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Avoiding the Void: Avicenna on the Impossibility of Circular Motion in a Void

Jon McGinnis, *University of Missouri - St. Louis*

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The topic of the void was of significant philosophical and scientific importance in the ancient and medieval world. Some, such as the atomists, maintained that the void was essential if one were to explain motion. Others, such as Aristotle, argued that the existence of the void would absolutely preclude the possibility of motion. Moreover, there were disputes concerning even how to characterize the void. Thus the atomists claimed that interstitial voids were dispersed throughout every body and existed alongside bodies in an infinite space. Others, such as the Stoics, held that all bodies were localized in a plenum that was itself situated in an extra-cosmic, infinite void. Still others, such as the Neoplatonist John Philoponus, thought that the void was finite, and although as a matter of fact it is never devoid of a body, it at least is capable of existing independent of any body.

The above roughly provides the gamut of positions concerning the void as it reached the medieval Arabic philosopher Avicenna (AH 370–428/AD 980–1037). In one form or another, Avicenna was aware of the various moves and counter-moves associated with the notion of the void. Like Aristotle, he maintained that the existence of the void would absolutely preclude the possibility of motion. His arguments in some cases simply rehearse those of Aristotle; in other places they expand on the thought of Aristotle in order to respond to new threats that arose after Aristotle's own time; and in certain situations Avicenna constructs new arguments against the void used neither by Aristotle nor, from what we can gather, Aristotle's later Greek commentators.

In what follows I do not pretend to present Avicenna's whole argument against the void; rather, I concentrate on one small subset within the broader complex of arguments associated with Avicenna's refutation of the void. This is his argument that circular motion would be impossible within an infinite, void space. This argument is significant in that it shows a marked departure from Aristotle and what we know of other Greek Aristotelians; for neither Aristotle nor apparently his Greek commentators ever specifically treat the impossibility of circular motion in a void. Their arguments instead focus on natural and violent motion, where it is argued that violent motion, or motion opposed to nature, presupposes natural motion. They in turn show that natural motion in a void is impossible, concentrating on natural motion in the category of place.

This study falls into two sections: one, Avicenna's argument and an analysis and assessment of it; and two, the historical and philosophical considerations motivating

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Avicenna's argument. I begin by reconstructing Avicenna's argument against circular motion in a void and defending various assumptions that Avicenna makes in that argument. In the second half I begin with some possible Greek sources for Avicenna's argument. I hazard the hypothesis that the most likely influence is an argument found in Aristotle's *De caelo*, and that Alexander of Aphrodisias in his *Physics* commentary may have offered Avicenna a hint on how to modify Aristotle's argument to Avicenna's own advantage. I then turn to Avicenna's motivation for presenting this apparently new argument, and consider possible historical and philosophical motivations. Under historical motivations, I entertain the suggestion that Avicenna was responding to the Stoics and their theory of the cosmos's being a plenum situated in an extra-cosmic infinite void. Any connection between Avicenna and the Stoics, however, is at best tenuous, given the relative absence of Stoic Arabica. Moreover, there were, I believe, more pressing philosophical and internal considerations that motivated Avicenna to construct his new argument. These concerns arose from certain modifications that he made to the Aristotelian physics he adopted. The most notable is his introduction of a new genus of motion, namely motion with respect to the category of position in addition to the canonical three – motion with respect to quantity, quality, and place – and the unique analyses of rectilinear and circular motions that this addition requires.

AVICENNA'S ARGUMENT AND ANALYSIS

At *Physics* II.8 Avicenna begins his formal refutation of the possibility of motion in a void, and starts by setting up his argument that natural circular motion would be impossible:

> We say that neither motion nor rest is possible in the void, but in every place there is motion and rest, and so the void is not a place. As for there being no motion in it, all motion is either violent or natural, but we maintain that there is no natural motion in the void. That follows because it would either be circular or rectilinear. There cannot be circular motion in the void, because it is not of the void's character that it comes to an end or is exhausted, unless there were in addition to it some infinite body, and so that body would prevent it from going on infinitely.[1]

The argument that follows, then, is intended to show that circular motion cannot occur in an infinite, extra-cosmic void with the cosmos being situated within this void. The qualification that this void space be infinite is important, since the impossibility that Avicenna derives is a direct result of the purported void's infinite expanse.

Avicenna has the reader construct a dynamic geometrical figure, that is to say a geometrical figure that rotates. In Figure 1 this dynamic element is represented by three different diagrams that correspond to different moments in the figure's rotation.

The argument assumes that a physical, rotating sphere, ABCD, with centre E, is situated within an infinite void space. Although Avicenna is not explicit, he clearly has

1. *Al-Shifāʾ*, *al-Ṭabīʿīyyāt*, *al-Samāʿ al-ṭabīʿī*, ed. S. Zāyed, Cairo, 1983, II.8, p. 127.1–5; henceforth *Ṭabīʿīyyāt*.

