
PYTHAGORAS**Presidential Address, 1979****J. L. WHITE**

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The subject of the Presidential Address is by tradition kept secret until the moment of its delivery. Over the 90 years since the foundation of the Association many of its Presidents have been men of distinction in various fields of astronomy and their addresses, subsequently published in our journal, represent contributions of considerable importance and lasting value to the literature of astronomy.

Often one has been able to anticipate the subject of the address because of the President's known interests and special knowledge. In particular one looks to a Director of one of the Sections for a dissertation on matters of direct concern to him and his members. Year by year it becomes increasingly difficult for the President to find a topic of sufficient interest for the occasion which has not already been very ably and adequately dealt with in the past. There is, therefore, a tendency to concentrate on the more recent developments in various areas of astronomical work which has been the subject of previous addresses, sometimes more than once.

I am not known to have any special interest in astronomy, any one overriding preoccupation within the scope of the Association's many activities, and I certainly have not achieved even the mildest distinction for actual contribution to any particular field. I have written no paper for the *Journal* for well over 20 years. Yet the British Astronomical Association has well over 4000 members, many of whom are highly qualified and professionally concerned in various branches of astronomy and allied disciplines. Many have specialized knowledge, practical skills and ingenuity which they bring to bear upon the all-important matter of astronomical observation and which they share with their fellow members. The prime object of the BAA has always been the encouragement of amateur astronomers with small telescopes to undertake systematic observational work under the guidance of the Directors of the Sections, and many hundreds of members do just that with varying degrees of assiduity.

The belief for so long cherished by some that through membership of the BAA they were taking part in work of scientific value is more than ever difficult to sustain in the context of present-day professional astronomy, and it is certainly not held by the hundreds of members who derive great personal satisfaction from their own direct experience of the

night skies in a wide diversity of astronomical occupations. There are others who are attracted in an uncommitted manner to our subject without knowing why, just as they are to other branches of science, and on occasion they sit here in this hall listening with complete fascination, and total incomprehension, to some of the more highly specialized papers presented at our meetings, just as they watch with thousands of other viewers some of the epic science television programmes. It is those of our members who do nothing in the Association, but who gaze at the celestial bodies and *wonder*, as man has done since time immemorial, who are my special concern this evening—those who seek more than scientific explanation of phenomena solely in terms of scientific principles already educed in other fields.

They are in the position of the ancient astronomers who could see no more than was visible to their own unaided eyes and who therefore *thought* all the more about what they did see. When for centuries the whole of practical astronomy could be reduced to a few pages it was only thought and speculative ideas about what could not be seen which maintained its pre-eminence as the noblest of the sciences. The ultimate aim of the philosopher-astronomers was to formulate a system of the universe which incorporated, in addition to its physical description, what was deemed to be a *sine qua non* of any acceptable system, namely an understanding of a more than transient relationship of man to the whole of the starry heavens.

I shall later draw parallels between some of the ideas of antiquity and those proposed by modern astronomers, especially by the cosmologists, and between the contexts within which these ideas were and are formed. I have chosen to develop my theme under the title of my address, "Pythagoras".

The date of the birth of Pythagoras on the island of Samos, like almost everything else about him, is given in wide variation by a number of scholars, ranging from 600 to 570 BC, and that of his death at Metapontum from 510 to 497 BC. From these I have selected the years 591 and 504 BC. In spite of the legendary character of so much attributed to him, his name has been universally known and venerated at all places of learning for 2500 years, and it is immortalized in the famous theorem of right-angled triangles which has constant application to every branch of practical science and not least in astronomical computations. To him also is attributed the foundation of the musical scale through the discovery that vibrating strings, the lengths of which are in the ratios of 1 to 2, 2 to 3 and 3 to 4, produce the notes of the octave, the fifth and the fourth. In modern musical theory the term Pythagorean is used in the comparison of the intonation of stringed instruments with that of tempered keyboard instruments. By extension Pythagoras sought to interpret all the phenomena

of Nature in terms of numbers and ratios of numbers, hence Pythagorean philosophy is concerned with relationships and, above all, with the relationship between man and every other thing and creature in the universe.

