Combinatorial Wheels and Movable Alphabets: from Ramon Llull to Leon Battista Alberti

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Abstract

This article reconstructs an alternative pre-history of late medieval cryptography by situating letter-based cipher devices within a broader tradition of combinatorial wheels, volvelles, and alphabetic diagrams. Starting from Ramon Llull's *Ars Magna*, it analyses how rotating systems of letters functioned as engines of combination designed to generate knowledge, and traces how similar visual–mechanical principles reappeared in divinatory practices (onomancy, *sortes* literature, and divinatory volvelles), ritual magic, and mnemotechnics. The core cryptographic contribution lies in the discussion of alphabetic wheels that no longer encode divine attributes but human secrets, culminating in Leon Battista Alberti's polyalphabetic cipher disk and Giovanni Fontana's hybrid mnemonic–cipher machines. By comparing these devices structurally rather than doctrinally, the article argues that medieval cryptography emerged within a shared manuscript culture of movable alphabets, permutation, and controlled randomness. While direct lines of influence can rarely be demonstrated, the persistence of concentric letter wheels across divination, magic, mnemotechnics, and cryptology suggests a common visual and combinatorial grammar that shaped the earliest mechanical thinking about encryption.

1 Introduction

Circular diagrams were widespread members of the group of visual representation schemes in medieval manuscripts and early modern printed books. They served for classificatory, representational, and pedagogical purposes. They visualized, among others, the universe's structure, the earthy elements' relations, and the analogies between the macrocosm and microcosm. Wheels were also widely used in computus texts; they helped calculate the moveable feasts and other dates.

Within the large family of such circles and wheels, which has deserved serious scholarly attention (Wickersheimer, 1914; Evans, 1980; Friedman, 1985; Murdoch, 1984), this article concentrates on a particular sub-group. This sub-group contains movable concentric wheels on which changeable combinations are represented by letters, and by combining the letters, the user has access to secret knowledge, let it be knowledge about God or knowledge only accessible to a few selected persons. By tracing the history of such wheels, the article seeks to reconstruct the intellectual origins of Leon Battista Alberti's famous cipher disk.

2 Wheels and alphabets

One can undoubtedly trace back the ancestry of circular combinatorics beyond the Catalan philosopher Ramon Llull (ca. 1232-ca. 1315). Yet, his oeuvre was so decisive in this history that later authors rarely failed to note his contribution. He was a Christian mystic receiving a vision, after which he dedicated his missionary activity to convert Jews and Muslims by demonstrating Christian truths.

In his *Ars Magna* (and in many of his other works bearing somewhat similar titles), Llull constructed a sophisticated combinatorial wheel system to lead the user to know God and prove the reality of universal Christian truths. In this system, letters of the alphabet were placed on revolving wheels to denote God's attributes and a wide range of knowledge elements. These letters could be combined with each other and other data to solve problems in all knowledge fields. This was a universalist system.

Ramon Llull's importance could hardly be overestimated. It is well known that he became the target of Jonathan Swift's sarcasm. Swift's thinking "engine" that its inventor intends to enable anyone to "write books in philosophy, poetry, politics, laws, mathematics, and theology,

without the least assistance from genius or study" is a mockery of Llull's system. But this was undeserved. Llull's intellectual influence was so significant that only its 14th-century French history filled five hundred pages (Hillgarth, 1971). And 14th-century France was not the most crucial chapter in the history of Lullism. Instead, its golden age was the late medieval and early modern era when such authors were concerned with the *Ars Magna* as Nicolaus Cusanus, Pico della Mirandola, Agrippa von Nettesheim, Giordano Bruno, Juan de Herrera (the architect of Escorial), Athanasius Kircher, and even René Descartes and Gottfried Wilhelm Leibniz. Frances Yates claimed that "The European search for method . . . began with Ramon Lull" (Yates, 1982: 7), while others see him as a pioneer of computer science. The intellectual movement of encyclopedism exemplified by the Lullist author Johann Heinrich Alsted also deserves to be mentioned.

Applied Lullism had a great tradition in poetry and music. In the 17th century, Georg Philipp Harsdörrfer and Quirinius Kuhlmann experimented with permutational poem writing. In the 20th century, Raymond Queneau published his *Cent mille milliards de poèmes* (Queneau, 1961), which is nothing more than ten sonnets printed on ten consecutive pages, each consisting of fourteen lines. Once the reader cuts the pages along the lines and opens the book at random, each time they open the book, they will read a new combination of lines, giving birth to one of the 100,000,000,000,000 possible sonnets. Parallelly, Johann Philipp Kirnberger experimented with combinatoric composition using random combinations of musical elements in the eighteenth century.

