ALTERNATIVES TO PTOLEMY:
ASTRONOMY IN CAROLINGIAN SCHOOLS

Wesley Stevens

As a humanist, I wish to discuss astronomy and some other aspects of science in Europe during the middle ages[1]. But was there any real science in those tumultuous times?

Actually, my studies focus on perhaps the worst of times, the sixth to eleventh centuries after Christ in the Latin West. Well-educated people always ask whether the Dark Ages were a bad time for science. Of course it was a bad time! After all, it was the period after the Roman soldiers and lawyers and tax collectors had withdrawn and before the new universities arose in Western Europe. I believe that we might do without tax collectors, but we cannot do without universities. Figure 1 will suggest how the world looked in the early middle ages, yet that is not the same way that contemporary maps of Asia/ EuropeAfrica appear. This evidence suggests that the world was round in A.D.800, but that about 1900 it must have been flat! That conclusion is only preliminary and must be reviewed.[2] The part which interests us here is western and central Europe, especially the Carolingian Empire.

Figure 1
Map from Louis Halphen *Les Barbares: Des grandes invasions aux conquêtes turques du XIe siècle.* (4 ed, Paris: Presses universitaires de France, 1940) carte 1.

---

[1]The author is grateful to the Humanities Research Group of the University of Windsor for inviting him to present this paper in its Distinguished Speaker Series on 30 September 1998. He also expresses appreciation for the Board of Board of Governor and officers of the University who support the Humanities Research Group and this lecture series. It is an example of academic integrity which other universities could well follow. The idea of this paper was first offered on 15 July 1994 at the Nymphenburg Palace (München) to guests of the Alexander von Humboldt-Stiftung sponsored also by the Siemens-Stiftung. Several stages of its development were presented to the Department of Physics of Guelph University, the Early Medieval Seminar of the Institute for Historical Research (London), and the Department of History of the University of Durham.

[2]Medieval models of heavens and Earth were also discussed in a seminar for the Humanities Research Group on Thursday, 1 October, 1998 by this author, "En route with medieval cosmology." See also his articles, Cosmology and the Earth in Antiquity" and "Earth, Models of before 1600" *Sciences of the Earth: An encyclopedia of events, people, and phenomena,* ed. Gregory A Good (New York: Garland, 1998).

The public knows with unwonted certainty that the dreadful Germans invaded Western Europe and destroyed all good things, the Roman Empire fell, and then came many wars. This opinion is often offered by research professors in our universities. Historians however do not usually agree with the public, including some of their vociferous colleagues. Today, historians throughout the world recognise that wars and taxes, plagues and famines occur in every period, and the darkest age is usually the current one. They emphasize that in the sixth century most of the new immigrants came into the western lands peacefully, and that many had been invited because of the skills they could bring.[3]

Goths, Alemanns, Bavarians, Burgundians, Franks, Angles, and Saxons came West in order to settle and farm. They built houses, barns, mills, and bridges. Together with earlier local inhabitants, they created markets and new cities like Munich and Paris which did not exist before. A good and healthy life was possible for them at that time. The population increased steadily in all areas of Europe from the sixth to the thirteenth century.[4] A part of the increase and the well being in the early middle ages came with the new immigrants. From the sixth to eleventh century, 90 percent of the people of all races were peasants who raised grain, herded cattle, shovelled manure, and dug their gardens. In Europe the origin of schools came specifically from the demands and the support of farmers.

The Franks were diverse Germanic tribes that immigrated to middle and western Europe during the fifth and sixth century. There was a particular family called "Karolinger." The Carolingians settled in the lands which today are known as the Netherlands, Belgium, and Luxemburg, and they also moved up the Rhein into regions around Metz and Koblenz. From this family in the eighth century came a king of the Franks, known to us as Karl der Große or Charlemagne. He, his son, and four grandsons became the greatest patrons of schools and libraries in the history of Europe. See Figure 2.

General map of Europe and the Mediterranean

Figure 2
Kingdom of Karl des Große AD 771 from Donald Bullough *The Age of Charlemagne* **(London: Elek, 1965) 19**

---

[3]Bernard Bachrach, *Merovingian Mlitary Oganization*, (Minneapolis: University of Minnesota Press, 1972),481-751

[4]Robert Lopez, *Naissance de l'Europe* (Paris: Librarie Armand Colin, 1962).

Karl der Große ruled the Franks from 768 to 814, during which time he received diplomats from Istanbul, Cairo, and Zaragoza. He attracted scholars to his court from England, Ireland, Spain, Italy, and Austria. Not only did he ask the bishops and abbots within his rule to develop schools and give them guidelines for doing so, but he also gave large amounts of land for support of schools and libraries. That active and continuous interest set an example which led his faithful officers to give yet more lands under their control to support them, too.

Schools always require organised, continuing support. In the ninth century the only institutions with sufficient stability to support schools and libraries were the cathedral churches and monasteries. Bishops needed to train students to become priests for service in parish churches; and monks wanted to leave the busy life of family and markets in order to form communities for prayer, reading the Holy Scriptures, and singing the praises of the Creator. They formed communities to work and to pray together, as St Benedict said. But this leaves us with a problem.

We know that priests and monks learned to read and write. They learned Latin by reading Virgil and Cicero, in order to understand better the biblical literature. Thus, it seems today that the education of medieval monks must have been rather limited, fixed upon the Bible, and restricted to a low intellectual horizon. Would young men training to become priests and monks also analyse earth and water, air and sky? Would they develop the skills needed for understanding and coping with our natural world? Would they study arithmetic and geometry? If we expect not, we would be mistaken. Amongst the biblical, liturgical, and grammatical texts which survive in medieval Latin manuscripts, we also find scientific texts and diagrams. What did those schools actually teach?

