

What Curiosity in the Structure:

The Hollow Earth in Science.

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What Curiosity in the Structure...ought not we to expect in the Fabrick of this Globe

Edmund Halley 1692

The idea of the hollow Earth has blossomed prodigiously in myth, religion, literature, and other facets of popular culture, but it has failed to thrive in the realm of orthodox science. The reasons for this failure are simple: science traffics in observations and explanations that can be used to make accurate predictions about the behavior of phenomena in nature. There is no empirical evidence for an intraplanetary void, a great deal of evidence to the contrary, and the hollow Earth model explains nothing about the physical world that cannot be explained more simply and completely (if more prosaically) by other means. This has not always been the case, however, and the hollow Earth does intersect the realm of science at least twice.

The first is through the works of 17th and 18th century natural philosophers—most notably Edmund Halley (1659-1743)—who helped pioneer the body of knowledge and practice that led to modern science. For some of these early scientists the hollow Earth was a perfectly plausible proposition, a theory that bridged important gaps in empirical observation, theoretical, and/or theological understandings of nature. The second intersection occurred nearly three hundred years after Halley's introduction of the idea, when Mostafa Abdelkader, an Alexandrian mathematician, proposed that a geometric transformation could be applied to lend theoretical support to the religious conception of a geocosmos (i.e., an inverted cosmos contained within a hollow planet). Abdelkader's proposition that is interesting because, it is empirically irrefutable. Halley and

Abdelkader represent, as it were, the Symmes' Holes through which the theme of the hollow Earth has entered modern science, and in this essay I trace their polar geographies.

A more ample Creation than has hitherto been imagined: Edmund Halley's hollow Earth theory of 1692

Nicholas Kollerstrom (185) has pointed out that the first prediction to be deduced from Newton's *Philosophiae Naturalis Principia Mathematica*, the work that forms the foundation for modern physical science, was Edmund Halley's proposal that Earth's interior structure is that of a series of nested hollow spheres. Insofar as the publication of the *Principia* marks the beginning of modern science, Halley's hollow Earth theory can thus be treated as the first prediction of the modern scientific era. The credit is fitting, since Newton might never have produced the *Principia* (he claimed to have distilled his ideas in 1666, but had never bothered writing them down for dissemination) without Halley's encouragement, and without his editorship and financial backing it certainly would not have been published when it was.

The particular form of Halley's proposal was unique, but the general idea that the globe is hollow is, of course, ancient and widespread. Earthquakes and volcanoes, karst swallow holes and sinkholes, springs, and wells suffice to show that all is not solid underfoot. Caverns and caves provide direct access to strange inverted worlds below Earth's surface, while (in the absence of a mechanistic understanding of how they form) fossils and other unusual geofacts reasonably suggest that an inner world not only exists, but harbors strange creatures as well. Little wonder, then, that chthonic realms figure

prominently in so many cosmologies, including those that Edmund Halley and the other scientific revolutionaries of his day inherited from their intellectual forebears.

Halley's world was poised on a cusp between ancient superstition and modern systematic science, and only in retrospect can we recognize how awkward a time the last decade of the 17th century really was. The final key to the Copernican Revolution—Newton's *Principia*—had been published in 1687, providing both the tools and methods for the unprecedented human ability to understand and control natural phenomena that characterizes modern physical science. But the shining crown of the *Principia* rested on a head wreathed thick with the mane of medieval habit and thought. The conceptual skills and social structures necessary to use the new tools had only begun to develop, lineaments to the Ptolmaic and Hermetic traditions remained strong, and most importantly, there was an overarching need to reconcile the old and new viewpoints in a way that was consistent with the Bible.

The necessity of reconciling growing amounts of geological and geographical information with Mosaic accounts of the creation and deluge made the formulation of theories of Earth both a popular activity and a moral necessity among 17th century intelligentsia, one that generated scholarly debate and popular interest alike (see Drake 69-70). Two works from this period stand out in particular: the German Jesuit Athanasius Kircher's *Mundus Subterraneus*, first published in Amsterdam in 1664, and the British cleric Thomas Burnet's *Sacred Theory of the Earth*, first published in 1681, with a revised English edition in published in 1690/91.

Kircher's *Mundus Subterraneus* is a lavishly illustrated, 800 page, two-volume compendium of all things subterranean (see Godwin 106-108 and Kafton-Minkel 50-52).

Drawing on classical and medieval knowledge, the influx of material and information arriving at Kircher's headquarters in Rome from the Society of Jesus' missionary corps, as well as his own fertile imagination, Kircher describes all that was then known about geology and physical geography. His encyclopedia covers topics such as the origin of earthquakes, volcanoes, minerals, ores, "figured stones" (fossils), springs, and rivers. Furthermore, despite his claims of critical skepticism regarding second-hand information about the wonders of nature, Kircher provided extensive coverage of such topics as dragons, giants, and subterranean demons. The *Mundus Subterraneus* includes maps of the solar surface and the island of Atlantis, the earliest chart of the global ocean circulation, and what are probably the earliest cross-section views of the planet.

Kircher's cross-sections illustrate a Central Fire (fed by cosmic rays—an old alchemical theme) and a network of smaller lava-filled chambers, underground lakes and fountains, and numerous passages and channels through which water and lava circulate and sometimes escape to the surface in the forms of springs or volcanoes. His hydrodynamic charts illustrate many patterns familiar to modern eyes (the Gulf Stream, for example) but others that are not.

Among the latter are the global circulatory system through which the oceans disappear into a great vortex at the north pole. Kircher acknowledges his source in this regard (see Godwin 106) as the medieval geographer Bartholomew of England, who claimed that the north polar opening was marked by a black magnetic rock, fifty kilometers in diameter, with four entrances into which the ocean flowed to an immense whirlpool (this is, of course, the black rock that Poe mentions as finding on Mercator's map in *M.S. Found in a Bottle*). According to Kircher, the waters flow into Earth's

center, where they are heated by the Central Fire and expelled again at the south pole after (without this heating and circulation, Kircher noted, the polar regions would freeze solid, and the oceans become stagnant and foul; Godwin 106-107).

Burnet's *Sacred Theory of the Earth* is less exuberant (if more fanciful) than Kircher's opus. In it, Burnet outlines a "Christian geology" explaining the historical development of Earth's current structure and future transformation as a physical manifestation of the divine plan. True to his Christian Neoplatonist roots, Burnet describes the edenic Earth as an egg, with the planetary crust as its perfect shell and the watery interior abyss as the yolk. The current and imperfect world we inhabit, with its non-uniform topography, ragged coastlines, and off-kilter axial orientation, is the result of "the frame of the Earth" having broken and fallen "down into the *Great Abyesse*," releasing the Deluge (65).

Kircher knew that Earth is hollow, at least in the sense of being pierced through with passageways, because it never would have occurred to him that any alternative was possible. He had witnessed volcanoes, caves, and springs firsthand, and despite his claims of (and doubtlessly his earnest attempt at) critical empiricism, Kircher's perception was tightly bound up in the received wisdom of his day, from Plato's *Phaedo* all the way down to the medieval alchemists who he dismissed as charlatans. So the suggestion of a solid planet, had one been proffered, would have struck him as singularly naive.

Burnet, on the other hand, had at least one alternative model available. In 1668 Robert Hooke proposed that gravity would act on the materials of the planet, arranging "every one in its distinct Order according to its Density and Gravity," resulting in a spherical Earth with an interior structure "not unlike the Orbits of Shells...of an Onion"

(215). But Burnet had larger intentions than Hooke's model could encompass, and he needed the Hermetic hollow egg as a device for bringing about the Deluge. It also supported the alchemical subtext that, as Nelson (141) notes, dominates the metaphorical structure of the *Sacred Theory*.

Halley would have been familiar with all of these ideas, as well as the hollow Earth descriptions of Plato, Aristotle, Lucretius, Seneca, and Dante. Not that it seems to have mattered much: in his address to the Royal Society in 1691, published a year later in their Transactions under the title "An account of the cause of the change of the variation of the magnetical needle with an hypothesis of the structure of the internal parts of the Earth," Halley invented the world anew.

