THOMAS HARRIOT ON COMBINATIONS

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ABSTRACT. — Thomas Harriot (1560?–1621) is known today as an innovative mathematician and a natural philosopher with wide intellectual horizons. This paper will look at his interest in combinations in three contexts: language (anagrams), natural philosophy (the question of atomism) and mathematics (number theory), in order to assess where to situate him in respect of three current historiographical debates: 1) whether there existed in the late Renaissance two opposed mentalities, the occult and the scientific; 2) whether all mathematical science was clearly demarcated from natural philosophy at that time; and 3) whether all enquiry into nature (including that pursued through mathematics) entailed a consideration of the attributes of God Himself. The paper argues from the case of Harriot that as a man capable of highly abstract mathematical thought, his work on combinations of all kinds is scarcely marked at all by the social, political and religious context from which it arose (which is not to say that his work on alchemy or on practical mathematics is unmarked in the same way), and that he, like many of his contemporaries, was capable of compartmentalising his mind, and of according different modes and degrees of intellectual commitment to different areas of his mental universe.

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Résumé (Les combinaisons chez Thomas Harriot). — Thomas Harriot (1560?–1621) est célèbre pour ses travaux novateurs tant dans le domaine de l'algèbre que de la philosophie naturelle. Dans cet article, on se propose d'examiner sa pensée sur les combinaisons dans trois contextes ; celui du langage (les anagrammes), celui de la philosophie naturelle (les atomes) et celui de la théorie des nombres. On considérera cette pensée dans le cadre de trois débats historiographiques, à savoir : 1) si ou non, il existe deux mentalités opposées au seuil de la modernité, à savoir l'occulte et la scientifique ; 2) si à cette époque les « sciences mathématiques » sont distinctes de la philosophie naturelle ; et 3) si cette philosophie comprend, au-delà d'une étude de la nature elle-même, celle des attributs du créateur de la nature. Du cas Harriot, on concluera que ce mathématicien est capable d'une pensée mathématique fort abstraite, libérée de l'idéologie sociale, religieuse et politique de son temps (sans que ce contrat s'étende à ce qu'il a à dire sur l'alchimie, ou sur les problèmes des mathématiques appliquées, comme celui de la longitude), et qu'il est capable, comme bien de ses contemporains, de compartimenter son esprit de façon à s'engager mentalement selon des modes fort divers dans les différents domaines de son univers intellectuel.

1. INTRODUCTION

Thomas Harriot (1560–1621) is known today as an elegant and innovative mathematician, a natural philosopher and astronomer, a traveller to the New World, on which he published, and a member of the Northumberland circle with wide intellectual horizons. This paper will look at his interest in combinations in three contexts: language, natural philosophy (the question of atomism) and mathematics, in order to assess where to situate him in the range of occult and scientific mentalities associated with the late Renaissance. At his death in 1621, he left many pages of mathematical workings and drafts, but relatively little discursive prose; this fact has been linked to the privacy with which he surrounded his work, and his notorious reluctance to publish his discoveries.[1] Hilary Gatti has even gone so far as to suggest that his use of symbols and diagrams in his manuscripts reflects a "distrust of words" [Gatti 1999, p. 66]. Whether or not this is the case, it means that much has to be made out of a few not always legible gnomic sentences; these are often subject to almost contradictory readings according to the context in which they are placed.

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[1] See Sir Thomas Lower's letter to Harriot dated 6 February 1609/10, quoted by Batho [1999b, p. 286]. I should like to thank Juliet Fleming, Ruedi Imbach, Sachiko Kusukawa, Isabelle Pantin and Jackie Stedall for their bibliographical help.

I shall give one example of this here, as a way of introducing the interpretative problems which this paper will address: it is a passage from the letter Harriot wrote in 1615 to his physician Théodore Turquet de Mayerne (1573–1655). After a recital of his symptoms (consistent with a cancer induced by smoking, which he had acquired as a habit while in the New World), he writes:

> "Think of me as your most affectionate friend. Your interests therefore are as mine. My health will be your glory too, but through the Omnipotent who is the author of all good things. As I have said from time to time, I believe in three things. I believe in one almighty God; I believe in the art of medicine as ordained by Him; I believe in the physician as His minister. My faith is sure, my hope is firm. I wait patiently for everything, in its own time, according to His providence. Let us act resolutely, battle strenuously, and we shall win. The world's glory passes away. Everything will pass away; we shall pass, you will pass, they will pass. I wrote to your apothecary for the pills. Perhaps I will receive one dose before Advent".[2]

As Hugh Trevor Roper [1999] notes, this is a strange passage to find in a letter to one's physician, and it invites comment. Mayerne, as is well known, was a Montpellier-trained doctor who was sympathetic to Paracelsian ideas. Two contexts occur to me which might throw some light on the sense to be attributed to the passage. The former is the following statement by Jean Hucher (d. 1603), Mayerne's colleague when he was at Montpellier, that:

> "The most high and great God, the lord of all of nature, freely administers, impels, hastens, delays, hinders or altogether prohibits the forces, actions and effects of nature [...] therefore Aristotle's disputations about chance and fortune as two unknown efficient causes are rightly laughed off the stage by pious men, for God is alone the author of all spontaneous events and their contingency".[3]

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[2] British Library (hereafter BL) Add. MS 6789, f. 446v (letter to Théodore Turquet de Mayerne, 1615): "*cogita de me tanquam tui amantissimo. Tua res igitur* (Scott Mandelbrote [1999, p. 247], reads "*auspicat*") *sicut et mea. Mea salus erit etiam tua gloria sed per omnipotentem qui omnium bonorum est author. Ut aliquando Dixi, tripliciter credo. Credo in Deum omnipotentem Credo medicinam ab illo ordinatam, Credo medico tanquam illius ministro. Fides mea certa spes firma. Expecto tamen cum patienta omnia suis temporibus* [Harriot adds "*suo tempore*" as an alternative above these words] *secundum illius providentiam. Agendum serio, pugnandum strenue, sed eius nomine, et vincemus. Sic transit gloria mundi. Omnia transibunt, nos ibimus, ibitis, ibunt. Scripsi ad tuum pharmocopaeum pro pillulis fortasse unam dosim capiam ante adventum.*" On Turquet de Mayerne, see [Nance 2001].

[3] Hucher [1602, sig. ** 6v]: "*Deus optimus maximus totius naturae dominus, vires actiones et effectus eiusdem libere administrat, impellit, urget, tardat, interpellet aut omnino prohibet... Merito igitur Aristotelis de casu et fortuna tanquam effectricibus duabus causis ignotis, disputationes a piis*

This might suggest that the Harriot, who was "waiting patiently for everything, in its own time, according to God's providence", concurred in a Montpellerian belief that the doctors are no more than vehicles through whom divine will is implemented (a view consistent with Paracelsianism, and implicitly hostile to the claims of rational Galenic medicine).[4]

The second context comes from a book published in the same year as Harriot's letter by the physician and proto-chemist Andreas Libavius (1550–1616) entitled the *Examination of the new [*Paracelsian*] philosophy, which is opposed to the old and seeks to abrogate it*; Harriot owned at least one of Libavius's other works (a pamphlet against the Rosicrucians), and it is possible that he knew this one. In it, Libavius argues that to philosophize in a Christian way is to follow Aristotle, not magic, cabbalah, alchemy, astrology, chiromancy, or, of course Paracelsus; that conventional Aristotelianism represents the order of God; and that rational medicine (as opposed to Paracelsianism), which looks upon itself as the "minister and corrector of nature", is a gift of God.[5] The similarity in terms and sentiment with Harriot's letter is pretty clear, but its implication is the opposite of the meaning which can be derived from a comparison with the Hucher text. I do not doubt that Harriot was writing to please Mayerne, but it is difficult to know what he was trying to say: the first of my contexts would suggest that Harriot was recognizing the Paracelsian mission of his physician as a passive channel of God's grace, and the second that he was stressing his active ministry. I shall return to this choice of interpretations at the end of this paper, in the context of Harriot's religious beliefs. Before that, I shall place some other enigmatic or elliptical of Harriot's comments in contexts: mainly drawn from continental writers quoted by Harriot himself, such as the mathematician Michael Stifel (1487–1567) and the polymath Girolamo Cardano (1501–1576).

