Newton and the Infinite Universe

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Newton and the infinite universe

Newton said that if the starry heavens were of finite extent they would "fall down to the middle" and there "compose one great spherical mass," yet he avoided calculating the time for gravitational collapse.

Edward Harrison

Isaac Newton formulated his ideas on space and the universe during his early years at Cambridge[1] in response to René Descartes's 1644 publication *Principles of Philosophy*. Sometime between 1666 and 1668, in an unpublished manuscript that we refer to by its opening words, *De gravitatione*, Newton wrote[2] that an "infinite and eternal" divine power coexists with space, which "extends infinitely in all directions" and "is eternal in duration." Descartes claimed that where there is no matter there can be no space; on the contrary, argued Newton, space, by virtue of omnipresent spirit, exists where there is no matter. Descartes claimed that matter extends indefinitely; on the contrary, argued Newton, God has created in infinite space a material system of finite extent.

We can imagine, wrote the young Newton, "that there is nothing in space, yet we cannot think that space does not exist, just as we cannot think that there is no duration, even though it would be possible to suppose that nothing whatever endures. This is manifest from the spaces beyond the world, which we must suppose to exist (since we imagine the world to be finite)."

At this stage Newton shared with many others a picture of the universe consisting of a sidereal system beyond which extends limitless extramundane space. This picture looks much like the Stoic universe, a starry cosmos immersed in an infinite void, proposed[3] in the third century BC. Newton's ideas on the nature of space changed surprisingly little during his lifetime. But his ideas on the nature of the universe, as I will discuss in this article, changed considerably after he developed the theory of universal gravity in *The Mathematical Principles of Natural Philosophy* (1687), refered to as *Principia*.[4]

Drawing on old systems

The bursting of the outer boundary of the Aristotelian system during the late Middle Ages, caused primarily by the growing notion that the supreme being cannot be confined, revived the old Stoic cosmic system in modified form.[5] The Stoic natural philosophy of an infinite extracosmic void surrounding a finite starry cosmos greatly influenced the scientific revolution of the 16th and 17th centuries, then dominated astronomy in the 19th century[6] and finally expired in the early decades of this century.[7]

The rival Epicurean cosmological system, portrayed around 70 BC by the Roman philosopher Titus Caras Lucretius in *De rerum natura*, consisted of numberless worlds strewn throughout an infinite void, all composed of atoms and regulated by natural laws. (See the table on page 27.) According to Lucretius,[8] "whatever spot anyone may occupy, the universe stretches away from him just the same in all directions without limit."

The Aristotelian, Stoic and Epicurean systems formed the conceptual framework of 17th-century cosmology. Descartes combined Aristotelian and Epicurean elements and favored a nonatomic material system of indefinite extent; Newton combined Epicurean and Stoic elements and favored an atomic material system of finite size immersed in a void of infinite extent. In the course of some correspondence with the theologian Richard Bentley during the winter of 1692–93, Newton abandoned the Stoic cosmic picture and adopted the Epicurean picture of a uniform material universe of unlimited extent in space.

The Bentley correspondence

Robert Boyle in his will left an endowment to provide sufficient income for an annual lectureship to combat the atheism widely professed by wits in taverns and coffeehouses. Perhaps on Newton's recommendation, the trustees of the endowment selected the young and scholarly clergyman Bentley to give in 1692 the first series of eight Boyle Lectures. To prepare his last two lectures, which he titled "A

