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## *Copernicus, Thomas Digges and the problem of cosmological infinity in Renaissance England*

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### **The problem of Infinity in Copernicus' Cosmology**

**I**t was well known since Antiquity that the main cosmological repercussion of the heliocentric system is that it considerably enlarges the universe, so that the distance from the Earth to the Sun, however long it may be, is incommensurable with the distance between the Sun and the starry sphere. Archimedes discussed explicitly this problem in his famous treatise called *Arenarius* (The Sand-Reckoner). Indeed it is true that Copernicus died just before the publication of Archimedes' works<sup>1</sup>. It does not mean that Copernicus could not have heard of this famous text ; but since the same question was widely discussed by the ancient and numerous compilers<sup>2</sup> who reported this argument (in order to reject the heliocentric system, because of its unacceptable consequences), there is no doubt that Copernicus was quite aware of this argument.

#### **1°) The immensity of the heavens as a necessary consequence of the Copernican heliocentric system.**

At first Copernicus deepens in detail Ptolemy's arguments developed in his *Almagest* in order to demonstrate that the Earth has negligible dimensions in comparison with those of the starry sphere. But Copernicus' own argumentation follows a double movement : 1°) at first he begins by showing that "*on the testimony of the senses the earth is related to the*

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<sup>1</sup>The *princeps* edition has only been published in 1544 by Thomas GECHAUFF VENATORIUS in Basel, Hervagium. As for Commandino's translation, it has been published in Venice in 1558. Cf. Sir Thomas HEATH, *A History of greek Mathematics*, 1921, new edition Dover, 1981, volume II, p. 25 sq.

<sup>2</sup>Among these compilers, see especially : STOBÉE, *Eclogarum Physicarum*, I, ch. 25; PSEUDO-PLUTARQUE, *De placitis philosophorum*, II, ch. 24; PSEUDO-GALIEN, *Historia philosophica*, ch. 14; SIMPLICIUS, *Commentarii in Aristotelis libros De Coelo*, II, ch. VII ; SEXTUS EMPIRICUS, *Adversus Mathematicos*, X, 174; PLUTARQUE *De facie in orbe Lunae*, art. 6 (confirmed by DIOGENE LAËRCE in *Vie, Doctrines et Sentences*, VII ch. Cléanthe); or even PLUTARQUE, *Platonicae Quaestiones*, VIII.

heavens as a point to a body"<sup>3</sup> ; 2°) then he shows that this argument is valid in the heliocentric view, because : "*the size of the universe is so great that the distance from the earth-sun is imperceptible in relation to the sphere of the fixed stars*"<sup>4</sup>.

This incommensurability of the starry sphere in relation to the dimensions of the Earth becomes obvious with the naked eye in the appearances of the twelve zodiacal constellations. Here, the most interesting is not so much the demonstration in itself as the conclusions drawn from it by Copernicus :

"Yet a line drawn from the earth's surface [to a point in the firmament] must be distinct from the line drawn from the earth's centre [to the same point]. Nevertheless, because these lines are immense in relation to the earth, they become like parallel lines. Because their terminus is enormously remote they appear to be a single line. For in comparison with their length the space enclosed by them becomes imperceptible, as is demonstrated in optics. This reasoning certainly makes it quite clear that the heavens are immense by comparison with the earth and present the aspect of an infinite magnitude, while on the testimony of the senses the earth is related to the heavens as a point to a body, and a finite to an infinite magnitude. But no other conclusion seems to have been established. For it does not follow that the earth must be at rest in the middle of the universe"<sup>5</sup>.

This quotation means that if one could stand on a fixed star, then the terrestrial diameter would vanish and become as small as an imperceptible point. Copernicus takes into account in the same time the geometrical Optics and the visual effects produced by the immensity of the heavens "*on the testimony of the senses*". Copernicus does not go beyond the gap which is between immensity and infinity. He only points out to us that "*on the testimony of the senses*" infinity and immensity have in common a lack of proportion between the measure unit and the thing to be measured. The

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<sup>3</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, Warsaw, 1978, Book I, ch. VI, p. 13.

<sup>4</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, Warsaw, 1978, Book I, ch. X, p. 20.

<sup>5</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VI, p. 13.

measure cannot be an aliquot part of what is to be measured ; in other words, it's impossible to determine a fixed number of measurement units in both cases.

Copernicus does not lose sight of this problem when going on to the second point. Though Copernicus views the problem in the way of heliocentric system this time, the very large orbital revolution made by the Earth around the sun does not change anything to the problem of heavenly immensity. On the contrary, the fact that it does not change anything to the problem confirms obviously the immensity of the heavens, though rejected by Archimedes and Ptolemy in the Antiquity. Copernicus considerably enlarges, so to speak, this immensity. In fact, it's not only the diameter of the Earth but also the diameter of its annual revolution which must be regarded as a point in comparison with the immense size of the starry sphere according to the lack of stellar parallax. In the end of this chapter, Copernicus uses Cusa's terminology when comparing the Earth to an atom and its annual orbit to a compound of atoms so small that it passes unnoticed :

"That proof establishes no conclusion other than the heavens' unlimited size in relation to the earth. Yet how far this immensity extends is not at all clear. At the opposite extreme are the very tiny indivisible bodies called «atoms». Being imperceptible, they do not immediately constitute a visible body when they are taken two or a few at a time. But they can be multiplied to such an extent that in the end there are enough of them to combine in a perceptible magnitude. The same may be said also about the position of the earth. Although it is not in the centre of the universe, nevertheless its distance therefrom is still insignificant, especially in relation to the sphere of the fixed stars"<sup>6</sup>.