One of the most studied subjects was the *computus*, for which the English word is calendar reckoning. At least nine thousand medieval Latin manuscripts survive today which contain essays and tables of data about calendar reckoning. Some modern codicologists estimate that for every surviving manuscript, perhaps fifteen have been lost. That indicates a large number of computistical texts given the question of setting the date of Easter in any year and projecting the dates of future Easters. It was a religious need to be met in a reasonable way with all the resources of science.

Every calendar of every culture must reckon every year on the basis of the course of the Sun or the course of the Moon, in order to anticipate recurring dates and celebrate important feasts. The first Christians were Jews who used a lunar calendar, in order to determine the date of Passover. Jesus celebrated the Passover before he was arrested and killed. Jews and Christians lived however in the Roman Empire which used a solar calendar. Its beginning point was the founding of Rome, from which other dates were reckoned. Christian scholars tried to bring the lunar and solar cycles into coordination, but without success. It looked like a problem which would be easy to solve, but in fact it has still not been solved precisely even today.

Did you know that the year 1998 ended on 31 December with its final minute elongated to sixty-one seconds? According to the agreement first organized by the Bureau international des poids et mesures, since 1958 Jan 1^d 0^h all clocks have been regulated by International Atomic Time, a system which is based upon a new definition of one second determined by resonance frequency of Cesium atom 133. Then, the proper number of seconds are added up to complete each year. Unfortunately, because deterioration of the Cesium atom cannot keep up with rotation of the Earth, an adjustment of an extra second is required at least once every fifteen to eighteen months.[5] Somehow, as it is keyed into atomic physics and despite exceptions and irregular adjustments, that system is supposed to be more scientific than the old way of measuring time by orbits of Sun and Moon with their exceptions and irregularities. Some of us may suspect that such claims to science may be merely a difference of perspective.

The possibility of coordinating the lunar and solar cycles in order to make a proper calendar however was attractive to priests and monks whose studies went well beyond the needs of prayer and Holy Scriptures. They were stimulated to study mathematics and astronomy in monastic schools. What sort of mathematics is found in the Latin manuscripts from those schools?

The *Calculus* of Victurius of Aquitaine was used and commented upon by masters in those schools, which means that arithmetic, as we know it today, could be learned. Added to that during the ninth century was Boethius' *Arithmetica*, one of whose sources was the arithmetical books of Euclid's *Elementa VII, VIII,* and *IX*: the best available arithmetic. Several schoolbooks survive which actually show problems which school masters

---

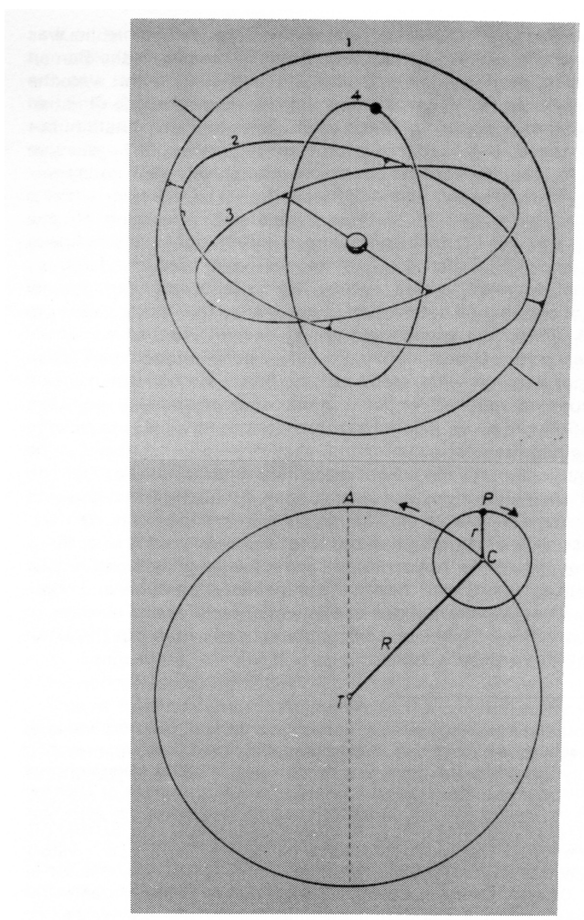
[5]The current time-keeping system is operative at the U S Naval Observatory, 3450 Massachusetts Avenue N W, Washington, D C. The Cesium atom system was once duplicated by the Royal Greenwich Observatory at Herstmonceux Castle, Hailsham (UK), the National Research Council of Canada at Ottawa, Centre CEA de Sanclay (France), Le laboratoire pour la physique des particules at Neuchâtel (Switzerland) of the Organisation europóene pour la recherche. The Cesium atom system was once duplicated by the Royal Greenwich Observatory at Herstmonceux Castle, Hailsham (UK), the National Research Council of Canada at Ottawa, Centre nucléaire (CERN), and the National Center for Atmospheric Research at Boulder, Colorado (USA). Canada, France, the UK, and CERN are no longer willing to support their laboratories for this purpose however and depend upon time signals from Washington.

set for their students, some of which were still used in my own school work in arithmetic and algebra.[6]

Plane Geometry is often found in early Latin manuscripts of Christian schools. The masters taught the first four books of Euclid's *Elements*.[7] This geometry serves no pious purpose, but the monks in many schools were obviously interested, and you may well guess why that was so: Plane Geometry served basic needs of a developing nation. It survives as part of a large collection of texts, gathered and used by surveyors and engineers trained in those same schools.

But what about astronomy? Unfortunately, most works of Greek astronomers were not known in Latin, save for very few and very short excerpts. The work of Eudoxios (408-355 BC), made too complicated by Kallippos (370-300) and Aristotles (384-322), was little known. The brilliant works of Apollonios (262-190) and Hipparchos (190-120) had also disappeared, save for the selective use made of them later by Ptolemaios (A D100-165).

In order to account for the apparent erratic course of each planet, some ancient Greeks had imagined two regular circular motions that interacted. (Figures 3a,b) Each planet moved on an epicycle whose centre was set upon a larger circle, and the larger circle centred on the earth. It was this model which was selected in the second century after Christ by Ptolemy for his mathematical conjectures to describe three planetary orbits. But the *Megale Syntaxis*, later called *Almagest*, was absent from Carolingian schools. And Ptolemy's *Tetrabiblos*, full of money-making astrology, was also absent from those schools. Was there any alternative to Ptolemy?