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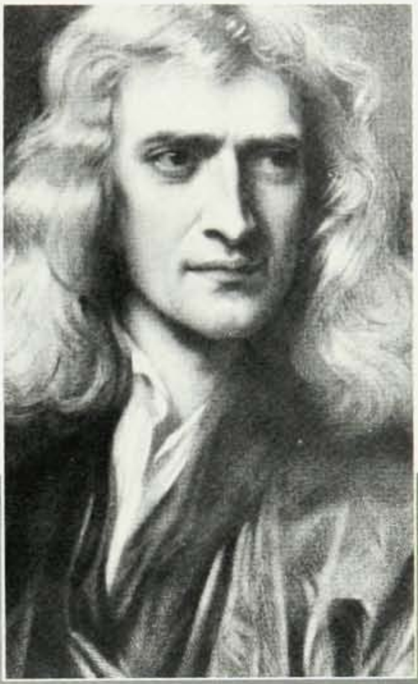
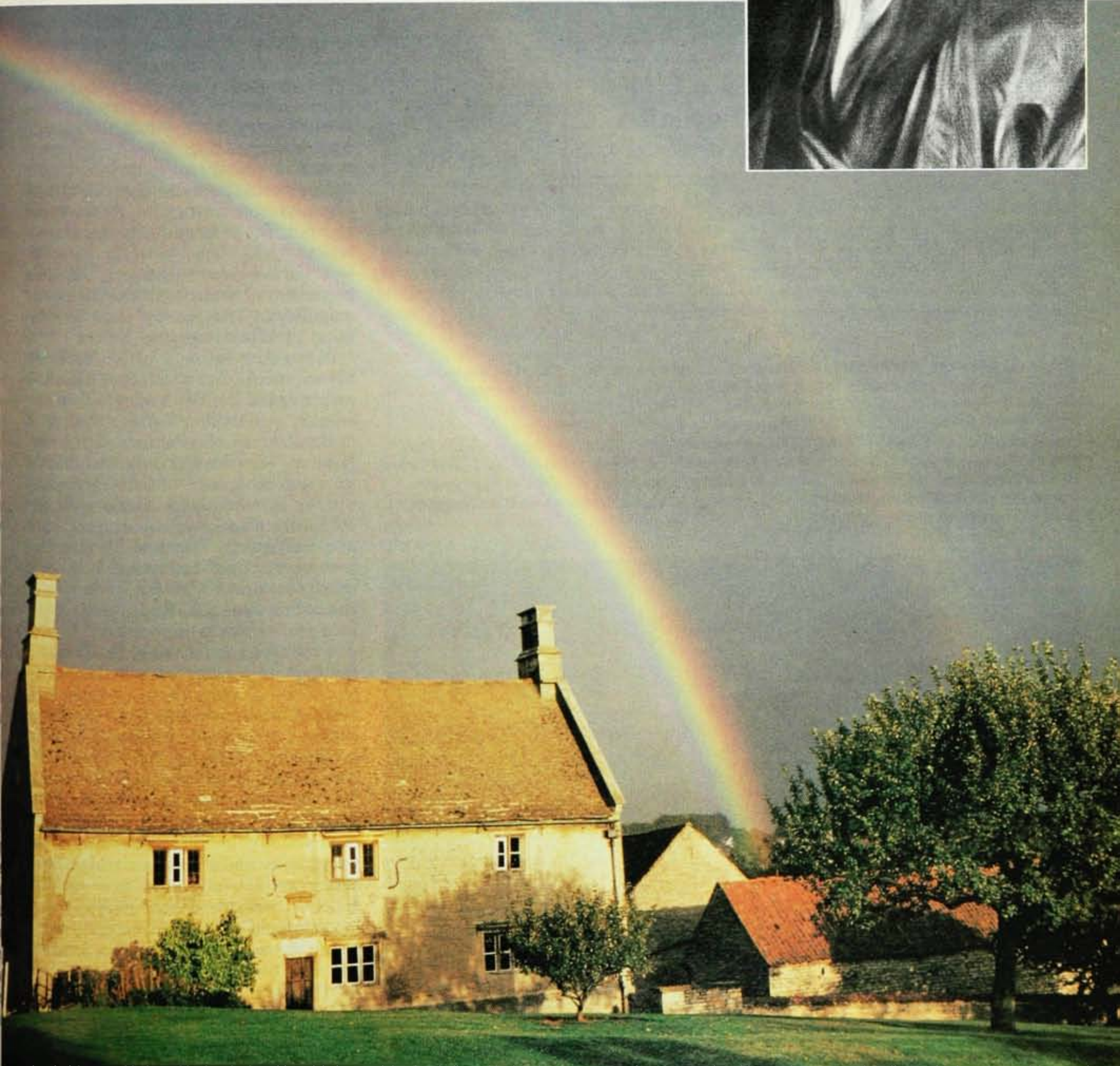
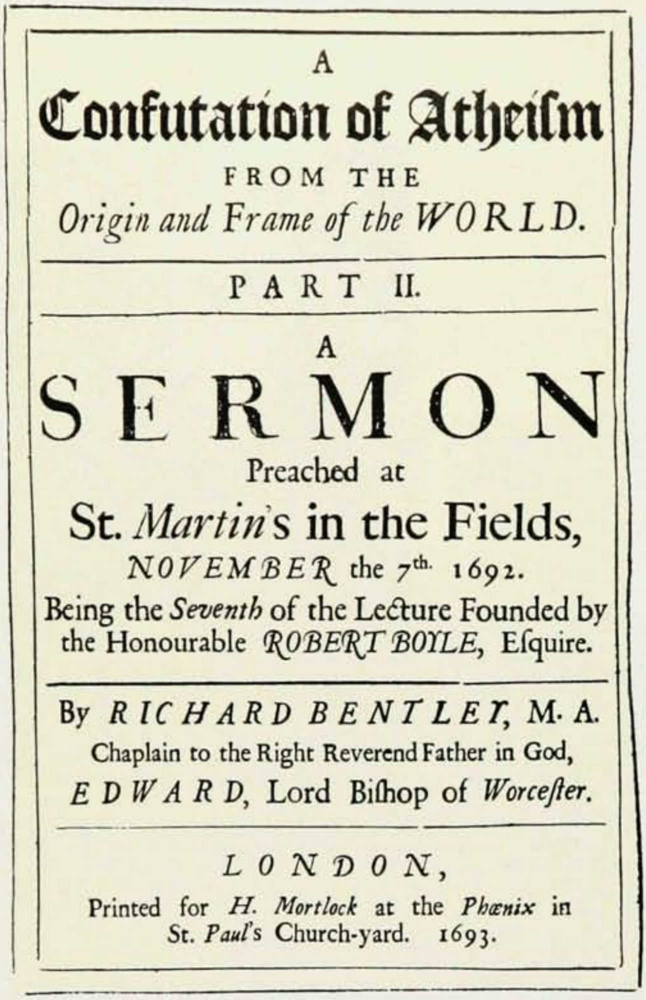


