Why Gerbert of Aurillac added to the letter to brother Adam the clime table where the longest day of the year reaches 18 hours?

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Abstract This paper tries to solve the question why did Gerbert of Aurillac in his brief letter to brother Adam (written in 989) elaborate a table for climate (horologium) where the longest day of the year reaches 18 hours. The standard summaries of climates, available during Gerbert's time, did not mention such climate. Gerbert added this table to his letter because the table of clime with 18 hours solstitial day (similarly like the second added table for the climate of Hellespont) is an exemplary guideline according to which Adam can make his own horologies. Gerbert used this extraordinary climate as a suitable explanatory example due to its mathematical simplicity appropriate demonstrating the astronomical theory of yearly Sun movement.
Sommario Perché Gerberto d'Aurillac nella sua breve lettera a frate Adamo (scritta nel 989) elaborò una tabella per i climi (un orologio) in cui il giorno più lungo dell'anno raggiungeva le 18 ore. I manuali standard sui climi, disponibili al tempo di Gerberto, non menzionavano questo clima. Gerberto aggiunse questo clima con 18 ore al solstizio estivo (similmente alla seconda tavola per il clima dell'Ellesponto da 15 ore) perché Adamo potesse calcolare il suo proprio orologio per interpolazione. Gerberto volle usare una matematica semplice per la teoria del movimento annuale del Sole.
Keywords: Gerbert of Aurillac; horology; timekeeping; climate; astronomy

1. Introduction

This paper discusses a relatively short letter by Gerbert of Aurillac written to his friend Adam in the spring of the year 989.[1] This Gerbert's epistle deliberates partial theoretical findings, which were fundamental for contemporary timekeeping. There are several immensely interesting details in this letter. Gerbert describes changes in the presence of daylight over the horizon

1 Cf. Rossi, Paolo, "Sinossi delle principali differenti proposte di datazione". In: Gerbert D'Aurillac/Silvestro II. *Lettere* (983–997). Transl. P. Rossi. Pisa: Pisa University Press 2009, p. 204.

during a year in relation to geographical latitude of that place, i.e. according to the length of solstitial day. The letter is accompanied by two tables by means of which Gerbert illustrates described changes. The text was obviously addressed to an erudite recipient because Gerbert uses terms from the field of contemporary timekeeping, astronomy and geography without any further explanation. It can be assumed that Adam was fairly familiar with the contemporary astronomical theories representing the necessary intellectual equipment for timekeeping. This paper focuses on this Adam's possible knowledge and its main goal is to answer the question from the title of the paper: Why Gerbert added to the letter a clime table where the longest day of the year reaches 18 hours?

2. Gerbert's horological letter

Gerbert's letter is apparently a response to the prior Adam's request for the clarification of some partial knowledge necessary for timekeeping. We know practically nothing about brother Adam.[2] The opening of the letter provides justified reason for a hypothesis that Gerbert and Adam were friends. Gerbert claims that he wrote the letter in order to bring the missing friend to mind and, as a token of their friendship, he chose several astronomical theses.[3] They describe the ascend and the descend of the Sun according to the theory stating that the changes in duration of the presence of the Sun over the horizon are irregular

2 See e.g. The *Letters of Gerbert with His Papal Privileges as Sylvester II*. Transl. H. Pratt Lattin. New York: Columbia University Press 1960, p. 190.

3 *Die Briefsammlung Gerberts von Reims*. *Epistola* 153. Ed. F. Weigle. *MGH Briefe d. dt. Kaiserzeit* 2. Weimar: Hermann Böhlaus Nachfolger 1961 [hereafter cited as Gerbert, *Epist*.], p. 180, 11–14: *Ut vero tui memoriam habere cępi, ne penitus otio torperem et amico absenti aliqua in re satisfacerem, litteris mandavi tibique in pignus amicitię misi quędam ex astronomicis subtilitatibus collecta, …*

during the year and are in contrast with the interpretation which suggests that every month at a specific place the length of daily sunlight increases (or decreases) regularly.[4]