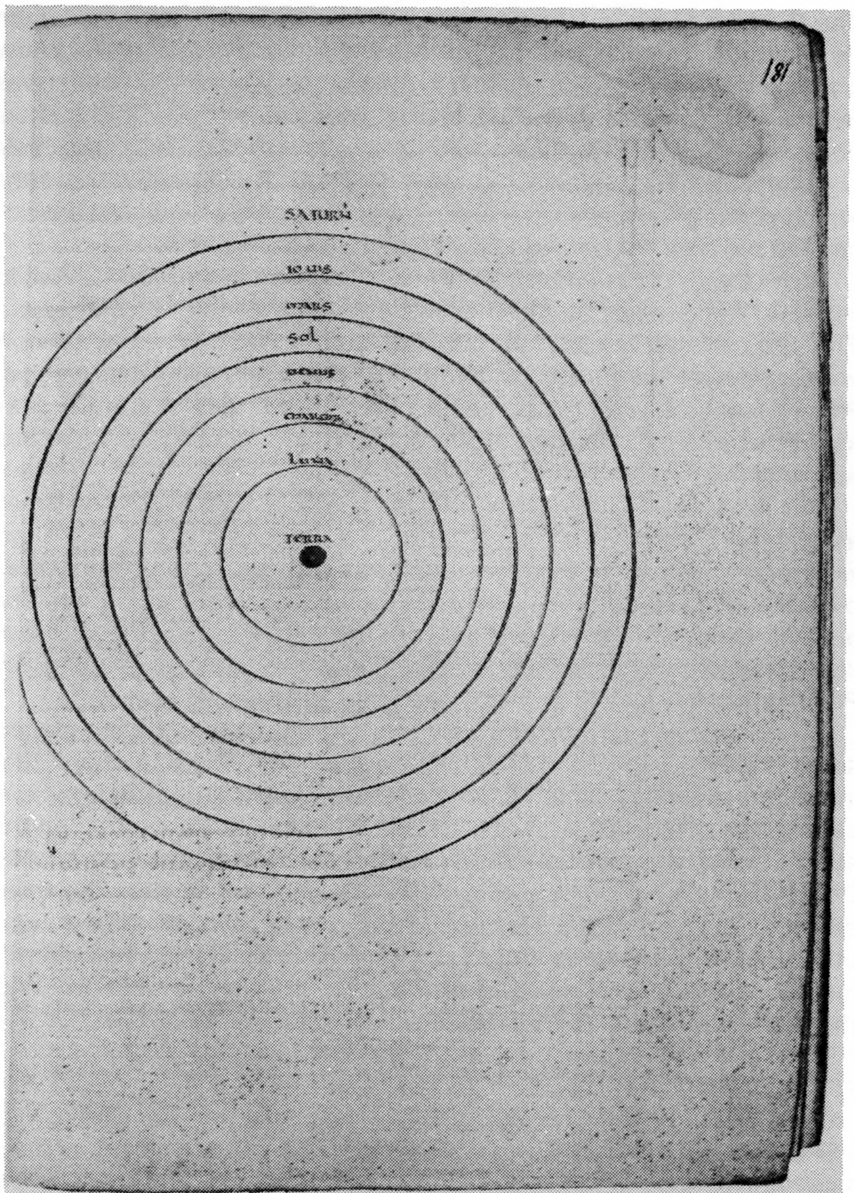
Figures 3 a & b
Nest of circles: Eudoxos, Aristoteles.
Deferent circle with epicycle: Ptolemaios.

---

[6]Euclidis *Elementa*; Victurius, *Calculus*; Boethius, *De arithmeticae institutione libri duo*. See also the several Carolingians works: *Calculatio Albini magistri, Propositiones ad acuendos iuvenes, De arithmeticus propositionibus, Altercatio duorum geometricarum*. Editions were cited by Stevens.

[7]Due to the state of manuscripts, Menso Folkerts, *"Boethius" Geometrie II* (Wiesbaden: Franz Steiner, 1970). Appendix I, presented some propositions out of order with glosses interspersed, giving an appearance of confusion. In proper sequence, the plain text is Euclid in Latin, of which I am preparing a critical edition and translation.

Indeed, there were several other ways in which the available astronomical data would also make good sense. One of the early Greek models of planetary orbits was an interactive system of nested orbs represented as concentric circles with the earth as centre (Figure 4), a concept which had been taught by Aristotle. That too was lost, but a simplified diagram survived in the ninth century which only served to display the Aristotelian sequence of planets in their distances from the Earth. Another Greek model which survived in Frankish schools displayed the relative distances between orbits, that is, harmonic intervals of older style Pythagoreans which they called tones or tonal intervals of orbits.



Planetary orbits in sequence. Ms Paris BN, N.a.lat. 1615, f. 181.

Figure 4
Seven Planets in Concentric Circles ms Paris BNN. A. lat. 1615 (A.D. 820) f.181.

Aristotelian sequences and Pythagorean intervals could be visualised in terms of concentric circles, and it is from those well known diagrams that an idea was created in modern times that during the Middle Ages all astronomers thought that the orbits of planets were circular and centred on the Earth. The ninth century

diagrams however may not be fitted into those more recent assumptions.

You may wish to look up at the heavens tonight, wherever you may be, and then return each night or two for about one month. Usually, you will discover one or more very bright planets wandering among the other bright stars. Some planets not only rise and fall with the other stars; they are easily observed to wander back and forth. If you go out into the countryside the entire heavens will open up their riches for you. Watching the planet Mars, night after night, you will observe its irregularities, and you can map out the resulting data on that scale which is called the Zodiac. From the restricted skies seen from some city apartments, you may even do it with Venus because it is so bright and so easy to locate. Mercury is always near the horizon where light distortion, if not low lying clouds, seldom allow any series of observations.