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viris exploduntur; cum omnium spontaneorum casuum solus Deus sit author, eorumque contingentiae." For Melanchthon's view of this problem, see [Kusukawa 1993].

[4] See [Maclean 2001, pp. 87–90].

[5] Libavius [1615, p. 298]: "*ordo Dei est Philosophia quae docetur in Gymnasiis, Scholis, et Academiis, ut et Theologia syncera declarata Augustanae Confessione. Dei donum est medicina dogmatica et aliae artes scientiaeque.*" On Harriot's possession of another of Libavius's works, see [Mandelbrote 1999, p. 252]. For the views of a Paracelsian, see [Kahn 2004].

2. HISTORIOGRAPHICAL DEBATES

Three recent debates in the historiography of science are relevant to this article. The first of these concerns the thesis that there are separate "scientific" and "occult" mentalities in the late Renaissance. The latter mentality has been dubbed by W.B. Ashworth, Jnr, the "emblematic world view", according to which the book of nature was believed to be written not, as Galileo was to aver, in the language of mathematics, but in an intricate metaphorical discourse of symbols and emblems whose decoding yielded understanding of the meaning of the cosmos and of human existence.[6] In the recent anthology of essays edited by Robert Fox, entitled *Thomas Harriot: an Elizabethan man of science,* some bracingly different views on this very issue are juxtaposed. The "occult" or "emblematic" view owes much to Frances Yates and the discovery she claimed to have made of an elite Christian neo-Platonic humanist intelligentsia in England in the latter years of the sixteenth century, interested in natural magic and humanity's future; one may take as the antipode of this view the claim that at the same time there are thinkers with a scientific outlook struggling to break free from "backward Renaissance thinking". Naturally, a number of intermediate or variant opinions are also expressed: according to one, Harriot was not an orthodox Christian but an atheist in the sixteenth-century sense of that term; or he was a humanist and atomist beguiled by Giordano Bruno's neo-Platonic hermetic vitalist version of this doctrine; or again, he was "scientific in one sense but still linked to animistic precepts of Renaissance magic, alchemy and the regrettable concomitant Hermetic traditions of secrecy and concealment" (the view of Charles Nicholl and to some degree J.W. Shirley); or yet again, the claim made by Stephen Clucas [1999] that the dichotomy between scientific and occult comes out of a modern mind-set, and is inappropriately applied to Elizabethan thinkers. A further possibility not there considered is that the dichotomy can indeed be applied to these thinkers, but that their commitment to one or the other side is intermittent, or determined by the matter in hand.

The debate is seen most starkly in the opposition between the figure of Harriot the natural philosopher and Christian on the one hand, and

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[6] [Ashworth 1990]. See also [Vickers 1984].

Harriot the mathematician on the other. Here we may catch echoes not only of the debate about social constructivism in scientific thought, and the role of ideological commitments and practical concerns (including subjugation to the wishes of patrons) in the most abstract mathematical speculation; but also of the second debate to which I wish to draw attention: that between Andrew Cunningham and Roger French on the one hand and Edward Grant, David Lindberg and Ronald Numbers on the other as to whether there can be a secular outlook in medieval and early modern Europe; whether there is a continuity between the investigations of natural philosophers and modern scientists, or whether "natural philosophy" has a quite different character, involving necessarily a consideration not only of God's creation but also of the attributes of God Himself.[7] Several of the contributors to Robert Fox's volume clearly believe that there is such mental activity as "thinking like a mathematician" which is perennial, utterly untheological, and immediately recognizable: Muriel Seltman writes that "Harriot's shorthand of mathematics brings the reader today into direct contact with historical mathematics [...] [a] little idiosyncrasy [of his] takes one to the heart of the mathematician, to give us an emotional fellow-feeling spanning four centuries" [Seltman 1999, p. 167], and Jim Bennett avers that "if anything comes over from a look at Harriot's manuscripts it is surely that [...] he was a mathematician" [Bennett 1999, p. 141]. I defer to these views; but they do not prevent me from asking whether one can detect ideological or other commitments in Harriot's work, by drawing comparisons with other Renaissance mathematicians and philosophers who may differ in their approach.

A third debate concerns the relationship of the "mathematical sciences" on the one hand and "natural philosophy" on the other in the early modern world. What is at stake here is clearly set out in J.A. Bennett's article "the Mechanics' philosophy and the mechanical philosophy" of 1986. He criticizes the distinctions made by T.S. Kuhn and others between empiricists and mechanists, and between high and low science, for their anachronism, and suggests that the category known as the "mathematical sciences" as used in the late Renaissance covers all sort of mathematical

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[7] On the constructivism debate see Jardine & Frasca-Spada [1997]. See also French & Cunningham [1996]; Lindberg & Numbers [2003]. The battle lines are clearly set out by Cunningham [2000] and Grant [2000].

activity, whether undertaken by learned figures such as Harriot or by artisan instrument makers; there is, according to him, a continuum of mathematical practice which unites the theoretical and the utilitarian at this time. It will be pertinent here to test Harriot's interest in combinations against this characterisation of mathematics.

3. VERSIONS OF COMBINATIONS

The combinations to which I shall here refer are to be found in language (the combinations of letters to make words), natural philosophy (the combination of atoms which go to make up matter) and, of course, mathematics. Combinations in mathematics and language are explicitly linked in the tradition of Cabbalah, as we shall see; combinations in language and natural philosophy were explicitly linked in the Middle Ages, as the work of Zenon Kaluza has shown. He has revealed that there were philosophers known as "*Epicurei litterales*" in the early fourteenth century in Paris who lay claim to "*libertas philosophandi*" (in this case, liberation from the sanctioned interpretation of Aristotelian physics) and describe matter in anti-hylemorphic terms through a linguistic metaphor (matter is composed of atoms in the same way as words are composed of letters).[8] Epicurean philosophy as then understood was a version of Democritic atomism (known in summary form through various Aristotelian works, notably the *De caelo*, iii.4, 303a 3ff.); it has the possible further implication of the doctrine of purposelessness in nature, which was anathema to Christian theology. I doubt very much whether this very debate was known to Harriot and his circle, but they were manifestly aware both of atomism and its implications, and of the notion of the "freedom to philosophise", as we shall see.

The three areas in which I shall discuss combinations are linked in the wording of the memorial erected by Harriot's patron the Earl of Northumberland in the Church in which he was buried, which contains the words:

> "he devoted himself to all the whole field of knowledge; he excelled in all things mathematical, philosophical, theological; a most diligent student of truth, and a most pious worshipper of the triune God".[9]

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[8] [Kaluza 1986; 1988]; [Bianchi 1999].

[9] The inscription on Harriot's memorial in St Christopher le Stocks reads: "*Qui omnes scientias caluit/Qui in omnibus excelluit/Mathematicis, Philosophicis, Theologicis/Veritatis indagator studiosissimus/Dei Trini-Unius cultor piissimus*" : quoted from [Shirley 1983, pp. 473–474].