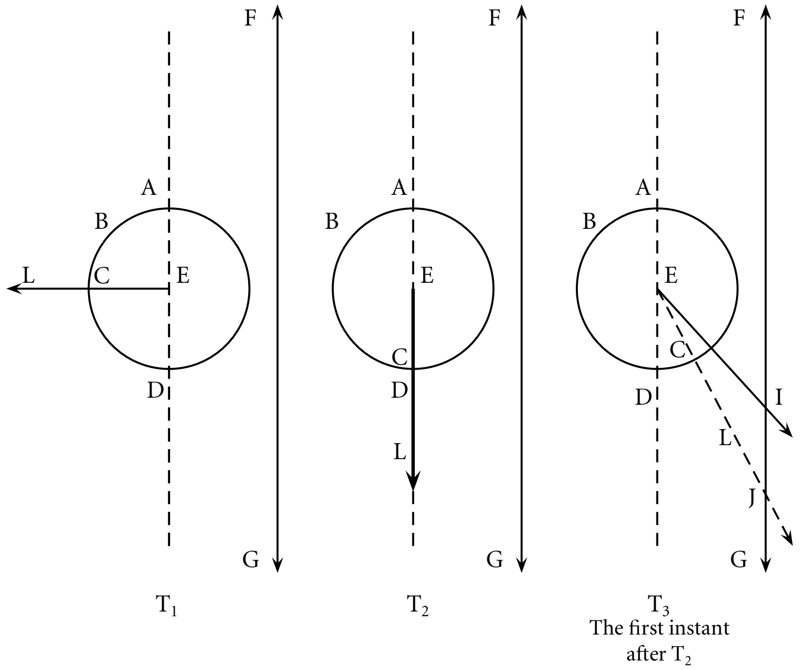


FIGURE 1

in mind something like our own cosmos as it would have been understood in the ancient and medieval worlds, where the cosmos was viewed as a finite sphere whose outermost limit, i.e. the sphere of the fixed stars, rotates once approximately every twenty-four hours. He next posits a line, FG, extended infinitely in the supposed infinite extra-cosmic void space, such that FG is in the same plane as and is parallel to a line AD that bisects the sphere. Clearly, at some moment of time, T_1, the line EC is pointing away from FG; and so even if extended infinitely through L, the line would not intersect FG. At T_2 the line ECL is parallel with FG, but again does not intersect FG.

At the first instant after T_2, T_3, the line ECL does intersect FG. Now since one is considering the motion of the line at an instant, it can intersect FG only at a single point; for if ECL were to intersect more than one point, then one would be considering the motion of ECL over a period of time and not at an instant. Thus, call the point of intersection at the first instant after ECL is no longer parallel with AD, I. Moreover, since the line ECL is extended infinitely, in ECL's motion between points D and A, it sweeps through every point on the line FG. In addition, since the line FG is infinite, for any point posited on it there are likewise an infinite number of points on either side of the posited point. Thus, there must be a point J that comes before I. Since ECL sweeps through every point on FG, and J comes before I relative to ECL's motion, then ECL intersects FG at J before it intersects at I; however, it was assumed that I was the first point at which ECL intersects FG, and so ECL could not intersect any point before I. This is a contradiction. Thus the initial assumption, namely that there could be circular motion, such as the rotation of the outermost celestial sphere, in an infinite void must be wrong.

The argument makes a number of explicit and implicit assumptions. Thus, if Avicenna is to draw his conclusion validly, it must be shown that only the assumption of an infinite void space produced the contradiction, not one of the other auxiliary assumptions. Avicenna assumes the following:

(1) there is an infinite void space in which a moving sphere is located;
(2) the diagram that he constructs can be physically instantiated;[2]
(3) for a given point I on the infinite extension FG there is a point J before I;
(4) ECL during its motion between D and A sweeps through every point on FG;
(5) there is a first instant when ECL intersects FG.

(1) is the assumption that Avicenna will deny and so it can be granted for the sake of argument. Assumption (2) must likewise be granted, since the rotation of a sphere such as the one Avicenna constructs just describes the universe as ancient and medieval cosmologists conceived it: namely, the physical cosmos is a sphere with the outermost heavens rotating approximately once every twenty-four hours.

(3) is a corollary of (1); for if there were no prior point J, then I would be a limit of FG, but FG was posited to be infinite, i.e. without limits. Admittedly, FG could be considered infinite only in one direction, such as an infinite ray, but such a view hardly seems to be the position that a proponent of an infinite, extra-cosmic void would want to take. First, as Avicenna himself says, if the void were to be exhausted or limited, then this characteristic would not belong to the void of itself, but because some infinite body prevented it from extending further. Second, if one direction were bounded, then there is no principled reason for saying that both directions are not bounded, in which case one is considering a finite void; but Avicenna had another set of arguments against a finite void, which we need not consider here.[3] Third, Avicenna's argument would still go through, *mutatis mutandis*, by reversing the motion of ECL – that is, have ECL move from A to D – and so there would still be a first moment at which ECL intersects the infinite void space on the infinitely extended side.

Assumptions (4) and (5) are more difficult to justify, but ultimately, I believe, they must be accepted. Concerning (4), the line ECL would not sweep through all the points on FG if either (*a*) it somehow fell short of some points on FG or (*b*) it 'leapt' from being in the direction of AD to being in the direction of EI, not intersecting any of the points between the angle CEI. On the one hand, since ECL was posited as a line extended infinitely, it would be nigh on impossible to say it 'fell short' in some way; for however far FG extends, ECL extends an equal distance. On the other hand, the

2. This assumption is implicit; however, since Avicenna wants to show that the actual existence of an (infinite) void space out in the world would preclude the actual existence of circular motion out in the world, the model he constructs must be such that it could be instantiated out in the world. The exception to this instantiation criterion is, of course, the infinite lines assumed in the construction; for it is positing them that ultimately generates the absurdity.

3. See *Ṭabīʿīyyāt*, II.7, pp. 119.9–123.3.

notion of a 'leap' would presuppose an atomic conception of either motion or time. It would take us beyond the scope of the present study to consider Avicenna's reasons for denying either kinematic or temporal atomism, but suffice it to say that he had arguments, and by my lights good ones, for rejecting any type of atomism that would have been current at his time.[4]

Thus we are left with assumption (5), namely, that there is a first instant when ECL intersects FG. Although intuitively this assumption seems plausible, there are philosophical reasons, grounded in Avicenna's own account of continuous time, that seemingly make it suspect. Consider the following: the instant, T_2 when ECL is parallel to FG is distinct from the purported first instant, T_3, at which moment ECL intersects FG; however, if time is continuous, as Avicenna believes, and so dense, then between T_2 and T_3 there must be a potentially infinite array of instants, all before T_3 but after T_2. Consequently, any of these points, it would seem, has a better claim to being the 'first instant' than T_3, and yet is itself equally susceptible to the same argument that precluded T_3's being the first instant.