Halley's genius, we now recognize, lay in the art of reducing large amounts of data into meaningful summaries (see, e.g., biographies by Cook and Ronan). He was the first person to attempt to relate age and mortality rates (based on data from Breslau transmitted to the Royal Society), thus laying the groundwork for modern actuarial science. He compiled the first star catalog for the southern sky as well as historical astronomical records that, together with the theory and method that Newton's *Principia* provided, allowed him to predict the return of the comet that bears his name. He produced the world's first meteorological chart, showing prevailing wind directions over the world's ocean surfaces. He also pioneered the use of isometric contours—the basis of our now-familiar topographic maps—to portray statistical surfaces for his 1701 map of magnetic compass variations, and it was during the early stages of assembling the data on which that map is based that Halley encountered the "two difficulties not easie to surmount" (564) that his hollow Earth theory sought to explain.

Earth's magnetic field is not perfectly aligned with its axis of rotation, nor is its orientation fixed. Lines of magnetic declination rarely run parallel to lines longitude, a fact noted early in the history of navigation. What had only recently been discovered in Halley's day, however, was the fact that lines of magnetic declination gradually shift from year to year. These spatial and temporal patterns of variation had important implications for 17th century navigation and had attracted the attention of many eminent natural philosophers of the time, Descartes, Kircher, and Hooke among them.

The young Edmund Halley turned his attention to the problem beginning in 1676 and in 1683, using data on compass variations that he and others had collected, concluded "that the Globe of the Earth might be supposed to be one great Magnet, having four Magnetical Poles or Points of Attraction" (*A Theory* 564). The "two difficulties" were, first, that "no Magnet I had ever seen or heard of had more than two opposite Poles, whereas the Earth had visibly four, and perhaps more," and second that "these Poles were not, at least all of them, fixt in the Earth, but shifted from place to place...whereas it is not known or observed that the Poles of a Load-Stone ever shifted their place in the Stone" (564). So there it was. Earth was clearly like a magnet, but it was different from any magnet known in having a variable field and too many poles.

We now know that Earth's magnetic field does, in fact, have only two poles, but Halley was working with incomplete data, especially for the high latitudes, where magnetic variation is the most extreme. He simply filled in the polar blanks, just as Kircher and his medieval forebears had filled them in their way, and as John Cleves Symmes would fill them so memorably more than a century later. Still, Halley might never have arrived at his novel hypothesis had it not been for another error, Isaac

Newton's mistaken estimate of the relative densities of Earth and the Moon included in the first edition of the *Principia*.

The twin difficulties of the four magnetic poles and their ceaseless wandering, Halley noted, "had wholly made me despond, and I had long since given over an inquiry I had so little hopes of; when in accidental discourse, and least expecting it, I stumbled upon the following Hypothesis..." (364). Halley doesn't provide any details about this discourse, but it almost certainly concerned Newton's low-density Earth. Historian of Science Nicholas Kollerstrom reconstructs the sequence of events that led to Newton's lunar mass error and its importance to Halley's theory and shows that, based on the relative tide-raising powers of the Sun and Moon, Newton had estimated the mass of the Moon to be 1/26 that of Earth, which is slightly more than three times the actual ratio of 1/81. He points out (186) that "Halley viewed Newton's tidal theory as one of the finest achievements of the *Principia*'s first edition," so he clearly had no reason to question its validity. Quite the contrary: Newton's dense moon provided the key to resolving the geomagnetic dilemma that Halley had lived with for eight years.

Halley knew that the fruit of his insight was radical in the extreme, and warns his readers that "if I shall seem to advance anything that looks like Extravagant or Romantick; the Reader is desired to suspend his censure, till he have considered the force and number of the many arguments which concurr to make good so new and so bold a Supposition" (564-565). He then proceeds to outline some of those arguments, beginning with several examples illustrating the gradual temporal changes in Earth's magnetic field, then proceeding to a consideration of potential causes within the planet.

After rejecting the possibility that something moving through the solid part of the globe (either some sort of magnetic body or some form of magnetic liquid) might be responsible for the magnetic variation, Halley is left with the conclusion that whatever it is that causes the movement must “turn about the Centre of the Globe, having its Centre of Gravity fixt and immoveable in the same common Centre of the Earth,” (567), but must be “detached from the external parts” and thus able to move independently. He continues: “So then the External Parts of the Globe may well be reckoned as the Shell, and the Internal as a *Nucleus* or inner Globe included within ours, with a fluid medium between” (568). In other words, Halley is proposing an internal structure for the planet that is strikingly similar to our modern model, with its solid core separated from the solid outer layers by a liquid (molten iron) outer core.

Halley proposed that the four magnetic poles he had identified in each hemisphere were the result of slight differences in the alignment of the magnetic poles of the nested spheres, and that the slow drift in lines of magnetic declination were due to minute differences in their rates of diurnal rotation. Over time, he reasoned, this minute difference would magnify, and “the Internal parts will by degrees recede from the External, and not keeping pace with one another will appear gradually to [move] either Eastwards or Westwards by the difference of their motions” (568).

Halley then goes on to deduce which of the four poles are most likely to be fixed and which in motion, the direction of the magnetic drift (westward), and the period of rotation (about 700 years.) Halley acknowledges that all of these deductions are based on limited information, “so that the nice Determination of this and of several other particulars in the Magntick System is reserved for remote Posterity; all that we can hope

to do is to leave behind us Observations that may be confided in, and to propose Hypotheses which after Ages may examine, amend, or refute” (571). He then takes the opportunity to advance the Baconian ideal on which the Royal Society is founded by admonishing “all Masters of Ships and all others, Lovers of natural Truths” to continue collecting data on magnetic variation, and offers a suggestion to improve the technique for so doing.

Had Halley actually stopped at that point, leaving his ideas about how spheres might be nested within a planet somewhat vague (especially if he had collaborated more closely with Hooke than with Newton), he would doubtlessly be remembered today for having correctly surmised the structure of Earth’s interior more than two hundred years before it was confirmed by seismic data.

Fortunately for those who appreciate the hollow Earth idea and its strange modern history, Halley was just getting warmed up. He clearly knew what he was in for, and it is worth quoting the turning-point passage in full:

But to return to our Hypothesis, In order to explain the change of the Variations, we have adventured to make the Earth hollow and to place another Globe within it: and I doubt not but this will find Opposers enough. I know ‘twill be objected, That there is no Instance in Nature of the like thing; That if there was such a middle Globe it would not keep its place in the Centre, but be apt to deviate therefrom, and might possibly chock against the concave Shell, to the ruine or at least endammaging thereof; that the Water

of the Sea would perpetually leak through, unless we
suppose the Cavity full of Water, That were it possible yet
it does not appear of what use such an inward Sphere can
be of, being shut up in eternal Darkness, and therefore unfit
for the Production of Animals or Plants; with many more
Objections, according to the Fate of all such new
Propositions. (572)

Having outlined what he thought were the main critiques of his bold vision, Halley deploys counter-arguments in his defense. He invokes Saturn's rings as a natural analogy and as evidence that that nested bodies can share a common center and be held in place by gravity. He acknowledges the seriousness of the critique that the oceans would leak through cracks in the outer shell, but notes that "the Wisdom of Creator" has doubtlessly "provided for the Macrocosm by many more ways than I can either imagine or express" (573). A few lines later, however, he proposes that the "Internal parts of this Bubble of Earth should be replete with such Saline and Vitrolick Particles" that would seal any rent in the fabric of the shell, an idea probably borrowed from Hooke (c.f. Hooke 208).