Cleverly, Copernicus does not look upon the dimensions of the heavens or of the Earth as absolute values, but he only shows that even large bodies may be compared with atoms if they are related to other bodies with which they are incommensurable. The concepts of large and small are purely relative. The main thing in astronomy is the proportionality or commensurability between magnitudes and quantities. As soon as incommensurability appears, all scientific knowledge become out of reach, all calculus is impossible and observation (at least with the naked eye) makes no sense. It is obvious that from the heliocentric standpoint, the

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<sup>6</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VI, p. 14.

depths of the heavens become much more unfathomable than ever, namely than from the geocentric standpoint. When Copernicus says that the distance between the Earth and the centre of the universe "*is still insignificant, especially in relation to the sphere of the fixed stars*"<sup>7</sup>, he means that this distance cannot be used as a sufficient basis to triangulate the distance of any fixed star. For Copernicus, however, the problem of incommensurability cannot be a good reason to forsake the heliocentric system ; for the polish astronomer the incommensurability is not longer a source of trouble, at least from a theoretical standpoint.

For Copernicus, there was no doubt that this lack of parallax was a resulting effect of the huge remoteness of the starry sphere with respect to the distance between the Earth and the Sun. Indeed, Euclid had demonstrated in his *Optics* that the apparent dimensions of the objects is determined by the angle according to which they are perceived. Ptolemy had also written a treaty of *Optics* in which he demonstrated geometrically that the apparent magnitude of sensible things varies in inverse ratio to their distance with respect to the observer. Then it was plain to see that a mathematical law connected the angle of sight, the remoteness and the apparent dimensions of the sensible objects. Copernic knew perfectly Euclid's works on Optics and he understood clearly what means the incommensurability for the sphere of the fixed stars. Copernicus was aware that the lack of stellar parallax only means that it is materially impossible to make a measurement, but he does not conclude, however, that the universe is infinite :

"That proof establishes no conclusion other than the heavens' unlimited size *<indefinitam magnitudinem>* in relation to the earth. Yet how far this immensity *<at quousque se extendat haec immensitas>* extends is not at all clear *<minime constat>*"<sup>8</sup>.

There may be incommensurability between two finite magnitudes just as well as between a finite magnitude and an infinite one. Besides, Copernicus had made no secret that he was inclined to favour the finiteness of the universe, enclosed in the sphere of the fixed stars, rather than the opposite hypothesis. That's precisely what he claims at the beginning of his

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<sup>7</sup>*Ibid.*, p. 14.

<sup>8</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VI, p. 14.

*De Revolutionibus* : "The universe is spherical"<sup>9</sup>. Copernicus' universe is finite, but immense and at rest. For him it's certain that the third dimension is astronomically unfathomable, but this statement depends on the specific array of the planets' orbes he chose and on the measurements available to him. In his astronomical research, it was enough to do as if the sphere of the fixed stars was at a great (but unknown) distance away from the sun, in order to project onto it (as onto a backcloth) the results of measurements related to the centre of the universe. However, Copernicus never rejected the possibility of an infinite universe. Besides he often says that the problem is not solved :

"But beyond the heavens there is said to be no body, no space, no void, absolutely nothing, so that there is nowhere the heavens can go. In that case it is really astonishing if something can be held in check by nothing. If the heavens are infinite, however, and finite at their inner concavity only, there will perhaps be more reason to believe that beyond the heavens there is nothing. For, every single thing, no matter what size it attains, will be inside them, but the heavens will abide motionless"<sup>10</sup>.

Copernicus does not linger over this question, because he thinks that it's not of the competence of astronomy, but only of natural philosophy as he writes it himself :

"Let us therefore leave the question whether the universe is finite or infinite to be discised by the natural philosophers. We regard it as a certainty that the earth, enclosed between poles, is bounded by a spherical surface. Why then do we still hesitate to grant it the motion appropriate by nature to its form rather than attribute a movement to the entire universe, whose limit is unknown and unknowable? "<sup>11</sup>.

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<sup>9</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. I, p. 8.

<sup>10</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VIII, p. 16.

<sup>11</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VIII, p. 16.

At this point of our analysis, it is clear that the observational finding of the heavens' incommensurability in comparison with the orbit of the earth necessarily raise the question of the cosmological infinity.

**2°) The problem of the «*constitutio universi*» : finiteness or infinity.**

Though Copernicus had admitted that the immensity of the universe brings necessarily up the question of its possible infinity, in fact he shows obviously that the principal ground in favour of cosmological infinity is not its immensity, but the *immobility* of the eighth sphere, the sphere of the fixed stars. Indeed, asserts Copernicus, as a good reader of Aristotle's *De coelo* :

"For, the chief contention by which is sought to prove that the universe is finite is its motion"<sup>12</sup>.

Since Copernicus immobilised the sphere of the fixed stars and reduced its apparent diurnal motion to the real axial rotation of the earth, the traditional arguments in favour of the finiteness of the universe become irrelevant. Nevertheless, Copernicus remained attached to a certain kind of cosmological finitism based on geometrical grounds (the sphere as a geometrical invariant and as "*the most capacious of figures*"<sup>13</sup>), on aesthetic and teleological grounds (perfection and beauty of the sphere suitable for "*the divine bodies*"<sup>14</sup>), and finally on physical grounds (natural tendency of the bodies striving to be circumscribed by a spherical boundary<sup>15</sup>). Anyway, Copernicus gives up the idea of basing his cosmological finitism onto the arguments drawn from the apparent motion of the starry sphere. Then it follows that the argumentation in favour of cosmological finitism gets weaker, because it has lost its chief ground drawn from the motion of

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<sup>12</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VIII, p. 16.

<sup>13</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. I, p. 8 : "the sphere [...] is the most capacious of figures, best suited to enclose and retain all things".

<sup>14</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. I, p. 8.

<sup>15</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. I, p. 8 : "or that wholes strive to be circumscribed by this boundary, as is apparent in drops of water and other fluid bodies when they seek to be self-contained".

the eighth sphere. In the opposite, the attachment to the idea of a starry sphere enclosing the whole world is very handy for practical astronomy, operating angular measurements.