Gerbert subsequently quotes the eighth book *De nuptiis Philologiae et Mercurii* of Martianus Capella and he reminds us that the increase of daylight, following the winter solstice, proceeds in this way: In the first month daylight increases by one-twelfth of the difference between the length of the day during winter and summer solstice; in the second month, the daylight increases by one-sixth of the same difference; during the third and fourth month, the increase is one-quarter of the difference between the length of the day during winter and summer solstice; in the fifth month the increase is one-sixth again and in the sixth month it is one-twelfth of the same difference.[5] Gerbert does not waste time by adding that during the second half of the year this process is reversed – the length of the day shortens according to the same calculation. According to this theory, as Gerbert states, he outlined horologies of two climates after he had admeasured specific length of day for every month in both climates using accurate time intervals (hours). It concerns the climate of Hellespont (Dardanelles), where the longest day of a year is 15 hours long, and the first *horologium* is meant surprisingly for the climate whose inhabitants can enjoy daylight

4 Gerbert, *Epist*. 153, p. 180, 14–16: ... *scilicet accessus et recessus solis non secundum eorum opinionem colligens, qui ęquales fieri putant singulis mensibus, sed eorum rationem persequens, qui describunt omnino inęquales*.

5 Gerbert, *Epist.* 153, p. 180, 16–20. Cf. Martiani Minnei Felicis Capellae *De nuptiis Philologiae et Mercurii* VIII, 878. Ed. J. Willis. Leipsic: Teubner 1983 [hereafter cited as Martianus Capella, *De nuptiis*], p. 333, 2–5: *Interea bis climatibus quibusque crescunt decrescunt que luces, sciendum que a bruma ita dies aecrescere, ut primo mense duodecima eiusdem temporis quod additur aestate accrescat, secundo mense sexta, tertio quarta, et quarto mense alia quarta, quinto sexta, sexto duodecima.*

during the longest day of a year for full 18 hours.[6] Gerbert processed mentioned tables on the basis of this method in order to pose as an example, which can be used by Adam to construct his own horologies for any climate. It is enough for Adam to find the length of solstitial day for specific place using water clock, clepsydra.[7] It is comparatively easy to determine the length of a solstitial day: During a solstice, we must separately mark the amount of water which flows through clepsydra in the course of the night and during the day and, subsequently, we must convert the sum of these values (litres) to the 24-hour system.[8]

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6 Gerbert, *Epist*. 153, p. 181, 1–16:

HOROLOGIUM SECUNDUM EOS, QUI DIEM MAXIMUM HABENT HORARUM ĘQUINOCTIALIUM XVIII.

Iunius et Iulius	Di. Ho. XVIII	Nox Ho. VI
Maius et Augustus	Di. Ho. XVII	Nox Ho. VII
Aprilis et September	Di. Ho. XV	Nox Ho. VIIII
Martius et October	Di. Ho. XII	Nox Ho. XII
Febroarius et November	Di. Ho. VIIII	Nox Ho. XV
Ianuarius et December	Di. Ho. VI	Nox Ho. XVIII

ITEM HOROLOGIUM ELLESPONTI, UBI DIES MAXIMUS EST HORARUM EQUINOCTIALIUM QUINDECIM.

Ianuarius et December	*Di. Ho. VIIII*	*Nox Ho. XV*
Febroarius et November	*Di. Ho. X et semis*	*Nox Ho. XIII et semis*
Martius et October	*Di. Ho. XII*	*Nox Ho. XII*
Aprilis et September	*Di. Ho. XIII et semis*	*Nox Ho. X et semis*
Maius et Augustus	*Di. Ho. XIIII et semis*	*Nox Ho. VIIII et semis*
Iunius et Iulius	*Di. Ho. XV*	*Nox Ho. VIIII*