Moreover, if one should suggest that two instants could be immediately adjacent to one another, then either the immediately adjacent instants have some positive magnitude and so are minimal units of time, or they have zero magnitude and so are like temporal points. On the one hand, if the instants were to have some positive magnitude, one would be endorsing a type of temporal atomism, and I have already claimed that Avicenna had good philosophical reasons for rejecting temporal atomism. On the other hand, if the instants have zero magnitude, and so are like temporal points, with time being the aggregate of these successive temporal points, then one cannot explain how time is a certain positive magnitude; for the aggregation of that which has zero magnitude never gives one a positive magnitude.

Although Avicenna does not respond to this problem in the present context, he does address it elsewhere in his *Physics*. He takes his lead from a passage in Aristotle's *Physics* VI.5 (235^b6–236^b18), where Aristotle considers a change from one contradictory state to another. Roughly, Aristotle's general point is that when something *S* changes from not-*x* to *x*, there cannot be a period of time, no matter how small, when *S* is neither *x* nor not-*x*, since this would involve a violation of the Law of the Excluded Middle. As a brief aside, the Law of the Excluded Middle, namely 'necessarily either *P* or not-*P*', is not the Principle of Bivalence, viz. that necessarily every premiss is either true or false.

4. For Avicenna's analysis of continuous motion see A. Hasnawi, 'La définition du mouvement dans la *Physique* du *Shifā*' d'Avicenne', *Arabic Sciences and Philosophy*, 11, 2001, pp. 219–55; and my 'On the Moment of Substantial Change: A Vexed Question in the History of Ideas', in *Interpreting Avicenna: Science and Philosophy in Medieval Islam*, ed. J. McGinnis, Leiden, 2004, pp. 42–61. For a discussion of Avicenna's theory of time see my 'Ibn Sīnā on the Now: Text and Commentary', *American Catholic Philosophical Quarterly*, 73, 1999, pp. 73–106; and for his specific criticisms of temporal atomism see my 'The Topology of Time: An Analysis of Medieval Islamic Accounts of Discrete and Continuous Time', *The Modern Schoolman*, 81, 2003, pp. 5–25. For more general discussions of Avicenna's critique of Atomism see F. A. Shamsi, 'Ibn Sīnā's Argument against Atomicity', in *Uluslararasi Ibni Sīnā Sempozyumu Bildirileri*, eds M. Cunbur and O. Doğan, Ankara, 1984, pp. 479–94; and P. Lettinck, 'Ibn Sīnā on Atomism: Translation of Ibn Sīnā's *Kitāb al-Shifā', al-ṭabīʿiyyāt* 1*: al-Samāʿ al-ṭabīʿī*, Third Treatise, Chapters 3–5', *Al-Shajarah*, 4, 1999, pp. 1–51.

Aristotle himself thought, and Avicenna would concur, that the Principle of Bivalence had to be qualified, in that it applied only to the truth-value of premisses concerning either past or current states of affairs, not future contingents. Assumption (5) does not concern the truth-claims of the premiss, but the premiss's content, namely, the line ECL is either in contact or not in contact with FG. Moreover, even if the assumption were to appeal to the Principle of Bivalence, it would be acceptable, since it concerns the current or present state of the line ECL, not a future contingent.

To return to Avicenna's argument, he observed that there are two ways of understanding Aristotle's point that when something *S* changes from not-*x* to *x*, there cannot be a period of time when *S* is neither *x* nor not-*x*.[5] This point may be understood as either:

(I) there is some first instant when *S* is *x*, but no last instant when *S* is not-*x*,

or:

(II) there is some last instant when *S* is not-*x*, but no first instant when *S* is *x*.

Although Avicenna hesitates to say absolutely which alternative must be the case, he at least tentatively suggests that when something goes from not being in contact to being in contact – Avicenna's own example – there is a first instant of being in contact, even though no last instant of not being in contact.[6]

Avicenna's position concerning a first or last instant is directly relevant to justifying assumption (5); for the problem we generated concerning assumption (5) involved saying that the last instant at which the line ECL is not in contact with FG, T_2, is distinct from the first instant at which ECL is in contact with FG, T_3. This claim, however, must be false, since during the period between T_2 and T_3 the line ECL would neither be in contact nor not in contact with FG; however, being and not being in contact are contradictory predicates, and so one or the other must apply to ECL, otherwise one violates the Law of the Excluded Middle. Given that law, one is forced to say that there is either a first instant of being in contact with FG or a last instant of being in contact with it, though not both. Avicenna opted for the first alternative. In fact, even if one preferred to say that there is a last instant, but no first instant, of being in contact, Avicenna's argument against circular motion in an infinite void would go through once properly modified: for he can merely point out that there would still need to be some point, *x*, on FG that corresponds with the last instant of being in contact, and yet on FG there is a point *y* after *x* with which ECL comes into contact. Thus, there would be a point after the last point, which is just the same contradiction *mutatis mutandis* that Avicenna had himself deduced. In short, one cannot deny assumption (5), or some variation of it, without denying the Law of the Excluded Middle; however, since that law is one of the most basic in rational discourse, at least within an Aristotelian framework, for someone

5. *Ṭabīʿīyyāt*, II.12, pp. 162.14–163.11.

6. See my 'Ibn Sīnā on the Now', pp. 78–9 and 93–7, for a translation and analysis of Avicenna's argument.

working within that framework, such as Avicenna, to deny it would be to give up the very possibility of rational discourse and so science.

Since all of the assumptions used in Avicenna's argument are justified with the exception of (1), namely that there is an infinite, extra-cosmic void, Avicenna can conclude that this assumption is what generates the contradiction. Consequently, his argument is demonstrative; and so on the assumption of an infinite void there could not be circular motion, which there in fact is.

HISTORICAL INFLUENCES AND PHILOSOPHICAL MOTIVATION

Having considered Avicenna's argument against the possibility of circular motion in an infinite, extra-cosmic void, I now want to consider the historical and philosophical considerations motivating the argument. This section involves three parts: first, suggesting classical sources or influences for the argument; second, identifying its possible historical targets; and third, considering certain philosophical and internal motivations that Avicenna had for its construction.