Having laid these criticisms sufficiently to rest, Halley proceeds to conjecture further, twice invoking Newton's *Principia*. First, Halley points out that, according to Newton's law of gravity, "all those Particles" on the concave surface of the outer shell that "shall molder away or become loose...would fall in, and with great force descend" onto the surface of the inner sphere. Halley solves this problem by suggesting that, since the only attractive force in nature we know to be stronger than that of gravity is magnetism, it is only reasonable to suppose that the concave surface of the shell "be lined

throughout with a Magnetical Matter, or rather to be one great Concave Magnet” (254). Conveniently enough, this explanation provides a perfect account for the “Cause of the admixture of the Magnetical Matter in the Mass of the Terrestrial parts of our Globe.” That is, the only reason Earth should have any magnetic charge at all is to “make good and maintain the Concave Arch of the Shell” (574).

Kollerstrom (187) recognizes that Halley might have gotten the seed of the idea of a hollow Earth from Burnet, but he attributes the main source of the idea to Halley’s second argument from the *Principia*, which is based on Newton’s lunar density error. “Now if the Moon be more solid than the Earth as 9 to 5,” Halley wrote (595), “why may we not reasonably suppose the Moon...to be solid...and this Globe to consist of the same Materials, only four ninthes thereof to be Cavity, within and between the internal Spheres, which I would render not improbable.”

So there it was. Halley had resolved his twin geomagnetic conundra and provided a grand vision of the planet’s structure, its particulars derived and supported (in part) by no less authority than the *Principia* itself. There still remained the final objection he anticipated, the question of utility. In Halley’s day, a full century before Kant would caution against teleology as a constitutive principle in his *Critique of Judgement*, the question of utility was a significant issue that could not be ignored.

“To those that shall inquire of what use these included Globes can be, it must be allowed, that they can be of very little service to the Inhabitants of this outward World, nor can the Sun be serviceable to them, either with his Light or Heat” (575). Fortunately for Halley, this presented little obstacle at all, because Bernard le Bovier de Fontenelle had already argued in his spectacularly popular book *Plurality of Worlds* that life must

exist on the other planets if only because of the impossibility of imagining any other use for them (Crowe 18-19). Thus Halley was able to simply argue: “But since it is now taken for granted that the Earth is one of the Planets, and they all are with reason supposed Habitable...Why then should we think it strange that [this] prodigious Mass of Matter...should...serve [only] to support its Surface? Why may not we rather suppose that [it]...is so disposed by the Almighty Wisdom as to yield as great a Surface for the use of living Creatures as can consist with the conveniency and security of the whole” (575). Furthermore (if this were not convincing enough) Halley points out that “We ourselves, in Cities where we are pressed for room, commonly build many Stories, one over the other, and thereby accommodate a much greater multitude of Inhabitants” (575). Surely God would provide no less for his creatures.

There remains the issue of light for the inner worlds, without which “there can be no living, and therefore all this *apparatus* of our inward globes must be useless.” Here too, Halley professes humble ignorance, pointing out merely that “there are many ways of producing Light which we are wholly ignorant of.” But once again, the temptation to speculate proved too strong. “The Concave Arches may in several places shine with such a substance as invests the Surface of the Sun; nor can we, without a boldness unbecoming a Philosopher, adventure to affect the impossibility of peculiar Luminaries below, of which we have no sort of *Idea*” (576). In support of this latter possibility, Halley quotes Virgil and Claudian on the illumination of the Elysian Fields. He recognizes, however, that this oversteps the bounds of rational natural philosophy, and explains “this [is] not to be esteemed as an Argument, yet I may take the liberty I see others do, to quote the Poets when it makes for my purpose.” (576).

Having dispatched the problem of interior light, Halley is finally free to unfurl his full schema (Figure 1) “wherein the Earth is represented by the outward Circle, and the three inward Circles are made nearly proportionable to the Magnitudes of the Planets *Venus*, *Mars*, and *Mercury*, all which may be included within this Globe of Earth” (577). Halley saw fit to “allow five hundred Miles [ca. 800 km] for the thickness of [Earth’s] Shell, and another space of five hundred Miles for a Medium between, capable of an immense Atmosphere for the Use of the Globe of *Venus*” (577). To Venus and Mars, Halley allots the same proportion of shell and intervening medium, with Mercury a “Ball we will suppose solid, and about two thousand Miles [ca. 3200 km] Diameter.” (Ironically, Halley’s figures for the outer shell of Earth and the inner sphere of Mercury are fairly close to the modern estimates of 700 km for the thickness of Earth’s mantle and 2432 km for the diameter of its core.)

At this point, Halley addresses those who may yet remain skeptical: “Thus I have shewed a possibility of a much more ample Creation, than has hitherto been imagined; and if this seem strange to those that are unaquainted with the Magnetical System, it is hoped that all such will endeavor first to inform themselves of the Matter of Fact, and then try if they can find out a more simple Hypothesis, at least a less absurd, even in their own Opinions.” Almost apologetically he continues: “And whereas I have adventured to make these Subterraneous Orbs capable of being inhabited, ‘twas done designedly for the sake of those who will be apt to ask *cui bono*, and with whom Arguments drawn from *Final Causes* prevail much” (577).

In Halley’s day such arguments prevailed much on just about everybody in the British intelligentsia. Newton, for example, was a supporter of Burnet’s *Sacred Theory*

(Drake 74-75), and in the very year that Halley's essay was published, Robert Boyle initiated a lecture series dedicated to the scientific proof of Christianity (Crowe 22). Moreover, Halley had recently been charged with "atheism" (the term held different connotations at the time than it does now) and denied the Savilian chair at in Geometry at Oxford (Kollerstrom 189), so the polite bow to Aristotelian teleology was necessary if not exactly heartfelt. Another motivation may have simply been the fact that Halley was testing the intellectual waters to see if his idea should be pursued. "If this short essay shall find a kind acceptance," he writes near the end of his essay, "I shall be encouraged to enquire farther, and to Polish this rough Draft of a Notion.." As such, one suspects, Halley could ill afford to have an issue that he clearly considered peripheral to distract attention from his substantive argument.

Halley's essay proved popular and was reprinted several times during the 18th and early 19th centuries. The geomagnetic data Halley compiled excited considerable scientific interest, but the hypothesis he proposed to account for them received a mixed reception. The American puritan, Cotton Mather, admired Halley's hollow Earth and included the theory in his book *The Christian Philosopher*. William Whiston, a mathematician and cleric who served as Newton's assistant and then successor as Lucasian professor at Cambridge, not only accepted Halley's theory, but believed the sun, other planets, and comets to be hollow and inhabited as well (Crowe 31). Most members of the nascent scientific community responded less enthusiastically. Newton, for example, never incorporated the hollow Earth idea into subsequent editions of the *Principia* (no doubt in part because he recognized the error in his lunar density estimate and revised it downwards).

Perhaps because its acceptance was less than kind, Halley never expanded and polished his hypothesis. But neither did he abandon it, even after Newton revised his estimates of lunar density in subsequent editions of the *Principia*. Indeed, he invoked the hollow Earth theory in 1716 to explain spectacular displays of aurora borealis that marked the end of a sixty year lull in solar activity, reasoning that the aurora were luminous vapors escaping from Earth's interior through the relatively thin crust of the polar regions. Perhaps the greatest indication of Halley's regard for the idea is his portrait as Astronomer Royal (painted in 1736 when he was 80 years old), in which he holds a copy of the nested spheres diagram from his 1692 paper (Kollerstrom, 190).

Interregnum

The approach to understanding nature that Newton pioneered with the *Principia* grew increasingly secular and potent during the 18th century, relieving the necessity of theologically-inspired divagations such as Halley's. There was, however, still room for speculation about Earth's interior, and at least one member of the scientific mainstream, physicist Sir John Leslie (1766-1832), gave serious consideration to the idea of a hollow Earth, and the mathematician Leonhardt Euler (1707-1783) may have. According to DeCamp and Ley (305), Euler proposed a single hollow sphere that was illuminated by an interior sun, while Leslie proposed two suns (presumably inspired by Sir William Herschel's discovery of binary star systems), which he named Pluto and Prosperina.