**a) The traditional grounds in favour of a closed world :**

The Aristotelian inquiry had shown that the question about the infinity of the universe could be reduced to the possibility of an endless body<sup>16</sup>. Aristotle considered as self-evident that compound bodies, made of simple finite bodies in finite number, are themselves finite. Since the bodies are either compound or simple, the question is to examine whether a simple body can be infinite. Nonetheless, it is strange to see Aristotle saying, without any demonstration, what would be concluding a special demonstration : "*Anyway, the simple bodies are limited <πεπερασμενων των απλων>*"<sup>17</sup>. Then, Aristotle demonstrates that it is impossible for a simple body to be endless so that, according to the principle of non contradiction, the finitism is well-founded. Of course, Aristotle chose among the simple bodies the "*Ether*" or the "*fifth Element*" or the "*first body*"<sup>18</sup>. There are six different arguments based on the same ground, namely : what is in rotation or in circular motion cannot be infinite ; in other words, what is infinite cannot revolve. So, Aristotle can demonstrate easily that : "*every body which revolves in a circle must be finite*"<sup>19</sup>. However, it would be possible to object to Aristotle that, though he had clearly demonstrated that an infinite body cannot be in circular motion, it does not prevent a body *at rest* to be infinite ! But this kind of objection against the Stagirit is irrelevant, because Aristotle starts off with observational data of the diurnal circular motion of the starry sphere. The founder of the *Lycée* does not call into doubt the observational data :

"If then it is impossible to traverse an infinite space, and in an infinite body the space between the radii is infinite, the body cannot move in a circle. But we ourselves see the

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<sup>16</sup>ARISTOTE, *Traité du ciel*, tr. fr. Paul MORAUX, Paris, Belles Lettres, 1965, I, 5, 271 b, p. 13.

<sup>17</sup>*Traité du ciel*, tr. fr. Paul MORAUX, Paris, Belles Lettres, 1965, I, 5, 271 b 20, p. 13.

<sup>18</sup>*Ibid.*

<sup>19</sup>*Traité du ciel*, tr. fr. Paul MORAUX, Paris, Belles Lettres, 1965, I, 5, 271 b 27, p. 13.



heavens revolving in a circle, and also we establish by argument that circular motion is the motion of a real body"<sup>20</sup>.

But since Copernicus had rejected or reduced the geocentric and geostatic appearances, all the Aristotelian arguments in favour of a closed world completely fall down. That's exactly what Bruno understood and explained in his *De l'Infinito*<sup>21</sup> :

**b) Copernicus' hesitation between a closed world and an infinite universe :**

Copernicus asserts unhesitatingly the earth' s motion, which follows from its spherical form. It seems to him more reasonable to attribute motion to the contents rather than to the container, as he puts it :

"it would seem quite absurd to attribute motion to the framework of space or that which encloses the whole of space, and not, more appropriately, to that of which is enclosed and occupies space, namely, the earth"<sup>22</sup>.

Though nothing stands in the way of an infinite universe, since the sphere of the fixed stars has been "immobilised" and immensely enlarged, Copernicus refuses, however, to go beyond cosmological *immensity* into

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<sup>20</sup>*Traité du ciel*, tr. fr. Paul MORAUX, Paris, Belles Lettres, 1965, I, 5, 272 b16-17, p. 16.

<sup>21</sup>BRUNO, *De l'infinito, universo e mondi*, 1584, engl. tr. Singer, New York, 1950, Second Dialogue, p. 276-277 : "This reasoning is good but it answerth not his adversaries. For never hath one been found so barbarous and so ignorant as to have posited the infinite world, infinite in size, and to have attributed motion to it. And he sheweth himself forgetful of that which he relateth in his *Physica* ; that those who postulated a single being, one infinite origin, have similarly regarded it as immobile. Neither he nor any other person among his supporters can name a single philosopher or indeed any simple man who hath attributed motion to infinite size. But like a sophist he taketh one part of his argument from the conclusion of his adversary ; positing his own principle that the universe is mobile, also that it moveth and that it is of a spherical form. Now observe whether, among the reasonings adduced by this beggar there is even one that doeth militate against the belief of those who proclaim an infinite, motionless and formless immense universe, containing innumerable moving bodies which are the worlds, by some called stars, by others spheres. Just note in this and in other reasonings whether the premises that Aristotle adduced have been accepted by anyone".

<sup>22</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VIII, p. 17.

*infinity*. The chief ground of his reserve is certainly epistemological. Copernicus starts off with the impossibility of knowing what is beyond the starry sphere: "*the entire universe, whose limit is unknown and unknowable? <totus mundus, cujus finis ignoratur sciri que nequit>*"<sup>23</sup>. Nevertheless, the epistemological advantage, indeed even the superiority, of infinitism on finitism, lies in the fact that the conception of an infinite universe removes the aporias of limitation :

"If the heavens are infinite, however, and finite at their inner concavity only, there will perhaps be more reason to believe that beyond the heavens there is nothing"<sup>24</sup>.

Indeed, if the conception of an infinite universe allows to avoid the aporias of the limitation, on the other hand it leads to the traditional paradoxes of infinity, which were set out in detail since Duns Scot in the scholastic handbooks, and were useful to refute the infinitist cosmology of the Atomists. In this respect, it seems that Copernicus did not want to confront the paradoxes of infinity.

Though the immensity of the starry sphere produces, exactly as its hypothetical infinity, the same impossibility to measure the third dimension of the universe, the thesis of immensity is also perfectly suitable for Copernicus' finitist cosmology based on a strange conception of natural gravity<sup>25</sup>. Indeed, Copernicus attributes the same gravific properties to the contents as to the universal container, that is to the wholeness of the universe. Thanks to that way of thinking, Copernicus succeeds in overcoming Aristotle's dualist cosmology :

"First of all we must note that the universe is spherical <*globulosum*>. The reason is either that, of all forms, the sphere is the most perfect, needing no joint and being a complete whole, which can be neither increased nor

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<sup>23</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VIII, p. 16.