The tradition of pseudo-Lullian alchemy should also be mentioned even though it was entirely fictitious, but the fact that Llull was chosen as an attributed author also shows his fame (Pereira, 1989). While Llull was a common inspiration, what his method really consisted of was a subject of debates and reconstructions. Beyond doubt, his *Ars Magna* was meant as a thinking machine, a debating tool to prove knowledge claims and generate new ideas. By combining religious and philosophical attributes selected from a fixed set of preliminary concepts and represented on rotating and concentrically arranged circles, the conclusions were meant to be automatically deducted. His A figure listed God's attributes (in Llull's word: dignities): Goodness, Greatness, Eternity, Power, Wisdom, Will, Virtue, Truth, and Glory, all of which he meant as commonly acceptable categories in each monotheistic religion (Figure 1). His T figure, another sophisticated circle, represented the so-called relative principles, including Majority, Minority, Equality, Concordance, etc. The 3rd figure, a series of rubrics arranged triangularly, listed 36 possible two-letter combinations of the dignities and the relative principles taken from the two previous figures. The system was flexible: the double letters could signify principles from both the first and the second figure, such as Goodness is great, Goodness is eternal, etc. The real thinking machine was the next figure, three movable concentric wheels, each representing nine letters of the alphabet, generating all the possible 3-digit combinations of these letters.

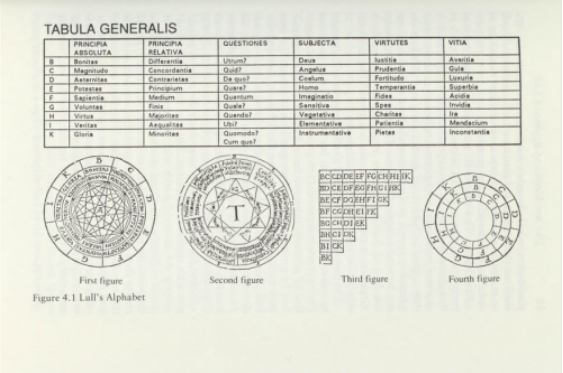

Figure 1. Llull's dignities and four figures

Another figure listed the same combinations in a tabular arrangement with a T inserted among the three letters, thus rendering BCD as BCTB, BCTC, and so on. Here T merely marks that the preceding letters belong to the first, and the following letters to the second figure. Altogether 1,680 possibilities appear here, many of which are, of course, repeated.

Once the user has a religious or philosophical doubt, they are to translate his question into the language of the Ars. Such a question is, for example, BDTB, meaning: *Utrum in aeternitate sit differentia*? Is there difference in eternity? Another question is BDTD. *Utrum inter divinam bonitatem sit contrarietas*? Is there contrast within divine Goodness?

While Llull was confident that his method could interpret and answer questions, his

followers were often uncertain about how to translate a scientific, logical, or theological question into the language of the *Ars* and how it should be answered. Do the combinations really generate new thoughts? Do they really provide answers? Or do they rather facilitate thinking, and the *Ars* is rather a mnemotechnic tool? Can it be rather used as a rhetorical aid? Agrippa, Bruno, and Alsted aimed to explain these issues in their lengthy commentaries to the *Ars*.

3 Sources of the *Ars Magna*

Before turning to the impact of the Lullian thought, it is worth reviewing shortly what can be known about its sources. That the Kabbalah might have played some role in the generation of the idea of combining alphabets, always sounded plausible. The golden age of this form of Jewish mysticism (including the Zohar's writing by Mose ben Sém Tóv and Abraham Abulafia's ecstatic Kaballah) took place close to Llull, both temporally and geographically. Frances Yates and Gershom Scholem argued that Llull's *Ars* could be traced back to the ecstatic Kabbalah of Abraham Abulafia and the Kabbalah of the Sefirot. There was even a work attributed to Lull entitled *De auditu cabbalistico*, which however turned out to be a forgery. It was written by a certain Pietro Mainardi (1456-1529), who tried to confirm the Renaissance philosopher Pico della Mirandola's theory on the relations of Lull and the Kabbalah.

The starting point of Moshe Idel, who found decisive evidence for the link between the two areas in 1988, was also a similar claim by Pico della Mirandola (Idel, 1988). However, he argued that it was not so much the Neoplatonic emanations of the Sepher Yetsira, but rather a particular type of Kabbalah, close to but not identical to Abraham Abulafia's method. This existed in the 13th century, and Pico perceived it as especially similar to the art of Ramon Lull. A close reading of Pico reveals that he may have thought of these combinations and revolutions of the alphabet when seeing similarities between the *Ars Magna* and the Kabbalah. Idel quotes a 13th-century commentary on the liturgy, an anonymous work which had not attracted the attention of Kabbalah scholars. This commentary contains a figure that particularly corresponds to Pico's reference to the "*revolutio alphabetorum*" since the concentric circles were intended to revolve to generate all possible combinations of the letters of the alphabet. Another figure, a triangular one, is strikingly close to Llull's third figure. And the ideas combined by the letters were indeed not very far from those of Llull, as the letter alef symbolizes Primeval Light, God, Lord, One, Truth–quite similarly to the references of Llull's letter A. Further research since then confirmed Idel's hypothesis that Pico must have had access to the Latin translation of this Cabbalistic work: the *Commentum Sefer Iesire* was part of his library, and he plausibly supposed that it could have been a crucial source for Llull (Idel, 2007: 280; Buzzetta, 2012; Mantovani, 2018).

4 Divinatory wheels

The following part of the article will review three interconnected fields, where circles and wheels play a central role. A common feature is that these fields–just like Llull's method–were concerned about godly privileges, but in a different way than the Catalan philosopher's work. And on at least one of them, Lullism exercised an implicit (never really proved and rarely pointed out) but significant impact.