For example at the end of twilight in mid-January 1999, the Moon is in waxing crescent and will not give much light, thus allowing you to see better. At sunset, Venus could be seen briefly in the Southwest at 220°, but only 12° above the horizon. Jupiter will be near Venus and 26° above the horizon. Looking due South, Saturn will be 13° to the East and 46° high.[8]

In the early ninth century, many diagrams show the motions of Mercury and Venus turning about the Sun as their centre, while the group of three planets circles the earth together.(Figure 5a) Two such diagrams were known in schools on the Reichenau: one shows the earth-centred circle of only five planets with two Sun-centred circles of Venus and Mercury; the second displays only Venus and Mercury on circles moving about the Sun. One circle is distorted in order to show its inclination from the plane of the Sun's orbit. Other diagrams showed all three planets on separate centres, as their orbits were studied. (Figure 5b)These diagrams and texts were widely known in schools throughout the Carolingian empire, Italy, Spain, and the British Isles.[9]

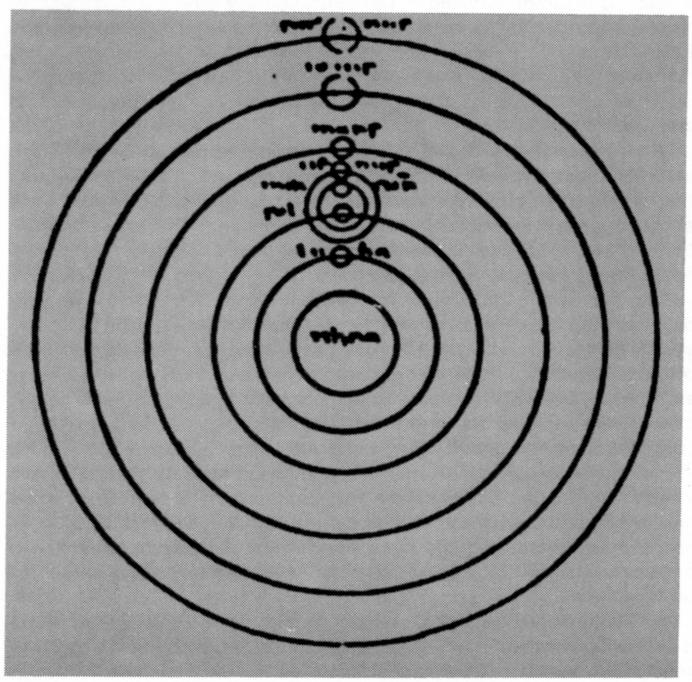


Figure 5 a
Planets with Sun/Venus/Mercury: ms Karlsruhe Aug.167 (Reichenau 825-850) f.16.

---

[8]The skies for any period of the year have been mapped by Terrence Dickinson, *Nightwatch: A Practical Guide to Viewing the Universe,* 3d rev ed (Willowdale, Ontario: Firefly Books, 1999). Current planetary positions are also published and displayed for each month in *Sky & Telescope.*

[9]I am grateful to Professor Eastwood for his advice on these materials and for allowing me to review two early versions of his "Astronomical images and planetary theory in Carolingian studies of Martianus Capella" (expected in 2000). Also by Bruce S Eastwood:"Plinian astronomy in the middle ages and renaissance" in *Science in the early Roman Empire: Pliny the Elder, his sources and influence*, ed R French and F Greenaway (London: Croom Helm, 1986), 202-209. "Plinian astronomical diagrams in the early middle ages," in *Mathematics and its application to science and natural philosophy in the Middle Ages,* ed E Grant and J Murdoch (Cambridge University Press, 1987), 141-172, with illustrations. "The astronomies of Pliny, Martianus Capella, and Isidore of Seville in the Carolingian world" *Science in Western and Eastern Civilization in Carolingian Times*, ed P L Butzer and D Lohrmann (Basel: Birkahuser, 1993). 161-180.

