1 INTRODUCTION

1.1 THE ASTROLABE AND MEDIEVAL MATHEMATICAL THOUGHT

In the ninth century of our era, in the Arabic-Islamic culture, the astrolabe was a well-known astronomical and computational instrument.[1] It was usually made out of metal and embodied a two-dimensional projection of the Ptolemaic cosmos. During the tenth century, knowledge of the astrolabe entered Latin Europe where, at the time, very little mathematical and astronomical knowledge was present. What was the astrolabe for Latin medieval Europeans? Why did they take an interest in it? More than one century of research has brought to light the complexity of this question.[2]

Historical studies often describe the medieval Latin astrolabe as an astronomical instrument, but, when it comes down to explaining what it was actually used for, they offer a varied list of possible roles: timekeeping device, abstract model of the cosmos, analogical computer, status symbol or didactic tool. The present study builds upon previous works in the hope of adding something to the richness of the picture.

Although my research subject is the astrolabe in tenth- and eleventh-century Latin Europe, this is at the same time an investigation of medieval mathematical thought, of its modes of communication and of the image (or images) of knowledge in which medieval mathematics was embedded.[3] This double focus is both necessary and fruitful: on the one hand, the assimilation in Latin Europe of astrolabe knowledge of Arabic origin can be fully appreciated only by taking into account the features of the mathematical culture in which that knowledge was being assimilated. On the other hand, the astrolabe offers a valuable key to explore and better understand the medieval mathematical arts and constitutes an ideal testing ground for hypotheses.

When speaking of the context of Latin medieval astrolabe studies, I will refer to 'high medieval mathematics', meaning the four arts of the quadrivium (arithmetic, geometry, astronomy and music) as they were being taught and practised in the tenth and eleventh centuries. Although the primary focus of this research shall be on the mathematics involved in the study of celestial phenomena, this subject cannot be confined to the discipline of astronomy: in the tenth and eleventh centuries, the borders between the four mathematical arts were

1 An overview of the early history of the astrolabe is given in 1.4. For an astronomical and mathematical introduction to the astrolabe, its structure and its possible uses see, for example: Hartner (1939), Michel (1947), North (1974), Hartner (1979), Poulle (1981) p. 29–34, Pingree (1987), Stautz (1999) p. 1–7 and p. 99–122, Kunitzsch (1996), Wintroub (2000), Maddison/Savage-Smith (1997) p. 186–199, King (2003b), Proctor (2005).

2 Historical research on the Latin medieval astrolabe started at the latest in 1899, with Nicolaus Bubnov's publication of the mathematical works of Gerbert of Aurillac Bubnov (1899).

3 On Yehuda Elkana's concept of 'images of knowledge', see 1.7.

ries, the borders between the four mathematical arts were constantly being redrawn, bringing them closer to each other.[4]

In Latin medieval Europe, the astrolabe occupied a very special - if not unique - position as the focus of an early interest for Arabic knowledge and for its real or imagined ancient roots. Still, it is not easy to provide a satisfactory definition of it, and possibly even to say whether the Lain medieval astrolabe was a material object or an abstract geometrical pattern, as discussed in the following section.

1.2 THE ASTROLABE AND ITS ASPECTS

Behind the Latin terms which are translated as 'astrolabe' (among them 'astrolabium', 'astrolapsus', 'plana sphaera', 'wazalcora') lies one of the most complex conglomerates of evidence the Latin Middle Ages has left us, involving artefacts, drawings, manuscript descriptions, illuminations and philosophical reflections. Historians face the difficult task of weaving this material into a coherent picture, while still evaluating every single kind of evidence taking into account its own unique character. Evidence on the astrolabe has to be approached with much care, because some of it can be readily understood in modern terms, and may be too easily interpreted according to patterns which are not fitting to medieval thought and practice.

The problem is the following: at the immediate level of the sources, it is quite easy to distinguish between, for example: (a) astrolabe artefacts made out metal, (b) astrolabe lines drawn on parchment, (c) texts describing in words the drawing procedures, (d) texts commenting upon the importance of learning to perform the construction, (e) texts describing how to use an 'astrolabe'.

At the level of interpretation, though, problems immediately arise. For example: should texts describing procedures for drawing astrolabe lines be regarded as instruction booklets for making astrolabe artefacts out of wood or metal? They often are, but this might be incorrect, as I shall argue later on. Should preserved Latin astrolabe artefacts be regarded as tools which were used in the way described in contemporary texts? This, too, is a very problematic issue, as we shall see. Were the astrolabe lines drawn in Latin manuscripts actively constructed by Latin geometers, or had they been passively copied from Arabic originals?