The first is the general application of circular diagrams in a particular type of divinatory text, the so-called "Sphere of life and death". This was a simple practice of onomancy, name magic, where the user might learn about a given illness's outcome. As will be argued below, despite the seeming similarities, there is no accurate analogy with Llull here, as wheels are not capable of turning, there is no randomization procedure involved, not even letter (or other) combinations, and there is no alphabet applied. Last, the earliest Spheres of life and death considerably predate Lull's life.

The second example, however, is closer to the mechanism of the *Ars Magna.* We will analyze the mechanism of randomization devices in the so-called *Sortes* literature, another category of divination. This practice aims at reading signs that denote specific details of the knowledge only accessible to God. We have fixed combinations here, a specific randomization procedure, and numbers and letters are involved, just as in the *Ars Magna*.

Third and finally, we will see the volvelles, the movable disks, that were not only tools of the calendar (as most readers of medieval codices certainly know them) but also of divination. Here combinations of letters correspond to specific

parts of divine knowledge, which are randomized with dynamic turning methods using numbers and letters.

All three of these fall within the category of divination, a general term denoting the procedure of foretelling the future and discovering hidden knowledge through the interpretation of signs (Láng, 2008; Burnett, 1977; Burnett, 1998-99; Skeat, 1954; Savorelli, 1959). These signs might be written somewhere in the natural world (on various body zones such as in chiromancy), or they might be generated artificially by the users themselves, as in the so-called geomantic practices. Halfway between the natural and the artificially generated signs, there is a specific form of divination that operates with the numerical value of human names, called onomancy. A common–and easily recognizable–feature of divinatory texts is the ample use of diagrams, circular, tabular, quadrangular, and some of these combinatoric.

Strictly speaking, divination is not magic. Even though it shares the fate of being prohibited by theologians, the reasons for that were different. Acquiring foreknowledge of the future by human procedures–the theologians argued–is an abuse of God's privilege and contradicts the concepts of human free will and divine omnipotence. The users of divination, even when they are unaware of that, and even when this is not obvious in the seemingly non-demonic text, implicitly cooperate with demons. The repeated prohibitions and argumentations based on the demonic nature of this practice were undoubtedly motivated by the fact that palmistry (divination by the signs of the hand), geomancy (using randomly generated dots in the soil, and later on the parchment), scapulimancy (interpretation of the signs occurring in a sheep's shoulder blades), crystallomancy (gazing into crystal balls), catoptromancy (divination employing a mirror) and other similar texts remained popular among medieval readers.

4.1 The Sphere of Life and Death

The Sphere of Pythagoras, sometimes attributed to Apollonius, but most often named the Sphere of life and death is a much more frequent companion of medieval manuscripts than catalog entries suggest (Figure 2). As it is usually not longer than half a page and is often inserted between longer tracts, it does not always get the attention it deserves. This divination method takes the numerical value of the user's name as a starting point, and indicates whether the person inquiring about his fate will die or recover from his illness (Edge, 2015; Wickersheimer, 1914). Numbers are arranged in a circle (or less frequently in a rectangle), where the numerical values of the name of the client can be found. This value is then subjected to a series of mathematical operations, the result of which we should find either in the upper or in the lower hemisphere of the inner part of the circle. If it is in the upper part, the patient will survive; if in the lower, they are to die. Among our three examples, this diagrammatic device of onomancy shows the most minor traces of an analogy with the Lullian impact, as the circles are not turning, there are neither combinations nor permutations in the system, and no randomization takes place apart from the fact that the numerical value of names is substituted.

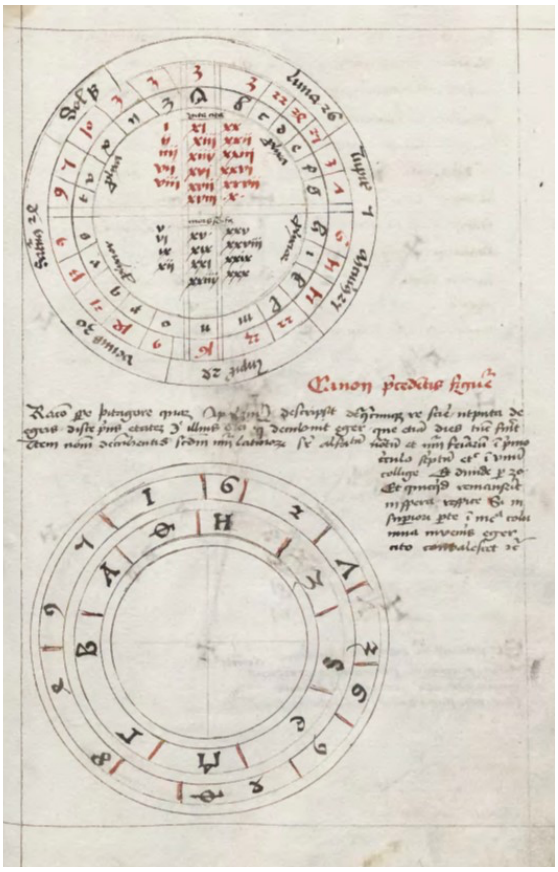

Figure 2. Biblioteka Jagiellonska (BJ), MS 793, f. 87r above: Sphere of life and death, below: a circular figure of unknown function

4.2 The *Sortes* literature

Sortes literature is a particular subclass of divination. The sorsbooks (in other words: books

of fate) are usually (but not always) shorter, and they are also usually (but not always) less sophisticated than other divinatory texts. Many of them bear a close resemblance to geomancy; that is, they take patterns of dots as a starting point, and then they go through a complicated procedure, a set of tables and circular diagrams, to arrive at an answer to the question of the user. Some texts are anonymous, and others are attributed to Albedatus, Socrates Basileus, Pythagoras, King Amalricus, and other real or imaginary authors (Burnett, 1996; Savorelli, 1959).