Concerning possible classical sources for Avicenna's argument, the following Greek commentaries on Aristotle's *Physics* were available in Arabic and most likely known by Avicenna: Themistius's paraphrase of the *Physics*; the first half of Alexander of Aphrodisias's commentary, probably only in a paraphrastic form, which would have included his discussion of the void; Proclus's *Institutio physica* (while not a commentary *per se* on Aristotle's *Physics*, it was a handbook of arguments drawn both from the *Physics* and from the first book of the *De caelo*); and finally a paraphrase of John Philoponus's *Physics* commentary.[7] Of these, three – Themistius's paraphrase, Proclus's handbook, and Philoponus's commentary – are still extant in Greek with parts of Proclus's *Institutio* and Philoponus's commentary still extant in Arabic. The *Institutio physica* does not treat the void and so is of little help here. Moreover, neither Themistius nor Philoponus in their commentaries on the void provides anything like Avicenna's own argument against circular motion in an infinite void. As for Alexander of Aphrodisias, although his commentary on the *Physics* is no longer extant, much of what would originally have been in his commentary would have been saved by Simplicius in his commentary on the *Physics*. Simplicius conscientiously noted the additions to and deviations from Aristotle's text by earlier Greek Aristotelian commentators. Consequently, his *Physics* commentary is our primary source for surmising the content of Alexander's own commentary, which was available to Avicenna in Arabic translation. Again, however, Simplicius mentions nothing concerning Alexander's comments on the void that would lead us to believe that Alexander's *Physics* commentary was the source of Avi-

7. Themistius, *In Aristotelis Physica paraphrasis*, ed. H. Schenkl, Berlin, 1900; Proclus, *Stoicheiōsis physikē*, ed. A. Ritzenfeld, Leipzig, 1912 (Arabic fragments may be found in Shlomo Pines, 'Hitherto Unknown Arabic Extracts from Proclus's Stoicheiôsis Theologikê and Stoicheiôsis Physikê', in *The Collected Works of Shlomo Pines*, vol. II, Jerusalem, 1986, pp. 287–93; and *al-Aflāṭūnīyya l-muḥdatha ʿinda l-ʿarab*, ed. A. Badawī, Cairo, 1955, pp. 43–9); John Philoponus, *In Aristotelis Physicorum libros quinque posteriores commentaria*, ed. H. Vitelli, Berlin, 1888 (the Arabic paraphrase of Philoponus is found in *Arisṭūṭālīs, al-Ṭabīʿī*, ed. A. Badawī, 2 vols, Cairo, 1964–5, s.n. Yahyā).

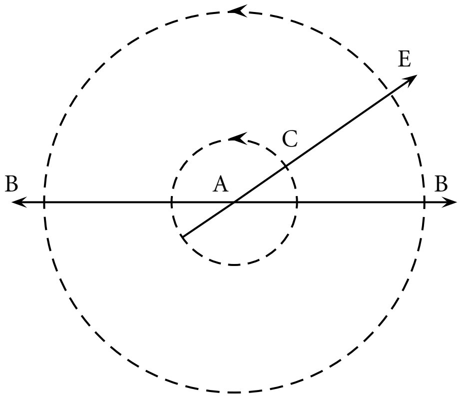
[1] In the diagram, should we delete the radius extending downwards from A to the perimeter of the inner circle?

[2] I am not sure what 'it' is in 'from it'. (And is 'from' the correct preposition?)

cenna's critique of circular motion in an infinite void. In short, it would appear that nothing like Avicenna's argument ever explicitly appeared in Greek commentaries on the *Physics*.

Despite this fact, I believe that key elements of Avicenna's argument did have classical Greek roots, albeit not within the context of the *Physics* and its commentaries, but in the *De caelo* and its commentary tradition. In the *De caelo* Aristotle occasionally returns to the topic of the void, but never with the same level of sophistication and technical proficiency as in the *Physics*. Still, he does take up the issue of whether the universe is infinite, arguing emphatically that it is not at *De caelo* I.5, and, as I have already mentioned, Avicenna's *reductio* argument derives its contradiction from the assumption that the void is infinite, with the notion of an infinite actually underlying the contradiction. Although Aristotle specifically directs the numerous arguments in *De caelo* I.5 against the idea that the body of the heavens is infinite, and so not against an infinite void space *per se*, Avicenna apparently appropriates elements from one of these arguments for his own purposes.

I cite the relevant parts from the Arabic translation of the *De caelo*, since it appears to be slightly different from the Greek version of the argument: QUERY [1]



> Let there be an infinite line, ACE, and another line, ⟨BB⟩,[8] infinite at both of its extremes. Also let both of the lines be in a circular, infinite body. Let us posit that the line ACE originates from the centre of this body and let this centre be A within the circle. We now say that the line ACE will describe a circle resulting from C and cutting the line BB, since as long as the circle moves it makes its rotation during a finite period of time – because the whole time of the motion of the heaven, in which the circular motion is being moved, is finite. Thus the time taken from it, during which it was passing along the line describing the circle and [cutting] the line infinite at both of its extremes, is finite. Consequently, there might exist, then, a beginning of line ACE's cutting line BB, but this is impossible. So it holds true now that the infinite body cannot be moved circularly and QUERY [2]

8. The text here is EA, but subsequently corrected to EB. I have preferred Aristotle's BB for clarity, and nothing seems to be at stake in so lettering the line.

> consequently it is obviously clear that the entire world likewise cannot be moved, if it is infinite.[9]

It is fairly clear that during the rotation of line ACE the segment AC will describe a circle such that C cuts or intersects BB and will do so after a finite period of time. In contrast, since the rays AB and AE are both infinite, and consequently the arc BE is also infinite, E would have to travel an infinite distance in order to cut the line BB. Moreover, since C and E are both on the same rotating line, and C intersects BB after a finite period of time, E should intersect BB after a finite period of time; however, Aristotle assumes that an infinite cannot be traversed in a finite period of time, which is exactly what E must apparently do.