"Things theological" is here ambiguous; I don't think that the Earl meant Christian dogmatic theology, but rather metaphysics in general (the standard edition of Aristotle's works of 1619 refers to his metaphysics as theology); he may even have had in mind Bacon's attenuated version of this – the accumulation of axioms which must precede any enquiry into nature.[10]

Theology in its broadest sense is relevant to my first topic: words, and their possible mystical associations; my second will be atomism and its place in Harriot's natural philosophy; and my last will be numbers and mathematics. At the end of this paper I shall venture to comment on the connection between natural philosophy and mathematics in the light of the debates evoked above, and on the description of Harriot as "a most pious worshipper of the triune God" in the context of the debate about the meaning to be ascribed to the term "natural philosophy".

4. WORDS

There are two broad schools of thought about words as combinations of letters which would have been known to Harriot : the neoplatonist and Cabbalistic on the one hand; and the anagrammatological on the other. The former of these unites a tendentious interpretation of Plato's dialogue *Cratylus*, which is about names, with Christian interpretations of the Jewish Cabbalah. The *Cratylus* was made available in Latin by Marsilio Ficino in the fifteenth century; it was developed most energetically in the mid-sixteenth century by Jean Dorat or Daurat, the charismatic humanist tutor of the French group of poets known as the Pléiade who were study-ing at the Collège [de] Coqueret of the University of Paris. It claimed (in the words of the most famous of these poets, Pierre de Ronsard) that "*les noms ont puissance et efficace et vertu*"; they are moreover linked to the essence of that of which they are the name.[11]

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[10] [Aristotle 1619, 2.84] (on "*theologia naturalis*" as the study of "*ens quatenus ens*": a definition possibly derived from the division of metaphysics made by Pereira [1576], on which see [Lohr 2002]; [Bacon 2000, pp. 76–78].

[11] [Nolhac 1921], [Ronsard 1970, p. 109 (ii.6: "Anagramme"), line 9]; and Smith's notes, pp. 109–110. There is a considerable anagrammatological literature in nearly all countries of Europe at this time.

Cabbalah was made known in the Renaissance through the works of Giovanni Pico della Mirandola (1463–1494) and Johannes Reuchlin (1455–1522), whose accounts were used in a great deal of subsequent literature; the French writer Blaise de Vigenère (1523–1596) linked Cabbalah to cryptology in 1586, in his *Traité des chiffres*. Words are given a very important role in cabbalistic writings: the world is said to be created out of the 22 letters of the Hebrew alphabet, whose very shapes have significance; each individual letter has two meanings, one open and one hidden; Holy Writ contains all the names of God, and these can be revealed by textual manipulations; Adam named all things under guidance from God and thereby provided things with a path to help them establish their identity; the cabbalist can apply three operations to letters (transmutation, commutation and combination); if he were to produce all possible combinations of Hebrew letters, then the names of all created things would be given (including the secret and unutterable names of God), and man would have equalled God's feat of counting the stars, the grains of sand in the world, and all the hairs on the combined heads of humanity.[12] Blaise de Vigenère points out that merely combining all the letters of the Hebrew alphabet (not counting the additional combinations which could be achieved by the application of points) would result in 11.240.025.908.719.680.000 words (he is commendably close to the right answer); the fact that it is beyond man's capacity is a demonstration of the gap which divides the finite from the infinite, the human from the divine.[13] There is some reception in England of these

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[12] These comparisons are Biblical: see *Psalms* 147:4, *Jeremiah* 33:22, *Matthew* 10:38.

[13] [Vigenère 1587], f. 33v (reference to transmutation, commutation and "*accouplemens de lettres*"); f. 37r: "*tous les chiffres Hebraïques ont double sens, l'un appert et l'autre caché*"; f. 38r (Adam naming creation); f. 41r: "*il est expressement dict, que le monde fut fabriqué par les 22 lettres de l'alphabet*"; f. 42r: [*rapport des lettres de l'alphabet Hebraïque, aux choses créées*] "*et ont este les Cabalistes si speculatifs, peraventure trop curieux, entant que la coniecture de l'esprit humain s'est peu estendue, de penser par les divers assemblemens des lettres, atteindre à sçavoir le nombre des choses créees [...] Car de la diversité des Ziruphs, ou accouplemens, et suittes de lettres, sans aucun meslange de points, vient à resulter un nombre, qui est autant comme infini pour nostre regard: assavoir 11240025908271968000000. Que si l'on y veut adiouster les points, le nombre ne se pourroit pas exprimer, ny concevoir presque de nous.*" See also [Dan 1997]. The sum of combinations of the alphabet is found also in the medieval period: see BL MS Sloane 2156 f. 128v (Henry of Hesse), cited by Clagett [1968, p. 447].

ideas, as Frances Yates notes; they are also detectable in the works of writers such as John Dee and Robert Fludd. There is moreover a connection to Biblical chronology (in which Harriot appears to dabble) and even to millenarianism; and to the belief in the power of incantations invoked in sympathetic magic and medical cures.[14]

Anagrammatology is a somewhat different affair. The best known treatise on it, which traces its history back to ancient times and sets out its practices, is that of Guillaume Le Blanc (1551–1601), the bishop of Toulon; this appeared in Rome in 1586, and in Frankfurt in 1602.[15] It is linked in its origins to Hebrew, Greek and Christian number and letter manipulations, and its popularity throughout Europe in the late sixteenth century is attributed to the Cratylic enterprise of the Parisian-trained poets; but in fact it does not make much of their claim to release mystical properties contained in words and to reveal higher orders of knowledge about the universe. A prosaic definition is given (an anagram is "a short clause which is made up of the artful transposition of all (not just some) of the letters of a given name"[16]); the practice is extended to chrono-anagrams (ones by which numbers or dates are extracted from a text by giving values to the Roman letter numerals M D C L X V I); and it is related to the rhetorical practice of etymology (that is, the attribution of meanings to parts of words which account for their definition: e.g. "testament" as "*testis mentis*").[17] Its practice is a great deal laxer than its definition suggests, for Le Blanc allows anagrammatologists to leave out letters when it suits them, to repeat letters for their own convenience, to add letters, to exploit the ambiguity in Renaissance printing between "i" and "j", "u" and "v", to use alternative spellings of proper names (Guglielmus: Guliermus), and to mix languages (to derive French from Latin, or vice versa, for example). It is hardly surprising after this catalogue of laxities that he can find only one fully satisfactory example: CUIAS

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[14] [Yates 1979]; also [Dan 1997]; BL Add. MS 6789 f. 471v; [Maclean 2001, pp. 111–112].

[15] [Le Blanc 1586]; [Reusnerus 1602]. See also [Mathieu-Castellani 1980]; [Zumthor 1980].

[16] Le Blanc in [Reusnerus 1602, sig. A7v]: "*clausula, quae ex artificiosa literarum omnium, neque plurium alicuius nominis transpositione componitur.*"

[17] On this practice, see [Maclean 1992, pp. 109–110]; also Le Blanc in [Reusnerus 1602, sig. C 4v] (which refers both to Cratylism and etymology in this sense) .

(the distinguished French Jurist Jacques de Cujas) CAIUS (the Roman jurisprudential writer); and even this relies on substituting an "i" for a "j".[18] Anagrams were used as a learned humanist game; as means of flattery or celebration; as satirical weapons; and as a suitable courtly pastime, "meete", as George Puttenham pointed out in *The Art of English poesie* of 1589, "for Ladies, neither bringing them any great payne nor any great losse unless it be of idle time" (quoted by [Fleming 2001, p. 123]). It is sometimes implied that anagrams release hidden significance from the rearrangement of letters, but this is not a programmatic claim.