Isaac Newton (1642–1727) at age 46 (inset) and Woolsthorpe Manor, England, his birthplace. Newton spent many years of his life engrossed in alchemical pursuits and absorbed in theological studies. He became Lucasian Professor of Mathematics at Cambridge University at age 27, and resigned from this position 32 years later, in 1701, while master of the mint. Newton published the *Principia* in 1687 with Edmund Halley's encouragement and editorial assistance. (Photograph by Roy L. Bishop, courtesy AIP Niels Bohr Library.)





A

Confutation of Atheism

FROM THE

Origin and Frame of the WORLD.

PART II.

A

SERMON

Preached at

St. *Martin's* in the Fields,

NOVEMBER the 7th. 1692.

Being the *Seventh* of the Lecture Founded by the Honourable *ROBERT BOYLE*, Esquire.

By *RICHARD BENTLEY*, M. A.

Chaplain to the Right Reverend Father in God,

EDWARD, Lord Bishop of *Worcester*.

LONDON,

Printed for *H. Mortlock* at the *Phœnix* in St. *Paul's* Church-yard. 1693.

Title page of the published version of Richard Bentley's seventh lecture, "A confutation of atheism from the origin and frame of the world," delivered 7 November 1692 at St. Martin's in the Fields. Perry Miller notes[9] that Bentley, born in 1662, "achieved fame (and left an impress on British scholarship that still is felt) as a classical scholar of prodigious erudition, and also a certain infamy as the tempestuous Master of Trinity College, Cambridge, which he ruled from 1700 until his death in 1742 with so tyrannical a hand that he excited repeated insurrections of the Fellows."

The Stoic universe, a finite starry cosmos surrounded by a starless void of infinite extent. The Stoic system of philosophy, which appealed to all classes from slaves to aristocrats, was founded by Zeno of Citium (4th–3rd century BC), who lectured in a roofed colonnade called a *stoa*. The Stoics, influenced by the Pythagoreans and atomists, rejected the notion of a bounded universe inherited from mythology and preserved in the Aristotelian system. They argued that space by its nature is necessarily edgeless. At about the same time Epicurus of Samos established the Epicurean system, consisting of an infinite universe of numberless worlds composed of atoms. Lucretius vividly portrayed the Epicurean system in *De rerum natura (The Nature of the Universe)*.

confutation of atheism from the origin and frame of the world,"[9] Bentley used sources that Newton suggested. The figure at the left shows the title page from the published version of the seventh lecture. No one better than the immensely erudite Bentley could have been chosen for the task of confuting atheism by appeal to reason rather than faith.

Armed with Newton's "sublime discoveries," Bentley argued that the laws of nature are insufficient to explain the workings of the universe and must be supplemented by supernatural acts of a divine power. While the lectures were at the printer, Bentley took the precaution of consulting Newton on some technical points so that last-minute changes could be made. Bentley's probing and disturbing inquiries jolted Newton into reformulating his cosmological ideas, and Newton's four letters[10] to Bentley rank among the most important documents in the history of cosmology. The box on page 28 contains excerpts from the letters.

In his first letter, Newton declared his approval of the lectures. He then responded to Bentley's query about the effect of gravity in a material system of finite size. In this famous statement, Newton formed the opinion that a universe composed of self-gravitating matter is necessarily unbounded, for otherwise it lacks an equilibrium state and collapses. Perhaps Newton remembered that Lucretius had said much the same in *De rerum natura* (see the box on page 29). By drawing on the idea of "ceaseless movement," Lucretius realized vaguely what Newton and Bentley did not discuss: the possibility of a finite system of moving stars in a state of stable equilibrium. Rotating sidereal systems, considered by the imaginative Thomas Wright in 1750, received no attention from Bentley and Newton. The two agreed that stars stretch away endlessly (as in the Epicurean system), for if the sidereal system were finite (as in the Stoic system) the stars would fall into the middle. Neither considered how long the collapse would take. Lucretius, more comprehensive in a qualitative fashion, allowed "limitless time."