Unfortunately, the authors do not cite sources for this information, so its origin and exact details are obscure. Euler's supposed proposition of a hollow Earth is widely recounted but may be apocryphal. When he wrote his *Letters to a Princess of Germany*, probably his most popular and widely read work, between 1760 to 1762, he clearly

indicates his understanding that Earth is solid throughout. In Letter XLIX, concerning the “True Direction and Action of Gravity relatively [sic] to the Earth,” he introduces a thought experiment, stating (Vol. 1, 219) “...were you to dig a hole in the earth, at whatever place, and continue your labor incessantly...you would, at length, reach the center of the earth.” Moreover, in Letters LVI- LIX, concerning magnetic declination, he discusses Halley’s proposal at length. Concerning Halley’s “double loadstone in the bowels of the earth” and four magnetic poles, he states: “this hypothesis seems to me rather a bold conjecture...” (Vol. 2, 253).

Leslie describes his theory (absent any mention of the two suns) in an endnote to the 1829 edition of his *Elements of Natural History* (pages 449-453). Like Halley’s Leslie’s hollow Earth theory owes its existence to flawed observation and subsequent errors of induction and deduction. His hollow Earth theory follows directly from what he calls the “theory of the compression of bodies.” The theory is based in part on an experiment by British physicist John Canton that Leslie believed established the compressibility of water, an idea Leslie believed his peers had dismissed prematurely (they were actually correct—water is incompressible). The theory of the compression of bodies holds that the density of any substance is a function of its particular elastic properties and its distance from Earth’s center. According to Leslie’s calculations, this would result in material at Earth’s core (whatever it might be composed of) being almost inconceivably dense, which would result in Earth being thousands of times more massive than it was estimated to be based on Newtonian physics and other considerations.

Leslie gives no indication that he was familiar with Halley’s hollow Earth solution to his problem of an apparently over-massive Moon, but faced with the similar

problem of an apparently over-massive Earth, Leslie arrives at a similar solution. “Our planet, must have a very widely cavernous structure,” he wrote, and “we tread on a crust or shell whose thickness bears but a very small proportion to the diameter of its sphere” (452).

Because an absolute vacuum was inconceivable in Leslie’s day, he reasoned that something must fill the interplanetary void, but what? Certainly not air, because according to the theory of the compression of bodies, even air would be subject to “immense compression [that] would totally derange the powers of elective attraction, and change the whole form and constitution of bodies” (452). Rather, “the vast subterranean cavity must be filled with some very diffusive medium, of astonishing elasticity or internal repulsion among its molecules.” This left only one possibility: “[the] only fluid we know possessing that character is LIGHT itself” (452).

Leslie goes on to extol the elastic properties that light must possess, concluding with a flourish: “We are thus led...to the most important and striking conclusion. The great central concavity is not that dark and dreary abyss which the fancy of Poets had pictured. On the contrary, this spacious internal vault must contain the purest ethereal essence, *Light* in its most concentrated state, shining with intense refulgence and overpowering splendour” (453).

Leslie’s scientific peers roundly rejected his hollow Earth theory along with other conclusions from the theory of compression, such as the hypothesis that the ocean rests on a bed of compressed air. It might have slipped into complete obscurity had it not been for Jules Verne, who credits Leslie as the source for the subterranean world of his novel, *Journey to the Center of the Earth*.

The relationship between Leslie and Verne highlights another dimension of science and the hollow Earth idea, i.e., the role that science has played as a source of both style and substance for the flowering of the hollow Earth in popular imagination. One of the earliest and richest examples of this dimension is the story of John Cleves Symmes, the American visionary who devoted his life to the idea of a hollow Earth (see Kafton-Minkel 56-73, Peck, and Stanton 8-15).

Zirkle suggests that Symmes probably learned of Halley's theory by way of Cotton Mather's *The Christian Philosopher*, while Peck (34) presumes that he learned of both Halley's and Euler's proposal through one of his followers and benefactors, James McBride (McBride may be the source of the Euler story, though I could not locate his book on Symmes' theory). Symmes made the idea his own, however, by proposing that Earth is not only "hollow [and] habitable within," (quoted in Peck, 30) but open at the poles as well. Through speaking tours and books (written by McBride and later by his son, Americus Symmes) Symmes probably did more than any single person to popularize the idea of a hollow Earth in the United States.

Symmes' story also illustrates a less commonly examined, but important, dimension of the relationship between the hollow Earth in science and popular culture: the practice of hollow Earth promoters to adopt the tropes and outward appearances of science (or at least some imitation of what the adopter perceives these to be). These borrowings are almost always lacking the critical and reflective modes of practice and thought that characterize orthodox science, but they impart an air of authority and legitimacy that can be compelling, provided we don't scrutinize them too carefully. Dense thickets of peculiar jargon often serve to deflect such scrutiny and add a patina of

complexity and conceptual weight. This sort of borrowing is, of course, a primary trope in science fiction, but it has also been deployed to legitimate and justify any number of idiosyncratic psychological, spiritual, and even geopolitical claims and goals.

Symmes deployed this strategy with mixed success. For example, consider this fragment of a sentence explaining a part of his theory: "...thus causing a universal pressure, which is weakened by the intervention of other bodies in proportion to the subtended angle of distance and dimension, necessarily causing the body to move toward the points of decreased pressure" (quoted in Kafton-Minkel 58-59). Many of his listeners and commentators saw through such gobbledygook and pronounced his theory as ridiculous. But a great many others were won over, and Symmes gained something of a reputation among his countrymen as an American Newton (Stanton 10-11).

These examples represent the flow of authority and influence from science to popular culture. The direction has been reversed at least twice, however. The first was the indirect role that Symmes played in the development science in America.

Symmes and his followers agitated the United States Congress and scientific institutions worldwide to support him in a polar expedition in order to test his hypothesis and pave the way for exploitation and trade in the interior. His efforts were unsuccessful, but they tapped a deep vein of American patriotism and cultural inferiority that helped popularize and promote the cause of polar exploration. The interest generated by Symmes and especially the efforts of one of his followers, Jeremiah Reynolds (also notable for his influence on Poe and Melville), eventually led to the Great American Exploring Expedition of 1838-1842 (Stanton Chapter 2). The expedition marked a turning point in the status of science in America, and the nation's foremost museum, the Smithsonian

Institution, was established to archive the hundreds of thousands of specimens collected during its course.

The second reversal in the flow of authority is the role that another American hollow Earth promoter, Cyrus Teed, played in the development of the interior model of the hollow Earth, and how it found its most sophisticated supporter in Mostafa Abdeklader.

Mostafa Abdelkader and the Geocosmos

With the marginal exception of Euler's and Leslie's proposals, the hollow Earth remained entirely outside of the scientific community's consideration or even awareness (except as a novelty; see Sexl 174-176) until 1982, when Mostafa Abdelkader proposed a mathematically-based rationalization for the geocosmos, one of the mystical forms of the hollow Earth idea that arose in the 19th century. To say that Abdelkader reintroduced the idea to the modern literature of science is true. But to say that it had any noticeable effect whatsoever on the world of mainstream science would be an overstatement. The reasons lie in the ways that the practice of science as a conservative social construction, evolved during the nearly three hundred years separating Halley from Abdelkader.

In 1692, nothing, really, was known of the nature of Earth's interior, the boundary between the nascent modern, materialistic world view and the entrenched superstition of Christianity was vague, and the scientific community had not developed the system of peer review that lies at the heart of modern scientific practice. Halley was able to publish his theory in one of the premier scientific organs of the day, in part because of the valid empirical data it contained (his list of compass variations held considerable value for navigation) but also because of the general state of scientific knowledge at the time and

because his standing within the Royal Society meant that he could probably have published pretty much anything he pleased.

By 1982, modern geoscience had evolved, matured, and developed a robust description of Earth's (non-hollow) interior based principally on evidence from seismic waves. That understanding was developed and is maintained by the necessarily conservative process of peer review, and in 1982 there were few venues where it is possible to submit an idea as radical as the hollow Earth to serious review and consideration by an audience of scientific peers. One of those was the journal *Speculations in Science and Technology*.