<sup>24</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VIII, p. 16.

<sup>25</sup>Cf. *De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. I, p. 8. Copernicus mentioned his conception of gravity in *Op. cit.*, Book I, chap. IX, p. 18 "For my part I believe that gravity is nothing but a certain natural desire, which the divine Providence of the Creator of all things has implanted in parts, to gather as a unity and a whole by combining in the form of a globe".

diminished ; or that is the most capacious of figures, best suited to enclose and retain all things or even that all the separate parts of the universe, I mean the sun, moon, planets and stars, are seen to be of this shape ; or that wholes strive to be circumscribed by this boundary, as is apparent in drops of water and other fluid bodies when they seek to be self-contained. Hence no one will question the attribution of this form to the divine bodies"<sup>26</sup>.

According to this excerpt, the universe is closed because of its self-limiting gravity under the effect of a natural law or tendency. Correlatively, Copernicus' finite universe has a centre :

"Lastly, it will be realised that the sun occupies the middle of the universe. [...]. Hence I feel no shame in asserting that this whole region engirdled by the moon, and the centre of the earth, traverse this grand circle amid the rest of the planets in an annual revolution around the sun. Near the sun is the centre of the universe <*circa solem [...] ipsum esse centrum mundi*>. [...]. At rest, however, in the middle of every thing is the sun <*in medio omnium residet Sol*>. etc."<sup>27</sup>.

Copernicus' interest for a closed world, with a centre and an extreme boundary, is based on his conception of harmony. The Sun occupies the centre of the universe (or is very close to this centre) as if it was its Rector : it lights up equally the whole Creation. Every metaphor gives to understand that the cosmic edifice is governed by a strict symmetry, because the world must be well-proportioned according to the architectonic idea of the whole. Indeed, Copernicus uses expressions like : "*in this most beautiful temple*", of which the Sun is the "*lamp*"; he says also that : "*as though seated on a royal throne, the sun governs the family of planets revolving around it*"<sup>28</sup>. Whatever may be the detail of those metaphors, they all mean that the wonderful cosmic order reveals the perfect wisdom of its Author ; which would be impossible according Copernicus in the case of an infinite universe :

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<sup>26</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. I, p. 8.

<sup>27</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. IX, 18; ch. X, 20; ch. X, 22.

<sup>28</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. X, p. 22.

"In this arrangement, therefore, we discover a marvellous symmetry of the universe <*mundi symmetriam*>, and an established harmonious linkage between the motion of the spheres and their size, such as can be found in no other way. [...] So vast, without any question, is the divine handiwork of the most excellent Almighty <*divina haec Optimi Maximi Opifecis fabrica*>"<sup>29</sup>.

Thus Copernicus thinks that he has solved the cosmological problem, which traditional astronomy had raised and which he has very strictly criticised in his famous letter<sup>30</sup> to the pope Paul the III<sup>rd</sup>. If we go on analysing in detail the exact structure of the Copernican universe, we find out that its harmony is made of proportions between the orbes' magnitudes and the periods of their revolutions ; but in spite of that the cosmological harmony does not govern the immense empty space that extends from Saturn' orbit to the sphere of the fixed stars, which is used as an absolute system of reference for every measurement or observation<sup>31</sup>. Since this keeping still starry sphere has dimensions which cannot be measured, Copernicus comes up against a new problem insofar as he asserts that the world is closed, though its dimensions are unknown and unknowable :

"In comparison with any other spheres of the planets, the distance from the earth to the sun has a magnitude which is quite appreciable in proportion to those dimensions. But the

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<sup>29</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. X, p. 22.

<sup>30</sup>Cf. Copernicus' letter intitled : *To His Holiness, pope Paul III, Nicholas opernicus' Preface to his Book on the Revolutions* (3-6), in *De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, especially p. 4 : "Nor could they elicit or deduce from the eccentrics the principal consideration, that is, the structure of the universe and the true symmetry of its parts".

<sup>31</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. X, p. 21 : "[The sphere of the fixed stars] It is unquestionably the place of the universe, to which the motion and position of all the other heavenly bodies are compared".

size of the universe is so great that the distance earth-sun is imperceptible in relation to the sphere of the fixed stars"<sup>32</sup>.

Copernicus' cosmological position is rather delicate, because he has clearly understood that it is impossible to demonstrate, even with the help of measuring instruments, that the world is closed :

"Yet none of these phenomena appears in the fixed stars. This proves their immense height, which makes even the sphere of the annual motion, or its reflection, vanish from before our eyes. For, every visible object has some measure of distance beyond which it is no longer seen, as is demonstrated in optics. From Saturn, the highest of the planets, to the sphere of the fixed stars there is an additional gap of the largest size"<sup>33</sup>.

Though Giordano Bruno was an admirer and a follower of Copernicus' astronomy, he never could accept Copernicus' position relatively to the dimensions of the world, because it would be a nonsense to think that the Almighty and infinite Creator has only created a closed world, thus revealing God's miserliness and powerlessness, which is a contradiction in terms<sup>34</sup>. Indeed, Bruno's argument comes within the province of natural theology ; whereas Copernicus remains on the ground of astronomy and natural philosophy. But so to speak, the new Copernican immensity made possible the transition from a closed world to an infinite universe.

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### **Thomas Digges' Copernicanism and his Cosmological Infinitism :**

Let us take a closer look at the reception of Copernicus' heliocentric theory in Renaissance England in order to determine if it has exerted any influence over the problem of cosmological infinity. During the second half

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<sup>32</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. X, p. 20.

<sup>33</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. X, p. 22.