An example of the association of mathematical ratios with human relationships and reciprocity in ethical obligations is found in the Pythagorean symbol of the pentagram which abounds in demonstrations of the Golden Section, the unique proportion which yields the numerical value $(1 + \sqrt{5})/2 = 1.61803$, known as ϕ (Phi). The ratio states that the lesser is to the greater as the greater is to the whole, a reminder to the Pythagoreans that the less gifted among them contributed to the well-being of the more so as did those in turn contribute to the well-being of the whole community. Further, the Pythagorean community bore a relationship to the whole of mankind as did the human race to the universe.

Pythagoras was renowned as mathematician, physicist, astronomer, cosmologist, musician, healer and philosopher, but above all he was a mystic and religious leader, a 'trainer of souls', and the founder of a famous school at Croton in Southern Italy in 529 BC. All knowledge of his teaching rests upon the writings and commentaries of others, often referred to as the fragments, such as those of Hicetas, Philolaus, Archytas, Plato and Aristostle. Even if there is wide disagreement regarding what has been rightly ascribed to Pythagoras, there is no doubt that he was the main source of inspiration of many thinkers of his own and subsequent eras. It became the custom among Pythagoreans to attribute their own ideas to the Master, and both during the 200 years that scattered remnants of the Brotherhood exiled from Croton survived and the succeeding centuries there have been some individuals whose basic attitudes to science and religion can be loosely described as Pythagorean and others who professed formal commitment to the ideals of the Master; the man, in the words of Arthur Koestler, whose influence on the ideas, and thereby on the destiny, of the human race was probably greater than that of any single man before or after him. A somewhat more restricted though still tremendous tribute is paid by the science historian Benjamin Farrington: "He is the founder of European culture in the Western Mediterranean sphere".

From the vast amount of literature pertaining to Pythagoras and the Pythagoreans it is difficult to compose a reasonably complete, self-consistent synthesis of what one would like to call Pythagoreanism. In the comparatively short bibliography which I provide there are several impressive scholarly works which very vividly represent so much of what is the chief concern of most writers of the last few decades—the evaluation of all the relevant literature of the past 25 centuries, sources which, as

one of the authors so cogently states, have been used with infinite critical ingenuity. Just one brief example will suffice, one involving a topic familiar to even our most junior members. It is taken from *Lore and Science in Ancient Pythagoreanism* by Walter Burkert:

"Favorinus records the same rivalry for the discovery that the evening and morning stars are the same. This planet—did he already call it after Aphrodite?—had a special meaning for Parmenides, and he has it circling in the pure *aither* above the sun. This double-track tradition about Parmenides and Pythagoras can be understood in the light of a statement of Diogenes Laertius about Parmenides: 'He seems to have been the first to discover that the evening star and the morning star are the same, as Favorinus says...but some attribute this to Pythagoras; but Callimachus denies that he is the author of the poem.' Callimachus denied Pythagoras' authorship of a certain poem which dealt, among other things, with the planet Venus. Actually, Heraclides Lembus, in his list of the writings of Pythagoras, gives first place to a work *peri tou olou en epesin*. It is likely that this poem dealt not only with the heavenly bodies but with the spherical shape of the earth and its division into zones, borrowing from Parmenides, and certainly also from Empedocles. No one will claim that there was a didactic poem actually written by Pythagoras. Callimachus was right in rejecting the poem, and in doing so joins Theophrastus and Eudemos as a third witness against the 'Pythagoras' version of this tradition."

I am greatly indebted to Dr Gerard van der Horst of Leiden University who has very kindly given me an enormous amount of material from the Astronomy Section of the unique Pythagorean Library of Stichting Pythagoras at The Hague. Among a rich assortment of articles, reprints and book extracts I have found a paper by Professor S. K. Heninger, Jr, of the University of British Columbia delivered in Brussels in 1963 at a colloquy on Renaissance studies, a paper which so admirably presents my own view of Pythagoras as the originator in ancient times of an all-embracing cosmology and the continuing inspiration of those geniuses who in later centuries modified his system in the light of their own insight and investigation of the celestial phenomena around them. In much of what follows I shall lean heavily, and gratefully, on Professor Heninger.

