts by Apollonius, as well as on the collection and publication of the works of his teacher Metochites. Hunger [5] argued that the quantity and the quality of the manuscripts from the thirteenth and fourteenth centuries has to be credited partly to the activities and the efforts of Metochites and Gregoras.

### 4.5 *The Roman History*

The *Roman History* (*Byzantinae Historiae* [10] in the *Patrologiae Graecae* series of J.-P. Migne) is the best-known work of Gregoras. In its 37 books the writer described the events that took place from 1204 to 1358, together with astronomical, geographical and theological

information; these digressions enrich his narration of the political and military events of this period, and of the controversies within the Empire, such as the Hesychastic controversy. It is in these digressions that the extent of his interests is revealed, together with his perception of the human spirit, i.e. that the greatness of the human intellect is unveiled by confronting not only the unified but also the multiple nature of the world.

In the *Roman History*, Gregoras uses the term ‘cosmos’ in reference to the Universe of both heavenly and terrestrial bodies, a fact showing that he viewed the ‘microworld’ (in the sense of terrestrial objects) and the ‘macroworld’ as deeply connected. This coincides with the ancient Greek principle ‘things in the upper world are as in the lower world’. When Gregoras refers to the Earth globally, he uses the term ‘below the sun’. Indirectly he accepts its spherical shape and he also refers to its subdivision into parallel circles and continents.

In one of his letters he wrote (see pp. 111–115 of [1]) that the border between Europe and Africa is the Straits of Gibraltar.

For the cardinal points he uses the terms: *προς αρκτον*, *αρκτικος*, *βορειος* and *υπερβορειος* for the north, *προς μεσημβριαν* and *νοτον ανεμον* for the south, *προς εως*, *εων μερος* and *προς ανισοντα ηλιον* for the east and *προς δυσιν* and *εξ εσπερας* for the west. He makes frequent references to distance measurements, using units such as stadium, mile, semi-acre, fathom, span and ‘inch’. The ‘inch’ is used by Gregoras for the measurement of the shadow formed during the lunar eclipse. When he mentioned a major earthquake in the area of Constantinople (October 1344), he wrote that the wave formed intruded ten stadia into the land; one Byzantine stadium equals 188.88 m.

For Gregoras, history is the work of God, revealing his unspeakable glory. With history, obviously in the general sense of narrative digressing into astronomy, geography, etc., man becomes acquainted with the beauty of heaven and earth, as well as the invariable harmony given to the world by God. He understands the eternal law of creation and destruction, and the cyclic path of events; he can draw conclusions about the future, having the past as an indicator. Thus, Gregoras reflected some ancient Greek views (Herodotus (484–426 BC) and Diodorus of Sicily (first century BC)), which he harmonized with the Christian positions of his period. The fact that he believed absolutely in the leading role of the Divine Providence in the world stage was not an obstacle in his tendency to try to interpret the events, and finally to be elevated to a distinguished scholarly figure of his epoch and, more generally, of the Byzantine world.

#### 4.6 *The last years in the life of Gregoras*

After 1349, Gregoras played an active part in the reaction against the Hesychasts, the followers of Gregorios Palamas. Hesychasm was a movement created in the ranks of the monks, aiming at spiritual completion through incessant praying and silence, hence giving the name of the movement (*hesychia* = silence). Palamas, the leader of the Hesychasts (1296–1360), even wrote a counter-speech against Gregoras entitled ‘Regarding the false writings as well as the impiety of Gregoras’ because Gregoras had objected intensively to his teachings. Indeed, Gregoras proved to be a great adversary of the Hesychastic movement and he was their feared opponent, heading the ‘antipalamic’ party in the Orthodox Church.

Unfortunately for Gregoras, the official Eastern Orthodox Church adopted the Hesychasm movement and canonized Gregorios Palamas. The Great Domesticus of the Empire, John Cantacuzen, appreciating the qualifications of Gregoras and his contributions in all branches of science and theology, and in order to calm the crisis, even offered Gregoras the Patriarchal Throne (on the condition, of course, that he would adopt the ideas of the Hesychasts). Gregoras

refused the offer and retreated into a monastery as a monk, continuing his antipalamic activity and writing.

As one should expect, Gregoras fell into disfavour as his activities turned him into an opponent of the official Orthodox Church. The Holy Synod of Vlahernae in 1351 condemned his ideas, while Gregoras himself was restricted in the Mone tes Choras by the Emperor John VI Cantacuzen (1347–1355), without the possibility of communicating with his followers. These were the years when the *Roman History* was written, together with many rhetorical, poetical and philosophical works, poems, speeches and 161 letters. Gregoras was liberated when John V Palaeologus ascended to the Throne once again in 1355.

Gregoras died at the beginning of 1360, without renouncing his ideas. Unfortunately, because of these ideas the fanatical crowd did not respect his corpse and desecrated it. The intense battle of ideas of the times aggravated fanaticism and restricted prudence.

In any case, Gregoras was an exceptional scientific personality and a very prolific writer. His work indicates his superiority compared with other Byzantine scholars, not only because of the quantity of his contributions but also because of the lucidity, the exactness, the originality and the special position and esteem that he reserved for ‘experience and perception’.

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