Speculations in Science and Technology was one of a handful of serious-minded, professional, scientific journals that have been established to examine topics and issues at the fringe of modern science's range of acceptable inquiry (a notable peer in this niche is the *Journal of Scientific Exploration*). There are doubtlessly many in the scientific community that would deny the journal all validity, and a great many more who don't even know it ever even existed. But *Speculations* was published from 1977 until 1998 by respectable publishers (Elsevier and then Kluwer, both powerhouses in academic publishing) and its contributors, reviewers, and editorial board members were generally (though not always) practicing scholars, some of them quite distinguished, in legitimate fields of science and philosophy. Nonetheless, the journal's stated purpose was to provide a forum for speculation on ideas that are outside the scientific mainstream (though not too far: topics related to UFOs and Extra Sensory Perception, for example, were not accepted).

So, while Halley's theory entered mainstream scientific discourse at its core, Abdelkader's geocosmos did so at its fringe. Moreover, it arrived there from an origin in religious mysticism. To appreciate Abdelkader's proposal in its appropriate context, it is useful to briefly consider the trajectory of hollow Earth ideas as they evolved among pseudoscientists and mystics during the 19th and 20th centuries.

The conception of Earth as a hollow sphere in an otherwise Copernican universe (as invoked by Kircher, Burnet, Halley, Euler and Leslie) is the most intuitive conception of the hollow Earth. The geocosmos, in which Earth's surface occupies the interior shell of a hollow sphere containing the entire universe, requires considerably more imagination. Its modern form originated in the mind of Cyrus Reed Teed, an Eclectical physician and practicing "electro-chemist" from Utica, New York (see Kafton-Minkel and Gardner for accounts of Teed's remarkable history). In 1869, Teed had a mystical experience in which he received the revelation that he was the living incarnation of Christ. He also came to understand that the Copernican conception of the universe was backwards. According to Teed's "Cellular Cosmogony," Earth is a hollow sphere that contains the entire universe. We live on the inside surface.

Teed changed his name to Koresh, established a religious cult ("Koreshenity") that grew to be national in scope, and eventually established a utopian commune in Florida. There, adopting the outer appearances of scientific inquiry, Teed and some of his followers organized the Koreshan Geodetic Survey and conducted an experiment to prove Earth's concavity. Using a specially-constructed apparatus dubbed the "rectiliniator," the Survey spent five months in 1897 patiently moving the device along a

six kilometer-long stretch of beach. Not surprisingly, the results of the survey were exactly as Teed predicted—Earth’s surface proved to be concave (Gardner, *Fads*... 24).

While it is not clear whether or not Teed was consciously aware of it or not, his geocosmos reflects the alchemical conception of the hermetic egg, the *rotundum* within which, as Nelson (137) notes, microcosm and macrocosm— “cosmos, globe, and human soul”—converge. Its genius lies in the fact that reconstitutes the geocentric universe (with the comfortable reassurance that Earth, and thus humanity, occupies a privileged place in a cosmos that is not only finite, but bounded at a humanly meaningful scale) in a way that is still consistent with contemporary astronomy, provided one doesn’t look too closely. Teed ensured that close examination would be unlikely by couching his theory within an excruciatingly complicated cosmology and adopting the strategy of describing it in impenetrable, scientific-sounding prose.

Teed died in 1908 (Koreshenity—including the commune of Estero, Florida—persisted into the early 1950s), a decade or so before a German pilot named Peter Bender came across several copies of the Koreshan’s *Flaming Sword* in a stack of American magazines in a French prisoner-of-war camp during World War I. Bender was won over by Teed’s geocosmos. After the war, he returned to Germany where he developed and promoted the idea, which he dubbed the *hohlweltlehre* (“hollow Earth doctrine,” sometimes also referred to as *hohlwelttheorie*). He abandoned the religious aspects of Koreshenity and simplified Teed’s byzantine labyrinth of concepts and ideas to a simpler, though still bizarre, mechanism to reconcile observed nature with the concave conception of Earth.

Bender's *hohlweltlehre* like other hollow-Earth theories before and since, attracted its share of supporters, though none from within the ranks of mainstream astronomers or Earth scientists. He was, however, able to muster enough political support to manage two tests of his theory. The first of these was an attempt, in 1933, to build a rocket and launch it straight up into the sky. If Bender's hollow-earth idea was correct, the rocket should have crashed into the opposite side of the planet. Instead, it failed to launch and crashed a few hundred meters from its launch pad.

The second test came about through Bender's connection (dating to his World War I pilot days) with Hermann Göring and the interests of a group of German Naval Research Institute officers who sought methods for locating enemy ships based on fringe ideas such as pendulum swinging and the *hohlweltlehre*. These officers gained approval to send an expedition to Rügen Island (in the Baltic Sea) to try and detect British ships using powerful telescopic cameras pointed *upwards* across Earth's concavity. Bender claimed that the apparent convexity of Earth's surface is due to the refraction of visible light passing through the atmosphere. If Earth's surface were concave, the officers reasoned, photographs taken using infrared filters (infrared radiation is not refracted by the atmosphere) should show parts of the North Atlantic and Baltic, and the positions of British ships in those waters could be known. The failure of the Rügen Island experiment proved embarrassing to the Nazi High Command, and Bender, his wife, and some of his followers perished in death camps as a result.

Another German, Karl E. Neupert, published a pamphlet titled *Mechanik des Aethers, Gegen die Irrlehren des Kopernicus* ("Mechanics of the Ether: Against the Erroneous Teachings of Copernicus") in 1901, and a book-length treatment titled simply

Geocosmos in 1942. Neupert collaborated with Bender until his unfortunate demise, and after the war, he and another of Bender's follower, Johannes Lang, continued to publishing booklets and magazines on the subject promoting the idea. Neupert died in 1949, but Lang carried on, publishing a journal called *Geocosmos* into the 1960s. Neupert and Lang, like Teed and his followers, distributed their writings widely, and at some point, one of these copies caught the attention of Mostafa Abdelkader, who alone among those who have encountered it was in a position to re-introduce the hollow Earth concept back into the realm of mainstream science.

The key to the geocosmos model lies in reconciling the geometry of an internal universe with observed phenomena such as the rising and setting of the sun and the motions of other celestial bodies. Teed attempted this reconciliation by proposing an absurdly complex clockwork model that invoked various gaseous layers within the hollow of the planet and "refocalization" of the true Sun (which he said was light on one side, dark on the other, and rotated like a beacon at the center of the universe) on the upper layer of the atmosphere (Kafton-Minkel 94).

The simplest way to achieve such a reconciliation, however, is to abandon the idea that light rays travel in straight lines, and have them travel in curves instead. The simplest way to achieve this curvilinear behavior, in turn, is to simply perform a mathematical mapping of the Copernican cosmos "outside," into the geocosmos "inside." This is precisely what Abdelkader did, using a mathematical manipulation called inversion to map the cosmos into the sphere of Earth.

Inversion is a geometric transformation that is useful for converting certain types of otherwise intractable (or exceedingly complex) geometrical systems into forms that are

amenable to mathematical analysis. It is especially useful for transforming unbounded regions into bounded ones; making the infinite finite, in other words. The geometry is quite simple. To invert a plane with respect to a circle, for example, we simply map every point outside the circle to a corresponding location within it. To invert the universe with respect to a sphere, we simply map every point to some corresponding point within the sphere, which is what Abdelkader proposes we do with respect to the sphere of Earth. But this simplification both obscures the beauty and undermines the primary weakness of Abdelkader's proposition. It is worth considering his proposition in some detail.