In seeking to understand the cosmology of Pythagoras it is of primary importance to remember that for him astronomy was a means to an end and not, as now for modern students and practitioners of the science, an end in itself. That end was the assimilation of the individual soul into the world-soul and ultimately into unity with God, the creative mind of the whole universe. This was to be achieved by the gradual acquisition of total knowledge of the natural world through systematic observation of all that was happening in nature. The final aim of the disciples of the

Master was apotheosis, "the freeing of the soul from its prison house, the body".

Pythagoras was a scientist, perhaps the first in the true sense of the word, and he established a mathematical tradition of number which bore a direct relation to the physical world through motion, weight and measurement. He fully justified the apparently paradoxical claim made by a modern writer that the mystic is the most practical of people, and although the feet of his followers were firmly planted on the Earth their faces were set in the direction of the world beyond.

Pythagoras was an experimental investigator of particular cases of what he had noticed in general, as in the case of the musical ratios, which according to an unlikely legend were suggested to him by the differing sounds of hammers in a blacksmith's workshop. As a result of this visit he is said to have discovered that strings under tension of weights in the ratios of whole numbers produce notes in harmonious ratio. From this he said that all things have innate numerical relationships, like the musical scale, and hence—what is our immediate concern—that the universe itself has order, harmoniously arranged by a creator.

The word *cosmos*, meaning order, beauty, was first used by Pythagoras to designate the universe, and the task of the astronomer was to find a single, whole system, an interrelationship, a unified whole. An isolated line of astronomical research, such as might then with limited means have been possible, would have no justification for a Pythagorean; he was completely absorbed in the idea of oneness, in the paradox of the unity of multiplicity.

The cosmology of Pythagoras was geocentric with a spherical Earth in the middle which rotated daily from east to west. Between the sphere of the fixed stars and the Earth, the Moon, Sun, Mercury, Venus, Mars, Jupiter and Saturn revolved in perfectly circular orbits with absolutely regular and uniform motion. This system was later taken over by Plato and introduced into his *Republic* and *Timaeus*. In turn the cosmology of Plato passed to Aristotle and eventually to Ptolemy.

Around 500 AD the Pythagorean sciences of arithmetic, geometry, music and astronomy, largely due to the influence of Boethius, became the basis of formal education and remained so for the succeeding centuries into the period of the Renaissance. The blessing of the Fathers of the Church having been bestowed on the harmonious geocentric world system, it seems that Pythagorean cosmology was as readily accepted by scientific thinkers as was the biblical story of creation. It is imperative, however, to emphasize that the Church did not acquiesce in any Pythagorean teachings other than in science, as became all too evident at the trial of Giordano Bruno at the end of the sixteenth century.

The world system of Pythagoras was well known through various editions of Aristotle's *De caelo*, and in that of Johann Eck in 1519 a diagram depicts at the centre the four elements. The Earth is surrounded successively by spheres of Water, Air, and Fire, followed by the orbits of the Moon, revolving in 28 days, Mercury, Venus and the Sun, each in one year, Mars in two, Jupiter in 12, and Saturn in 30. Beyond that is the sphere of the fixed stars, revolving in 1000 years, and then the crystal sphere bearing the 12 signs of the Zodiac with a period of 49 000 years. Last of all is the *primum mobile* turning in the opposite direction once in 24 hours. This universe of ten spheres is indubitably Pythagorean, for it is labelled the eight-stringed Lyre of Pythagoras, the Earth giving the lowest note. The idea of the Music of the Spheres is made apparent by the allocation of the note of each string to each of the eight planets, that of the eighth, an octave higher than the lowest, being assigned to Saturn. The scheme is offered as a scientific demonstration with metaphysical implications.