7 Gerbert, *Epist*. 153, p. 180, 20–26: *Itaque secundum hanc rationem duorum climatum horologia certis depinxi mensuris definitas horas singulis mensi bus attribuens. Alterum est Ellesponti, ubi dies maximus horarum ęquinoctialium est XV, alterum eorum, qui diem maximum habent horarum equinoctialium XVIII. Hoc autem ideo feci, ut sub omni climate ad horum exemplar propria horologia componere possis, cum agnoveris quantitatem solsticialium dierum ex clepsidris.*

8 Gerbert, *Epist*. 153, p. 180, 26–28: *Quod factu quidem facile est, si furtiva aqua nocturni ac diuturni temporis solsticialis, seorsum excepta, accedat ad dimensionem tocius summę, quę fit XXIIII partium.*

3. Movement of the Sun

Gerbert's letter explicitly introduces two different theories concerning the changes in daylight during the year. Medieval thinkers adopted ancient theories about the movement of the Sun, to which the two basic motions are ascribed. The Sun, as well as the whole celestial sphere, to which the stars and constellations are firmly embedded and they revolve around the Earth (from the east to the west) once per 24 hours and this movement is substantial for the definition of day and night. When the Sun appears over the horizon, we talk about the day, while the absence of daylight is characteristic for night. The Sun and its light distinguishes day from night in the same way as light separated day from night during the creation of the world. At the same time, it holds that the day is 24 hours long and one day equals to one orbit of the Sun around the Earth.[9] However, the Sun is not firmly connected with the celestial sphere (contrary to stars) and it does possess even another movement: from the west to the east. This movement spans over yearly period and during it the Sun follows its own circular orbit which is called ecliptic and it passes through twelve zodiacal constellations.[10] Yearly movement of the Sun and its retreating from the celestial equator causes the change of seasons and it, of course, causes the changes of daylight (the presence of Sun over the horizon). We can thus divide the annual path of the Sun by four basic milestones: there are two so called equinoctial days (the days when the Sun crosses the equator and it is over the horizon for the same time as it is under the horizon – we speak of spring or

9 See e.g. Beda Venerabilis, *De temporum ratione* 5. Ed. C. W. Jones. *Bedae Venerabilis* Opera *didascalica* 2. *CCSL* 123B. Turnhout: Brepols 1977 [hereafter cited as Beda, *De temp. rat.*], l. 3–8. Cf. *Gen*. 1,3–5.

10 Cf. Isidori Hispalensis *Etymologiarum sive Origines libri XX* III, 50–52. Ed. W. M. Lindsay. Oxford: Clarendon Press 1911 [hereafter cited as Isidorus, *Etym.*], l. 19-2 or Martianus Capella, *De nuptiis* VIII, 834–835, pp. 314–315.

vernal equinox in March and of autumnal equinox in September) and two solstitial days (the days when the Sun reaches the tropics and its departure from the celestial equator changes its direction and the Sun starts its way back to the equator).[11] For the inhabitants of the northern hemisphere this means that in June we can speak of summer solstice since the Sun reaches the tropic of Cancer and we have the longest day and the shortest night in year, while in December, during the winter solstice, the Sun departs to the tropic of Capricorn and we have the shortest day and the longest night. Apparently, Adam must have known all of these theories because Gerbert isn't speaking about the ecliptic or about the definitions of day and hour in his brief letter, despite the fact that Gerbert's statements would not have been comprehensible without this knowledge. Gerbert describes in greater detail the speed by which (on northern hemisphere) the day is prolonged and night is shortened during the winter and spring months, i. e. the daylight is declining and the night is increasing during the summer and autumn months. It is clear from Gerbert's text that at his time there were at least two different ways of characterising the chain of changes in the presence of the Sun over the horizon. Either the equal increase (or decline) of sunlight over a year was presupposed, or these changes were considered unequal.[12] For the geographical latitude where the length of day during the summer solstice is 15 hours (as in the second Gerbert's table), the first interpretation (the equal changes) would mean that since June till December the presence of daylight is shortened every day by 2 minutes, i.e. by one hour per month, and during the winter solstice the length of the day reaches 9 hours. This theory, which could have been

11 See Beda, *De temp. rat.* 16, l. 1–88.

12 Cf. Pseudo-Beda, *De mundi coelestis terrestrisque constitutione liber*. Ed. J.-P. Migne. *PL* 90. Paris: 1850, pp. 883D-884A.

advocated by computists of the Carolingian or Ottonian era, fulfils the requirements of regularity, stability and invariableness of sky events and their interpretation, however, it poorly corresponds to the empirical experience.