More generally, it is tempting to distinguish Latin medieval knowledge about the astrolabe into a theoretical understanding of its principles on the one side, and the practical recipes for building and using it on the other. Making this kind of distinction has often forced the question, whether Latin scholars from the eleventh century did or did not 'really understand' the astrolabe, or whether they were 'only' interested in it for utilitarian reasons, for example, timekeeping.[5]

4 The state of the four mathematical arts in tenth- and eleventh-century Europe is discussed in 4.1.5–7.

5 On this question, see 2.1.6, 4.1.7 and 4.4.2.

This question addresses a very important point, but it may be misleading in its clear-cut formulation. As I will argue, in the historical context studied here no distinction between theoretical and practical knowledge in the mathematical arts is possible.[6] In the eleventh century, a recipe-like list of instructions could be the most appropriate written form in which to store and transfer highly abstract knowledge. On the other hand, attention to abstract mathematical structures could be motivated by a desire to understand the rational structure ('ratio') behind carefully observed, and often also quantitatively estimated, natural phenomena. Because of this, it is not always hermeneutically productive to assume that in a medieval Latin text the term 'astrolabe' has to mean either an abstract pattern or a material object: it might mean both at the same time.

Another sharp distinction that may be misleading is the one between 'astronomical' and 'astrological' uses of the astrolabe. Medieval astrology was a form of rational natural philosophy and, therefore, if the astrolabe madeit possible to recognize an ordered, rational pattern ('ratio') in natural phenomena, its significance was at the same time astronomical and astrological.[7]

In conclusion, the Latin medieval astrolabe appears to carry different meanings which, by modern standards, are seemingly unrelated to or even incompatible with each other: an abstract geometrical construction and a practically useful timekeeper, a forbidden astrological tool and a device to compute the exact time of prayers, an exotic prestige object and a philosophical model for cosmic order. Since it is highly problematic to choose one among all these possible meanings, I will instead introduce, as hermeneutic tool, the idea of 'aspects' of the astrolabe. This means that I shall regard the research subject 'Latin medieval astrolabe' as a loose collection of co-existing 'aspects' corresponding to the various meanings listed above (and to a few more). For example, the mathematical aspects of the astrolabe will be abstract geometrical structures and methods, while its practical aspects shall be linked to sensory experiences such as holding an object in the hands and using it to obtain perceivable effects.

The various aspects of the Latin medieval astrolabe might or might not have been perceived and connected with each other by the historical actors: whether, when and how this was the case is the question which I will set out to answer in the following pages.[8]

6 See 4.1.7.

7 See 5.1.1–2.

8 The idea of considering the astrolabe not as an instrument, but rather as a loose collection of aspects, each of which might or not play a role according to the specific cultural and historical context, was suggested to me by the paper presented by John Michael Gorman at the 2004 Summer Academy of the Max-Planck-Institute for the History of Science (Berlin).

1.3 THE EARLY HISTORY OF THE ASTROLABE

The development of the geometrical structure of the astrolabe and its embodiment in an artefact were the work of Greek-speaking scholars and took place within the same context in which the main body of Greek-Roman astronomical and mathematical knowledge was produced.[9]

The earliest extant written and material evidence of a device with a geometrical structure similar to that of the astrolabe dates to the first centuries of our era.[10] The earliest extant treatise devoted to the geometrical construction of astrolabe lines was written by Ptolemy (Claudius Ptolemaeus, ca. 100–170) and is usually referred to as the 'Planisphaerium'.[11] The Greek original of this work is lost, and only its Arabic and Latin translations are preserved. The earliest extant description of an astrolabe artefact is a treatise by the Christian neoplatonic philosopher Johannes Philoponos of Alexandria (ca. 520–550). In the seventh or eight century of our era, the astrolabe entered the Arabic-Islamic world. The transmission of astrolabe knowledge from the Greeks to the Arabs was part of a wide process of knowledge transfer and assimilation involving, among other things, Ptolemaic astronomy, Euclidian geometry and neoplatonic philosophy.[12] The earliest preserved astrolabe artefacts were made in the tenth century in the Eastern part of the Arabic-Islamic world.[13]