They were certainly popular: Nicolaus Reusnerus's *Anagrammatographia* of 1602 contains 682 pages of them in nine books; a more humble collection closer to Harriot's home is that of William Cheeke, *Anagrammata, et chron-anagrammata regia* of 1613, written as a consolatory document for James I and VI after the death of Prince Henry Stuart in 1612, involving Latin and Greek, and chronological anagrams (and combinations of these with letter anagrams) of some complexity. At the same time in France, a certain Thomas Billon obtained royal favour from Louis XIII for a similarly sedulous (and according to him strictly accurate) book of anagrams, and was encouraged to continue producing them for the edification and amusement of the French court.[19] The appropriateness of the anagram to the character (in Cheeke, HENRICUS SEPTIMUS becomes PIUS ITEM SINCERUS; MARIA REGINA becomes EI ARMA NIGRA) is less striking than the aim to show ingenuity, to flatter, or to express opprobrium [Cheeke 1613, sig. E1v, E2v].

It is instructive to compare what Harriot does with the practice of other mathematicians. Michael Stifel, whose books on arithmetic Harriot cites and sometimes refutes, was a near-contemporary and follower of Luther who attempted to link the mystical force in names to the practice of anagrams in the work he entitled *A very remarkable word-reckoning together with a noteworthy explanation of some numbers in the book of Daniel and the book of Revelations*, which appeared in Königsberg in 1553. There he sets himself

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[18] Le Blanc in [Reusnerus 1602, sig. C8r]; see also [*ibid.*, A4-5], where cabbalistic practices are mentioned, and [*ibid.*, B2r-v], where there is a reference to Daurat and Ronsard.

[19] Billon [1613; 1616]. The claim that he obtained royal favour is found in [Curl 1982, p. 11].

the task of showing that Pope Leo X was the Antichrist (whose number, according to Revelations, is 666); he wrote Leo DeCIMVs and derived the chronogram MDCLVI 1656 from the name [but it could equally be 1654]; he then had revealed to him in a divinely-inspired dream that M stood for "Mysterium", not 1000, and that he was allowed to add in "X", this having "tenth" represented both as a word and a letter; from this he reached the desired total: 666.[20] Girolamo Cardano, another mathematician cited by Harriot, also writes about word patterns (such as those of bishop Rhabanus Maurus), hidden meanings, Sybilline utterances and mystical associations of words in his popularising works the *De Subtilitate* of 1550 and the *De rerum varietate* of 1557, although, to be fair to Cardano, it should be pointed out that in these contexts at least he pours scorn on them.[21]

What of Harriot himself? He also shows himself to be interested in the shapes of numbers: at one point, he sets out 1–9 all written in straight lines only, prefiguring the practice of digital screens [BL Add. MS 6789, f. 30v]. But this can hardly be said of itself to reflect an occult cast of mind.

He certainly rose to the challenge set by Galileo to Kepler in 1610 of an anagram hiding an astronomical message: s/mais/mrm/il/m/epoe/taleum/ibon/enugttauias (the answer being "*altissimum planetam tergeminum observavi*": "I have observed the most distant planet as thrice-begotten"); Harriot knew of the challenge from Kepler's answer to it [Kepler 1610], and must have been dissatisfied with Kepler's attempt to solve it ("*salve umbistineum geminatum Martia prolis*": "*greetings o lumpy son of Mars*"); so he set about trying to solve it himself. I found about ten attempts or partial attempts to solve the puzzle in Harriot's papers; John North [1974] reports that there are over fifty. There is some evidence that Harriot tried to adopt a methodical approach to the solution of Galileo's anagram (using techniques such as letter distribution), affording evidence of his analytical mind [BL Add. MS 6786, f. 251v, 303r]. This is a clear example of a mathematician's response to a parlour game, not of mystical meanings being attributed to letters.

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[20] [Stifel 1553, sig. A3r]. See also [Stifel 1532]. For reproductions of some of Stifel's mathematical texts referred to here see [Folkerts, Knobloch, & Reich 2001, pp. 66–89].

[21] See [Cardano 1663, 3.589-90 (*De Subtilitate*, xv: *De inutilibus subtilitatibus*)] and [*ibid.*, 3.207-8 (*De rerum varietate*, x.51)]; also below, note 36.

Harriot also engages in a number of anagrammatic transformations of his own name (sticking closer to the rules than many others); some of these may have been thought up as a witty response to the puzzle set to Johannes Kepler by Galileo: "*oho trahit musas*"; "*oho trahis mutas*"; "*oho sum charitas*"; "*tu homo artis has*"; "*homo hus ut artis*"; "*homo hasta utris/vitus/vutis*"; "*humo astra hosti*"; "*trahe hosti musa*"; "*a trahit has musa*"; "*oh, os trahit musa*" (all from "Thomas Hariotus")[22]. These look to me not to be claims about revelation of character (though "*oho sum charitas*" must have pleased him) but more like the product of a few idle moments spent by someone who if he lived today would have revelled in crosswords. From what I have seen of his manuscripts, Harriot, unlike Stifel or Cardano, seems to betray no inclination to see mystical or occult senses in letter combinations.[23]

5. ATOMS

Much has been written about the various accusations of impiety, atheism and atomism directed at Harriot or figures such as Ralegh and Marlowe with whom he was associated: I do not need here to repeat this material.[24] Nor do I need to set out the various versions of atomism current at this time: the work of John Henry [1982], John North [1999] and the volume edited by Christoph Lüthy and others [Lüthy, Murdoch, & Newman 2001] have done this task thoroughly. A popular source for this doctrine was Lucretius's *De rerum natura* (ii.61 ff.), which speaks of collocations and combinations of atoms (which are irreducible, and vary in size and density) in an infinite or indeterminate universe, in which the vacua between atoms is presupposed; Aristotle's various accounts of Democritean natural philosophy were also accessible, and were seen by some,

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[22] [BL Add. MS 6789, f. 475v].

[23] It is pertinent here to note that Harriot devised himself his own phonetic alphabet when in the New World: see [Shirley 1983, pp. 108–111].

[24] See [Shirley 1983, p. 198 ff]; [Roche 1999]; [Mandelbrote 1999]. Pumfrey [2003, p. 21] suggests that "Harriot was inhibited from writing or publishing even on the vacuum, let alone atomism, the motion of the Earth or the corruptibility of heavenly bodies" because of a lack of a powerful patron to protect him.

including Francis Bacon in the *Advancement of learning* of 1605, as a valid alternative to Aristotelian physics:

> "The Natural Philosophie of *Democritus*, and some others who did not suppose a Minde or Reason in the frame of things, but attributed *the form thereof able to maintain it self to infinite essaies or proofes of Nature*, which they tearme fortune: seemeth to mee (as farre as I can iudge by the recitall and fragments which remain vnto vs) in particularities of Phisicall causes more real and better enquired then that of Aristotle and Plato [...]" [Bacon 2000, p. 86].