Sorsbooks–in contrast to most of the standard texts–are not supposed to be read linearly: readers (more precisely: users) go through them intermittently and in sections, and random methods define the direction of this non-linear reading. They are also visually organized, and thus they are easily recognized in the manuscripts by the often colorful tables and wheels they contain (Heiles 2018a, Láng 2008).

These late antique and early medieval texts, to which the 11th century added many translations from Arabic, were relatively early translated to the vernacular (e.g., German), which fact testifies that they were seen as helpful tools that the medieval people used on an everyday basis (Heiles, 2018b). While books of fates were usually listed in theologians' discourses on superstitions as forbidden and sanctioned by the Church (Johannes Hartlieb and Thomas Aquinas, among others, considered the act of reading them as a violation of the First Commandment), the average users, in contrast, may have rather perceived it as an innocent game that helped them orient in everyday life, and copied and used them extensively.

Books of fate give the impression of being combinatorial systems and able to provide a large set of answers to the questions of the user. Still, in reality they are, as T. C. Skeat, their early historian put it "systems comprising a fixed table of specific questions with a fixed number of alternative answers to each question" (Skeat, 1954). The primary means of the procedure were the full-page tables, but an important–though not necessary–accessory of books of fate were also the large, often multicolor, concentric diagrams that may remind the reader of Llull's figures. However, most of them were not composed of movable wheels but were merely circular diagrams used as static tables indicating the correspondences of numbers and geomantic figures. They play the same role in the procedure as the tables, the digits and letters appearing on them refer to divine knowledge (foreknowledge of the future, after all), but these wheels do not provide new permutational possibilities. Such a diagram can be found in Biblioteka Jagiellonska MS 793, f. 67r (shown and analyzed in Láng 2008: 86, 123-143), where it follows and complements a *Sortilegium Geomanticum* text (Figure 3).

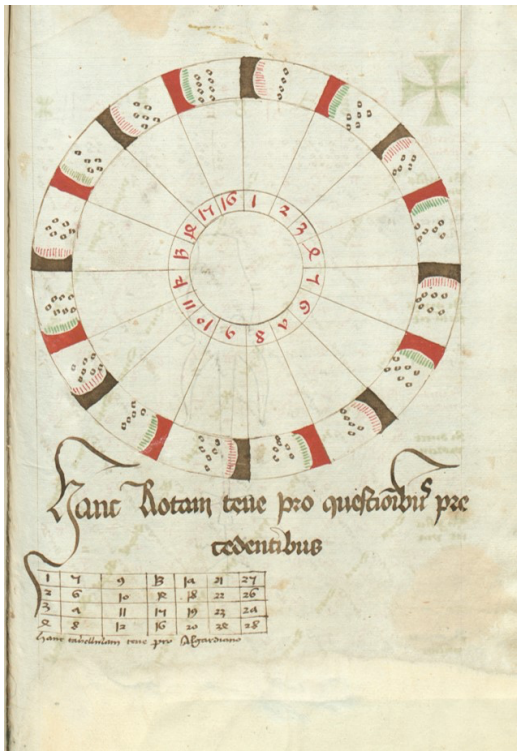

Figure 3. Biblioteka Jagiellonska (BJ), MS 793, f. 67r: Geomantic divination

4.3 Divinatory volvelles

Volvelles are best known as astronomical tools. They are concentric parchment (or paper) wheels constructed of several overlapping layers. With the help of a short rope or pin connecting them in the center, the middle one(s) was (were) able to turn independently around its central axis. Volvelles helped form new and new permutations of the numbers and letters written on the wheels. They were particularly useful for astronomical purposes and in computations of the calendar. As the volvelles could rotate, the reader did not need to turn the whole book as in the case of the traditional non-moveable figures in computus texts (Heiles, 2018a: 56; Crupi, 2016). The beginning of the history of

astronomical volvelles slightly predate Llull's circular figures, Matthew of Paris (1200-1259) already used them (Connolly, 2009; Gingerich, 1994; Crupi, 2019).