In Latin literature, no reference to the astrolabe can be found before the late tenth or early eleventh century. It is important to note that not even late ancient Latin authors such as Martianus Capella (fl. ca. 410–439), Ancius Manlius Severus Boethius (d. 524) or Cassiodor (d. after 580) mention astrolabes in the works they have left us although, as already noted, devices based on the same geometrical projection as the astrolabe are attested in late ancient Europe. The presence of such devices might have contributed to keeping alive knowledge on how to project the surface of a sphere onto a plane, even though written Latin texts made no mention of it.[14]

Around the year 1000, evidence of the diffusion of astrolabe knowledge in Latin Europe appeared in the form of manuscripts discussing the astrolabe's geometric design ('mensura') and its possible uses ('utilitates').[15] These manuscripts also contained drawings of the steps needed for the geometrical construction of astrolabe-lines, as well as drawings of finished astrolabes. The authors make large use of Arabic terms. Only one astrolabe artefact exists which can be assumed to

9 The following overview on the origins of the astrolabe is based on: Neugebauer (1949), Stautz (1994), Anagnostakis (1984) p. 9–43. For further details and bibliography on the subjects mentioned below, see the relevant chapters of Part Two of this study.

10 It is the device known as 'anaphoric clock', discussed in 3.1.1.

11 On the 'Planisphaerium' see 4.5.1–2.

12 For an overview of Arabic astronomy and its Greek and Indian sources see: King (1999b) p. 3–46 (with numerous further bibliographical indications), Morelon (1996).

13 On preserved astrolabe artefacts, see 3.2.

14 North (1975) argues in this direction.

15 On early Latin astrolabe manuscripts, see 3.3.

have been produced by Latin scholars and craftsmen in the tenth or eleventh century.[16]

1.4 LATIN SCHOLARS AND THE ASTROLABE

The transfer of astrolabe knowledge from the Arab to the Latin world in the eleventh century has a very peculiar character. Astrolabe knowledge was transmitted and assimilated into the Latin culture practically isolated from the body of astronomical, mathematical and astrological knowledge with which it had been regularly associated in the Greek as well as in the Arabic world. Apart from the astrolabe, there are only two further traces of the diffusion of new mathematical, astronomical and astrological knowledge in eleventh-century Latin Europe: Arabic-Hindu numerals which, like the astrolabe, made their appearance in Latin manuscripts around the year 1000 and the Latin text known as 'Liber Alchandrei', that deals with astrological subjects.[17] However, this should not be taken to imply that the Latin interest in the astrolabe had nothing to do with mathematics, astronomy or astrology: quite the contrary, as I shall argue. The point is that astrolabe knowledge seems to have appealed to tenth- and eleventh-century Latin scholars more than other elements of Greek and Arabic natural philosophy which might also have been within their reach.

The astrolabe was a device whose geometric structure, use and construction went well beyond the limits of contemporary Latin mathematics and astronomy. Moreover, it was a device that, although its roots could be traced back to classical Antiquity, still carried unmistakable signs of its immediate Arabic-Islamic origin. Even though the astrolabe can in principle be used as a timekeeping device, it is very doubtful whether tenth- or eleventh-century astrolabe artefacts could perform this function better than a simple sundial. In fact, one may wonder whether they could perform it at all.[18] And yet, the astrolabe awakened the interest of Latin scholars so much, that they devoted precious time and no less precious parchment to the effort of acquiring and spreading knowledge about it.

More than one hundred years later, around the middle of the twelfth century, a steady flow of mathematical and natural philosophical translations from Arabic into Latin began. The centres of this translating activity were Northern Spain and Southern Italy. In this period, along with other mathematical, astronomical and astrological works, recently composed Arabic treatises on the astrolabe were translated, too. At the same time, some Latin authors composed original works on the subject. In historiography, the assimilation of astrolabe knowledge in Latin Europe is often seen as a consequence of material imported or produced in the

16 On this unique artefact, see 3.2.5.

17 On Arabic-Hindu numerals, see 4.1.6. The 'Liber Alchandrei' and other high medieval Latin texts of astrological content have been studied and edited by David Juste: Juste (2000), Juste (2007), on this subject see 5.1.1.

18 On this question, see 2.3.4.

twelfth century, and not of earlier contacts.[19] One of the main arguments brought forward in favour of this view is that eleventh-century astrolabe texts, if judged by the standards of textbooks aimed at spreading astrolabe knowledge, appear to have quite a low pedagogical value, casting serious doubts on how far they might have actually contributed to the diffusion of knowledge.