Pythagoras is credited with being the first to assert that the Earth is spherical. Although this might have been inferred from the shape of the Sun and the Moon, visible to all, and, perhaps also, from the shadow of the Earth on the face of the Moon at times of lunar eclipses, mere observation alone would not satisfy the philosopher. For him the sphere was the perfect form, with all points on its surface equidistant from its centre. No one point marks the beginning or the end. It has a unique, unmistakable identity in an infinity of possibilities, appropriate to the cosmos, and has the greatest volume for a given surface area. It thus represents a maximum limit in the relationship between plane surfaces and solids. The circle was likewise regarded as the perfect figure, with all points on the circumference equidistant from the centre, encompassing the greatest area from a given length. It possesses the finitude of a closed figure, and yet, having neither beginning nor end, it symbolizes eternity.

The Master's preoccupation with perfection and harmony extended to the Pythagorean doctrines concerning the nature of the Creator. The intricacies of the cosmic system revealed an intelligent, orderly mathematical mind, while its graciousness pointed to a generous patron who could be conceived of as a divine geometrician bringing into being a cosmological whole corporeally manifesting the power of a benevolent mind.

For 2000 years all scholarly discussion of cosmology commenced with the geocentric system of Pythagoras, but its modification by later Pythagoreans was also well known. Of paramount importance, though not sufficiently widely recognized as such, was the theory that the Earth was not stationary but revolved around a central fire, thus accounting

for the apparent daily rotation of the heavens. It is described by Aristotle in *De caelo*:

"Most people say the Earth lies at the centre of the universe. But the Italian philosophers known as Pythagoreans take the contrary view. At the centre, they say, is fire, and the Earth is one of the stars, creating night and day by its circular motion about the centre. . . . They hold that the most important part of the world, which is the centre, should be most strictly guarded, and name it, or rather the fire which occupies that place, the Guard-house of Zeus."

Plutarch, a contemporary of Plato, refers to the theory thus:

"Philolaus the Pythagorean saith that the fire is the middle of the universe, as being the hearth of the world. Some hold the Earth to be unmoveable and quiet, but Philolaus saith that it moveth about the fire in the oblique circle, according as the Sun and Moon do."

Diogenes Laertius (he, Iamblichus and Porphyry wrote the three widest known biographies of Pythagoras about 700 years after his death) states:

"He was the first to declare that the Earth moves in a circle."

Although Hicetas of Syracuse and Aristarchus of Samos (quoted by Archimedes and Plutarch) also held that the Earth moved, they were both regarded as Pythagoreans. It must be emphasized, however, that the system of Philolaus, while being an alternative to that of Pythagoras, was not heliocentric. The central fire was said by some to be invisible because that part of the Earth on which we live was always turned away from it, but others have maintained that it never was to be taken as a literal fire. They believed the fire at the centre to symbolize the concept of the Hearth of the World, the source of all power. Fire, being considered the noblest of the four elements, was naturally given the most important place in the scheme, from where its beneficent, generative and restorative powers could reach out to the furthestmost sphere. The vital, all-important contribution of Philolaus was to displace the Earth from its central position and set it moving among the planets.

When Copernicus wished to propose a simplification of the Ptolemaic system he quoted Philolaus as his authority for supposing the Earth to move. He was strongly attracted by the fundamental Pythagorean belief that all things have mathematical relationships which can be expressed as ratios between whole numbers, and that the whole of Nature can be reduced to a simple system of harmonic proportions.

In the preface to the *De revolutionibus* Copernicus cites other Pythagoreans who favoured a heliocentric system, seemingly wishing, so some of his detractors have said, to forestall and indemnify himself against any possible attacks from the ecclesiastical establishment of his time for his own departure from officially approved geocentrism. The

more charitably minded assume that he quoted the Ancients in support of rather than in excuse of his own work. He refers to Hicetas writing of the daily rotation of the Earth on its axis and to Heraclides of Pontus and Ecphantus of Syracuse as follows:

"Heraclides of Pontus and Ecphantus the Pythagorean assign a motion to the Earth, not progressive, but after the manner of a wheel being carried on its own axis. Thus the Earth, they say, turns itself upon its own centre from west to east."

He then goes on to add:

"When from this, therefore, I had conceived its possibility, I myself also began to meditate upon the mobility of the Earth."

Expressing doubt as to the daily rotation of the outermost sphere, that of the fixed stars, Copernicus says the Pythagoreans shared his view that motion should be assigned to the things contained rather than to the container; they are his champions in challenging Ptolemy's edifice which had lasted 1400 years.