Bacon sets this comment in the context of his map of disciplines, to which I have already alluded: what he calls natural science or phisick is dedicated to the enquiry into "variable or respective" (i.e. material and efficient) causes, while metaphysick (in the sense I have already given of the collection of axioms which are presupposed in any investigation of nature) enquires into fixed and constant (i.e. final and formal) causes. Bacon records the view that these may lie outside the reach of man, but thinks them worthy of pursuit provided that their study can further man's capacity to manipulate nature. The particular deficiency he finds in metaphysick lies its pursuit of final causes (teleology), which he identifies as a feature not only of Platonic but also of Aristotelian and Galenic philosophy:

> "For to say *that the haires of the Eyeliddes are for a quic-sette and fence about the sight: Or, That the firmness of the Skinnes and Hides of liuing creatures is to defend them from the extremities of heate and cold: Or, that the bones are for the columnes or beames, whereupon the Frames of the bodies of liuing creatures are built;* [...]: and the like, is well inquired and collected in METAPHYSICKE, but in PHYSICKE they are impertinent".[25]

Bacon's recommendation of the study by natural philosophers of only material and efficient causes – he did not of course deny that God or nature could act purposefully as efficient causes in their own right, but consigns this question to metaphysics – and his exemplary translation of the etiology of the eyelash into a form which does not rely on the determination of purpose ("Pilsotie is incident to Orifices of Moisture") seems to me, by setting aside the study of teleology, to be the most radical critique

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[25] *Ibid.*: the examples appear to be taken from *De partibus animalium*, 653a 30; 654a 30 ff.; 658b 1 ff.), and Galen, *De administrationibus anatomicis*, i.2, K 2.220, 226 (on bones). It is more likely that Bacon found the Galen reference through an intermediary, such as [Vesalius 1543, i.1, p. 1].

of Aristotelian zoology of its day, and to mark a watershed in the recommended procedures of natural enquiry. This cannot proceed without presuppositions or axioms, but for Bacon these are provisional and revisable; the natural historian uses the keenness of his perception ("*sagacitas*") and his orderly approach to experiment to produce not a general theory with laws but no more than "interim regularities".[26]

I shall return to the theological implications of this below; I am here interested in Bacon's collocation of this broader discussion with his rejection of Aristotle and praise of Democritus, and his awareness that atomism leads to a physics of chance. Another feature of this rejection is the new importance placed on accidental features of phenomena in Aristotelian terms, which are dismissed from consideration in an essentialist natural philosophy driven by the pursuit of final causes and committed to a peripatetic account of matter.[27]

That Harriot was committed to an investigation of atomism is known through his letters to Kepler and through his pupil Nathaniel Torporley's refutation of his position, from which it is deduced that Harriot defends the eternity of the matter of the world and the doctrine "*ex nihilo nihil fit*", both doctrines being taken to be inconsistent with the Judaeo-Christian account of creation.[28] In fact, "*ex nihilo nihil fit*" is not just Lucretian; it is also Aristotelian, as orthodox exponents of that doctrine concede (it is the first of the Aristotelian Philip Melanchthon's nine "axioms of nature").[29] Harriot records the tag on at least one occasion in his papers[30], and links it to the perfectly unexceptionable doctrine of the "*impossibilitas penetrationis dimensionum*" [two bodies cannot occupy the same place at the same time]. The other two impossibilities of Aristotelian physics

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[26] See [Jardine 1990].

[27] See [Maclean forthcoming].

[28] [Torporley 1952]; [Wippel 1977].

[29] Melanchthon MS Vatican Pal. Lat. 1038, fol. 2 ("*Physicae seu naturalis philosophiae compendium*"): "1. *Ex nihilo nihil fit* 2 *In omni generatione oportet subiectum esse cognatum, quod recipit Formam* 3 *Contraria a contrariis corrumpuntur* 4 *Similia a similibus oriuntur et aliuntur* 5 *Generatio unius est corruptio alius* 6 *Nulla magnitudo est infinita* 7 *Nullum est actu infinitum* 8 *Natura determinata est ad unum* 9 *Omnis motus fit in tempore*" ; also Aristotle, *Physics*, i.4, 187a 27-9; Lucretius, *De rerum natura*, i.1,206.

[30] BL Add. MS 6788, f. 493r, cited by [Gatti 1999, p. 71]; [Mandelbrote 1999, pp. 258–259].

– the "*impossibilitas infiniti et vacui*" – are however attacked (the first at length), and there are other very unorthodox positions recorded in Harriot's manuscripts. Stephen Clucas has shown recently that he was interested in the doctrine derived from the medieval Islamic philosopher Al Kindi of "*vis radiativa*" (by which everything produces rays whether substance or accident, and the universe is a vast network of forces in which every creature is a source of radiation).[31] This leads Harriot to refer to the quality of whiteness as "accidental form", a scholastic term used in contradistinction to the more commonly encountered "substantial form", referring to an actual (not potential) accidental feature (of which "whiteness" is the standard example) which cannot exist separate from the subject in which it inheres.[32] Where the distinction between accident and essence sits uneasily in its scholastic context, and threatens the coherence of definitions in natural philosophy by excluding features of them (e.g. the blackness of a crow) and thereby making certain sorts of taxonomic claims sound very odd, it is much less out of harmony with atomistic (and alchemical) philosophy[33], as can be sensed in the letter which Harriot's patron, the Earl of Northumberland, wrote to his son about alchemical theory in 1594:

> "The doctrine of generation and corruption unfoldeth to our understanding the method general of all attomycall combination possible in homogeneall substances, together with the ways possible of generating the same substance as by semination, vegetation, putrefaction, congelation, concoction etc with all the accidents and qualities rising from these generated substances, in hardnes, softnes, hevines, lightnes, tenacitie, frangibilitie, fusibilitie, ductibilite, sound, coulor, tast, smell, etc." (cited by Stephen Clucas [1999, p. 108]).

The link between the size, shape and configuration of atoms and accidental features of matter such as weight, homogeneity, solidity, and brittleness is here made to sound more coherent than it is in the Aristotelian account.

There is no very clear message which emerges from the scattered references to fundamental physics in Harriot; but I would venture to suggest

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[31] BL Add. MS, 6786 f. 428r; MS 6789, f. 572r. The three impossibilities of Aristotelian physics are listed on the titlepage of MS Vatican Pal. Lat. 1038 (see above, note 29).

[32] Aquinas, *De ente et essentia*, vi.1.

[33] [Maclean forthcoming]; Clucas [2001] points out that everything (whether substance or accident) produces rays; the distinction therefore no longer causes taxonomic difficulties.

that he, like Bacon, sets aside a teleological view of nature, and tries to limit his investigations to circumscribed areas of enquiry. One document which as far as I know has not attracted much attention is the following list of the presuppositions of Aristotelian natural philosophy (recorded here sequentially to save space) which Harriot at one point felt moved to draw up:

> "1 *principium* 2 *causa* 3 *elementa* 4 *natura* 5 *necessarium* 6 *unum multa* 7 *ens* 8 *essentia* 9 *idem/differentia/simile/dissimile* 10 *opposita* 11 *prius, et posterius* 12 *vis facultas potentia/imbecillitas seu impotentia posse, seu possibile/non posse, seu impossibile* 13 *quantum seu quantitas* 14 *qualitas* 15 *Relata* 16 *perfectum* 17 *extrema, seu terminus* 18 *kata ti, seu id quod per se* 19 *dispositio Habitus* 20 *affectio seu passio* 21 *privatio* 22 *habere* (*aliquid in alio*) 23 *unum ex alio* 24 *pars* 25 *totum* 26 *mancum seu imminutum seu mutilum* 27 *genus differen[tia] generis* 28 *falsum* 29 *accidens*

Tempus	| *est, non est*	
Spatium	| *finitum, infinitum*	
vis	| *potentia, actus*	*esse posse*
materia	| *simplex compositum*	*mi[x]tio element[orum]*
	| *universale particulare*	
	| *idem diversum*	*simile dissimile*
	| *per se, per aliud*	*subiectum, accidens*
	| *reale, rationis*	
determinatum	|*absolutum, aut aliud totum pars perfectum imperfectum*	
indeterminatum	| *mutabile, immutabile bonum, malum, indaiphoron*	
	Aeterna, temporale	
coitus [permeandi]	*In fluxu*	*in facto, in fide*
discretio	*unum plura*	*pauca multi*
		magnum parvum"[34]