This could have been the main reason, why Gerbert himself inclined to the second interpretation and to support this thesis he quotes Martianus Capella who in the eighth book of *The Marriage of Philology and Mercury* wrote that between the both solstices the duration of Sun's presence over the horizon changes unequally. According to the aforementioned algorithm, the day on the example of the longest solstitial day (which means 15 hours in this particular case) would be shortened by 30 minutes in the second decade of July compared to the same day in June; by another 60 minutes in August; by another 90 minutes in September and October; then by another 60 minutes in November; and at winter solstice in December the day is shortened by 30 minutes (see Fig. 1). In Martianus's text this unequal course of changes in the length of day over the year is accompanied by interesting reasoning concerning this irregularity. The Sun is directly intersecting the equator of the celestial sphere, when it goes from the south to the north in March or when it travels in the opposite direction during September, while during the solstices it must change the direction of its movement, which causes the slowdown because the journey to the north changes into the journey to the south and vice versa. This necessity for the change of direction and the description of curve invokes the slowdown of movement of the Sun, therefore around the equinoctial days the faster changes occur, while during the solstitial days the changes are slower.[13]

13 Martianus Capella, *De nuptiis* VII, 878, p. 333,6–7: … *zodiacus circa Cancrum Capricornumque flexior aequinoctialem paene directim secat*.

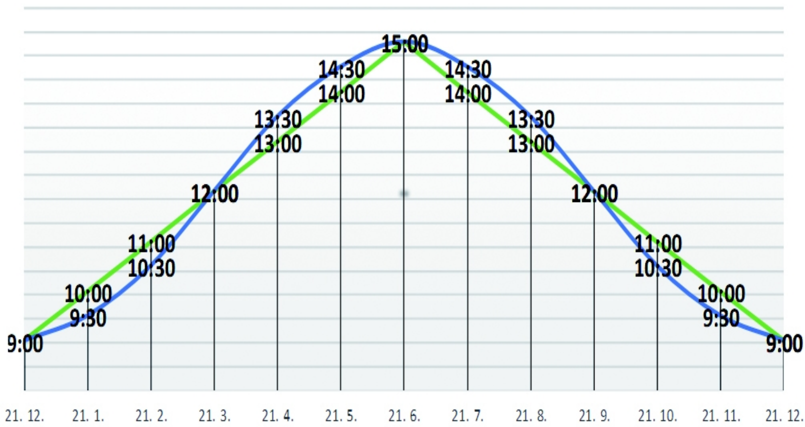

Fig. 1: Daylight in the climate of Hellespont according to theory of equal changes (computists, green colour) and according to theory of unequal changes (Martianus Capella, blue colour).

This reasoning could have been perceived as plausible by Gerbert and its application would explain the regularities in Sun's movements to certain extent which would also correspond to the sky observations in a better way.

4. Geography and climatic zones

Since Gerbert prepared two horologies for Adam according to this second theory – one for the climate of Hellespont (Dardanelles), the other for the geographical latitude where the longest day of the year reaches 18 hours – and even then, there is no explanation of what the climates are. We can assume that the author of the letter anticipated such geographical knowledge to be known to the addressee.

Adam, as well as his other educated contemporaries, evidently knew about contemporary division of the Earth into five basic parts, which was done by five parallel circles of celestial sphere (polar circles, tropics and equator)[14] see Fig. 2.

14 Ambrosii Theodosii Macrobii *Commentarium in Somnium Scipionis* II, 5, 13–17. Ed. J. Willis. Leipsic: Teubner 1970, p. 112,3–31.