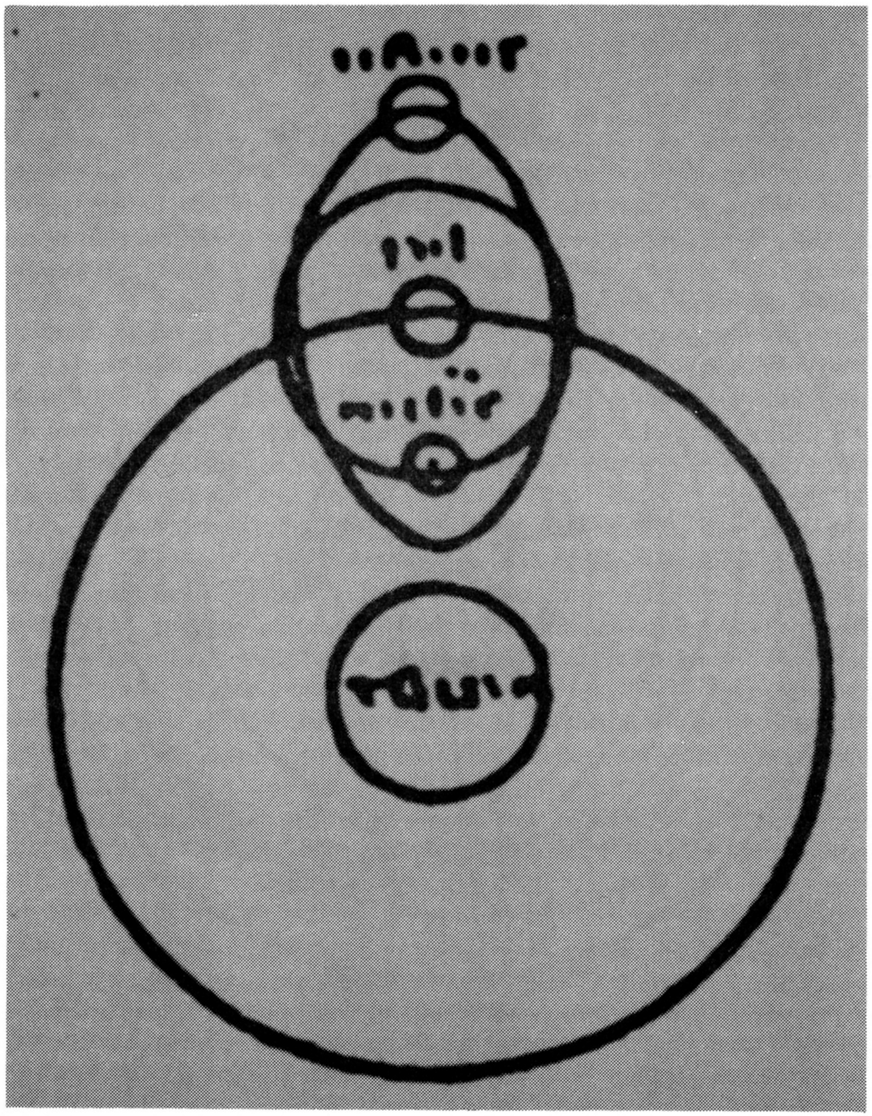


Figure 5b
Three Planets: Venus and Mercury orbit the Sun: ms Karlsruhe Aug. 167 (Reichenau 825-850) f. 16.

Two other types of manuscript drawings will also demonstrate that cycles of the planets did not require the Earth as centre. In the early ninth century the masters analysed the spatial relations of planetary *apsides* in apogee and perigee. (Figure 6a) *Apogee* is the greatest dis-tance of the planetary orbit from the Earth during its cycle; *Perigee* is the least distance.

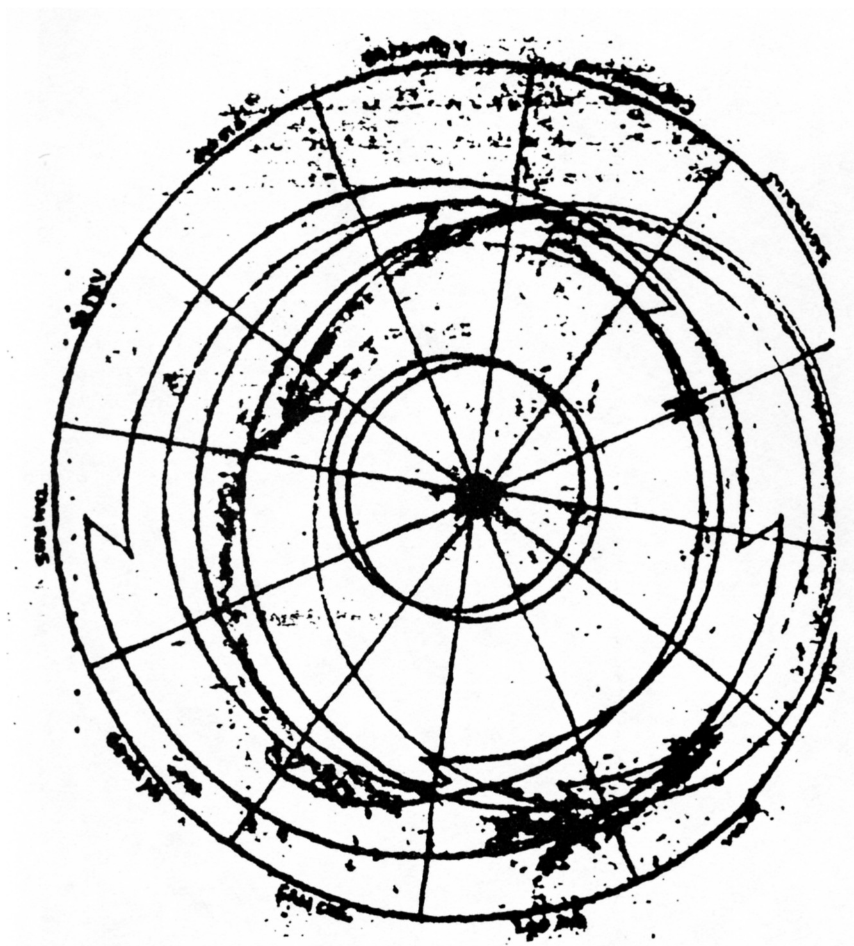


Figure 6 a
Apsides of planetary orbits: ms Paris BN a. lat.1615 (A. D. 820) f.160ᵛ.

Deviation in latitude from the ecliptic path of the Sun was also newly diagrammed. On the next drawing of planetary latitudes, the Zodiac was first drawn and then the planetary paths placed upon it. (Figure 6b) It is difficult to pick out the paths of the planets until you notice that the motion of each one incorporates an elongated, reversed Z. Carolingian masters lacked a general concept of epicycles, as used by Hipparchos or Ptolemy, but they could represent the phenomena of apparent stations and retrogradations for each planetary orbit with that zig-zag notation.