The composition of this list is in itself worthy of detailed study, for which there is no space here: it is an amalgam of presuppositions and premisses drawn from parts of the Aristotelian Organon (notably the *Categories*) with relevant passages from the *Physics* and the *Metaphysics*. I do not believe that Harriot set this down (sequentially, over two pages, as if to stress the extent of the presuppositions) in the spirit of a Baconian metaphysics, but rather as a way of surveying critically the extensive metaphysical baggage which Aristotelian physics carries with it. To set out all the presuppositions of an argument was enjoined upon disputants in traditional universities, and although it was condemned as a practice in the medieval period for being potentially subversive to the doctrine of

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[34] BL Add. MS 6789, f. 511r-v. Cf. the remark by Jacquot [1974, p. 125]: "[Harriot] did not rely on metaphysical speculation but on evidence."

the unicity of truth[35], it is a frequently encountered practice in textbooks of natural philosophy, and is a feature of the "*mos geometricus*" [Maclean 2001, pp. 114–118]; Harriot's version of this exercise is perhaps more perspicacious than many.

6. NUMBERS

I come finally to last section of this paper. The mathematics of the Renaissance is sometimes characterised as transitional, lying between the "passive, mystical and irrational approach" of the Middle Ages and the "active rational problem-solving" which characterises the new science of the seventeenth century; according to this rather Whiggish account, the sixteenth century continues to study mathematics for what it reveals about the cosmos, the soul and the divine, and it pursues enquiries into the properties of numbers in a Pythagorean spirit [Moyer 2002]. Cardano gives coherent expression to this approach:

> "[By arithmetic] we are taught that everything is bound together by a certain marvellous and hidden order. Nor is it to be believed that this connection is fortuitous, but rather the shadow of a divine bond, through which everything is mutually tied together in a certain order, measure and time: for this reason the Pythagoreans and Academics not altogether randomly constituted numbers as the origins of things: and who would doubt, if Aristotle had not egregiously misunderstood them on this matter, that they meant anything else than that numbers are the shadows of that order by which God constituted, made and ordered everything? [...] The order [of arithmetic] [...] is infinite in itself [per se], and nothing other that the shadow or trace of the infinite order. [...] Our mind, by contemplating it, sees the godhead as if through a tiny chink".[36]

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[35] The proposition "*quod nihil est credendum, nisi per se notum, vel ex per se notis possit declarari*" was condemned by Bishop Tempier in 1277: [Serene 1982, p. 507].

[36] Cardano [1663, 1.143 (*De libris propriis*)]: "*arithmeticae contemplatio subtilissima est: et per se felicissima, tum quia docemur cuncta esse miro quodam ordine et arcano connexa. Neque enim credendum est illam connexionem esse fortuitam, sed umbram quandam vinculi divini, quo cuncta invicem colligata sunt certo ordine, mensura, tempore: ob id non tam temere Pythagorici et Academici numeros constituerunt rerum principia: quos si non per calumniam Aristoteles voluisset interpretari, quis dubitat non aliud per hoc aenigma illos significasse, quam numeros umbras esse eius ordinis quo Deus cuncta constituit, fecit et ordinavit? Sed ordo ille in Deo quasi involutus est, et unum quoddam, extra autem multiplex: qui cum sit infinitus undequaque, quis non videt infinitam primi boni esse naturam? Nam neque numerus per se est, est enim accidens: neque sui autor: Deus enim non est: nec αὐτοποιός, neque animae nostrae figmentum, sic enim falsus esset: natura igitur quaedam per se infinita est, nec aliud quam umbra aut vestigium ordinis infiniti. Ecce quam parvo deprehendimus infinitam esse naturam. In illum igitur intuens animus noster, divinitatem quasi e rimula inspicit.*" See also Aristotle, *Metaphysics*, i.5, 985 b 20 (on Pythagoras); i.9, 990 a 30 (on Plato).

These sentiments are found also at this time in France and England, in works by Jacques Lefèvre d'Etaples, Josse Clichtove, Girard Roussel and Jacques Peletier du Mans on the one hand, and John Dee's "Mathematical Praeface" to the translation of Euclid's *Elements* by Sir Henry Billingsley of 1570 on the other.[37] According to these writers, the patterns and correspondences of mathematics reveal the beauty of the order of the cosmos, and with this some of the attributes of God (his infinite nature and his design for the world); among the ways these are to be discovered is the investigation of numbers, including the properties of their combinations and permutations.

The combinations I wish to look at here are found in the prehistory of what we now know as Pascal's triangle, some of whose properties have been known since ancient times; for its history I shall be relying mainly on the excellent recent monograph by A.W.F. Edwards, who distinguishes three contexts in which a triangle which generates similar numbers and properties arises: figurate or polygonal numbers; combinatorial numbers; and binomial coefficients.[38] The first of these are generated from the practice of arranging dots into shapes such as triangles or squares, or three-dimensional figures such as triangular pyramids or tetrahedra. From the progression of numbers, tables can be drawn up such as the one to be found in Stifel's *Arithmetica integra* of 1544.[39] Michael Stifel uses this in connection with the extraction of roots, and hence links it to binomial coefficients, which are obtained from the expansion of $(1 + x)^n$. The table of combinations has the same progression of numbers, combination being given in modern notation by ${}^nC_r = n!/r!\,(n-r)!$ where ${}^nC_r$ is the

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[37] See, for example, [Pantin 2002, pp. 383–389], and Dee quoted by Marr [2003, p. 127]: "and for us Christenmen, a thousand mo occasions are, to have need of the help of Megethodicall Contemplations: whereby, to trayne our Imaginations and Myndes, little by little, to forsake and abandon, the grosse and corruptible Objects of the outward senses: and to apprehend, by sure doctrine demonstrative, Things Mathematicall. And by them readily to be holpen and conducted to conceive, discourse, and conclude of things intellectual, spirituall, aeternall, and such as concerne our Blisse everlasting."

[38] [Edwards 1987]. On figurate numbers see also [Murdoch 1984, p. 99]. According to [Edwards 1987, p. 12 f.], figurate numbers were first explicitly subsumed under binomial coefficients in the work of Pascal.

[39] [Stifel 1544, f. 44v], illustrated in [Folkerts et al. 2001, p. 81].

number of selections that can be made from n objects, taken r at a time, regardless of any different arrangements which can then be made (thus the permutations of abc (acb, bca, bac, cab, cba) count as one selection only). Cardano reproduces the figurate table and the table of combinations in one of his last works, the *Opus proportionum* of 1570, in which he also notes the relation of his table of combinations to the geometrical progression 2^n (for $n \geq 2$, $2^n - 1 - n$ gives the total number of combinations of n things taken 2 or more at a time), and enunciates another rule which relies on use of the figurate table to discover sums of combinations (some of this material had already appeared in his *Practica arithmetice* of 1539).[40]

These passages are transcribed by Harriot in his worksheets headed *Of combinations* and the treatise entitled *De numeris triangularibus et inde de progressionibus arithmeticis* which Edwards dates to 1611 or before.[41] Harriot seems to have contemplated the publication of a work on triangular numbers, because at one point he sketches out its titlepage.[42] In it, he draws on all the accumulated work of the sixteenth century, and adds to it a statement of some axioms which are not found in the work of his predecessors, linking his work on combinations with his interest in infinites.[43]

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[40] [Cardano 1663, 4.73 (*Practica arithmetice*, li)]; [*ibid.*, 4.557-8 (*Opus novum de proportionibus*)]. The rule (quoted by Harriot, BL Add. MS 6782, f. 44r) reads: "*ut autem habeas numerum singulorum ordinum, in quavis multitudine, deducito numerum ordinis a primo, et divide per numerum ordinis ipsius reliquum, et illud quod provenit, ducito in numerum maximum praecedentis ordinis, et habebis numerum quaesitum.*" Cardano felt obliged to give an example of this working: "*velut si sint undecim, volo scire breviter numeros, qui fiunt ex variatione trium. primo deduco pro secundo ordine* 1 *ex* 11 *fit* 10. *divido per* 2. *numerum ordinis, exit* 5. *duco in* 11 *fit* 55. *numerus secundi ordinis. Inde detraho* 2. *qui est numerus differentiae ordinis tertii a primo ex* 11. *relinquitur* 9. *divido* 9 *per* 3 *numerum ordinis exit* 3. *duco* 3 *in* 55. *numerum secundi fit* 165 *numerus tertii ordinis.*"

[41] BL Add. MS 6783, ff. 403 ff.; [Edwards 1987, p. 11].