<sup>34</sup>Bruno concentrates his chief argument in a short formula, cf. *De l'infinito, universo e mondi*, 1584, engl. tr. Singer, New York, 1950, First Dialogue, p. 263 : "Wherefore he who denieth infinite result, denieth also infinite power".

of the sixteenth century, England was not really in the forefront of the Renaissance astronomical researches. The greatest English scientists being acquainted with Copernicus' works were not very numerous, but it is not a question of number here. We could hold as examples : Robert Recorde (1510-1558), John Feild (1520-1587), John Dee (1527-1608) and his famous follower Thomas Digges (1546-1595). But nevertheless, the impact of Copernicus' heliocentric theory became quickly significant in England, especially thanks to the popular accounts in common language published in the middle of the 16<sup>th</sup> century. It is certainly not enough to have heard of Copernicus' works to become a convinced Copernican, it is a necessary but not sufficient condition. Thus, Robert Recorde praises Copernicus in his book *The Castle of Knowledge* (1556) and gives an account of his geokineticism showing that he is able to face up the traditional objections against the motion of the Earth. However, Robert Recorde does not seem to have accepted Copernicus' heliocentric theory nor its infinitist possible implications :

*"-Master. That is truly to be gathered : how be it, Copernicus, a man of great learning, of much experience, and of wonderful diligence in observation, hath renbewed the opinion of Aristarchus Samius, and affirmeth that the earth not only moveth circularly about his own centre, but also may be, yea and is, continually out of the precise centre of the world 38 hundred thousand miles ; but because the understanding of that controversy dependeth of profounder knowledge than in this Introduction may be uttered conveniently, I will let it pass till some other time"<sup>35</sup>.*

Moreover, Robert Recorde refused to become involved in this Copernican way : in fact, his book *The Castle of Knowledge* was just an intended textbook for young students, and it is the reason why his author had to put off giving further details about Copernicanism, which had only been mentioned here with respect and interest. Unfortunately, it has been impossible for Robert Recorde to go deeper into Copernicus' heliocentric theory because he died too soon in 1558.

As for John Dee, who was Thomas Digges' Master, it is sure that he was perfectly aware of Copernicus' astronomy (we know that he possessed two copies of Copernicus' *De Revolutionibus* and that he was making use of the Reinhold's *Tabulae Prutenicae*); but he does not seem to have accepted personally Copernicus' heliocentric theory because he asserts in his

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<sup>35</sup>Robert RECORDE, *The Castle of Knowledge*, London, Reginalde Wolfe, 1556, p. 164-165.

*Propaëdeumata aphoristica*<sup>36</sup> (1558) the diurnal movement of the heavens and the annual orbit of the Sun. Though John Dee's geostatical finitism was plain to see, he could have exercised at least some influence in an indirect way over some infinitist cosmologists as Ursus<sup>37</sup> whom he met during his tour of the German countries before 1588. Moreover, it is possible that John Dee informed Ursus about Nicolaus de Cusa's infinitist cosmology, because he possessed de Cusa's works in his own library at Mortlake. In return, Ursus dedicated to his friend John Dee one of the diagrams illustrating his own system of the world in his famous *Fundamentum Astronomicum*<sup>38</sup>. On the other hand, it is definitely sure that John Dee (who was a reader of the *Asclepius*, just as Giordano Bruno was, but also many other Renaissance learned men) has *not* met Giordano Bruno in England between 1583 and 1585, because at that time he was gone off on a long journey on the Continent where the English scholar had many friends<sup>39</sup>. However, it is very obvious that John Dee, who wrote a preface for John Feild's *Ephemeris anni 1557 currentis iuxta Copernici et Reinholdi canones [...] supputata*, had not been convinced by Copernicus' arguments. For his own part, John Feild had entirely accepted Copernicus' heliocentric theory, as he mentions it expressly in his foreword :

"That is the reason why I have followed, in these Ephemeris for the year 1557, the Authors N. Copernicus and Erasmus Reinhold, whose writings have been established and based on true, sure and sincere demonstrations"<sup>40</sup>.

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<sup>36</sup>John DEE, *Propaëdeumata aphoristica*, London, 1558, cf. aphorismes 58 et 66.

<sup>37</sup>Nicolaus Raimarus Ursus Dithmarsis or Nicolai Reymers called Ursus (♠ 1599).

<sup>38</sup>Nicolaus RAIMARUS URSUS DITHMARSIS, *Fundamentum Astronomicum: Nova Doctrina sinuum et triangulorum*, Strasbourg, 1588. See especially p. 39b, where Ursus presents a diagram of his own infinitist cosmology mentioning above : "*Ioanni Dee Anglo dedicatum*".

<sup>39</sup>That is exactly what Mrs. Frances Yates claims in her article about Dee and Bruno : "*During the whole two years of Bruno's time in England, Dee was absent abroad. Thus Dee and Bruno are moving rather close to one another in England in 1583, but there is no record that they met. Bruno pursues his mission in England in the following years whilst Dee is absent abroad, pursuing his own mission*". Cf. "Renaissance Philosophers in Elizabethan England : John Dee and Giordano Bruno", republished in *Lull and Bruno*, London, 1982, vol. 1, p. 211.

<sup>40</sup>John FEILD, *Ephemeris anni 1557 currentis iuxta Copernici et Reinholdi canones [...] supputata*, London, Thomas Marshe ; 1556, Sig. A3r : "*Quapropter hanc tibi pervulgavi*

All in all, it's only in a short popularising English work that an infinitist cosmology stemming from a reflection on Copernicus' heliocentric theory could be found. Of course, the short work in question is Thomas Digges' *A perfit description of the Caelestial Orbes*, which was published for the first time in 1576, on the occasion of the second edition of his father's book : Leonard Digges' *Prognostication everlastinge*<sup>41</sup> as an appendix. As soon as Francis R. Johnson and Sanford V. Larkey discovered Thomas Digges' short work, they published a copy of it in their interesting and famous article of 1937<sup>42</sup>. Though this short work became nowadays very rare to find, it does not mean that it did go at that time unnoticed. In fact, Thomas Digges' *A perfit description of the Caelestial Orbes* had been a bestseller, because it had been republished six times in less than thirty years<sup>43</sup>. Nevertheless, I shall remain much more reserved than Johnson and Larkey about the meaning and the import of Thomas Digges' cosmological infinitism, but for reasons which are different of Koyré's ones.