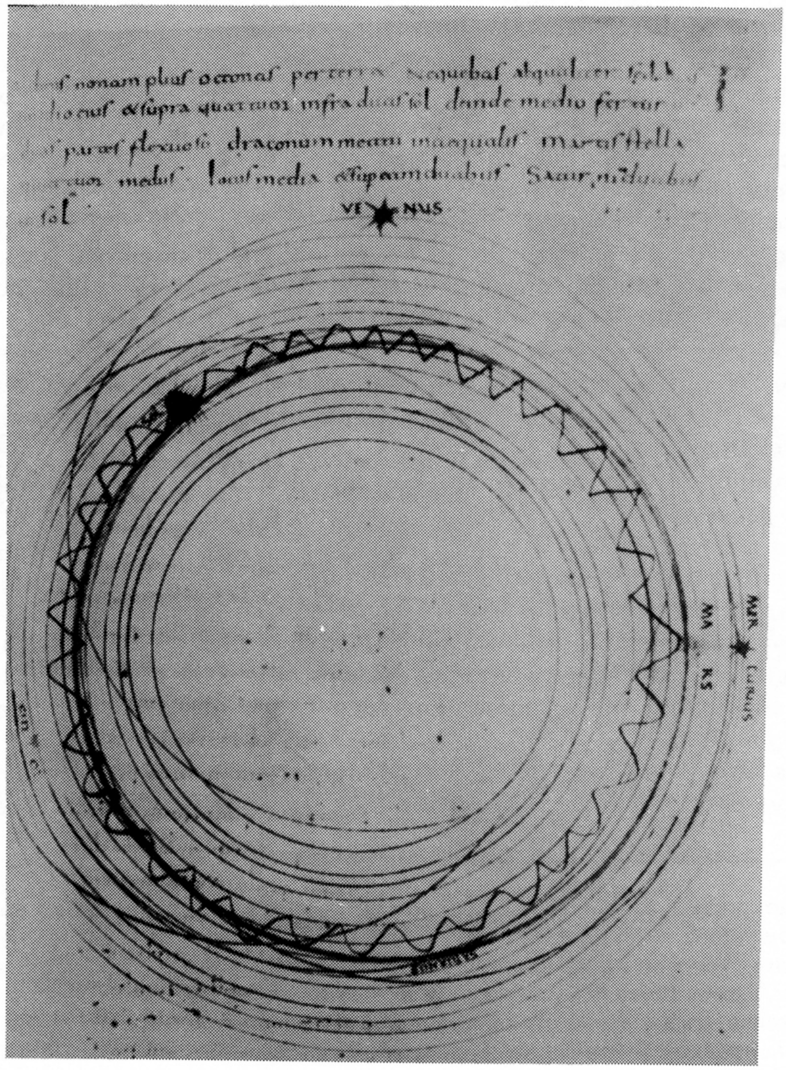


Figure 6 b
Latitudes of planetary orbits: ms Paris BN N.a.lat. 1615 (A.D.820) f.161.

The Moon's extreme deviations are seven parts of latitude above and five parts below the ecliptic by which the breadth of the zodiacal scale is defined. The ecliptic itself was a theoretical construct: a line along which or near which the Sun moved daily. For Carolingian scholars as for Greeks and Romans, the Sun seemed to move in a path which wavered in a range of one *pars* or step of latitude above or below that circle. All other planetary latitudes could be read within this scale of the Zodiac, but on occasion Venus passed beyond it by one or even two steps.

Sectors of the zodiacal scale are always shown from the observer's position; but don't be misled by that. Projection of planetary latitudes on the Zodiac gives the appearance of roughly concentric orbits, but in fact the orbit of each planet has its own centre which may not be clear from the reproduction in Figure 8b but which you would be able to pick out easily on the manuscript folio itself.

These drawings of *apsides* and *latitudines* were not physical images of reality of course but were abstract representations of theoretical elements of Astronomy. The Earth was the point of observation but often was not shown on diagrams of orbital *apsides* or *latitudines*. Except for Sun and Moon, the Earth was usually not the centre of the orbits, contrary to Ptolemy.

Some of these ideas about the stars in the heavens could also be of interest to wealthy patrons. Quite an elegant manuscript[10] was prepared about A.D. 830-840 either at Aachen in the court of Ludwig der Fromme (814-840) or perhaps at Ingelheim in the court of his beautiful Bavarian wife, Judith (819-843) where Ludwig

[10] *Arates."Nachbildung der Handschrift Ms Voss. Lat.Q.79 der Rijksuniversiteit Leiden"* (Luzern: Faksimile Verlag, 1997/1989).

made his home. The Leiden codex features zodiacal signs and other star-groups represented by handsome coloured drawings of the heavenly figures drawn from the popular Hellenistic myths, in order to help the viewer remember star positions and locate them in the sky.

These manuscript illuminations were in glorious colour, with stars applied to the parchment in gold leaf. But the substance should not be ignored, for this very expensive book also includes some of the astronomical theories and constructs which were studied in the Carolingian schools. The technical drawings seen earlier in figures 5 and 6 were here combined into a single planetary configuration created by an astronomer. (Figure 7) The great circles were carefully drawn; Mercury and Venus are circling the Sun; orbits of the planets are eccentric to the Earth. The origin of this planispherium was the 18th of March, A.D.816, if planetary positions are correct.[11]