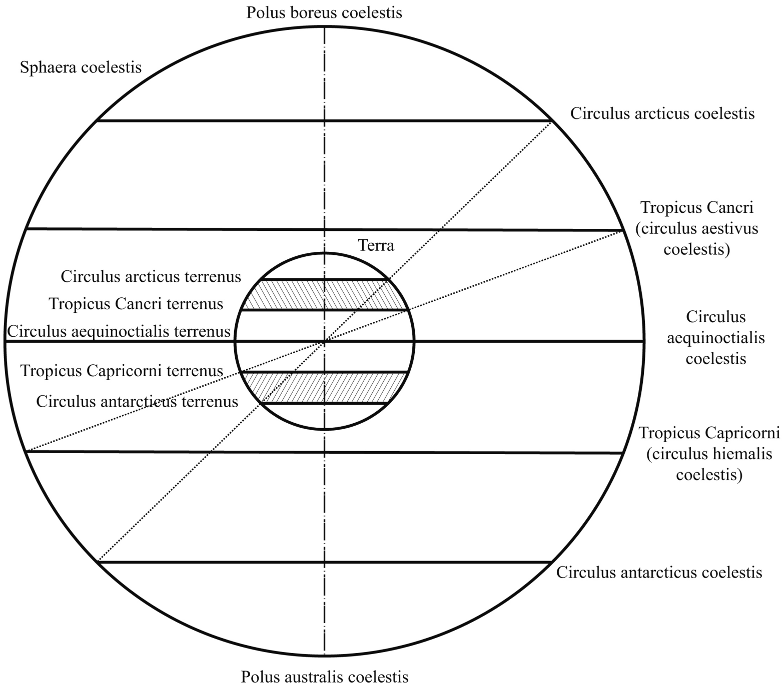

Fig. 2: Division of the Earth.

The territories around Earth's poles, which are in direction towards the equator demarcated by polar circles, cover the northern and the southern polar areas which were, according to medieval theories, uninhabited because the climate is too cold and it does not provide the conditions for human population. Similar situation can be found also in another part of the Earth which is located between both tropics, which enclosing the equator on the northern and even on the southern side, and life does not flourish there because of overly hot weather. There are two parts of the Earth left, delimited by two zones stretching between the tropics and polar circles. The question whether southern part of the Earth is inhabited or not was often tackled during the Early Middle Ages,[15] but in relation to the analysis of

15 See McCready, William D., "Isidor, the Antipodeans, and the Shape of the Earth", *Isis* 87/1 (1996), pp. 108–127.

Gerbert's letter and to the estimation of Adam's knowledge we only need to focus on the northern hemisphere. The northern inhabited part of Earth was further subdivided into three continents: the east was formed by Asia, the western part consisted of the northern (Europe) and the southern (Africa) areas. All three continents were divided by the Mediterranean Sea.[16] A detailed division into climatic (and time) zones, i.e. parallel zones passing through the continents across the same geographical latitude came into medieval geographic descriptions from the antiquity, and therefore they featured similar climatic conditions, the occurrence of comparable fauna and flora, and resembling customs of its inhabitants.[17] For timekeeping purposes is important that these climates were also delimitated according to the length of the longest day and the shortest night during the year.

Scholars usually distinguished between seven zones – that is: (i) Meroë, (ii) Syene (Aswan), (iii) Alexandria (Lower Egypt), (iv) Rhodos, (v) Hellespont (Dardanelles), (vi) Mesopontus (the Black Sea) and (vii) the mouth of river Dnieper, i.e. Borysthenes,[18] to which other climates were added according to the actual need for the differentiation of a certain area or in case they want to include various extremes or curiosities like the mythical Rhypaean mountains or the island Thule in the far north, etc.[19]

The zone of Hellespont, which was introduced by Gerbert into

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16 Cf. Hiatt, Alfred, "The Map of Macrobius before 1100". *Imago Mundi* 59/2 (2007), pp. 149–176.