The first thing that must be said is that the most part of Digges' short work is but a rough (and yet relatively faithful) translation of Copernicus' *De Revolutionibus orbium coelestium* (book I, chapters VII, VIII and X). On the other hand, it may be asserted that Thomas Digges introduces some interesting personal remarks now and again. To put the whole matter in a nutshell, it would be more accurate to say that Thomas Digges represents the infinitist way that Copernicus had only foreseen when he observed with much truth : "*Let us therefore leave the question whether the universe is finite or infinite to be discised by the natural philosophers*"<sup>44</sup>. In the face of such alternative, Digges has decided in favour of the infinitist way, whereas Copernicus, who had clearly established the incommensurability and the

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*Ephemeridem Anni 1557, in ea authores sequutus N. Copernicum et Erasmus Reinholdum, quorum scripta stabilita sunt et fundata veris, certis, et sinceris demonstrationibus".*

<sup>41</sup>The first edition of Leonard DIGGES' *Prognostication everlastinge* dates from 1553.

<sup>42</sup>Francis R. JOHNSON & Sanford V. LARKEY, "Thomas Digges, the Copernican System, and the Idea of the Infinity of the Universe in 1576", in *The Huntington Library Bulletin*, April 1934, n° 5, p. 69-117. Th. Digges' paper appears from p. 78 to p. 95.

<sup>43</sup> Thomas DIGGES' *A perfit description of the Caelestial Orbes*, had six editions which appeared successively in 1578<sup>1</sup>, 1583<sup>2</sup>, 1585<sup>3</sup>, 1592<sup>4</sup>, 1596<sup>5</sup>, 1605<sup>6</sup>.

<sup>44</sup>*De Revolutionibus orbium coelestium*, Nürenberg, 1543, engl. transl. ROSEN, in *Complete Works*, II, 1978, Book I, ch. VIII, p. 16.



immensity of the universe, remained obviously attached to a finitist worldview. It should be stressed that the passages, in which Digges asserts that the universe is infinite, are relatively rare. The most important one appears in the famous diagram taking place just before Digges' Introduction entitled "*To the Reader*" [cf. fig. 1]. The following inscription placed next to the eighth sphere, the sphere of fixed stars, can be seen :

*"This orbe of starres fixed infinitely up extendeth hit self in altitude sphericallye, and therefore immovable the pallace of foelicitye garnished with perpetuall shininge glorious lightes innumerable farr excellinge our Sonne both in quantitye and qualitye the very court of coelestiall angelles devoyed of greefe and resplendished with perfite endlesse joye the habitacle for the elect"<sup>45</sup>.*

This short commentary given by Thomas Digges is perhaps less bold than his diagram, because the latter represents the fixed stars as scattered beyond the «sphere of fixed stars» and spread out at different distances from the centre of the world occupied by the Sun. On the contrary, the commentary claims that the infinite space is filled with innumerable stars and beings who belong traditionally to the «realm of the blessed», namely to the «theological heavens» as Koyré pointed it out rightly. It is as if the destruction of the sphere of fixed stars had led to blend the sensible world with the suprasensible entities, physics with theology. An other important passage concerning cosmological infinity is inserted as a parenthesis in Digges' translation of Copernicus' *De Revolutionibus* [book I, chapter X] :

*"The first of the movable Orbes is that of Saturn, whiche beinge of all other next unto that infinite Orbe immoveable garnished with lights innumerable is also in his course most slow, & once only in thirty yeares passeth his Periode. [...] We may easily consider what litle portion of gods frame, our Elementare corruptible worlde is, but never sufficiently be able to admire the immensity of the Rest. Especially of that fixed Orbe garnished with lightes innumerable and reachinge up in Sphaericall altitude without ende"<sup>46</sup>.*