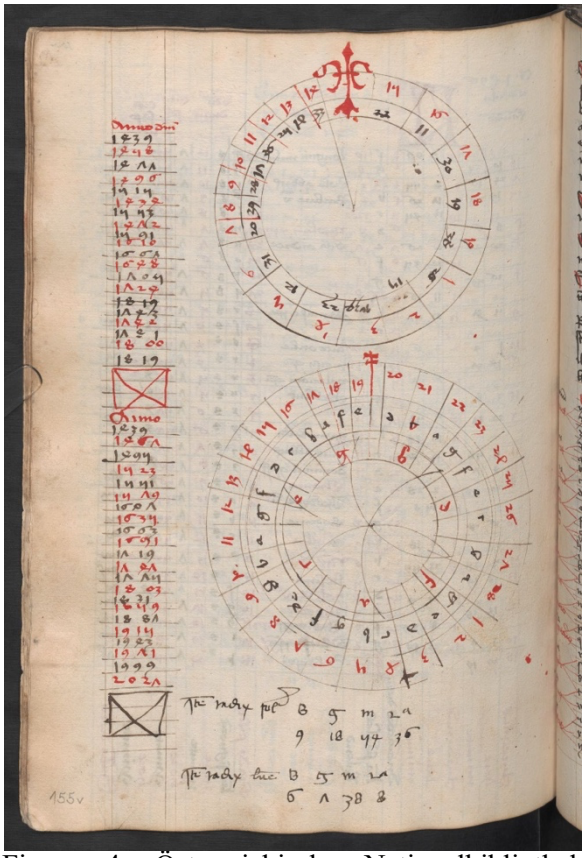

Figure 4. Österreichische Nationalbibliothek (ÖNB), 5327, f. 155v.

Such wheels with movable parts were equally prevalent in divinatory texts as dynamic randomization devices. In some cases, they are integral parts of a given sortes text. In an extensive multicolor divinatory handbook, the MS BJ 793 (Láng, 2008), for example, such a volvelle (BJ 793, f. 87v) belongs to the *Sortes regis Amalrici* text following it in the codex, and it provides the number necessary for the consultation of the *sortes*. Another example is in ÖNB 5327, f. 155v (Figure 4), where it is part of a sortes text, the "Prenostica Socratis Basile" (f. 155v–175r).[1] The oldest exemplar of this text can be found in Oxford, Bodleian Library, MS Ashmole 304 (Heiles personal consultation, see also Guardo, 2015; Iafrate, 2015). An interesting sortes volvelle can be found in Wolfenbüttel, Herzog August Bibliothek, Cod. 75.10 Aug. 2°, where a short alphabet is written along its arch. Elizabeth Wade explicitly names the Lullain tradition as a possible inspiration source when presenting this source (Wade, 1998). However, like the earliest astronomical volvelles, the earliest divinatory volvelles predate Lull. The "Presnostica Socratis Basile" in the Arabic version first appeared before 1250 (MS. Bodleian Library, Ashmole 304) and in the Christian version at the end of the 13th century (British Library, MS Add. 15236) (Marco Heiles, personal communication).

Other volvelles serving for divinatory purposes can be found in several medieval manuscripts; they were not extremely widespread nor infrequent.[2]

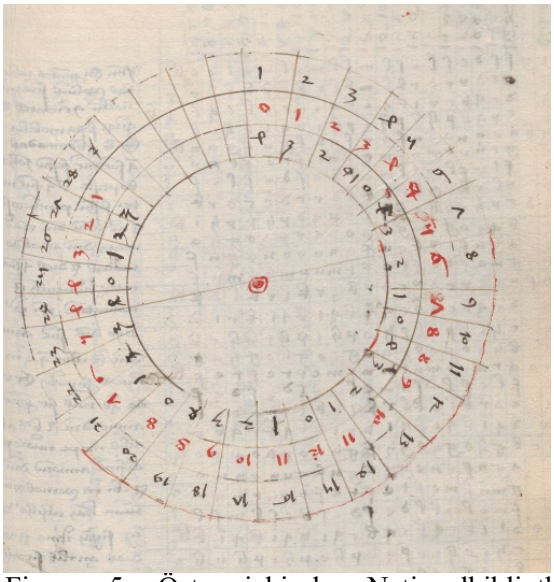

Figure 5. Österreichische Nationalbibliothek (ÖNB), 5327, f. 158

In many cases, the wheels–with or without moving accessories–are inserted between the *sortes* texts, but they are not strictly speaking parts of the text tradition. However, one may plausibly suppose that they were meant to complement the divinatory method, served either as a kind of illustration of the text or a mnemotechnic device serving to recall the method's details or as a tool of the randomization procedure. Even when the construction is not

[1] https://viewer.onb.ac.at/10027927/ (accessed: 2026.04.26).

[2] Berlin, Staatsbibl., mgf 642, f. 1r/v (pointer is missing); Heidelberg, Universitätsbibl., Cpg 552, front cover; London, British Libr., MS Add. 25435, front cover; München, Staatsbibl., Cgm 472; front cover (pointer missing), Olmütz/Olomouc, Heimatkundliches Museum, K-14905, front cover (Heiles, personal consultation).

movable, these drawings depict a real movable volvelle (Figure 5).

5 Ritual magic

Texts of ritual magic belong to an increasingly researched branch of medieval and early modern intellectual magic, the common feature of which is invocation of spirits of malign or benign nature. Users of this type of magic address the spiritual–demonic or angelic–powers through prayers and conjurations (Fanger, 1998; Fanger, 2012). Due to its apparent similarity with the Church's rituals, the expression "magic in a Christian framework" was also introduced as a helpful and rather precise description of ritual magic (Page, 2016). The best-known texts of ritual magic are the *Ars Notoria* (Boudet 2000, Veronese, 2007), the *Liber visionum* by John of Morigny (Fanger, 2015), the *Liber iuratus Honorii* (*Sworn Book of Honorius*) (Boudet, 2006), all of which survived in several copies and testify to a significant intellectual interest towards this kind of magic. Explicitly demonic types of handbooks, such as the Munich necromantic handbook published by Richard Kieckhefer (1997), much more rarely survived but still existed.