"You argue," said Newton in his second letter to Bentley, "that every particle of matter in an infinite space has an infinite quantity of matter on all sides & by consequence an infinite attraction every way & therefore must rest *in equilibrio* because all infinities are equal." Newton agreed with Bentley that providence had designed a universe of infinite extent in which uniformly distributed stars stand poised in unstable equilibrium like needles standing on their points (see the figure on page 29), but he explained how finite forces may still remain when infinite gravitational forces are subtracted from one another.

Apparently Bentley's remarks prompted Newton to draft and redraft a long statement[11] for inclusion in a second edition of the *Principia*. In this treatment he attempted to show that astronomical observations supported the idea of a uniform distribution of stars. He assumed that all stars resemble the Sun and arranged their distances according to their apparent magnitudes. Out of this inconclusive investigation came eventually the terse remark,[12] "the fixt Stars, every where promiscuously dispers'd in the heavens, by their contrary attractions destroy their mutual actions."

In the General Scholium of the second edition of the *Principia*, Newton described how providence had set the stars far apart:

> This most beautiful System of the Sun, Planets, and Comets, could only proceed from the counsel and dominion of an intelligent and powerful being. And if the fixed Stars are the centers of other like systems, these being form'd by the like wise counsel, must be all subject to the dominion of One.... And lest the systems of the fixed Stars should, by their gravity, fall on each other mutually, he hath placed those Systems at immense distances from one another.

In Query 28 of Newton's *Opticks* we read:[13] "Whence is it that Nature doth nothing in vain; and whence arises all that Order and Beauty which we see in the World?... what hinders the fix'd Stars from falling upon one another?" Newton believed that not only the formation but also the maintenance of the solar system offered proof of the existence of God. The wide separation of stars gave additional evidence of providential design and maintenance.

Cosmological systems

Aristotelian	Geocentric celestial spheres bounded by a sphere of fixed stars.
Stoic	A finite cosmos of stars in an infinite void.
Epicurean	A uniform material universe of unlimited extent in space—an infinity of worlds strewn throughout an infinite void, with all matter composed of atoms and regulated by natural laws.

Puzzling issues

Why did Newton change from the Stoic to the Epicurean system? He could have achieved an equilibrium state in the Stoic system by assuming that all stars have motion, thus anticipating the idea of a rotating Milky Way later proposed by Wright. Or he could have achieved a static nonequilibrium state by simply assuming that a divine power prevents collapse.

In fact Newton raised this second possibility in his fourth letter (see the box on page 28). William Whiston, who succeeded Newton as Lucasian Professor, took this option in his 1717 book *Astronomical Principles of Religion*, in which he said that God supports the universe and prevents it from collapsing. For "unless a Miraculous Power interposes to hinder it," the stars will "approach nearer and nearer to the common Center of all their Gravity," and "in a sufficient Number of Years, they will actually meet in the same common Center, to the utter Destruction of the whole Universe."

Bentley wanted neither self-sufficient natural laws that explained everything nor *ad hoc* miracles at which atheists could scoff. He wanted natural laws aided by supernatural acts, thus providing proof of God's existence. A Stoic system conserved by mechanical motions or divine will offered no proof.

Newton referred more than once to finite material systems collapsing and also to uniformly distributed matter convening into separate masses. Newtonian scholars, however, have not found among his unpublished papers any indication that he calculated the cosmic time scales of gravitational collapse and gravitational instability. Let us perform these calculations and determine whether or not they could have been done in Newton's day.

A finite sidereal system

Newton said that a sidereal system would collapse into its middle were it of finite size. He ignored the possibility of random or systematic motion, which we nowadays take for granted in systems such as globular clusters or galaxies. Yet the concept of dynamic equilibrium, even though lacking a virial-theorem formulation, was not ahead of Newton's time.

William Thomson (Lord Kelvin) in 1902 made[14] the first gravitational-collapse calculation. He considered a spherical system consisting of a uniform distribution of stars of total mass M and initial radius r_0. He integrated the equation of motion and obtained the infall velocity of the boundary at radius r:

$$\dot{r}^2 = 2GM(1/r - 1/r_0) \qquad (1)$$

A second integration gave the time for the system to collapse to zero radius from an initial radius r_0:

$$t_K = \pi(r_0^3/8GM)^{1/2}$$

With a density of initial value ρ_0 given by $M/(4/3)\pi r_0^3$, the expression for the collapse time becomes

$$t_K = (3\pi/32G\rho_0)^{1/2} \qquad (2)$$

Hence the collapse time is independent of the initial size of the system. When each element of volume $\frac{4}{3}\pi a^3$ contains one star and all stars have the same mass $M_\odot$ as the Sun, the total mass M is $(r/a)^3 M_\odot$ and equation 1 becomes