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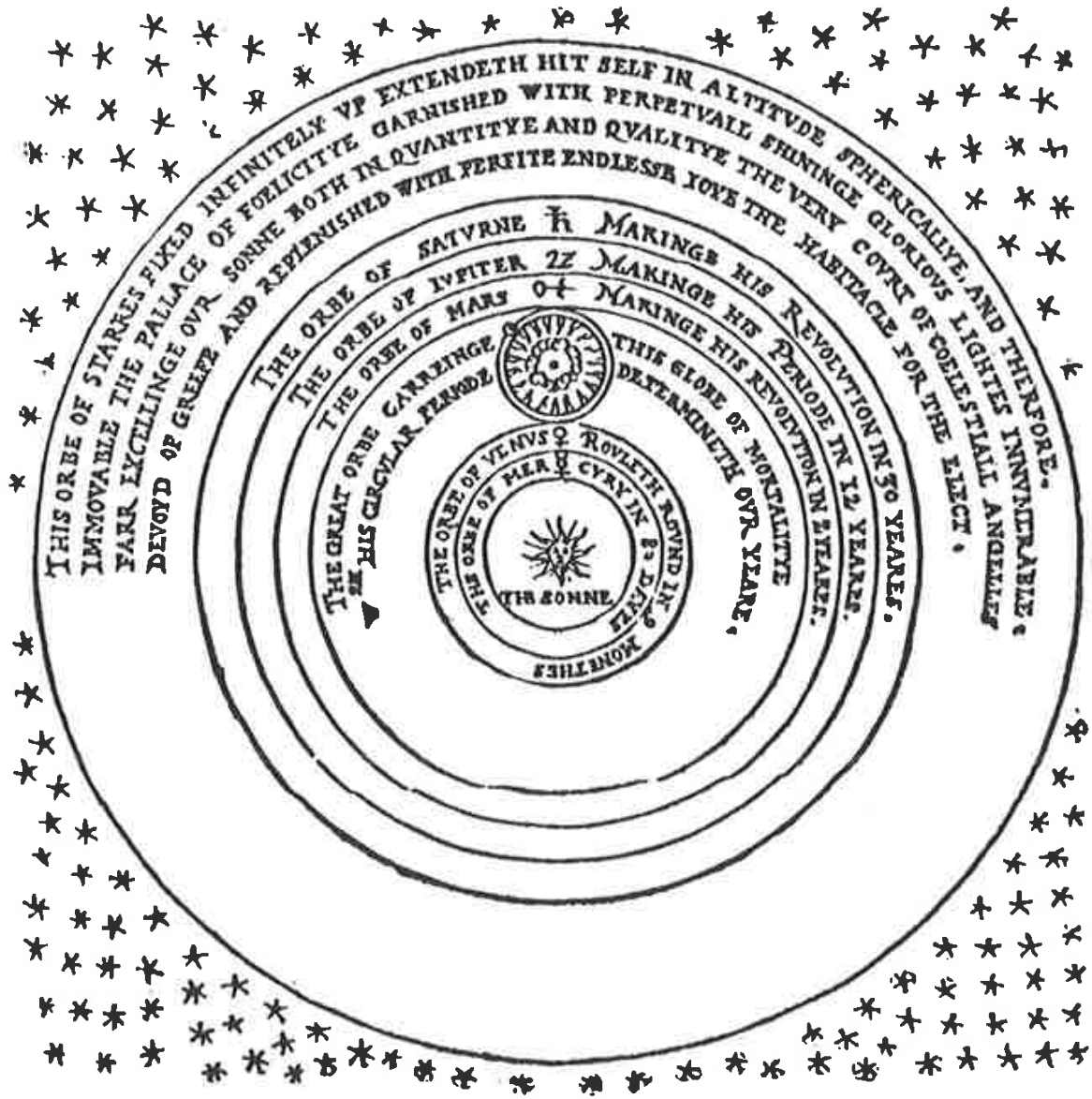
<sup>45</sup>This document is reproduced in the article of Francis R. JOHNSON & Sanford V. LARKEY, "Thomas Digges, the Copernican System, and the Idea of the Infinity of the Universe in 1576", in *The Huntington Library Bulletin*, April 1934, n° 5, p. 78, *Folio*. 43.

<sup>46</sup>*A Perfit description of the Caelestial Orbes*, p. 87-88; N 3r.

Fig. 1 Thomas Digges, *A Perfit description of the Caelestial Orbes*, 1576.

Folio.43

☽ A perfit description of the Caelestiall Orbes,  
according to the most auncient doctrine of the  
Pythagoreans. &c.



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This brings us to the difficult question of determining why Thomas Digges became a supporter of infinitism, for there is no document of that time explaining directly this fact. The only means of clearing up this point at our disposal are to be found in clues. The main clue consists in the fact that Digges refers very often to the famous infinist Italian poet Marcellus Palingenius Stellatus (*alias* Pier Angelo Manzoli) whom he calls himself «*the Stellified Poet*». Besides, Digges quotes widely Latin verse of Marcellus Palingenius' *Zodiacus Vitae* first published in 1531. Marcellus Palingenius' *Zodiacus Vitae* was already very famous in England, because it was on the syllabus of the schools as much on the continent as in England, so that it is impossible to determine the exact number of its new editions during the second half of the sixteenth century. Johnson & Larkey draw our attention to the fact that Marcellus Palingenius' *Zodiacus Vitae* had been translated into English by Barnaby Googe between 1560 and 1565, and that Digges knew by heart long excerpts of it he used to declaim publicly<sup>47</sup>. It was as if Digges had been combining Copernicus' heliocentric theory with Palingenius' outer infinite space. It should never be forgotten that Digges' infinite universe has however a central area occupied by the Sun. That is the reason why I wish to focus our attention on the fact that Digges remains certainly one of the very first Copernican supporter of cosmological infinity (much earlier before Giordano Bruno). But it may be asserted, however, that Digges never did become aware of what really means or implies this infinity. An infinite universe with a central area is a nonsense, all the more reason for a great scientist and an expert in mathematics as Thomas Digges. That is why it seems to me hard to agree with Johnson & Larkey' s interpretation.

It is undoubtedly true that Digges' infinitism has a chronological priority on Giordano Bruno's one, but Johnson & Larkey' s following statement seems to me quite unconvincing about Thomas Digges : «*Bruno, unlike Digges, was not an eminent mathematician and scientist and, although he at times gave lip service to the experimental method, he never deigned to practice it. In short, Bruno's ideas of the infinite were arrived at by purely metaphysical speculations*»<sup>48</sup>. In actual fact it would be more accurate to say that, even if Digges certainly is a scientist, Digges' own argumentation in support of cosmological infinity falls also within the province of

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<sup>47</sup>Francis R. JOHNSON & Sanford V. LARKEY, "Thomas Digges, the Copernican System, and the Idea of the Infinity of the Universe in 1576", in *The Huntington Library Bulletin*, April 1934, n° 5, p. 101-103. Koyré also admits a possible influence of Palingenius over Digges' thought, *Op. cit.*, p. 59.

<sup>48</sup>*Op. cit.*, p. 114.

metaphysics and theology, but is not at all a matter for mathematics. Besides, Nicolaus de Cusa and Giordano Bruno, who were themselves only amateurs in mathematics, used to assert always that the infinite universe is like an infinite sphere : «*nowhere having a centre nor a circumference*». Added to that, Johnson & Larkey confess expressly that they do not know which intellectual progression led Digges to his cosmological infinitism<sup>49</sup>. In spite of this ignorance, they venture however an hypothesis that should not go unchallenged. For my part, I think that Johnson & Larkey' s conjecture does not rest on real mathematical or astronomical arguments. Nevertheless, they assert :

*"We may nevertheless be sure, from our knowledge of Digges' work as a scientist and from his own statements on astronomical questions, that in approaching this problem he consistently kept to the scientific point of view. Hence, although the metaphysical speculations on infinity found in Palingenius and in other poets and philosophers may have originally directed his thoughts toward these matters, scientific considerations played the decisive part in the formulation of this hypothesis, and no one was more eager than he to try to verify it by observation and experiment"*<sup>50</sup>.