The geometrical figure that Aristotle describes here is roughly similar to the one Avicenna uses, but with certain differences both in what the figure is intended to describe and in the contradiction inferred from such a motion. Thus, unlike Avicenna, Aristotle imagines that the rotating line ACE describes the motion of an infinitely extended circular body, whereas Avicenna simply imagines a finite body's rotating in infinite space. Moreover, the arguments differ in what the supposed contradiction is. On the one hand, for Aristotle the impossibility arises since he assumes that an infinite cannot be traversed in a finite period of time. On the other hand, since Avicenna wants to conclude that if there were infinite void space, then during a finite period of time the circular motion of a finite body would be impossible, he, unlike Aristotle, cannot simply assume that the infinite cannot be traversed in a finite period of time; for this would beg the very question he wants to answer. Thus, Avicenna must explicitly show how a first instant of cutting or intersecting an infinite rectilinear line involves a contradiction, a point Aristotle simply asserted as impossible.

Avicenna could have received some help in this endeavour from Alexander of Aphrodisias, whose commentary on the *De caelo* was translated into Arabic and so may have been known to Avicenna. Unfortunately, like Alexander's *Physics* commentary, his *De caelo* commentary is no longer extant in either Greek or Arabic; none the less, Simplicius preserved a portion of Alexander's commentary on this passage in his own commentary, and the comments there are relevant to our discussion.[10] Simplicius tells us that Alexander drew two absurdities from Aristotle's argument: one, the infinite would be traversed in a finite period of time; and two, there would be some 'first beginning'

9. Aristotle, *De caelo*, I.5, 272ᵃ11–20, in *Fī-l-Samāʾ*, ed. A. Badawī, Cairo, 1961, pp. 151–2. Cf. the Greek:

> Let, then, the line ACE be infinite in one direction, E, and the line BB infinite in both. If, then, line ACE described a circle with C as centre, ACE will move in a circle while cutting BB for a finite time, since the whole time in which the heavens move in a circle is finite. The time subtracted from this, therefore, for which the line was moving while cutting the other, is also finite. There will thus be a beginning at which ACE first cut BB. But this is impossible. It is therefore not possible for the infinite to turn about in a circle. So nor could the world, if it were infinite. (Translation after Aristotle, *On the Heavens I & II*, ed. and transl. S. Leggatt, Warminster, 1995)

It is of note that though Proclus treats many of the arguments from *De caelo* I.5 in his *Institutio physica*, he does not treat this one, and thus that work could not have been a source of inspiration for Avicenna's argument.

10. Simplicius, *In Aristotelis De caelo commentaria*, ed. I. L. Heiberg, Berlin, 1894, pp. 210.20–211.18.

[3] In the footnote, I think we need the reference in full: 'Ap. Simplicium, *In Aristotelis Physica commentaria*, ed. H. Diels, 2 vols (Berlin, 1882–95), p. 648.17–23'? (Or do we need to add a volume number as well?)

where ACE cuts BB.[11] Clearly, Alexander's second absurdity, which seems to suggest that there would be some first moment when ACE begins cutting BB, is what Avicenna needs.

There are reasons, however, for thinking that Avicenna did not take a fully constructed argument from Alexander here and rather that Alexander merely mentioned the second absurdity as a possible conclusion of Aristotle's argument without presenting the reasoning behind it. For Simplicius criticizes Alexander's addition, arguing that the second absurdity is derived from the first: that is, the second absurdity assumes that an infinite magnitude cannot be traversed in a finite time. Simplicius then goes on to say that since Aristotle does nothing in vain, he had no reason to add the second absurdity.[12] We have seen, however, that in Avicenna's argument he nowhere assumes that an infinite cannot be traversed; for had he made this assumption, his argument would have begged the very point it was trying to make, namely, that circular motion in an infinite void space is impossible. If Alexander had presented an argument akin to Avicenna's – one that neither explicitly nor implicitly assumes that traversing the infinite is impossible – then, I contend, Simplicius simply could not have levelled the criticism against Alexander that he did. In short, I suggest that Aristotle provided Avicenna with the raw material for the latter's argument against the possibility of circular motion in an infinite, void space; Alexander suggested how Aristotle's argument might be germane to Avicenna's enterprise, but it was Avicenna himself who ultimately gave the argument its final form.

I now want to turn to the possible historical target of Avicenna's argument. In Aristotle's own discussion of the void he identifies two of its advocates, who had apparently different theories about its nature: the atomists Democritus and Leucippus, and the Pythagoreans. Porphyry distinguishes the positions of these two, claiming that the atomists made void inseparable (*ἀχώριστον*) from body and thus pervading body, whereas, according to Porphyry, the Pythagoreans made void separate from body – that is, an extra-cosmic empty space with the universe itself being a plenum surrounded by this void.[13] Porphyry's synopsis of the *Physics* was available in Arabic translation, and QUERY [3]
so Porphyry's distinction between the atomists and the Pythagoreans may have been known to Avicenna. If this is the case, then the target of Avicenna's argument could have been this Porphyrean interpretation of the Pythagoreans' position concerning an extra-cosmic void.

The connections are tenuous, and if Avicenna in fact had some historical target in mind, the more likely opponent, I believe, would be the Stoics, who wrote after Aristotle. Concerning the Stoics' conception of the void, Stobaeus relates that for the Stoic Chrysippus

> [P]lace [is] what is occupied through and through by an existent [. . .] [whereas] the void is said to be infinite. For what is outside the world is like this [i.e., infinite], but place is finite since no body is infinite. Just as anything corporeal is finite, so the incorporeal is

11. Ibid., p. 210.20–25.
12. Ibid., p. 210.26–31.
13. Ap. Simpl. *In Phys.*, p. 648.17–23.

> infinite [. . .]. For as nothing is no limit, so there is no limit of nothing, as is the case with the void.[14]

Stobaeus likewise gives witness to the Stoic Zeno of Citium, who endorsed the view that our world is situated in an infinite, extra-cosmic void: '[. . .] all the parts of the world move towards its centre [. . .]. There is an identical explanation both for the world's stable position *in infinite void* and similarly for the earth's being settled in the world with equipollence at its centre.'[15] In general, the Stoics argued for the reality of an extra-cosmic void space using a thought-experiment suggested by the Pythagorean Archytas.[16] The argument is that if one were at the edge of the physical or corporeal universe and extended one's hand, there must be something outside of the physical universe either into which the hand extends or by which the hand is prevented from extending, and so there must be something beyond the physical cosmos. Since this same thought-experiment can be repeated recursively, there could be no limit on the extent of extra-cosmic void space, and so it must be infinite.