$$\dot{a}^2 = 2GM_\odot(1/a - 1/a_0)$$

Thus the time for a particle to fall into the Sun from a distance a_0 is also the Kelvin collapse time:

$$t_K = \pi(a_0^3/8GM_\odot)^{1/2} \qquad (3)$$

In Kepler's units of time and distance—years and astronomical units, respectively—the quantity $GM_\odot/(2\pi)^2$ is unity. (An astronomical unit, or AU, is the Sun–Earth distance.) With these units the collapse time becomes

$$t_K = \tfrac{1}{2}(a_0/2)^{3/2}$$

We can think of a body falling toward the Sun as following a highly elliptical orbit with a period P of $2t_K$ and a semimajor axis A of $\tfrac{1}{2}a_0$. Thus we can obtain Kelvin's gravitational-collapse time directly from Kepler's third law, $P^2 = A^3$, by applying the law to an orbit of high ellipticity that extends halfway to the neighboring stars.

Kelvin assumed that the average distance a_0 between stars is 1 parsec (3.26 light-years, or 2×10^5 AU), giving a collapse time of about 20 million years. Various methods yield similar and even larger estimates of the collapse time, which I shall take to be on the order of 100 million years. Angelo Secchi, an Italian pioneer in the classification of stellar spectra in the 19th century, in fact stated that the period of a comet reaching at aphelion midway to the nearest star is 100 million years.

Estimating the infall time from the orbital motion of a particle in the gravitational field of a mass M was well within the scope of the *Principia*. Newton knew from James Gregory's ingenious photometric method[11] of comparing the brightnesses of the outer planets and the brightest stars that the nearby stars are at a distance of roughly 5×10^5 AU. There seems little doubt that Newton could have discovered that the time for collapse depends on the density of the sidereal system and not its size, and that the time is on the order of 100 million years.

Extracts from Newton's letters to Bentley

As to your first Query, it seems to me, that if the matter of our Sun & Planets & ye matter of the Universe was eavenly scattered throughout all the heavens, & every particle had an innate gravity towards all the rest & the whole space throughout wch this matter was scattered was but finite: the matter on ye outside of this space would by its gravity tend toward all ye matter on the inside & by consequence fall down to ye middle of the whole space & there compose one great spherical mass. But if the matter was eavenly diffused through an infinite space, it would never convene into one mass but some of it convene into one mass & some into another so as to make an infinite number of great masses scattered at great distances from one to another throughout all yt infinite space. And thus might ye Sun and Fixt stars be formed supposing the matter were of a lucid nature.

(First letter, 10 December 1692)

And much harder it is to suppose that all ye particles in an infinite space should be so accurately poised one among another as to stand still in a perfect equilibrium. For I reccon this as hard as to make not one needle only but an infinite number of them (so many as there are particles in an infinite space) stand accurately poised upon their points. Yet I grant it possible, at least by a divine power; & if they were once so placed I agree with you that they would continue in that posture without motion for ever, unless put into new motion by the same power. When therefore I said that matter eavenly spread through all spaces would convene by its gravity into one or more great masses, I understand it of matter not resting in an accurate poise. . . . So then gravity may put ye planets into motion but without ye divine power it could never put them into into such a Circulating motion as they have about ye Sun, & therefore for this as well as other reasons I am compelled to ascribe ye frame of this Systeme to an intelligent agent.

(Second letter, 17 January 1693)

The Hypothesis of deriving the frame of the world by mechanical principles from matter eavenly spread through ye heavens being inconsistent with my systeme, I had considered it very little before your letters put me upon it, & therefore trouble you with a line or two more about it if this comes not too late for your use. . . . [Newton continues the argument that planets cannot arrange themselves in circular orbits without the aid of providence.] I would now add that the Hypothesis of matters being at first eavenly spread through the heavens is, in my opinion, inconsistent with ye Hypothesis of innate gravity without a supernatural power to reconcile them, & therefore it infers a Deity.

(Third letter, 11 February 1693)

And tho all ye matter were at first divided into several systems & every system by a divine power constituted like ours: yet would the outward systemes descend towards ye middlemost so yt this frame of things could not always subsist without a divine power to conserve it.

(Fourth letter, 25 February 1693)

FOUR

LETTERS

FROM

SIR ISAAC NEWTON

TO

DOCTOR BENTLEY.

CONTAINING

SOME ARGUMENTS

IN

PROOF of a DEITY.

LONDON:

Printed for R. and J. DODSLEY, *Pall-Mall*,

M DCC LVI.

Pamphlet containing Newton's letters to Richard Bentley from the winter of 1692–93. Bentley preserved the four letters and his executor published them with this title page in 1756.