5.1 The book of the runes

Within this category, we find a text that only survived in four copies, the *Liber runarum* (Lucentini, 2001). It is specific because it mixes ritual magic elements, Scandinavian runes, and the talismans of astral magic. This fairly short text explains how to write the names of the spiritual forces of certain planets in a cryptic alphabet, the letters of which are called *runae*. The names constructed from these recognizable runes carry magical power. The text delves into the field of astral magic and gives detailed directions on how to inscribe the angelic names on specific metals and stones attributed to every planet. The runes corresponding to the planets and angels appear next to the text's main body. The reason why this text is included in the present typology of circular diagrams is that in one of the surviving copies held presently in the Biblioteca Apostolica Vaticana (BAV), the runes also appear on a *Rota runarum*, which stands separately, one hundred and fifty folios before the main text (Pal. lat. 1439 f. 348r-v: text; and 199r: rota, Figure 6). Apparently, in the unknown scribe's eyes, the wheel seemed to be an adequate representative form to represent the correspondences of letters and divine entities, the spirits.

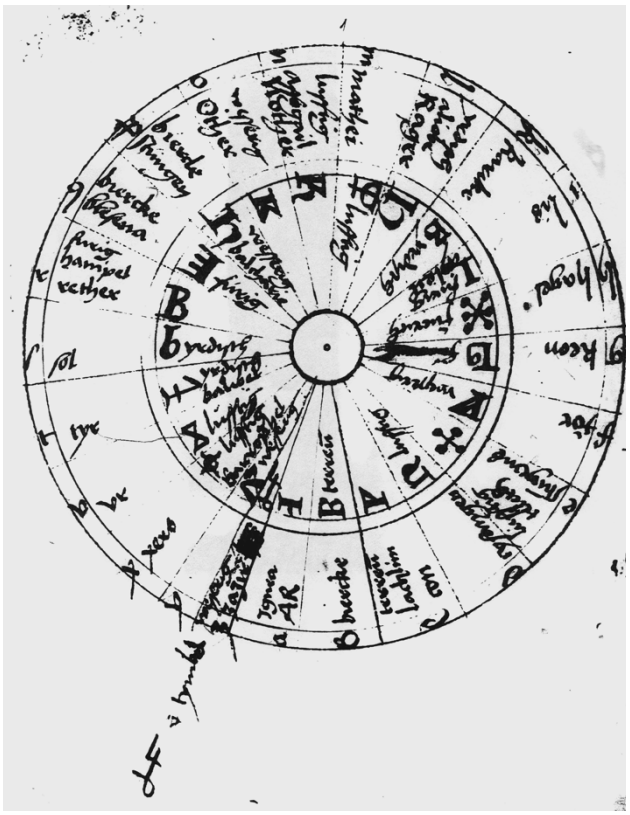

Figure 6. Biblioteca apostolica vaticana (BAV), MS Pal. lat 1439, f. 199r. *Rota runarum*

5.2 The Mirror of Floron

Another circular form representing spirit names and corresponding characters is the Mirror of Floron which survived both as a real object and in medieval textual depictions (Kieckhefer, 1997: 104-106; magical mirror, Mathematisch-Physicalischer Salon in Dresden, Figure 7). Here the–otherwise deliberately ambiguous–spirits can be rather called demons: texts on the Floron mirror appear in a demonic context. According to the description and the actual object, particular figures appear on a metal disc in a circular arrangement alongside names that seem to refer to the spirits. "Floron" is usually written in the inner circle of the object. The Munich necromantic handbook specifies that the mirror is to be prepared in the name of the spirit Floron according to detailed rituals involving suffumigations, clean clothes, and virgin boys. If appropriately prepared, an armed knight sitting on a horse will appear in the mirror, and then the master might ask him about the past, the present, and the future. Although the secret characters and the spirit names of the Dresden metal disc

are not identical to those given by the Munich manuscript, their number is the same (ten), and the arrangement of the elements and placement of the inscription "Floron" are analogous. This is one more example–besides the *Rota runarum*– where divine entities (demons, this time) are signified by letters or other characters, and represented in a circular form.

Figure 7. Magical mirror, Mathematisch-Physicalischer Salon in Dresden

6 The Cryptographic Application of Combinatoric Wheels

While they do not combine divine attributes or pieces of superhuman knowledge, the following two examples are nonetheless relevant for the present history, because of the combinatoric element, the circular arrangement of the letters, and the Lullian spirit are apparent in them. It is no surprise that historiography discussed a possible Lullian impact in the case of both of them. The following wheels combine letters that denote other letters in cryptography and pieces of earthly knowledge in mnemotechnics.