[42] BL Add. MS 6782 f. 146v: "*THOMAE HARIOTI/Magisteria/Numerorum Triangularium/Et Inde/Progressionum Arithmeticarum*"; he is not alone among late Renaissance scientists to engage in this innocent act of vanity: see also Milan Bibliotheca Ambrosiana D 235 Inf, ff. 13,15 (two mock-ups of titlepages of unpublished works by their aspiring author Guiseppe Moletti). I am grateful to Roy Laird for this reference.

[43] E.g. BL Add. MS 6786 363r: "And yet for an ease in describing progressions we must [...] understand a quantity absolutely indivisible but multiplicable infinitelie [...] till a quantity absolutely unmultiplicable be produced which I may call universally infinite." For Harriot's

He demonstrates moreover a clear consideration of negative and fractional values in respect of combinations, and what has come to be known as the Newton-Gregory forward-difference formula in numerical analysis, as well as dealing with permutations and binomial coefficients.[44] He aspires to find a "generall rule to get the mayne summe of all the complications of any number of species" and "a general method for the particular summe without the table of combinations or complications." As in the case of Cardano, this falls short of purely symbolic notation (an innovative feature of Harriot's work on algebra), as it relies on verbal formulae, worked examples and the location of numbers in a table.[45]

I refer the reader to Edwards's very positive judgement and clear exposition of Harriot's achievement; I intend here to measure it in another way, by comparing what Harriot writes with the work of other near-contemporary mathematicians. I shall offer one or two very brief examples: Michael Stifel uses the figurate numbers in his millenarian work

consideration of infinites, see BL Add. MS 6782, f. 199, 362-74: MS 6784, ff. 359-64, 428-29; MS 6785, ff. 190-1, 436-67.

[44] BL Add. MS 6782, f. 29, 46, 74v, 96 ff., 147r (figurate numbers); f. 30 ff. (Pascal's triangle); f. 108-9 (binomial coefficients); f. 145 (negative numbers and fractions), f. 150 (an algorithm for figurate numbers); f. 180 ff., 331 ff. (tables of combinations); BL Add. MS 6783 f. 403 ff. ("*De numeris triangularibus et inde de progressionibus arithmeticis*").

[45] BL MS 6782, f. 38r: "according to the number of species, understand as many termes to be given in continuall proportion, or progression, beginning at the [unit] and making everie terme double to his precedent: the double of the last term less [a] unit is the summ desired [...] As for example I would knowe all the complications of 6 species together with the number of the simples the sixth terme of such a progression I spake of is 32. The double less [a] [unit] is 63, the summ of all the complications with the number of simples which were sought. Of the number of species be greate the last term desired is to be gotten by the rule of progression in arithmetick. The reason of the rule is easilie to be contrived out of the particular constructions in another paper annexed." There is another formulation derived from Cardano on f. 35v: "by this manner of construction and generation of the variety of combinations or complications [a set of tables setting out combinations of letters from *a* to *g*] these propositions are manifest: The number of complications with the number of their simples is double to the number of complications with their simples of the next precedent order [and] one more. In any order of complications the number of bynaries (ternaries, quaternaries, &c) is equal to the number in the precedent order of binaries and simples (ternaries and binaries, quaternaries and ternaries, &c)." The rule $2^n - 1 - n$ is shown in a table but not set down in symbols. See also Harleyan MS 6002 ff. 10v-13v for a clearer transcription of some of this material.

A very remarkable word-reckoning to which I have already referred. There he makes letters correspond with figurate numbers; for the purpose of his apocalyptic chronology he needs to get to the figure 5200 (the sum of two alphabets of figurate numbers) which is the sum of two mystical numbers taken from book of Daniel (1290 + 1335) and two taken from the book of Revelations (666 (number of the beast) + 1260). The sum very nearly works (it is short by 49); to make this up, he chooses to add in the sums of two words ecce (42) + ac (7), in a way which would have been grudgingly allowed by the lax anagrammatologist Guillaume Le Blanc, but by few others.[46] The calculation is linked to biblical chronology, in which Harriot also dabbled: as Stephen Clucas [1999, p. 103] says, such an activity does not "sit well with a progressive scientific narrative". It is not clear to me, however, that Harriot is doing this on his own behalf; it may very well have been an enquiry commissioned by a colleague or patron.

Other writers link combinations to practical concerns: Luca Pacioli (c. 1445–1514), to table placements; Cardano and Niccolò Tartaglia (1499–1557), to gambling; the medical professor Sanctorius Sanctorius (1561–1636), to diagnosis: in his *Methods of avoiding error* of 1603, he wanted to compute the combinations of 3 and 4 malignant humours out of the possible 165 such humours in a human body, to show how many combinations had to be considered by the rational doctor, and gets the sum horribly wrong, by extrapolating the rule of two combinations [$^{n}C_2 = \frac{1}{2}n(n-1)$] to combinations of three and four in the form $\frac{1}{2}(n-1)(n-2)$ and $\frac{1}{2}(n-2)(n-3)$.[47] It is interesting to note, in respect of practical concerns, that the first printing of Pascal's triangle was on the titlepage of a book of arithmetic produced for use in commerce (Peter Apian's *A new and sound book of instruction in accounting for merchants* of 1527).[48] Harriot's manuscript treatise contains no suggestion as to any practical application. The pure speculation about numbers and their properties is found elsewhere in the manuscripts.[49] There is never any

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[46] [Stifel 1553, sigs. C4-D1]; see also [Barnes 1988, p. 188 ff].

[47] On Pacioli, Tartaglia and Cardano, see [Edwards 1987, p. 37 ff.]; [Sanctorius 1630, vii.9, pp. 630–639]; [Maclean 2001, p. 176].

[48] [Apian 1527]; see [Folkerts et al. 2001, p. 81].