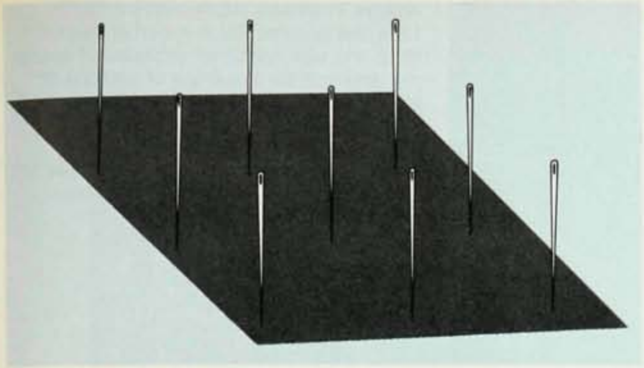
An infinite universe

Edmund Halley said[15] in 1721, in the first of two famous short papers on the infinity of the universe, that a finite system would be surrounded by a void or "infinite inane." He continued:

> But if the whole be Infinite, all the parts of it would be nearly *in equilibrio*, and consequently each fixt Star, being drawn by contrary Powers, would keep its place; or move, till such time, as, from such an *equilibrium*, it found its resting place; on which account, some, perhaps, may think the Infinity of the Sphere of Fixt Stars no very precarious Postulate.

Halley thought that the equilibrium of an infinite and uniform universe is stable. Newton in his letters to Bentley was under no such illusion, and fully realized that the assumed equilibrium of an infinite and uniform universe, like that of needles standing poised on their points, is unstable.

Newton apparently did not attempt to estimate a time scale for this instability. Let us imagine that throughout the heavens uniformly spaced stars stand poised in states of unstable equilibrium. We now nudge one star out of its equilibrium state and let it fall toward a neighboring star. Given two stars of equal mass $M_\odot$ separated by a distance $2a_0$ and initially stationary, how long do they take to fall and approach each other? The answer, which Newton could have calculated easily, even without pen and paper, is half the gravitational-collapse time of equation 3. James Jeans used a less



Needles. Newton and Bentley agreed that stars cannot form a finite and bounded system, for they would all fall into the middle of such a system. They formed the opinion that stars were uniformly distributed throughout space in a state of equilibrium, which they realized was precariously unstable. The stars, said Newton, are like an array of needles all standing upright on their points, ready to fall one way or another.

crude approach and derived[16] for the instability time scale

$$t_J = (4\pi G\rho_0)^{-1/2}$$

a result very similar to equation 2.

Without doubt Newton could have estimated the time scale for the growth of irregularities in his assumed state of equilibrium; had he done so, he would have discovered a value on the order of 100 million years. When he wrote, "thus might ye Sun and Fixt stars be formed," he had the means of estimating from the infall of matter this time scale for the formation of stars.

More than once Newton said the stars do not rush together because of their wide separation. We have seen that the gravitational-collapse time and the instability-growth time increase as the $^3/_2$ power of the average distance between stars. Thus wider separation increases both of these cosmic-dynamical time scales. Newton had within his power the means of demonstrating quantitatively, using little more than Kepler's laws, what he meant by "wide separation."

In 1718 Halley reported[17] that at least three stars had changed their positions in recorded history, and argued that perhaps other stars are not fixed in the heavens. To us it seems obvious that even with modest speeds—1 AU per year, for example—stars traverse interstellar gaps in a time much less than the cosmic times hitherto discussed. Yet in 1721 Halley ignored his discovery when he imagined stars maintaining their fixed equilibrium positions.

Newtonian cosmology

The problem raised by Bentley is easily stated. In a fixed element of solid angle the number of stars increases as the square of the radial distance, whereas each star exerts a pull inversely as the square of its distance. Hence in an infinite universe uniformly populated with stars the integrated gravitational force in any direction becomes infinitely great.

The problem of normalizing infinite gravitational forces submerged in the 18th century amid the hierarchical astronomical schemes of Wright, Immanuel Kant, Johann Lambert and William Herschel, and then resurfaced in the late 19th century when astronomers realized that it still existed in a limitless universe full of galaxies. The gravitational potential and its derivatives are undefined in an unbounded system of uniform density. This is properly known as the Dirichlet problem and improperly as the gravity paradox. We cannot fault Newton for thinking that an unbounded uniform distribution of self-gravitating matter can exist in equilibrium, with gravitational forces at each point pulling in all directions and canceling one another. Kelvin and Jeans thought the same as Newton, and so did everyone else until after the discovery of general relativity. Hugo Seeliger, director of the Munich Observatory, introduced in 1895 a Yukawa-type gravity potential having a cutoff at large distances, and Carl Charlier, director of the Lund Observatory, reinstated in 1908 an infinite hierarchical astronomical system in which the gravitational potential remains finite and single valued.