Abdelkader begins his paper with the proposition that Earth's surface can be considered a sphere (it is not, actually, but the slight equatorial bulge can be safely ignored) of fixed radius with its center located within an absolute rectangular coordinate system having x , y , and z axes. All points outside Earth's surface can be denoted by X , Y , Z and those inside the sphere by x , y , z . Abdelkader notes that in the Copernican system, Earth rotates about its axis and revolves around the sun which, in turn, rotates around the center of the Milky Way galaxy, and so on. By establishing the coordinate system in relation to Earth's center, however, Abdelkader has subtly dispensed with the Copernican universe and reestablished geocentrism: "We shall regard the earth [*sic*] as at rest, so that all celestial objects are moving in the coordinate system (xX , yY , zZ)" (81). Having prepared us, as a magician would, by framing the situation just so, Abdelkader announces that he will perform the crux move of his trick: "In the following section, the whole of space will be subjected to a purely mathematical mapping taking infinite space outside the earth's surface into its inside, and vice versa" (81). What follows are the necessary mathematical manipulations.

The inversion operation is illustrated in Figure 2. Every point outside the sphere of Earth maps to an analogous image point within it. “Thus,” Abdelkader explains (82), “the earth’s surface is mapped into itself (with us living on the inside surface of a hollow earth), all of outer space becomes embedded inside this hollow earth, with infinitely distant points” mapping to the origin point of the sphere, and “objects such as stellar galaxies and quasars distant several billions of light years, are shrunk to microscopic size.”

After inversion, the moon, our closest celestial neighbor, maps to a sphere 955 meters across that circulates 6265 kilometers above Earth’s surface. The sun, on the other hand, shrinks to about 2.5 meters across and recedes to a location just 253 meters from the origin point (i.e. the center of the universe). Pluto shrinks to the size of a single bacterium floating seven meters from the origin, while Alpha Centauri, the star closest to our own Sun, becomes an infinitesimally small speck situated a mere millimeter from the origin. Every other star and object in the cosmos, therefore, is contained in a sphere less than two millimeters across that hovers 6371 kilometers above our heads.

Having inverted the Copernican cosmos to fit comfortably within Earth’s shell (which becomes infinitely thick as a result of the inversion), Abdelkader goes on to explore some of the implications of the transformation, first with regard to the shapes of spheres and then the behavior of light. Because everything in the geocosmos shrinks with distance from Earth’s surface, spherical bodies become slightly deformed in the direction perpendicular to Earth’s surface (the Moon, for example, would be about one percent smaller between the points nearest and furthest from Earth than it would be from pole to pole).

The degree of deformation is relatively slight if we assume that the origin is, in fact, a point. But Abdelkader notes that, while this assumption is perfectly acceptable in a mathematical system, it is unrealistic in a physical one, so he substitutes a sphere of arbitrary diameter for the origin point. If the radius of the origin sphere is very small relative to the radius of Earth, the distortion is negligible. Larger radii for the origin sphere, however, can result in a significant degree of distortion.

The changes in the behavior of light rays after inversion are perhaps the most striking feature of Abdelkader's model. In the Copernican cosmos, rays of light travel in straight lines, as shown in 3A. Note that for an observer positioned where ray *H* intersects Earth, *E*, (along the circle of illumination), the Sun would be visible on the horizon and be seen as setting. For an observer positioned below ray *J*, it would be solar noon.

The inverse mapping preserves angular relationships, so that observers positioned in the geocosmos would experience exactly the same phenomena as those in a Copernican universe, as shown in Figure 3B. Ray *H* maps into *e* as ray *h*, and an observer positioned at ray *h*'s intersection point would observe the sun on the horizon. Moreover, because the Sun rotates around the origin, *O*, the observer would see it as setting, exactly as does the observer in the Copernican cosmos (the Sun travels in a conical helix in the geocosmos, which accounts for seasons). It is solar noon where ray *j* intersects Earth, and halfway between solar noon and sunset below ray *i*. A person observing *i* would see the sun as being somewhere between the horizon and the solar zenith at exactly the same position in the sky as a person observing ray *I* in the Copernican universe.

Rays *K* and *L* do not intersect Earth in the Copernican universe and, assuming they do not intersect anything else, will continue traveling to infinity. In the geocosmos,

however, k and l travel in arcs that lead back to the origin. The rays never actually reach the origin, however, because the inversion operation affects not only the direction of light rays, but their velocities as well. The speed of light is constant in the Copernican universe, but variable in the geocosmos, ranging from ca. 3×10^9 cm/second at the surface of e to zero at O .

The result of these conditions, Abdelkader notes, is that “all observations and estimates of the size, direction and distance of any celestial object would lead to exactly the same results” for an observer on the outside of Earth in a Copernican universe “and his image observer inside, whether situated on or above” Earth’s surface (86). Furthermore, as the case of the speed light illustrates, all physical laws that apply in the Copernican universe can be inverted to apply in a geocosmos as well, provided we invoke appropriate conditions to support them. The movement of Foucault pendulums and the Coriolis effect, for example, are explained conventionally as effects arising from Earth’s rotation about its axis. As Abdelkader notes, it is meaningless to attribute motion to Earth in the geocosmos, but these phenomena can be explained in a geocosmos by the rotation of the origin sphere (this, in turn, he attributes to an “all-pervading perpetual *cosmic force*,” page 88). This isomorphism between the geocosmos and the Copernican universe is a critical feature of Abdelkader’s hypothesis, because it creates a situation in which it is impossible to empirically refute the geocosmos as a valid model of the universe on the basis of observational tests.

The bulk of Abdelkader’s paper constitutes, as he puts it (87), “the purely mental operation of geometrically mapping outer space...into the hollow earth..., a perfectly legitimate process of thought” to which “nobody could raise the slightest objection.”

Though Abdelkader seems to have been unaware of it, Roman Sexl invoked the *hohlweltlehre* in exactly the same vein in a paper on geo-chronometric conventionalism published in 1970. Sexl used the hollow Earth to show that topology of space-time is conventional, rather than intrinsic (he uses the example of “flatland”—c.f. Abbott—for the same purpose regarding dimensionality). But Abdelkader has a larger goal in mind, and he departs from the realm of idle mathematical curiosity in the last two pages of his treatise. “Consider now” he entreats us “the hypothesis that *our actual universe is the finite [geocosmos] and not the infinite [Copernican universe]*” (87; emphasis in original).

Abdelkader supports his proposition by arguing that observational evidence suggests that our universe is Copernican, provided we are willing to accept the untestable assumption that “light is propagated in straight lines for billions of years, so that the positions of celestial objects are in their observed directions...” (87). His point is not that this is an unrealistic assumption, but rather that it is empirically untestable and therefore the assumptions underlying the geocosmos are no more or less unreasonable than those on which the Copernican model depends. So, Abdelkader reasons, given the choice between two unfalsifiable models, both of which depend upon untestable assumptions and yield identical observational data there is no reason to accept the Copernican view *a priori*.

Abdelkader suggests that “there is no way of ascertaining the truth or falsity of the hypothesis that our actual universe is [the geocosmos] except by digging a tunnel right through the earth’s centre. ... If our universe is [Copernican], a tunnel 12,742 kilometres long brings us to the earth’s surface again. If our universe is [the geocosmos], nobody

knows what lies underground” (87). In fact, such a tunnel (if it were possible to dig one) would not necessarily solve the dilemma. As the drill creating the tunnel receded from the surface, it would become larger and larger, eventually becoming infinitely large and infinitely far from the surface. At that point, it would likely emerge from the opposite direction (some mathematicians and philosophers disagree on this point) and begin shrinking as it approached the surface, emerging at a location antipodal to its starting point.

There are, however, other grounds on which to reject the geocosmos, principally its complexity and the privileged position in the universe that it ascribes to Earth. Martin Gardner has discussed these objections in an essay entitled “Occam’s Razor and the Nutshell Earth” (16). Occam’s razor dictates that, given a choice between two theories with the same explanatory and predictive power, we adopt the simpler one. Complication is to be tolerated only if it yields a commensurate gain in explanatory or predictive power. Non-Euclidean geometry and Einsteinian relativity, for example, are more complicated than their Euclidean and Newtonian counterparts but provide greater explanatory and predictive power at astronomical scales. The same is true of quantum theory at the subatomic level. Abdelkader’s geocosmos carries a high cost in mathematical complexity (Figure 4) but, as noted above, there is no way to empirically determine which model, geocosmos or the Copernican universe, provides the better description of the cosmos.