Copernicus was not a revolutionary; he was the formulator of a system combining three separate yet, nevertheless, all Pythagorean ideas. First, and indispensably, a mathematically *simple* universe, a *cosmos* from Pythagoras himself; secondly, a theory that the Earth moves in an annual orbit, from Philolaus; thirdly, a theory that the Earth makes a daily rotation on its own axis, from Heraclides and Ecphantus. All of these, quite clearly identified as Pythagorean, he found in Plutarch's *De placitis philosophorum*.

In the early part of the seventeenth century there were some scholars who thought of Copernicus not as an innovator but as the restorer of an hypothesis which had been temporarily eclipsed by the Ptolemaic system. In spite of his own perhaps over-cautious and politically motivated self-effacement, however, his contribution to the history of astronomy was much more than a mere revival of the venerable doctrines of the Pythagoreans.

An example of such scholars is Diego de Zuniga, who wrote of "the opinions of the Pythagoreans, who hold the Earth to be moved by its own nature" and that "in our age Copernicus doth demonstrate the courses of the planets to be according to this opinion". A further example is part of an open letter by Paolo Antonio Foscarini, the Carmelite, reading "I resolved with myself to undertake the Defence of the lately Revived Opinion, *Of the Mobility of the Earth, and Stability of the Sun*, in times past found out first by Pythagoras, and at last reduced into Practice by Copernicus".

Both these writers were involved with Galileo in the censure of the Holy Congregation in 1616. Pythagoras came to be thought of by many

as the scientist who had placed the Sun at the centre of the universe, and Copernicus was regarded as his advocate.

Copernicanism had its widest acceptance in England, where in 1576 Thomas Digges published a little work under the title: *A Perfit Description of the Caelestiall Orbes according to the most ancienne doctrine of the Pythagoreans, lately revived by Copernicus and by all Geometricall Demonstrations approved*. Digges was a pupil of the famous Dr John Dee, and it was he who first postulated an infinite universe, realizing from the scale of his heliocentric solar system that the stars must be at an immeasurably greater distance from the Sun than the planets. By 1605 his treatise had been reprinted six times, proclaiming to the world again and again his belief in the "most ancienne doctrine of the Pythagoreans", and heralding a later general acceptance of an *infinite*, though still heliocentric universe.

The very extensive and elaborate celebrations in 1971 of the quatercentenary of the birth of Johannes Kepler included programmes of lectures and symposia at universities and astronomical societies throughout the world, the republication of much of his original writings, many authoritative articles and books, and tours to places where he had lived and worked. This wonderful tribute from the modern world of science and learning confirmed the pre-eminence of Kepler among the greatest astronomers of all time. What is not so generally known, and certainly not so well appreciated, is that throughout his troubled life until his death in 1630 his inspiration and most magnificent ideas came directly from Pythagorean cosmology.

Kepler was completely absorbed with the Pythagorean notion of God as a geometer, the Supreme Architect of a world created according to a mathematical plan. The basis of this plan rests upon the five Pythagorean solids, the five regular polyhedra more popularly associated with Plato. He was in no doubt as to the correctness of a Sun-centred planetary system, and in 1596 as a young man, 25 years of age, he announced his scheme to the world through his book *Mysterium cosmographicum*. Its relevance to the theme of this address, and indeed its justification of so complete an involvement of Kepler in that theme, is given on the inside title page where he recognizes Pythagoras as the Master in Cosmology and Copernicus as the reviver of Pythagorean theories. At all times Kepler showed respect for Copernicus, and in a most generous tribute of a great man to one of lesser attainments he writes:

"To me suffices the fame of being, thanks to my discovery, a guard at the door of the temple in which Copernicus serves God at the altar."