17 See for example Cassiodori Senatoris *Institutiones* II, 7, 3. Ed. R. A. B. Mynors. Oxford: Oxford University Press 1963 [hereafter cited as Cassiodorus, *Inst.*], p. 156,8–11 or Isidorus, *Etym*. III, 42, 4, l. 17–20.

18 Cf. Cassiodorus, *Inst.*, p. 156,12–17 or Isidorus, *Etym*. III, 42, 4, l. 20–23. See also Honigman, Ernst, *Die sieben Klimata und die ΠΟΛΕΙΣ ΕΠΙΣΗΜΟΙ*. Heidelberg: Carl Winter 1929.

19 See C. Plini Secvndi *Naturalis historiae libri XXXVII* VI, 33–34(39), 211–220. Ed. K. Mayhoff, L. von Jan Plinius. Vol. 1. Leipsic: Teubner 1906, pp. 517-522 or Beda, *De temp. rat.* 33, l. 1–98.

overview table in his letter, was not usually absent from the basic enumeration of seven climates. However, the standard summaries of climates, available during Gerbert's time, do not bring out the climate where the longest day lasts 18 hours, which is approximated by one of the Gerbert's horological table in the letter to Adam. There are only scarce references about such climate during the Early Middle Ages, for instance, can be mentioned the chronicle of Venerable Bede[20] or Eriugena's commentary to Martianus' *The Marriage of Philology and Mercury*,[21] however, even then the Gerbert's introduction of this climate can be surprising.

5. Conclusion: Why the climate where the longest day lasts 18 hours?

There could be several reasons why Gerbert created this clime table. Most frequently mentioned cause presupposes Adam's place of life could be in the northern part of Europe and because of it this table should be useful for his purposes.[22] I do not find this interpretation to be necessarily true. I consider the illustrative and explanatory character of Gerbert's schemes encompassing both climates to be the most probable reason for including this table. If he had wanted to introduce the theory of unequal change in the duration of sunlight over the course of a year by using specific examples, the most suitable climates for this pedagogical-didactic task would have been those climates where the difference of the length of both solstitial days reaches the numerical value which can be easily divisible by number 12 because the monthly change can be measured as either one-twelfth, one-sixth or one-quarter of the difference between the length of both solstitial days. The climate with the longest day of

20 Baedae *Historia ecclesiastica gentis Anglorum* I, 1. Ed. and transl. J. E. King. *LCL* 246. London: W. Heinemann 1962, p. 14.

21 Iohannis Scotti *Annotationes in Marcianum* 296.5. Ed. C. E. Lutz. Cambridge: The Mediaeval Academy of America 1939, p. 140,14–15.

22 Cf. *The Letters of Gerbert with His Papal Privileges as Sylvester II*, 190.

18 hours has the shortest day in the year 6 hours long, therefore the difference in their length is 12 hours, hence monthly changes can be easily described using the whole hours: i.e. 18 hours in June, 17 hours in July, 15 hours in August, 12 hours in September, 9 hours in October, 7 hours in November and 6 hours in December. Similarly, for the climate of Hellespont holds that the longest and the shortest day differs by 6 hours, therefore the table of this time zone can be managed with only hours and half-hours:

December		**January**		**February**		**March**		**April**		**May**		**June**	
Climate of Hellespont (*a*=6 hours)	1/12 *a*		1/6 *a*		1/4 *a*		1/4 *a*		1/6 *a*		1/12 *a*		
	9:00	→	9:30	→	10:30	→	12:00	→	13:30	→	14:30	→	15:00
Gerbert's first climate (*a*=12 hours)	6:00	→	7:00	→	9:00	→	12:00	→	15:00	→	17:00	→	18:00

Fig. 3: Daylight according to two Gerbert's horological tables; a = difference between the length of the day during winter and summer solstice.

I suppose this apparently illustrative power of both tables leads Gerbert to create these *horologia* as an exemplary guideline according to which Adam can make his own horologies, provided he considers the climate in which the given horology should be applied.

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