So what *does* the geocosmos provide in return for the computational burden it imposes? For Abdelkader, the answer is a sense of psychological comfort. At the end of his paper, the detached language of mathematics and minimalist rhetorical presentation

give way to prose that conveys a barely-contained sense of angst that is rare in the published discourse of modern science. The first paragraph of his conclusion bears quoting in its entirety:

For one who dogmatically insists on believing the *unprovable* hypothesis that light propagates in straight lines over distances of *billions* of light-years, the universe must be the universally accepted Copernican system. If one is open-minded enough to get rid of one's attachment to this dogma, then the only alternative universe is Geocosmos. The former, with its incredibly gigantic stellar galaxies and other celestial objects distant billions of light-years, and its stupendous energy sources, scattered aimlessly throughout space, reduces the earth and the solar system to nothing in comparison; whereas in the latter, the earth's surface is the finite boundary of the whole universe contained within it. Since both universes are equally possible, there is no valid reason for astronomers, astrophysicists, and other scientists to confine their attention exclusively to the study of [the Copernican system], totally dropping the competitive [Geocosmos] out of their consideration. Probably the majority of these scientists have never even heard of [Geocosmos]; it is never mentioned in the proliferating books on astronomy, either the technical or the popular ones, as far as the author is aware. (88 emphasis in original)

For Abdelkader (like his Koreshan and *hohlweltlehre* forebears), the geocosmos banishes the incomprehensible void of outer space to a speck contained within Earth's interior, simultaneously rendering the cosmos humanly comprehensible and restoring

Earth's pre-Copernican place of privilege in the cosmos. If, as most mathematicians believe, the idea of an inverted universe cannot be empirically refuted, is there really anything wrong with this? Does it matter?

From a practical standpoint, accepting the geocosmos would have little or no effect on most of us. We experience the universe as Euclidean space with Earth's surface or (occasionally) the Sun as our reference framework, and we can pass our entire lives without ever having to take an Archimedean perspective that views the framework itself.

The same cannot be said for the "astronomers, astrophysicists, and other scientists" Abdelkader lambastes for failing to give the geocosmos its due. The geocosmos model simply does not solve any scientific problems they face, and pre-Copernican nostalgia and apeirophobia are apparently not widespread enough within the space science community to justify the burden it would impose. Even if it were, the geocosmos would not necessarily provide a cure. Abdelkader's inversion banishes the topology of the Copernican universe, but does nothing (except axiomatically) to undermine the Copernican principle.

The Copernican revolution taught us that we should not assume that we occupy a privileged place in the cosmos. Inversion does not suspend this principle except by fiat, and as one of Gardner's correspondents points out (*On the Wild Side* 21), even if the geocosmos is a valid model, there is no reason to expect the universe to be inverted with respect to our little planet. There are, for example, an estimated 10^{10} galaxies in the known universe. Assuming that each of these contains 10^{11} stars, as does our own galaxy, and that each of these stars is orbited by a mere ten spherical bodies (planets, their moons, comets, asteroids, and small bits of rock or ice—any spheroidal body will do),

there must be 10^{22} objects in the universe (let us be clear here—this is a one followed by twenty two zeros) to choose from. The probability that any one of them, including Earth, is the preferred body is only $1/10^{22}$, which is vanishingly close to zero. Moreover, there is no reason why the inversion must be done in relation to a physical body at all. It is equally plausible to simply perform the inversion around an arbitrarily chosen spherical region of space, in which case the choice of regions and spheres is limitless. Regardless of which sphere we choose, if it is anything other than Earth, our planet becomes even smaller and less significant than ever.

The only way to retain Earth as the preferred body is to simply assume geocentrism, as Abdelkader has done. But if we are willing to indulge in this sort of axiomatic reasoning, why not take the logic a step further, to egocentrism? If banishing the extrasolar universe to a two-millimeter sphere provides relief from a feeling of cosmic insignificance, then surely inverting the universe with respect to one's own eye (remember—any spheroid will do) must be more satisfying still.

This is truly an experiment that you can perform at home. You need not perform a single calculation—simply declare that the cosmos is contained within your eye, and it is done. Revel in knowing that you have given new truth (not to mention ownership) to Walt Whitman's claim "I am vast, I contain multitudes," and no empirical test can refute the proposition. Thrill to the fact that your brain is now the largest object in the universe, and the question of what came before you and what will follow now have universal importance. Experiment to your heart's content, though it might be wise to keep the knowledge secret, hidden away in your own little hollow world.

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Figure Captions.

Figure 1. Halley's hollow Earth, reproduced from "An account of the cause of the change of the variation of the magnetical needle with an hypothesis of the structure of the internal parts of the Earth."

Figure 2. Abdelkader's inversion. Any point P outside Earth's sphere is mapped to point p inside the sphere according to the simple relation $xX = a^2$ where x is the distance between the surface E and p , X is the distance from E to X , and a is Earth's radius (for simplicity's sake, Earth is considered to be a perfect sphere, though in reality it is slightly flattened at the poles). We can obtain the distance x for any point P in the cosmos by $x = a^2/X$.

Figure 3. The behavior of light rays in a Copernican universe (3A) and Abdelkader's geocosmos (3B). Both diagrams are diagrammatic only, and not to scale.

Figure 4. A ray of light passing through two points (X_1, Y_1, Z_1) and (X_2, Y_2, Z_2) follows a straight line defined by the two equations in 4A. After inversion, its path is transformed into a circle (or, if it intersects Earth's surface, an arc thereof) passing through the origin and defined by the equations in 4B. Based on Abdelkader's equations 11-13.