That Avicenna would have had direct access to the writing of the Stoics in Arabic seems unlikely. Still, he may have known their philosophical position at second hand, either through later Greek commentaries on Aristotle's *Physics*, which at the very least mention the Stoics' position concerning extra-cosmic void space, or through various independent philosophical treatises directed against the Stoics. (In this latter case, I am thinking primarily of works by Alexander of Aphrodisias.) Concerning the *Physics* commentaries specifically, Porphyry's synopsis of the *Physics*, Themistius's paraphrase, and Alexander's and Philoponus's commentaries have already been mentioned. Both Themistius's paraphrase and Philoponus's commentary either explicitly or implicitly mention the Stoics' account of the void. Although Alexander's commentary is extant neither in Greek nor in Arabic, given his overall hostile attitude towards the Stoics it is extremely likely that he mentioned them in his commentary, if for no other reason than to criticize them.

It is of course possible that Avicenna did not have any classical Greek figure or school in mind, and instead was addressing a target within his native Arabic-speaking intellectual milieu. In that case, however, it seems unlikely that the attack would have been directed against the Muslim theologians, since virtually all of them denied the existence of an infinite, and yet Avicenna's argument is directed against *infinite* void space. For similar reasons it seems unlikely that the target would have been some Arabic-speaking philosopher working within the Neoplatonic–Aristotelian tradition, since again there was virtually a categorical denial of an actual infinite among them. Consequently, if Avicenna's target was someone working within the Arabic-speaking world, the most likely candidate would have been the independent thinker Abū Bakr

14. *The Hellenistic Philosophers*, eds and transl. A. A. Long and D. N. Sedley, 2 vols, Cambridge, 1987, 49A.
15. Ibid., 49J (emphasis added).
16. Ibid., 49F.

[4] Muslim Era date?

al-Rāzī (*c.* AH **000–000** or **000**/AD 864–925 or 932), who did in fact posit 'absolute place' understood as infinite void space.[17] QUERY [4]

Unfortunately, since Avicenna neither reveals his sources nor explicitly names those whom he attacks, the question as to whether the Stoics or al-Rāzī was the primary target of his argument against the possibility of circular motion in an infinite void must remain without a definitive answer. On the other hand, there is some reason for thinking that Avicenna did not have the Stoics specifically in mind when devising his argument; for precious little of the Stoic philosophical corpus was translated into Arabic. Thus if Avicenna was aware of their doctrine concerning the void, it would have been indirectly either by some oral tradition or through the various commentaries mentioned above.

In fact, there were inherent philosophical concerns within Avicenna's own physical system that would have provided him with sufficient motivation to construct an argument against the possibility of circular motion in a void even in the absence of some specific historical target. Avicenna had made certain changes to Aristotle's physical system, and though these might initially appear quite small, their far-reaching implications were significant. As a result of one of these changes, I maintain, it became incumbent upon Avicenna to provide an argument specifically against the possibility of circular motion in a void if his overall argument against the existence of a void were to be complete. A similar concern did not present itself to Aristotle and his Greek commentators; for given their understanding of the relation between rectilinear and circular motion, they had good reason for thinking that an argument specifically against the possibility of local motion in a void was sufficient to show the impossibility of circular motion in a void. In short, a special argument that shows that circular motion is impossible in a void would have been superfluous for Aristotle and most of his commentators.

In rough outline, Aristotle's reasoning against the possibility of natural motion in a void runs as follows. The void, should it exist, would be wholly indeterminate and so could not have naturally differentiated places, but if there were no natural places in a void, then *a fortiori* there could be no natural motion with respect to place, i.e. natural local motion. Local motion's two species for Aristotle and his Greek commentators, however, were circular and rectilinear motion.[18] Hence, since the void has no natural place, then no species of natural motion with respect to place could occur in it: that is, nothing could move naturally either rectilinearly or circularly. In short, Aristotle's argument was sufficient to disqualify the possibility of circular motion in a void, understood as a species of natural local motion, and so there was no need for a specific argument against it.

Such a move, however, was not open to Avicenna, given certain modifications that he had made to Aristotle's physics, and thus he was required to show specifically that circular motion in a void was impossible if his own physics were to remain consistent. This need for internal consistency in Avicenna's own physics is, I contend, his primary motivation for constructing the argument in question. In order to appreciate the prob-

17. See *Opera philosophica fragmentaque quae supersunt*, ed. P. Kraus, Cairo, 1939, pp. 243–52.

18. See *De caelo*, I.2, 268^{b}14–18.

[5] In the reference in the note, should we not have a line-number after '103'?

lem of internal consistency at stake, we must briefly consider another problem that arose in the later Greek Aristotelian tradition surrounding the *Physics*, one that was explicitly exploited by the Neoplatonic commentator John Philoponus.

Aristotle had defined place as an innermost limit of a containing body; Philoponus wanted to replace this with his own notion of place in terms of a finite absolute void space.[19] Philoponus posed a dilemma for Aristotle's account of place: either the outermost heavens had a place or they did not.[20] On the one hand, if the outermost heavens did have a place, then, given Aristotle's definition of place in terms of a containing body, there must be a body outside of the heavens that contains them, but for Aristotle there was nothing beyond the heavens that might contain them. On the other hand, if the heavens do not have a place, then it seems impossible to explain their apparent diurnal motion. For according to Aristotle – and his account was accepted by the entire Greek Aristotelian tradition as far as I can discern – there were only three kinds of motion: motion with respect to the categories of quantity, quality, and place. It is fairly clear that the heavens in their diurnal motion do not change either quantitatively or qualitatively. Thus, given the apparent fact that they do move, they must be moving with respect to place, but *ex hypothesi* they have no place and so *a fortiori* cannot move with respect to place. In short, concludes Philoponus, Aristotle's account of place as the innermost limit of a containing body is either philosophically or scientifically inadequate.