In general, the diffusion of astrolabe knowledge in tenth- and eleventh-century Europe is often regarded as a sort of prelude to the twelfth-century flowering of Arabic-Latin cultural contacts. In my opinion, instead, it was a key stage in the development of Latin natural philosophy and mathematics, taking place under the influence of the Arabic neighbour and having far-reaching consequences in the following centuries. In this study, I will attempt to reconstruct some elements of the cultural background that in the first centuries of the high Middle Ages contributed to making the astrolabe the ideal strategy for transferring and assimilating knowledge from the Arabic into the Latin culture.

1.5 THE TWO MAIN THESES OF THIS STUDY

Although the written word contributed to making the astrolabe known in tenth- and eleventh-century Europe, I shall argue that other methods of knowledge transfer also played an essential role in this process of transmission, diffusion and assimilation. These methods included oral teaching, discussions, drawings, repeated exercise in imagining, drawing and practically employing geometrical structures, watching and performing demonstrations with models, constructing and taking apart those same models, memorizing phrases, structures and procedures. Each of these non-written and/or non-verbal strategies of knowledge transfer has characteristics which make it unique and must be investigated in its own right as to how it could be employed as an alternative or complement to the other ones. The first thesis which I shall discuss in this work is that the assimilation of astrolabe knowledge in Latin Europe was the result of a combination of written and non-written, verbal and non-verbal strategies of knowledge transfer. Using these methods much more knowledge was stored and diffused in Latin Europe than would appear from the rather poor contents of the earliest astrolabe texts. In fact, the apparent evolution of early Latin astrolabe texts cannot be simply interpreted as a result of a growing level of astrolabe knowledge, but was also a result of the changing attitude to the written word among tenth-, eleventh- and twelfth-century scholars.

To reconstruct the motives behind the Latin scholars' early interest in the astrolabe, it is necessary to take into account the specific nature and epistemological implications of those strategies. In the particular context of medieval mathematics, 'the astrolabe' could be at the same time: (1) a material device to be taken in the hands and used, (2) a geometrical structure to be imagined and manipulated in the

19 For an overview on research results concerning 12th-century translations, see Brentjes (2000), where the problems inherent to the subject are also discussed.

mind to grasp the necessity behind celestial phenomena and (3) an abstract pattern to guide natural philosophical reflections. Not only were these aspects not mutually exclusive, as would appear today, but it was exactly because of their co-existence that the astrolabe was particularly interesting for Latin scholars.

The modes of communication used in medieval mathematics were closely linked to practice (e.g. geometrical drawing, building of sundials, surveying, architecture) and thus could foster interest in those mathematical methods, constructions and devices which could bring about material results, i.e. results that could be perceived by sensory experience. These were, for example, the correct prediction of celestial movements or the numerical estimate of inaccessible heights and distances, as well as of experienced duration. Mathematical structures of this kind could be perceived as a natural and divine 'reason' ('ratio') governing phenomena and accessible to human reason not only through abstract reflection, but also thanks to the construction and use of devices like the astrolabe. In short, my second thesis is that high medieval astrolabe studies could be linked to an image of knowledge in which the material effects of what we today regard as 'applied mathematics' were epistemologically relevant.

This epistemological stance, which is all but obvious, may appear similar to the modern scientific one. However, as I shall argue in 5.5, the differences largely outweigh any similarities that might be present, and a comparison in that direction will be avoided, because it might lead to a misinterpretation of the sources.

In this work, non-written strategies of knowledge transfer and the images of knowledge associated to them play a central role, and I will briefly introduce them in the two following sections.

1.6 STRATEGIES OF KNOWLEDGE TRANSFER: POSITIVE AND NEGATIVE DEFINITIONS

The characterization of a strategy of knowledge transfer as 'non-written' is, at first, purely negative. A positive definition becomes possible only when taking into account the specific context in which any such strategy is employed. Even then, it usually remains difficult to fully grasp how it functions.