6.1 Leon Battista Alberti's cipher disk

Leon Battista Alberti (1404-1472) is not only famous as a Renaissance architect (Grafton, 2000) but also as the inventor of an early version of a cryptographic method that seemed unbreakable for centuries: the polyalphabetic cipher. In this encryption method the cipher alphabet (i.e., the alphabet, the letters of which substitute the letters of the readable text) can be changed. In other words, letters of the plaintext are not replaced by letters from one single code alphabet, but several ones in order to increase the safety of the ciphers.

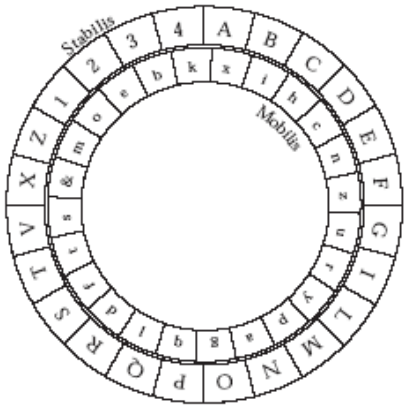

Figure 8. Alberti's moving circles, *De Componendis Cyfris*, 1446

When we start working with the plaintext with the help of Alberti's invention, we fix the inner ring and write down the lowercase letter that is opposite B. Then we start encrypting and do not rotate the ring until we wish to change code alphabets. However, if we do, we insert one of the four numerals 1, 2, 3, or 4 in the plaintext and the letter corresponding to these in the ciphertext. Then we rotate the rings so this lower-case letter is opposite B and continue the process until we change the code alphabet again. The method's strength lies in the fact that the code alphabet is constantly changed, and how it is changed has been long seen unpredictable.

With Alberti's method, one can shift the cipher alphabet after enciphering every letter of the plaintext, even though the Italian master designed his method so that alphabets are shifted less frequently, and not necessarily periodically. Periodicity was introduced by later authors, as a result of which, after a given number of such shifts, the user gets back to the already used

alphabets. This feature eventually led to the decryption of the polyalphabetic method, but only in the 19th century. For four hundred years, no one managed to break this method, true, it was rarely used for three centuries after its invention because it was thought to be too complicated and somewhat impractical. The practicability of such ciphers depends on the combinatoric "machine" that makes enciphering possible, the most famous of which was the enigma in World War II, and the first of which was Alberti's concentric circle-system (Alberti, 1906, 1997).

The movable disks represent the letters of the alphabet quite similarly to Llull's fourth figure. The functional similarity is so striking that David Kahn, historian of European cryptography, proposed the medieval Catalan mystic as a source of inspiration. "Although it cannot be proved that Lull's device inspired Alberti, there are grounds for suspecting that it did" (Kahn, 1980: 124). I find Kahn's suggestion convincing, but I would propose a more indirect way of impact: the Lullian circular diagrams may have influenced Alberti through the divinatory volvelles so widespread in the manuscript tradition (see above) and the mnemotechnic works of Giovanni Fontana so close to Alberti (see below). Alberti probably got acquainted with Fontana's work when they were simultaneously living in Northern Italy (Grafton, 2000: 84).

6.2 Giovanni Fontana's Mnemotechnics

Among the many exciting multitalented Renaissance engineers, Giovanni Fontana (c.1395?-1455) was one of the most exciting and multitalented ones, and compared to Leonardo da Vinci, and Leon Battista Alberti, he remained a relatively little-studied subject until recently (Battisti and Saccaro Battisti, 1984; Kranz, 2009). Fontana studied as a physician, and became a university professor and a dean, but left the academic career and served as a practicing doctor. His oeuvre forms an early chapter of many different histories: that of military engineering, that of mnemotechnics, and that of cryptology.

In his *Tractatus de instrumentis artis memorie,* mnemotechnics and cryptology are side-by-side. The reader is introduced into the functioning of memory devices suitable for storing and combining pieces of information and into enciphering methods convenient for secrecy practices. Bound together, under the title *Opera iuvenalia de rotis horologiis et mensuris* we find four Latin works on mechanical devices, clockworks, automates and rockets. The *Liber instrumentorum iconographicus,* the author's most famous book, describes complex military machinery in which illustrations play an increasingly important role. And *Secretum de thesauro experimentorum ymaginationis hominum* is entirely written on mnemotechnic devices. This last work constitutes a chapter in the surprisingly rich history of late medieval North Italian treatises on memory. Fontana was not without predecessors or companions; mnemotechnics was a major preoccupation in a period when the ability to store and recall information was crucial and when the automatization of these activities was only a futuristic dream. In several cases, Fontana's texts were written almost entirely in a simple substitution cipher using graphic symbols.

Both the *Secretum de thesauro* and the *Liber instrumentorum* are richly illustrated, text and image are closely related in them. Many of these illustrations are depictions of memory instruments that help memorize words. Some of them are mobile mnemotechnic machines. However, the present reader has difficulties imagining how they work as memorizing tools. It is much easier to imagine many of them as machines of encryption. This is particularly true for two figures. One is called *Speculum* (Kranz 2016, 98-99), which is composed of five concentric wheels meant to be movable by the author, on each of which the letters of the alphabet are listed, and that reminds us of Alberti's ciphering machine (Figure 9). And the second is the object called *Columna* (Kranz, 2016: 109), which looks like a famous cryptology device, the cryptex made of movable wheel containing the alphabet (Figure 10). And this is precisely the argument of the editor of the texts, Horst Kranz, (Kranz and Oberschelp, 2009). While Fontana does not refer to the possibility of using his machines for encryption, and apart from the fact that the book is written in cipher, there is very little reference to cryptology, these machines can be conveniently used for encryption, and for a most advanced type, the so-called polyalphabetic method, that was first documented a generation later, by Alberti, and then decades later by Johannes Trithemius (1462-1516) and Blaise Vigenère

(1523-1596) (Bayerl, 2024). Looking at the memory devices, the editors are certainly right that the early history of polyalphabetic cryptology still needs to be explored and that *ars memoriae* and the crypto-machines have a more intimate relationship than one would think.