Avicenna was aware of this dilemma and responded in what at first sight appears to be a relatively simple way, but one that would have far-reaching ramifications. His response was merely to deny that there were only three kinds of motion. Instead he maintained that there must be four kinds: motion with respect to the categories of quantity, quality, place, and also position, the latter defining circular motion or rotation.[21] Avicenna then denied that the cosmos has a place and insisted that instead of moving with respect to place, it moves with respect to position. QUERY [5]

Despite its apparent simplicity, the addition of a new genus of motion, viz. motion with respect to the category of position, had significant philosophical implications. The most notable is that Avicenna could no longer identify circular and rectilinear motion as two species of the same generic type of motion. Since on his analysis circular motion belonged to the category of position, while rectilinear motion belonged to the category

19. At *Physics*, IV.4, 211^{b}5 ff., Aristotle identifies four candidates for place: a body's (1) matter, (2) shape or form, (3) internal extension or volume, and (4) the outermost limit of a containing body. He subsequently argues against the first three and so concludes that place is the outermost (unmoving) limit of a containing body. For discussions of Aristotle's account of place see K. Algra, *Concepts of Space in Greek Thought*, Leiden, 1995; H. Lang, *The Order of Nature in Aristotle's Physics: Place and the Elements*, Cambridge, 1998; B. Morison, *On Location: Aristotle's Concept of Place*, Oxford, 2002. For a discussion of Philoponus's account of finite, void space see D. Sedley, 'Philoponus' Conception of Space', in *Philoponus and the Rejection of Aristotelian Science*, ed. R. Sorabji, Ithaca, NY, 1987, pp. 140–53.

20. Philoponus, *In Phys.*, pp. 565.1–567.7 Vitelli.

21. See *Ṭabīʿīyyāt*, II.3, for Avicenna's discussion of the categories in which motion occurs; and specifically pp. 103–105.13 for his discussion of motion with respect to position. For a discussion of the historical context of the problem of the motion of the outermost celestial sphere and a detailed analysis of Avicenna's solution see my 'Positioning Heaven: The Infidelity of a Faithful Aristotelian', *Phronesis*, 51, 2006, pp. 140–61.

of place, the two had to be generically different. Thus, if we consider the present case of the possibility of circular motion in a void, we see that the original completeness of Aristotle's argument is lost; for it showed only that motion with respect to the category of place, not position, was impossible. Consequently, Avicenna had either to show that Aristotle's original arguments could be phrased in terms of the category of position – and I think it is fairly clear that they cannot – or to construct a new argument specifically directed against the possibility of circular motion in a void in order to protect his more general claim, that motion in a void is absolutely impossible. He accomplishes this *desideratum* with the very argument we have been considering.

I conclude by summarizing the salient points of this study, both conclusions and qualifications. Avicenna would seem to have provided a new argument against the possibility of motion in a void, or at the very least circular motion in a void. Still, he was responding to and drawing upon elements already found in the Greek classical world. Most notably, a variant of his reasoning can be found in Aristotle's *De caelo*, where Aristotle argues against the possibility of an infinite circular body. Moreover, it seems reasonable to infer that Alexander of Aphrodisias suggested, without providing an explicit proof, one possible conclusion of Aristotle's argument, a conclusion that Avicenna would in turn pick up and develop. I do not want to exclude the possibility that the ultimate target of Avicenna's argument was the Stoics' suggestion that the cosmos is a spherical plenum situated in an infinite, void space, yet internal concerns seem to provide a more pressing motivation. These concerns, we might add, would have troubled neither Aristotle nor his Greek commentators. Although I have paid considerable attention to possible Greek sources, I have not considered possible Arabic sources prior to Avicenna, such as the thought of al-Kindī or al-Fārābī; however, a cursory examination of some of these Arabic authors' physical writings has produced nothing even vaguely similar to Avicenna's argument. Still, in the absence of a complete study of the physical writings of Avicenna's Arabic precursors, I only tentatively suggest that with Avicenna's argument we might be witnessing a creative moment in the history of science and philosophy.

APPENDIX

Translation of Avicenna's Argument

I take as my base text the critical edition of *al-Shifā'*, *al-Ṭabīʿīyyāt*, *al-Samāʿ al-ṭabīʿī* established by Saʿīd Zāyed.[22] Zāyed consulted five manuscripts, two of which contained additional marginalia.[23] I have consulted Jaʿfar Āl Yāsin's recent edition of *al-Samāʿ al-ṭabīʿī*,[24] which

22. *Ṭabīʿīyyāt*, II.8, p. 127.5–18.

23. Unfortunately, Zāyed does not give exact references for the manuscripts, but it would seem that these are (1) al-Azhar (and marginalia) 331 (185–226), (2) Dār al-Kutub H. 262, H. 753, H. 172 (F. VII), (3) Damad al-jadīda 822–5, (4) the British Museum Supplement 711, and (5) a Tehran manuscript (and marginalia) that we may tentatively identify as I, 144/6.