Research on literacy and non-literacy has taken its start from the study of oral poetry from ancient, medieval and modern times.[20] Because of this, much attention has been devoted to the opposition between the spoken and written word. One of the main results of these studies has been to underscore that the opposition between 'writing' and 'orality' is itself founded on premises given only in a culture with a high level of literacy. For members of a literate culture like ours it is difficult - if not impossible - to fully grasp how oral modes of communication work, since the relevant experience is limited or lacking. Thus, orality is inevitably de-

20 As a reference on the subject of orality, literacy and their implications I used: Ong (1982), Illich (1993). For a brief overview of the first stepping stones in the study of orality see: Ong (1982) p. 16–30.

fined in a negative way. In his seminal work on orality and literacy, Walter J. Ong remarked that:

> Thinking of oral tradition or a heritage of oral performance, genres and styles as 'oral literature' is rather like thinking of horses as automobiles without wheels. You can, of course, undertake to do this [...] explaining to highly automobilized readers who have never seen a horse all the points of difference in an effort to excise all idea of 'automobile' out of the concept of 'wheelless automobile' so as to invest the term with a purely equine meaning.[21]

Thus, even when dealing with non-written modes of communication, writing may implicitly remain the paradigm of knowledge transfer and storage. The idea itself of a clear-cut distinction between 'knowledge' and its 'storage form', between 'medium' and 'message' is strongly influenced by the paradigm of writing: for example, the function of memory in literate cultures tends to be assimilated to that of a page on which words are registered, whereas memory in oral or semiliterate cultures may have quite a different role, as we shall see later on.[22]

In the case of the Latin medieval astrolabe, the situation is even more complex, since not only the spoken and the written word come into play, but also drawings, geometrical and arithmetical patterns, artefacts and also the procedures to manipulate them.

When exploring the role of these modes of communication in medieval mathematics it is particularly important to distance oneself as far as possible from modern mathematical and scientific ways of reasoning. Because of this, I will make a special effort to introduce the mathematical aspects of the astrolabe without employing modern mathematical formalism and of axiomatic-deductive proofs. Since this approach is crucial for my arguments, I will devote part of chapter 2 to a discussion of prototypes of mathematical thought different from the modern one.

1.7 IMAGES OF KNOWLEDGE AS PREMISE AND SUBJECT OF RESEARCH

My two theses on eleventh-century astrolabe knowledge are formulated separately and will be discussed in different parts of this work, yet they are inextricably related to each other. This is because the modes of communication and storage of knowledge employed in a specific context are never completely independent from views relative to the possible sources, aims and justifications of that knowledge, for example, views on whether knowledge should or should not conform to sensory experience or spatial intuition.

In stating these theses, I take Yehuda Elkana's standpoint that "for each culture, society, group or community" there are "socially determined views on knowledge", ('images of knowledge'), determining such issues as the sources of

21 Ong (1982) p. 12.

22 Ong (1982) p. 57–68. On the medieval 'craft of memory' see below 4.1.2–4.

knowledge, its legitimacy, audience, location on the sacred-secular continuum, or its translatability into statements about nature.[23] I also agree with Elkana in considering Western science as a cultural system and that the difference between it and other modes of thought, for example high medieval natural philosophy, is no 'great divide', but rather a continuum, in which differences can be traced back to different images of knowledge.[24]

The connection between strategies of knowledge transfer and storage, on the one side, and images of knowledge, on the other, is very relevant to my arguments for two reasons: first, because gaining an insight into high medieval methods of knowledge transfer provides a key to understanding the related images of knowledge. Second, because using modern scientific knowledge as a reference point to study medieval mathematics, astronomy and philosophy inevitably brings with it epistemological implications that should be explicitly stated.

Both written formalism and the axiomatic-deductive style of exposition are part and parcel of modern science.[25] Consequently, whatever is 'non-written' also has to be considered as 'non-scientific' in the modern sense and so the gap between medieval natural philosophy and manual crafts, on the one side, and modern science and technology, on the other, may sometimes appear like a 'great divide' only because of the form in which medieval knowledge was produced, expressed and transmitted.

The contribution of non-written and non-verbal strategies of knowledge transfer to medieval philosophy and mathematics is for the modern historian a blind spot in two senses: first, because it cannot be directly grasped through extant sources and, second, because the gap between the modern literary experience and the medieval 'preliteral', 'illiteral', 'semiliteral' or 'quasiliteral' one is at risk of being too easily filled with oversimplifications.[26]

1.8 PLAN OF THE WORK

This study is organized in six chapters, of which the first one has an introductory character. Chapter 2 begins with a discussion of mathematical thought in general, explaining how it can exhibit great variety and be linked to very different modes of communication. After this, one specific kind of mathematical thought is described which is quite different from that linked to modern pure mathematics, and is instead nearer to the medieval mathematical arts (2.1). In section 2.2, the mathematical structures that can be embodied in an astrolabe artefact are introduced, using as far as possible a terminology fitting to that specific kind of

23 Elkana (1981). The issues determined by an image of knowledge, of which I only quoted some, are discussed on p. 15–21.