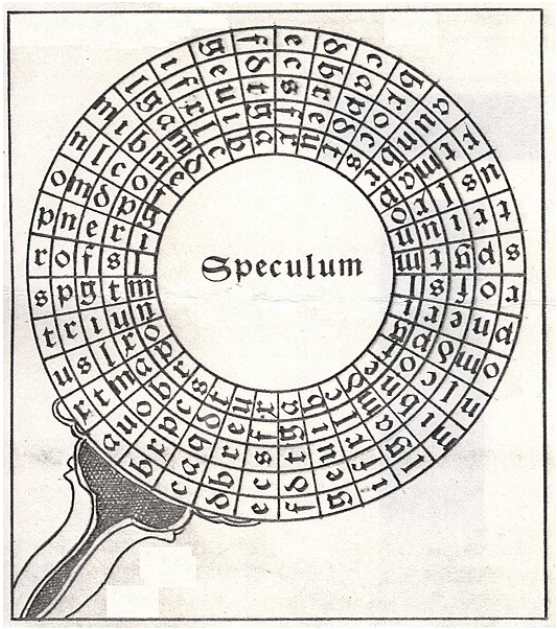

Figure 9. Giovanni Fontana, *Speculum*

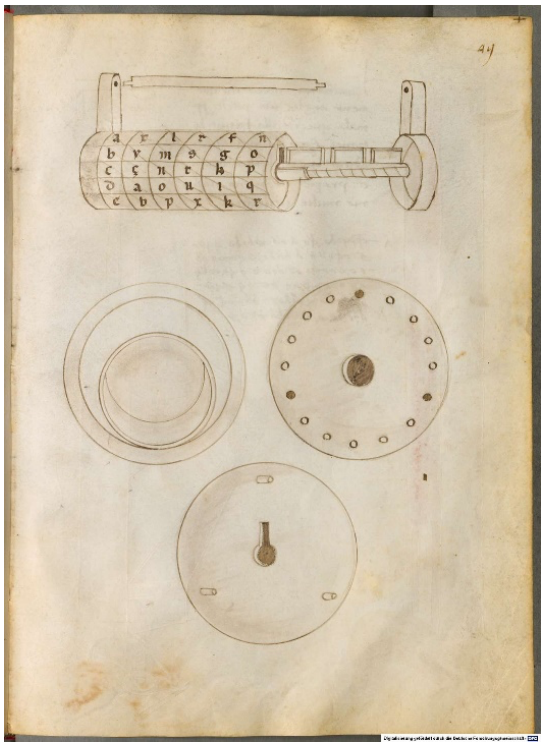

Figure 10. Giovanni Fontana, *Columna*

How far are these wheels analogous with the Lullian Ars? The disks are movable, and they contain letter combinations. However, what the letters refer to, are not divine but human secrets.

Conclusions

This article provided a catalog of medieval concentric wheel systems with the help of which letters of the alphabet or other characters could be combined in order to reveal divine or human secrets. Pieces of this confinable genre within the medieval codex illustrations might predate or follow the famous *Ars Magna* of Ramon Llull, some might have exercised an impact on his system, others were probably influenced by his heritage. Regardless of whether the letters signified divine traits, parts of divine knowledge, spiritual entities, human knowledge claims, or secret messages, the structural and visual similarities are striking. No tangible connection can be pointed out between Llull and the divinatory texts, nor can it be documented on textual grounds between Alberti's concentric wheels, Fontana's mnemotechnic devices and the Catalan philosopher's *Ars*. The links suggested by Elisabeth Wade, David Kahn and myself are just speculations.

In a particularly rich article, Gianfranco Crupi reconstructs the historical development of volvelles from the thirteenth to the seventeenth centuries and argues that, from Ramon Lull's combinatorial logic to their widespread use in astronomy, navigation, cryptography, and divination, volvelles functioned as material and cognitive devices that integrated manual manipulation with intellectual processes. While not asserting direct causal relationships, the article presents a tradition in which cross-fertilisation appears probable (Crupi 2019).

It can be argued that these figures belong to the same subclass of rotatable wheels in the Middle Ages, and also, that these visual representations might have influenced one another in the manuscript tradition. Llull was particularly influential through his own works and also through the Pseudo-Lullian alchemical corpus; thus it is highly possible that scribes of divinatory, magical, cryptologic, and mnemotechnic were influenced by his tradition, and that, in turn, they influenced each other. Astronomical, Kabbalistic, Lullian, divinatory and cryptographic volvelles might have mutually fertilized each other, while all the medieval authors lived in the middle of a much larger, in fact, cosmic volvelle: the universe.

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