24. Beirut, 1996, II.8, p. 159.

[6] The footnote has been expanded at Dr Adamson's suggestion for clarity. Is it OK now?

though correcting some of Zāyed's obvious typographical errors and in a few instances offering an alternative reading, for the most part agrees with Zāyed's edition, at least with respect to this passage. In addition to Zāyed's and Āl Yāsin's texts, I have consulted an 1886 Tehran lithograph of Avicenna's *al-Shifā'*, as well as the Latin translation of Avicenna's *Physics*, the *Sufficientia*.[25]

The most significant difficulty in translating this text is that in all the manuscripts, as well as the Tehran lithograph and the Latin translation, there is no consistent lettering of the points on the diagram. In other words, every text has at least some variant reading of the lettering of the points, such that there are multiple ways to construct the diagram, each different and sometimes significantly so. Moreover, no single manuscript's lettering suggests a coherent argument, as far as I can discern, nor do Zāyed's or Āl Yāsin's suggested reconstructions of the text fare significantly better. The task before us, then, is to suggest a reconstruction of Avicenna's diagram that both does justice to the texts that we have and makes sense philosophically. I offer the following possible translation:

> Let us posit a body that is moved circularly [describing] a circle ABCD as well as making the circle itself moved, and let the centre of [the circle] be E. Now let us posit outside of [the circle] a rectilinear line, ⟨F⟩G,[26] extending infinitely, parallel to AD, whether in a void, a plenum, or in both together. Now let the line EC, which connects the centre and the point C, move in a circular fashion. Because the line EC is either perpendicular, or as good as perpendicular, to AD in a direction other than FG, then if [the line EC] is extended from the direction of C infinitely, it would not meet FG, since there can be no doubt that LE [the line EC extended infinitely][27] is ⟨in⟩ a direction that does not come into contact with the interval FG. Also, whatever passes in [that direction] will not reach [FG], otherwise the interval FG will be something finite circumscribing the circle ABCD from every direction, but it was not posited as such. Thus, let EC be an interval or line that does not encounter FG as long as it is in that direction until it corresponds with the line AED,[28] and thereupon it crosses and so there it necessarily intersects FG. For, when it comes to be in the direction of FG, whether perpendicular to AD or not, then when it is extended infinitely, it necessarily intersects FG and meets one of its points, but not one and the same point.[29] For you can posit a plurality of points on the line FG and connect them with the centre, E, by a plurality of lines. Whenever the line E⟨C⟩[30] corresponds with one of those lines, then because of a projection (*fī samt*) [the line] comes to be

QUERY [6]

25. *Avicennae perhypatetici philosophi ac medicorum facile primi opera* [...], Venice, 1508; repr. Frankfurt a.M., 1961.

26. Although the letter *Ḥ* in the original diagram, here rendered as F in my translation, is missing in Zāyed's text, its inclusion is obvious and the correction is made by Āl Yāsin.

27. Although I follow Zāyed here, the Tehran lithograph suggests a variant not mentioned in Zāyed's apparatus. The variant, for which the Tehran scribe provides vowels, is *lā shakka annahū li-Ṭ jihatan*, 'there is no doubt that it [the extended line] belongs to *Ṭ* in a direction [...]', which the Latin translator had also read, hence his 'sine dubio punctum habet T partem'. The addition of *punctum* 'point' is justified in Āl Yāsin, whose text reads *lā shakka annahū li-nuqṭa Ṭ jihatan*, 'there is no doubt that it belongs to the point *Ṭ* in a direction [...]'.

28. Zāyed's text has *khaṭṭ hā' wa-alif dāl*. I follow both the Tehran lithograph and the Latin text, which have my AED. Zāyed's text here must clearly contain a typographical error; for AD was posited as parallel to *HZ* (my FG) and so Zāyed's text does not describe a line, but an angle. This is corrected in Āl Yāsin.

29. Reading *lāqī* with Āl Yāsin for Zāyed's *lā fī*.

30. I suggest that both Zāyed's and the Tehran lithograph's *khaṭṭ ṬḤ* should be emended to read *khaṭṭ*

[7] This part of the sentence, starting 'but it was said', seems to be tagged on rather unsatisfactorily, though you may want to keep it thus to remain close to the Arabic. If any adjustment is permissible, perhaps have a semicolon after the preceding 'I', and then give e.g. 'however, it was said', and after 'projects' perhaps e.g. 'so that this is a contradiction' rather than the balder 'but'.

intersecting the point from which that line was produced. And when it is something projecting towards [FG] after not projecting towards [it], there must be the first instant of the time of projecting towards [FG], which is a division between two times because of a projection of a point; let it be a point I. Let us also take a point J before the point I and connect E and J according to a line ELJ, so that when the line EC makes the rotation, up to the point that [the line extended from] C meets the point ⟨J⟩,[31] it then is something projecting towards the point J in the line FG before the point I,[32] but it was said that I[33] is the first point from the line FG towards which it projects, but this is a contradiction. Indeed, it must always be something projecting towards [FG] and distinct, but this is impossible. Therefore, then, there is no circular motion in the void that they posit. QUERY [7]

Below you should find the contact details (postal and e-mail addresses) that are on file. If the information is not there, please write it in so that we can be sure of sending offprints to the correct location.

Professor Jon McGinnis
Department of Philosophy
599 Lucas Hall (MC 73)
One University Boulvd
St Louis
MO 63121-4400
USA

e-mail address: mcginnis@umsl.edu

ṬJ, which in fact Āl Yāsin does, and which follows the Latin text and so suggests that the Arabic exemplar underlying the Latin had *jim*. Orthographically, the change is small, since it involves only the omission of a dot. There are also textual and philosophical reasons for the emendation. Philosophically, the argument, as I understand it, requires that the line be my EC. Textually, Avicenna formally introduces the point *Ḥ* only later in the passage (line 24); it would be odd for him to introduce the point *Ḥ* here and then formally reintroduce it later.

31. I believe that the point-letter *lām*, found in Zāyed's, Āl Yāsin's, and the Tehran lithograph's text, should be emended to read *kāf*. Here I am again following the Latin text. The difference in letters can be explained by the fact that both *lām* and *kāf* are quite similar orthographically in their separated forms as used when they indicate points on a geometrical construction. Moreover, the argument itself, if it is to be cogent, seems to require that the point in question be *kāf*.

32. I read with most of the manuscripts, as well as the Tehran lithograph and the Latin text, *Ḥ* for Zāyed's and Āl Yāsin's *J*.

33. Āl Yāsin reads *J*, which seems clearly to be wrong.