24 Elkana (1981) p. 6–10 and 29–42.

25 On the 'universality of science' and the problem of cross-cultural comparisons of knowledge production see: Turnbull (2000b).

26 On the interplay between different modes of communication in Latin medieval Europe see 3.1.6–7.

mathematical thought. After that, it will be shown how these structures were embodied in a planispheric astrolabe and in other material tools, and how they could in principle be employed to perform some specific functions (2.3). At the end of the chapter, I point out that it is important to distinguish between functions which an astrolabe artefact could in principle perform, and those for which the device could be successfully used in practice.

Chapter 3 offers a brief introduction to the cultural and historical context of early Latin astrolabe studies (3.1), followed by an overview of the different kinds of sources relevant to the subject: artefacts and drawings (3.2), and written texts (3.3). Since my analysis is for the most part based on manuscript sources (both texts and drawings), I offer a detailed analysis of some results of previous studies of astrolabe manuscripts. These results are the starting point to formulate my thesis that, in the assimilation of astrolabe knowledge in tenth- and eleventh-century Europe, the written word was complemented by other strategies of knowledge transfer (3.4).

In chapter 4 and in chapter 5, I argue in favour of the two main theses of this study, which have been summarily sketched in 1.5. At the beginning of each of these two chapters, the thesis to be discussed is stated in detail, to be followed by arguments supporting it. In chapter 4, I introduce the strategies of knowledge transfer that complemented the written word in medieval mathematics (the 'craft of memory', exercise, notes and drawings) (4.1) and then I offer evidence of the employment of these strategies in the diffusion of astrolabe knowledge. In particular, I will show that memory and drawings played a role in astrolabe studies (4.2 and 4.3), that the occurrence of the same labelled drawing in more than one early astrolabe text can be interpreted as a trace of a purely 'diagrammatic' form of knowledge transmission (4.4), and that in this way knowledge taken from Ptolemy's 'Planisphaerium' spread in Latin Europe (4.5). I will also argue that, when taking into account of the use of such strategies, eleventh-century astrolabe texts and drawings reveal that early Latin astrolabe knowledge was less 'defective' than usually assumed. As an example of this fact, I will show how early astrolabe texts and drawings dealt with the problem of the division of the zodiac circle on the astrolabe (4.6).

In Chapter 5, I will analyse some texts and drawings occurring in the eleventh-century manuscript BnF lat. 7412 (A.27).[27] In studying early Latin astrolabe literature, it is particularly important to discuss the texts not in isolation, but taking into account the structure of the manuscript in which they occur. The reason is that both texts and manuscripts often have a composite character, and it is only by considering the themes common to all the texts and drawings grouped in a single manuscript that the motivations of the authors and readers come to light. My analysis of BnF lat. 7412 (A.27) should offer evidence that the astrolabe was regarded as both a material and an immaterial instrument of rational natural philosophy. Thanks to the astrolabe, as a structure to be understood and as a tool to

27 For bibliographical references on this manuscript see app. A, item A.27.

be used, the human mind could grasp the ‘architectonica ratio’ according to which the Divine Artifex had created the world.

I chose to analyse the manuscript BnF lat. 7412 (A.27) because it is particularly rich in drawings, and also because it contains clear traces of Arabic-Latin contacts. However, the results of this analysis have a more general validity, since most texts and drawings present in BnF lat. 7412 (A.27) also occur in other eleventh-century manuscripts. I shall also attempt to connect the results of my analysis to artefact and pictorial sources, and more specifically to: (a) material evidence on medieval equatorial sundials (5.5.2), (b) some early European astrolabe artefacts (5.6.2) and (c) an eleventh-century illumination representing Abraham holding a compass and an astrolabe in his hands (5.6.3).

Finally, in chapter 6, after having summarized the previous results, I will suggest that, from the twelfth century onward, within the medieval mathematical arts a tension developed between two concurring images of knowledge in which respectively the written word and the experience of construction methods were regarded as the best - or even the only – way to gain knowledge about the ‘ratio’ of the natural world. According to the position taken with respect to this question, the astrolabe could appear as a forbidden tool or as a model to be imitated.