Albert Einstein pointed out[18] that one can treat only finite systems and certain infinite nonuniform systems with Newtonian theory. The gravitational potential in any case may not be very great because otherwise the velocities according to the virial theorem would exceed that of light. The Dirichlet problem in the case of gravity must be solved in the context of general relativity theory. The deceptively simple gravitational potential turns out to be a ten-component metric tensor descriptive of curved dynamic space–time.

A static equilibrium state of the kind imagined by Newton does not exist according to general relativity theory unless we adopt a cosmological constant having the Einstein value, and then, as Arthur Eddington showed, the static Einstein universe is unstable.

With the scaling factor R defined as the ratio r/r_0, equation 1 for the rate of infall transforms to

$$\dot{R}^2 = 8\pi G\rho R^2/3 - C$$

Here C is a constant. Alexander Friedmann and Georges Lemaître showed that general relativity gives this result for an unbounded system. Then Edward Milne and William McCrea derived[19] the same equation by Newtonian methods and established what has become known as Newtonian cosmology. We must note that the Newtonian derivation came after general relativity had demonstrated the validity of this equation for an unbounded system. Why Newtonian theory gives an exact result in this instance is not entirely clear.[20] Remarks to the effect that Newton could have discovered Newtonian cosmology must be treated with utmost reservation.

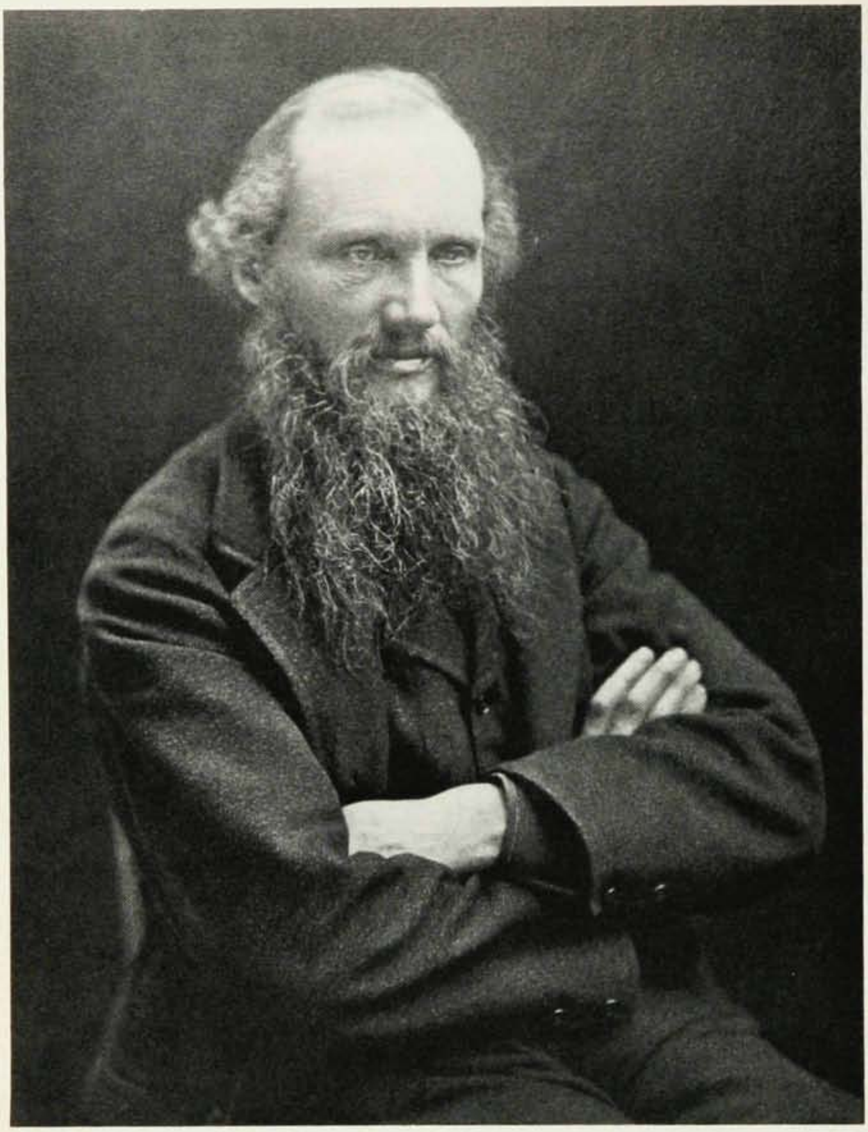
Newton's motives

Newton could have made some sort of calculation of the collapse time of finite material systems and the growth

Excerpt from Lucretius

In book I of The Nature of The Universe, *Lucretius argues that space is unbounded and infinite, and says:*

Moreover, if all the space in the whole universe were shut in on all sides, and were created with borders determined, and had been bounded, then the store of matter would have flowed together with solid weight from all sides to the bottom, nor could anything be carried on beneath the canopy of the sky, nor would there be sky at all, nor the light of the sun, since in truth all matter would lie idle piled together by sinking down from limitless time. But as it is, no rest, we may be sure, has been granted to the bodies of the first-beginnings because there is no bottom at all whither they may, as it were, flow together and make their resting place. All things are forever carried on in ceaseless movement from all sides, and bodies of matter are stirred up and supplied from beneath out of limitless space.