Figure 1

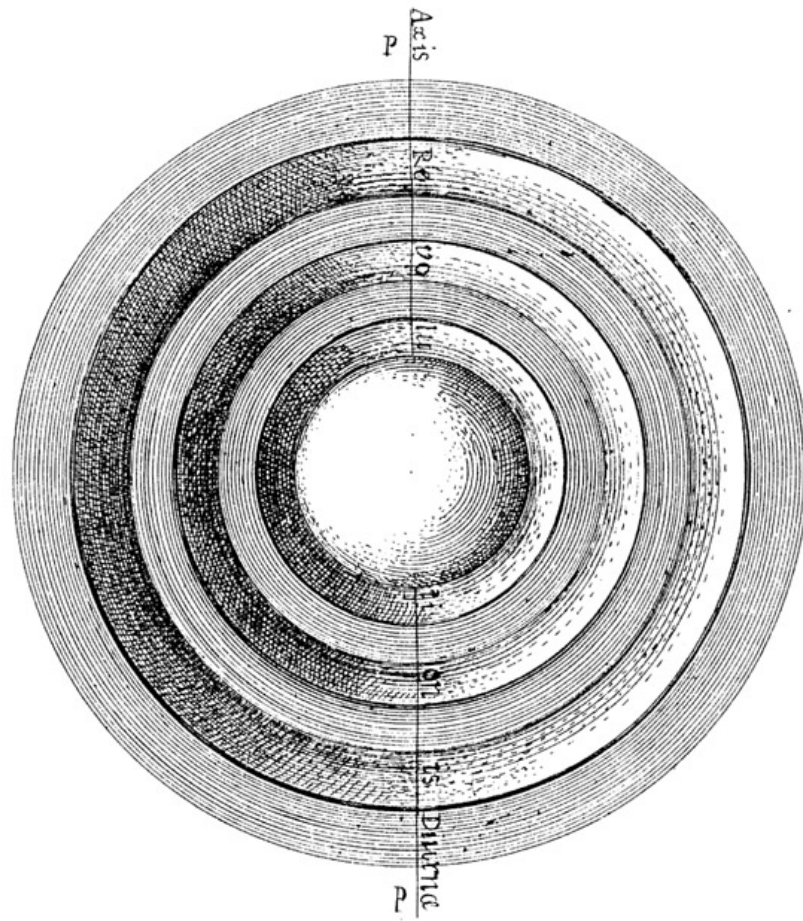


Figure 2

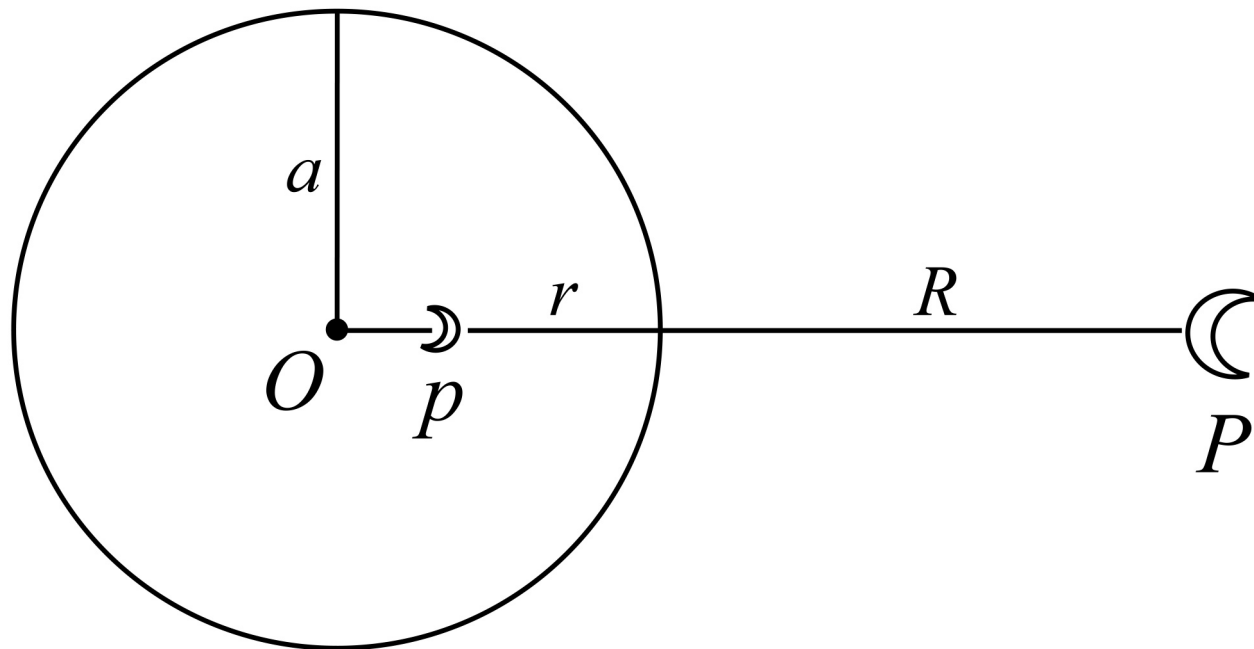
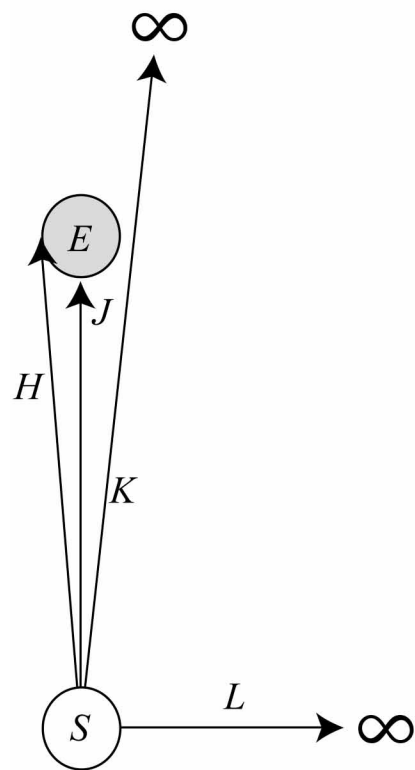
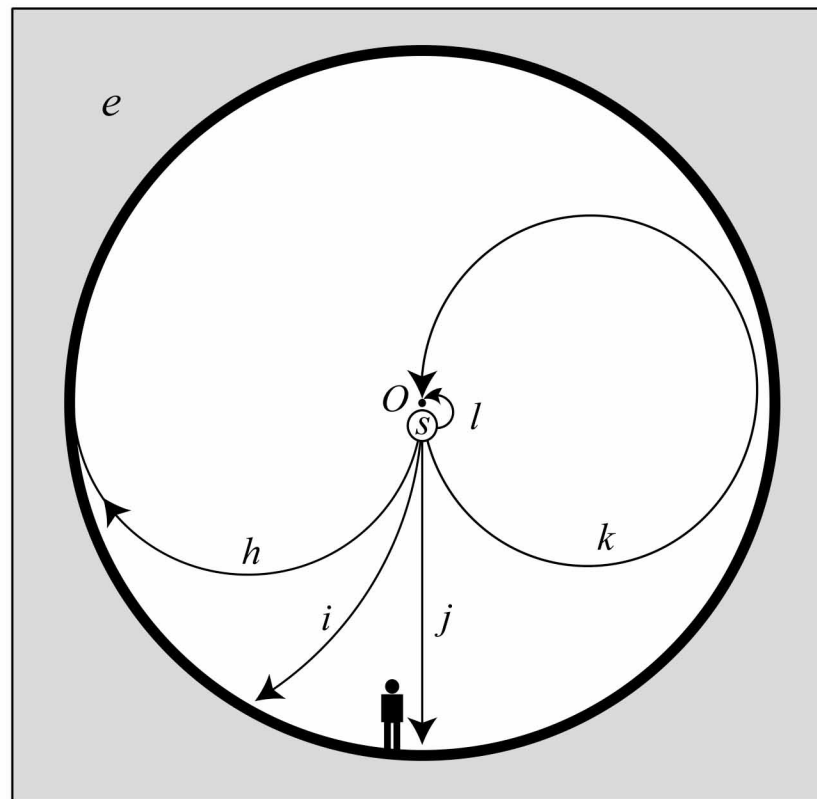


Figure 3



A



B

Figure 4

A. Copernican Universe

$$\frac{X - X_1}{X_2 - X_1} = \frac{Y - Y_1}{Y_2 - Y_1} = \frac{Z - Z_1}{Z_2 - Z_1}$$

B. Geocosmos

$$\Sigma_1 \left(\frac{x}{r_2(r_2 - \rho)} - \frac{x_1}{r_2(r_2 - \rho)} \right) = \eta_1 \left(\frac{y}{r_2(r_2 - \rho)} - \frac{y_1}{r_2(r_2 - \rho)} \right) = \zeta_1 \left(\frac{z}{r_2(r_2 - \rho)} - \frac{z_1}{r_2(r_2 - \rho)} \right)$$

where

$$x = \frac{a(a - \rho) \frac{X_1}{R^2} + \rho \frac{X}{R}}{r_1(r_1 - \rho)} \quad y = \frac{a(a - \rho) \frac{Y_1}{R^2} + \rho \frac{Y}{R}}{r_1(r_1 - \rho)} \quad z = \frac{a(a - \rho) \frac{Z_1}{R^2} + \rho \frac{Z}{R}}{r_1(r_1 - \rho)}$$

$$\Sigma_1 = \left(\frac{x_2}{r_2(r_2 - \rho)} - \frac{x_1}{r_1(r_1 - \rho)} \right)^{-1} \quad \eta_1 = \left(\frac{y_2}{r_2(r_2 - \rho)} - \frac{y_1}{r_1(r_1 - \rho)} \right)^{-1} \quad \zeta_1 = \left(\frac{z_2}{r_2(r_2 - \rho)} - \frac{z_1}{r_1(r_1 - \rho)} \right)^{-1}$$

$$r = \frac{a^2}{R} \quad R^2 = X^2 + Y^2 + Z^2$$

R = radius vector above Earth's surface, r = the radius vector inside a hollow Earth, ρ = radius of the origin sphere, and a = Earth's radius