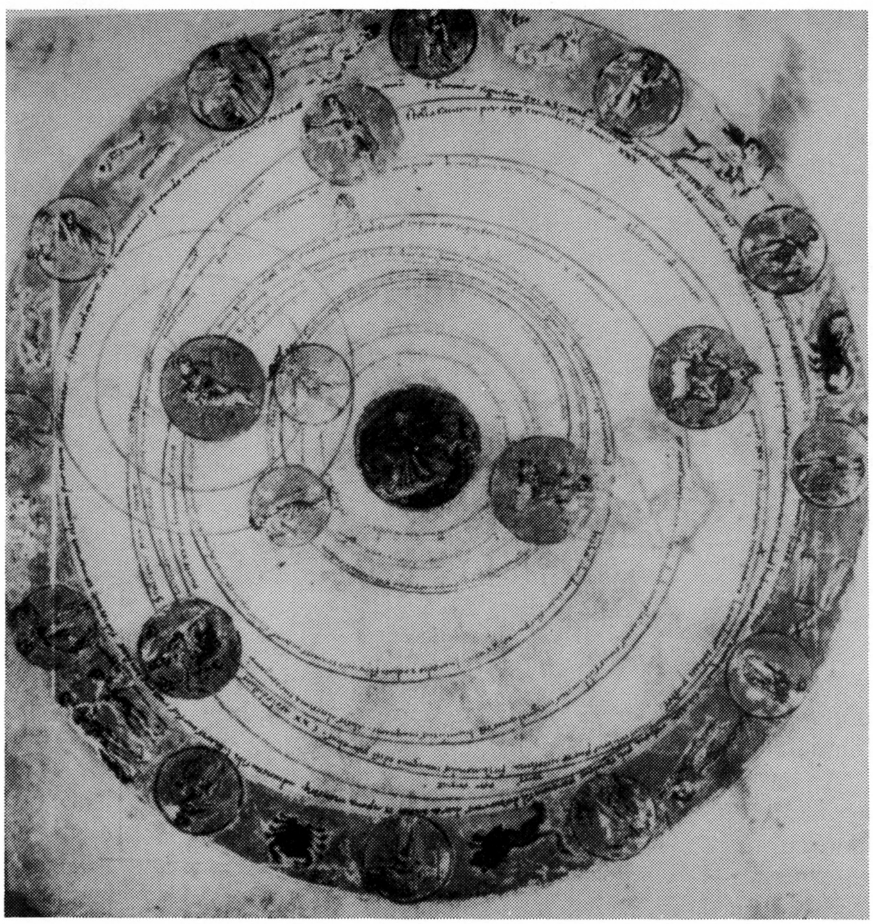


Figure 7
Planetary configuration: ms Leiden Biblioteek der Rijksuniversiteir Voss. 79 (A.D.830-40) f.93v.

These diagrams make it clear that the Aristotelian concept of planets moving on concentric circles was useful only as a beginning, in order to think about sequence of orbits and about intervals between them. Masters and students in the ninth century however developed much more complex theories for apsides, latitudes, epicycles on the sun, and varying inclinations. They could see that Sun and Moon circled the Earth. On the other hand, they could also see that, while five other planets orbited the Earth, their orbits were not Earth-centred.

It would be difficult to believe that Carolingian scholars contributed so much new astronomy without any works of the Greeks to guide them. But also, how could they do it without instruments which would allow improved observations of the heavens? Let me remind you therefore that the Zodiac itself was a standardised

[11]Referring to ms Leiden f.93v, Mosterts (1990) said that "...the configuration, and probably the manuscript, can be dated 8l6, around 18 March." Unfortunately, the evidence for this assertion is not entirely consistent or verifiable.

scientific ins-trument, with its twelve *signa*, with divisions of each sign called *puncti* for longitude and *partes* for steps of latitude. There were also other instruments.

In the early seventh century, Beda venerabilis referred often to his use of a *horologium* which heretofore all scholars have assumed to be a sundial. But recently, it has been noticed that Beda constructed his instrument on the ground and used it at night. That instrument was a *horologium in terra* whose markings on the outer circle were learned by comparison with those of the Zodiac. [12] Thus far, we cannot describe this instrument adequately; but we know that Beda was able to co-ordinate the lunar cycle with the flux of ocean tides so well in the early eighth century that his tidal theory prevails to this day in *The British Admiralty Tide Tables*, though without acknowledgement. [13]

In addition to the beautiful court planispherium in the Leiden manuscript, there are two other types of working planispheres from the same period which were studied in Carolingian schools, century after century, with two perspectives, both using stereographic projection. One is from the school of St Emmeram at Regensburg. The second was used in the monastery school at Fulda. Each was copied and used in schools of the ninth, tenth, eleventh, and twelfth centuries. The Regensburg illustration has been tested, and the instrument it represents must have been relatively accurate. [14]

Another instrument is the *horologium nocturnum* used in the schools of St Peter at Salzburg and of St Emmeram at Regensburg. It was copied about A.D.812-816 into two manuscripts, now at Munich and Wien. That instrument had movable plates lying on top of each other and fastened in the centre by a small mechanism which on an astrolabe would be called "horse" (because of its shape). The plates bore drawings and systems of *puncti* which conveyed data for co-ordinating 365 days in twelve months with 360 *partes* in twelve *signa* of the zodiacal scale, and a 28 day lunar cycle which allowed for the moon to be coordinated with the movement of the stars. In addition, 24 solar days could be coordinated with 16 moons probably to indicate potential days of eclipse. Most functions of this instrument have not yet been explained and invite further analysis.

A fifth instrument appeared in the early ninth century. The star which we now call Polaris, **α** *Ursae minoris*, the primary star of the "Little Bear" or "Little Dipper," but was then not the North Pole. Rather, it was almost four Sun's diameters away from the geometrical pole and turned about it regularly on a radius which we express as an angular distance of about 2°. There was a great teacher in the Cathedral of Verona, the deacon Pacificus who lived until A.D.844. Pacificus combined a sighting tube and a disk marked for twenty-four hours. (Figures 8a,b) With this instrument, the revolutions of the star **α** *Ursae minoris* could serve as a perfect clock during the night hours. He called that star *noctium horarum computatrix*.[15] That too met an immediate need for monks who had to rise from their beds for prayers during the night and certainly did not want to be called too soon, while the abbot did not want them to come to prayers too late. The instrument was a *horologium nocturnum* which Gerbert of Reims could explain to the young king Otto III of Saxony in 997 at Magdeburg.

More complex was the Greek *astrolabium* which came from the Arab world of southern or central Spain into Catalonia, Alemmania, and other western kingdoms during A.D.960-1030, along with Latin terminology and explanations of how to make one and to use it. Another appeared at Konstanz during the 980s, attested by surviving manuscript fragments. Hermannus Contractus on the Reichenau, Berthold of Konstanz, and others at Augsburg, Fleury, Micy, Chartres, Laon, Lüttich, and Köln began to use the astrolabe for lunar observations, for tracking the courses of other planets, and for correcting the Bedan calendar. [16]

During the early middle ages, dates of solstices and equinoxes were always expected at the wrong times, so that even the best calendar was not quite in accord with the heavens and the seasons. During the late ninth century however, both methods and data improved. In his *Ars calculatoria*, Heiric of Auxerre (860-903) developed a new method for observing solstices at sunrise on successive days by marking the point of sunlight passing through a narrow aperture on the eastern wall of a refectory to the western wall: that is called the pinpoint-method for observing the Sun, used much earlier than we had thought. [17]

---

[12] Stevens, "Astronomy in Carolingian schools," 425-32

[13] Wesley Stevens, *Bede's Scientific Achievement*. The Jarrow Lecture 1985 (Jarrow upon Tyne: Parish of Jarrow, 1986); revised edition in *Cycles of Time* (1995): item II.