William Thomson (1824–1907) in 1877. Thomson became Baron Kelvin of Largs in 1892. He was appointed professor of natural philosophy at the University of Glasgow at age 22. He held this position until his retirement at age 75 in 1899 and then enrolled as a research student. Kelvin's little-known work on gravitational collapse is reproduced as Appendix D in the revised *Baltimore Lectures* (Cambridge U.P., Cambridge, England, 1904).

time of irregularities in an infinite uniform medium. Furthermore, in terms of these time scales he could have defined more clearly what he meant by wide separation.

Perhaps Newton did not think of calculating the cosmic time scales. I find this an improbable explanation for a person whose mind was never at rest. Newton was confronted with a need for these time scales and an obvious need to define "wide separation." In the *Principia* Newton estimated that a globe of red-hot iron equal in size to the Earth would take more than 50 000 years to cool. He was not unmindful of the need to calculate cosmic time scales.

Perhaps Newton did not want to make the calculations. He was deeply interested in the study of Mosaic chronology[21] with its time scale of several thousand years since the biblical flood, and was the author of *The Chronology of Ancient Kingdoms Amended*, published in 1728. A person might feel free to talk vaguely and suggestively of other worlds formed before the creation of the Earth, as Newton[22] and others[23] did, but still fear to stir up ecclesiastical hostility by talking openly of a material universe created more than 100 million years ago. A reluctance to publicize such cosmic time scales could have come, however, only from an appreciation of their vastness, implying that Newton had in fact done the calculations. I am inclined to think that Newton performed the calculations but deemed it wise to remain silent.

Occasional statements hint at this possibility. At the end of Newton's first letter to Bentley he writes, "There is yet another argument for a Deity wch I take to be a very strong one, but till ye principles on wch tis grounded be better received I think it more advisable to let it sleep." There seems no doubt that Newton was greatly influenced by the Stoic and Epicurean cosmological systems of scattered worlds forming and reforming. In his fourth letter to Bentley he remarks, "For it may be said that there might be other systemes of worlds before the present ones & others before those & so on to all past eternity & by consequence yt gravity may be coeternal to matter & have ye same effect from all eternity as at present." Also, Newton firmly believed that providence played an essential part in the formation of each system, and in the same letter writes, "ye growth of new systems out of old ones without ye mediation of a divine power seems to me apparently absurd." In the 31st Query of the *Opticks*, he said that the solar system would continue for "many Ages," but irregularities of motion "will be apt to increase till this System wants a Reformation."

The cosmic time scales might thus have formed for Newton a rhythmic measure in which a divine power participated not just once, as in the Mosaic account, but repetitively throughout all space and time. The more numerous the systems, the more abundant the proof that a divine power participated in the running of the universe. A picture of worlds forming and reforming over vast spans of space and time, depicting innumerable acts of providential guidance, might have been Newton's hidden proof.

If this is true, he was well advised to let the idea sleep, for it was tainted with atheism and unacceptable even to the latitudinarian Anglican churchmen of his day. It is not implausible that he made Newtonian science more secure by delaying Newtonian cosmology.

* * *

I am indebted to many colleagues, in particular to Lawrence Owens and David Van Blerkom, for helpful comments.

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THE

CHRONOLOGY

OF

ANCIENT KINGDOMS

AMENDED.

To which is Prefix'd,

A SHORT CHRONICLE *from the Firſt Memory of Things in* Europe, *to the Conqueſt of* Perſia *by* Alexander *the Great.*

By Sir *ISAAC NEWTON.*

LONDON:

Printed for J. TONSON in the *Strand*, and J. OSBORN and T. LONGMAN in *Pater-noſter Row.*

MDCCXXVIII.

Publication in which Newton attempted to reconcile Genesis and the history of nations. In this book, summarizing the work of years of antiquarian study, Newton brought the history of the Babylonians, Egyptians, Greeks, Assyrians, Medes and Persians into conformity with scriptural records and squeezed the chronologies and genealogies of these nations into the brief time span of the Book of Genesis. "The Egyptians anciently boasted of a very great and lasting Empire," wrote Newton, "and out of vanity had made this monarchy some thousands of years older than the world." He concluded the *Chronology*, whose title page is reproduced here, with the words, "And while all these nations have magnified their Antiquities so exceedingly, we need not wonder that the Greeks and Latines have made their first Kings a little older than the truth." According to Genesis the Earth was created some 6000 years ago. This left intellectuals of Newton's day free to argue that the stellar universe was very much older.

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