[49] E.g. See also BL Add. MS 6789 f. 54v (on the properties of 4, 7 and 9); and BL Add. MS 6782 f. 27-8 (magic letter squares: on these see also [Shirley 1983, pp. 419–420]).

hint that the patterns are thought to be of mystical origin, or to offer paths to understanding the divine mind, or proofs of the immortality of the human soul[50]; this is also true, it seems to me, of Harriot's various enquiries into mathematical infinity.[51]

7. HARRIOT BELIEVER, NATURAL PHILOSOPHER, MATHEMATICIAN

It does not seem to me that Harriot, for all his interest in matter and "*vis radiativa*", was beguiled by hermetic or occult thought; he seems to me to have conducted his investigations into words, atoms and numbers in a dispassionate and highly abstract spirit, without direct reference to the utility or religious significance of any discoveries which might be made in these areas of research. Equally, although his work on alchemy or on practical issues such as longitude may be characteristic of the "mathematical sciences" in that they combine theory with strongly practical concerns, this does not seem to be true of much of the work recorded in the voluminous manuscripts which have come down to us. These reflections bear on the question of Harriot as "devout worshipper of the triune God". There are a number of tantalizing clues which might be picked up here, from Harriot's account of the religion of the Amerindians of Virginia (in which he includes a reference to the political justification for a doctrine of the after-life, a justification much decried by theologians)[52], to enigmatic asides in the MSS which have exercised a number of Harriot scholars. Harriot's pupil Nathaniel Torporley produced a work with the title *Corrector analyticus*, whose titlepage announces that as an outstanding mathematician, Harriot very rarely made a mistake; that as a reckless philosopher, he blundered more often; and that as a mortal man, he erred signally; the work was described by Torporley as a refutation of the "atomistical pseudophilosophy", which Harriot is said to have revived, and which, Torporley avers, merits stern reproach as well as anathema.[53] This

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[50] This is the case of Cardano: see [Maclean 2004, pp. 191–208].

[51] See above, note 43.

[52] See [Maclean 2004, p. 206]; [Rosen 1974, p. 13].

[53] [Shirley 1983, pp. 4–5, 472–474]; Sion Coll MS arc L 40.2/E.10, ff. 7–12: the Latin title begins "*Corrector analyticus artis posthumae Thomae Harrioti, ut mathematici eximii, perraro, ut philosophi audenti, frequentius, ut hominis evanidi insigniter errantis.*"

suggests that Harriot was known to hold views which were religiously un-
acceptable to an early modern Christian. But there are indications which
might lead us in the opposite direction. Bacon, whom I quoted earlier on
the soundness of the atomistical doctrine so abhorred by Torporley, was
aware of the implications of this doctrine for divine involvement in the
sublunary world, and rebuts the charge of atheism by an extraordinary
analogy in which God is made to play the part of a devious Machiavellian
Renaissance prince:

> "Neither does [Democritean philosophy, i.e. atomism] call in question or dero-
> gate from diuine Prouidence, but highly confirme and exalt it. For as in ciuill
> actions he is the greater and deeper pollitique, that can make other men the
> Instruments of his will and endes, and yet neuer acquaint them with his pur-
> pose: So as they shall do it, and yet not knowe what they doe, th[a]n hee [who]
> imparteth his meaning to those he employeth: So is the wisdome of God more
> admirable, when Nature intendeth one thing, and Prouidence draweth forth
> another; th[a]n if hee had communicated to particular Creatures and Motions
> the Characters and Impressions of his Prouidence" [Bacon 2000, p. 87].

This justification for ignoring the question of final cause is not found
in Harriot; he does however indicate what his attitude was to the inter-
vention of the divinity in his creation in the letter to Mayerne, which I
quoted at the beginning of this paper, even if he does not expatiate on it.

Speculation about any thinker's intimate religious convictions is espe-
cially dangerous: so rather than pursue this line of enquiry, I should like
to end on two clues which relate to his researches rather than his per-
sonal faith. The first of these is a sentence from his petition to the Privy
Council of 16 December 1605 for release from imprisonment in connec-
tion with the investigation of the Gunpowder Plot: "all that know me can
witness that I was alwayes of honest conversation and life [...] contented
with a private life for the love of learning that I may study freely" (cited by
[Batho 1999a, p. 36]. The second clue comes from a letter to Johannes
Kepler of 13 July 1608, in which idea of unfettered study recurs : "things
are in such a state here that I have not hitherto been allowed to philoso-
phize freely; we remain here stuck in the mud. I hope that Almighty God
will soon put an end to this state of affairs."[54]

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[54] [Kepler 1610, pp. 172–173 (no. 497)]: "*ita res se habent apud nos ut non liceat mihi adhuc
libere philosophari. Haeremus adhuc in luto. Spero Deum Optimum Maximum his brevi daturum
finem.*"

Phrases such as "*libere philosophari*" and "*libertas philosophandi*" have a long history, to which I have briefly alluded: in the second half of the sixteenth century, they became shibboleths of independent thought throughout Europe. In his 1563 edition of the works of Marsilio Ficino's pupil Francesco Cattani da Diacceto, a member of the Florentine Academy in the second half of the fifteenth century, Theodor Zwinger of Basle (1533–1588) dates the practice, if not the use, of the term "*libertas philosophandi*", to the humanist recovery of Platonic and ancient hermetic knowledge in Florence. The "Christian philosopher" Nicolaus Taurellus (1547–1606), who taught natural philosophy and medicine at Altdorf, describes "free philosophising" as of the product of a university training in the exercise of judgment in his book on the peripatetic Andrea Cesalpino which appeared in 1593; Francis Bacon does the same in his *Advancement of learning* a decade or so later. At about the same time, Galileo, in the wake of Rheticus and Kepler, adapts the Athenian Platonist Alcinous's adage about philosophy and freedom of birth to justify the unfettered meditations of the philosopher. In his *Apologia pro Galileo* of 1622, Tommaso Campanella (1568–1639) claims that freedom of thought is specifically a feature of Christian culture; and according to him, as well as the Lutheran philosopher Jakob Martini of Wittenberg (1570-1649), the book of nature was configured by God in such a way as to allow human enquirers, whether pagan or Christian, the freedom to read it. Thus Aristotle was indeed able to acquire true knowledge about the world, and his successors could continue to make new discoveries about it by their own free observation of it (a point made also by both Kepler and Galileo).[55]

It seems to me that Harriot consistently conducted his enquiries in that spirit; this, however, does not entail that we have to distrust his explicit declarations about his adherence to orthodox Christian faith. From his writings about words, atoms and numbers, I see no evidence that he was interested in their mystical powers or the meanings of the patterns in which they occur; and much that points in the direction of a man capable

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[55] [Gilly 1979, pp. 132–133]; [Taurellus 1597, sig *4v]; [Bacon 2000, p. 28]; [Martini 1608, sig a 5-6]; [Sutton 1953]; [Stewart 1994] (both with further references to Renaissance figures). I am grateful to Isabelle Pantin for pointing out that the epigraph of Rheticus's *Narratio prima* of 1540 bears the Alcinous adage, and that Kepler adopted this as a device from the publication of the *Mysterium cosmographicum* in 1596 onwards.

of highly abstract mathematical thought which was neither linked to the demands made upon him by patrons nor to an ideological commitment of any sort. In respect of the three historiographical debates to which I alluded at the beginning of this paper, it would seem to me that Harriot does not adhere to an "emblematic world view": he treats nature as an object of enquiry which does not necessarily yield up mystical knowledge, and looks on the patterns of mathematics as an area for free investigation, not as a means of contemplating the godhead. In this, his writing does not support the Cunningham-French view that the attributes of God are part of natural-philosophical enquiry at this time (which is not to say that Harriot's mental horizons are wholly and uniquely secular). The manner in which mathematical problems are set out in his surviving manuscripts would seem to me further to support the view that they were not driven by practical concerns, but by the speculations of a gifted mathematician. I come therefore to a conclusion that Harriot's work on combinations is scarcely marked at all by the social, political and religious context from which it arose; that he is not a "disciple of Bruno"; that he did not feel obliged to consider the attributes of the deity while engaging in natural philosophy; that he was able to speculate mathematically without linking such speculation to practical ends; and that he, like many of his contemporaries (including the Bacon of *The Advancement of learning*), was capable of compartmentalising his mind, and of according different modes and degrees of commitment to different areas of his mental universe.

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