[14] John D North, "Monasticism and the first mechanical clocks," in *The Study of Time* II, ed J T Fraser and N Lawrence (New York: Springer Verlag, 1975), 381-98.

[15] Joachim Wiesenback, "Pacificus von Verona als Erfinder einer Sternenuhr, in *Science in Western and Eastern Civilization in Carolingian Times*, ed P L Butzer and D Lohrmann (Basel: Birkhauser, 1993), 229-50.

[16] See also *The oldest Latin astrolabe* eds G Beaujouan, W M Stevens, A J Turner, a special issue of *PHYSIS* XXXII/2-3 (Roma 1995), with illustrations, and Arno Borst, *Astrolabe und Klosterreform an der Jahrtausendwende*. Sitzungsberichte der Heidelberger Akademie der Wissenschaften, Phil-hist.Klasse (1989), no 1.

[17] Wesley Stevens, "Astronomy in Carolingian schools," in *Karl der Große und sein Nachwirken. 1200 Jahre Kultur und Wissenschaft in Europa*, Band I, *Wissen und Weltbild*, eds PL Butzer, M Kerner, W Oberschelp (Bruxelles: Brepols, 1997),

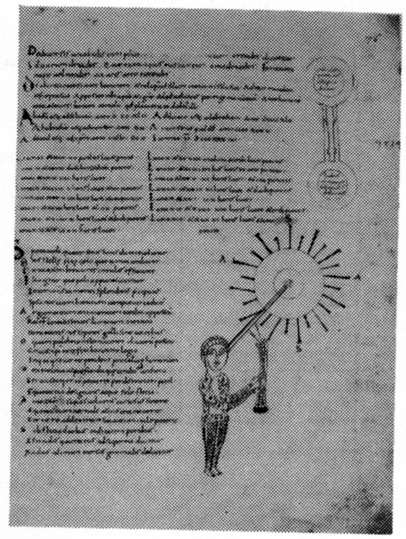


Figure 8 a
Pacificus, **Sphaera:** ms St. Gallen 18 (ca.A.D.1000) p.45.

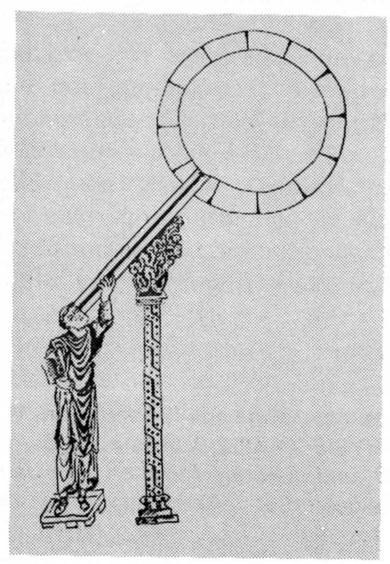


Figure 8 b
Pacificus, **Sphaera:** ms Vat. Lat.644 (s.X) f.76.

Other scholars during the tenth century were able to reason that the vernal equinox fell not on 21 March but as early as 18 or 17 March. Before A.D.1069, Wilhelm von St. Emmeram created a new instrument for astronomical observation at Regensburg and established true solstices and equinoxes. (Figure 9) With his *Sphaera*, magister Wilhelm could date the vernal equinox on 16 March, a correction by five days, truly a remarkable accomplishment. Wilhelm soon became abbot of Hirsau (1071-1091) where he played an important role in reform of feudal bishops and their accumulation of properties but could not continue this astronomical work, though many others did so, for example Sigebert (ca.1030-1112) who taught at Gembloux and Metz.[18] With

436-8.

[18]Wilhelm von St. Emmeram und Hirsau in ms München Staatsbibliothek CLM 14689 (St. Emmeram s.XII) f85-87v. See further Sigebert of Gembloux, *Liber decennalis*, ed J Wiesenbach, Monumenta Historica Germaniae. Quellen zur Geistesgeschichte des Mittelalters, 12 (München: MGH, 1986).

improved methods and observations in many schools, Marian Scottus (1078-1082/3) was justified in calling for calendar reform when he attracted students and other magistri to Fulda and Köln. [19]

This essay has called attention to studies of *computus*, arithmetic, geometry, and astronomy in early medieval schools. Frankish teachers used Aristotle very little, they did not follow Ptolemy, and their astronomy was not derived from a literal reading of the Bible. Books were scarce, but intelligence was plentiful. From the few sources available to them, Carolingian scholars made something new in science concerning accurate solstices and equinoxes; they introduced to western Europe the astronomy of planetary orbits, eccentric to the Earth; and between regular times of prayer they invented new methods and a series of new instruments which were used for observation and which allowed the creation of improved scientific theories. These are aspects of human creativity in the early Middle Ages which humanists sometimes forget but which all of us may appreciate.

ACKNOWLEDGEMENTS

The publisher and author express their appreciation to the following publishers and libraries for permission to reproduce manuscript pages, drawings, and printed maps: Alfred Knopf Publishers (New York), Badische Landesbibliothek (Karlsruhe), Bayerische Staatsbibliothek (Munich), Biblioteca Apostolica Vaticana, Biblioteek der Rijksuniversiteit (Leiden), Bibliothèque Nationale (Paris), Elek books (London), Presses universitaires de France (Paris), and Stiftsbibliothek (St. Gallen).

[19] Anna-Dorothée Von den Brincken, "Marianus Scottus als Universalhistoriker iuxta veritatem Evangelii," *Die Iren und Europa*, ed H Löwe (Stuttgart: Clett-Cotta, 1982), vol II, 970-1009.