Unfortunately, there is not the slightest evidence to justify such a claim about the cosmological infinity from a «*scientific point of view*». If this expression means that it was necessary to require mathematical knowledge at the time of Renaissance, it is very far from the truth, because mathematics were helpless to determine the properties of an infinite physical space (the parts of which are supposed to be *actually* coexisting), whereas the infinity of geometrical space has a *potential* existence. Furthermore, if Johnson & Larkey refer to astronomical measurements, it is obvious that measuring makes no sense as regards to an infinite space. At last, Johnson & Larkey stress that Digges was "*eager to verify* [speculations on infinity] *by observation and experiment*", but such a line of thinking may only mean that he tried to disprove thanks to observations different kinds of arguments supporting cosmological finitism. The only example of astronomical proof put forward by Johnson & Larkey appears in Digges' *Alae seu scalae Mathematicae* published in 1573. In his book, Digges

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<sup>49</sup>*Op. cit.*, p. 113 : "*However, the precise reasons which led Digges to assert that the universe should be conceived as infinite, with the stars at varying distances, must remain forever uncertain*".

<sup>50</sup>*Op. cit.*, p. 113.

asserted that it was possible to test Copernicus' heliocentric theory by means of astronomical observations of the new star (*nova stella*) appeared in 1572. To be more precise, Digges thought that the new star of 1572 could enable the astronomers to bring to the fore that the Earth *really* is in motion<sup>51</sup>. Of course, Johnson & Larkey give us rightly to understand that Digges is "eager to verify" theoretical statement as any scientist has to do it. However, there is a fundamental difference between testing if the Earth is in motion and testing if the universe is infinite. A definite piece of evidence about it is the fact that Copernicus himself had asserted at the same time that the Earth is in motion and that the world is closed, though he had admitted its immensity. Yet Johnson & Larkey make precisely this strange mixture of ideas. Added to that, Digges believed wrongly that the variations in brightness of the new star were due to the variations in distance of the Earth with respect to the *nova*, that is to say all the phenomenon is due to the annual movement of our planet. It is well worth noting that, though Digges suffered a setback in his observational astronomical tests, he remained unflinchingly a supporter of Copernicus' heliocentric theory. That just shows what Johnson & Larkey mean by «*the scientific point of view*» of their champion.

If we take a closer look at Digges' paper, it becomes clear that his cosmological infinitism is deeply rooted in the province of natural theology instead of the area of sciences. For Digges argues that only an infinite universe may be suitable for God whose Omnipotence and Majesty are infinite. So, the visible and immense part (according to the Copernican meaning of that word) of the universe allows us to infer or conjecture the invisible infinity of the whole creation. Only such a cosmological infinity is worthy to express the infinite Creator. That is exactly what means Digges' following parenthesis :

*"And this may wel be thought of us to be the glorious  
court of ye great god, whose unsearchable worcks invisible  
we may partly by these his visible conjecture, to whose infinit*

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<sup>51</sup>DIGGES, *Alae seu Scalae Mathematicae*, London, Thomas Marshe, 1573, sig. A2v-A3v : *"Fuit igitur causa praecipua cur Copernicus vir admirandi ingenii, & industria singulari, aliis hypothesibus uti, et novam Coelestis Machinae Anatomiam eruere conatus fiet : at proluxa nimis oratione et huic loco parum convenienti opus esset, ut dilucide collatis utriusque generis hypothesibus veritas elucesceret, hoc saltem admonere statui ansam oblatam esse, et occasionem maxime opportunam experiendi an Terrae motus in Copernici Theoricis suppositus, sola causa fiet cur haec stella magnitudine apparente minuat, nam si ita fuerit in Aequinoctio verno semper decrescens minima sua magnitudine conspiceretur, etc..."*.

*power and majesty such an infinit place surmountinge all other both in quantity and quality only only is conveniente*<sup>52</sup>.

The Neoplatonic and Christian echoes of the argument contained in the last quotation are obvious to everyone. We must acknowledge that this argument was relatively common and widely spread at the time of Renaissance. Moreover, the same argument will reappear a few years later in a more developed form in Giordano Bruno's works. On the other hand, there is a strong possibility that Thomas Digges' translation of the *De revolutionibus* had convinced many English readers of the XVI<sup>th</sup> century that Copernicus himself was a supporter of cosmological infinity, at least as long as an other translation of Copernicus was not available. Does this mean that, according to the old saying : «*post hoc, ergo propter hoc*», Digges' infinitism has been at the origin of Bruno's infinitism, under the pretext that the Italian philosopher went to England eight years later? This point remains to be seen. Anyway, it is what Johnson conjectures in his book published in 1937 concerning astronomical thought in Renaissance England<sup>53</sup>; but in spite of all the investigations undertaken in order to discover a real link between Digges and Giordano Bruno, until this day the question remains open<sup>54</sup>.

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<sup>52</sup>*A Perfit description of the Caelestial Orbes*, p. 89; N 4r.

<sup>53</sup>F.R. JOHNSON, *Astronomical thought in Renaissance England*, Baltimore, 1937, p. 164 sq, cf. en particulier p. 169 : "Edward Dyer, the friend and patron of Dee and Digges, was also a member of the Sidney-Fulke-Greville group, the circle Bruno knew in England".

<sup>54</sup> Cf. also n. 39 quoting of Mrs. Yates' conclusions on this subject.