I have a model of the Pythagorean solids and planetary orbits beautifully made from heavy gauge iron wire by Mr C. H. Myers, a member who several years ago attended my astronomy classes at Brighton. They are

provided with handles for easy presentation, and one can see that the largest hoop, corresponding to the orbit of Saturn, can be twirled to resemble a sphere and just accommodates the cube of six squares, within which can be placed the orbit of Jupiter. That circle accommodates the tetrahedron of four equilateral triangles, which in turn receives the orbit of Mars. The dodecahedron of 12 pentagons fits inside this and it is just large enough to take the sphere of the Earth, which accommodates the icosahedron of 20 equilateral triangles. This determines the radius of the sphere of Venus, which takes the octahedron of eight equilateral triangles. Finally, the orbit of Mercury fits suitably within this, the last of the five regular solids. All the hoops are now gathered together so that one may see that the concentric circles are a fair representation of the orbits of the six planets known up to the time of Kepler's death.

Kepler thought that through this remarkable assemblage he had discovered the hitherto secret plan of the solar system, and that it explained why there were only six planets and why their relative distances from the Sun were those determined by Copernicus. He did, however, realize that the solids and the spheres did not fit exactly, and being a scientist he tried to find observational evidence to reconcile the discrepancies, and although subsequent adjustment brought partial success he never succeeded in obtaining complete agreement. Nevertheless, as a result of this seemingly (to purely scientific minds) futile and absurd pursuit he undertook an enormous amount of mathematical investigation of the planetary orbits which eventually led to his discovery of the laws of planetary motion.

A very understandable opinion given by a modern scholarly admirer of Kepler, one which is no doubt shared by many others, is that it is unfortunate that Uranus at least was not discovered 200 years earlier, and that not even one solid failed to fit at all, as "otherwise Kepler would not have been drawn into this fantastic error" but might have looked beyond a closed world-system to an infinite universe, as Digges had done. But, of course, he might well have done nothing of the sort, for it was what is called his obsession with the solids which was the source of his prodigious driving power. Without it he might well not have bothered about the planetary laws at all, for in one of his hundreds of letters he begs God to deliver him from the bondage of astronomy and its demands, and in another he writes: "Do not force me onto the treadmill of mathematical calculations—leave me time for philosophical speculations, which are my only delight".

For the Pythagoreans and for Kepler the universe of heavenly bodies was finite. Nature was based on number, objects being described by varying numbers of points arranged in geometrical forms. One signified the monad, the single point, unity, indivisibility, and hence the perfection

of God. The Pythagoreans set themselves to discover the relationship between *unity* and *multiplicity*, between infinity and space composed of finite particles, and between eternity and time composed of separate moments.

The digit 1 is the number of *unity*, represented by a single *point*; 2 is the number of the *line*, the extension of the point in one dimension. A third point above the points at each end of the line is joined to both ends, forming an equilateral triangle, an *area* in two dimensions, generating the number 3. A fourth point extending upwards from the middle of the triangle and joined to its three points produces the solid tetrahedron and generates 4, the number of *volume* in three dimensions.

Ten points arranged in successive rows of one, two, three and four produce the equilateral triangle of the Tetractys, the sacred symbol of the Pythagoreans, "source of all nature (physics)", by which the most solemn oaths were sworn. It is clearly seen that $1+2+3+4 = 10$, the decad of fundamental importance in Pythagoreanism. It exhibits the musical ratios of 1:2, the octave, 2:3, the fifth, and 3:4, the fourth, and much else of esoteric Pythagorean significance.

Having learned that out of an infinite number of possible solids there were only five regular ones, a finite number, the Pythagoreans believed they had identified a relationship between the *infinite* and the *finite*. From this they concluded that the orderly, finite cosmos proceeded from the infinity of randomly spaced primordial particles.

Kepler's conviction that the Pythagorean polyhedra held the key to the plan of the universe was no mere passing fancy of youth, but a continuing and enduring passion, as is clearly demonstrated by the appearance in 1619 of his book *Harmonice mundi* 23 years after the publication of *Mysterium Cosmographicum*. In this he gives the Pythagorean association of the "elements" with the polyhedra. The firm, stable cube symbolizes *Earth*. The octahedron can be spun between the finger and thumb, holding its opposite corners, suggesting rapid mobility, hence *Air*. The sharp, thin flame-like tetrahedron signifies *Fire*. The icosahedron with 20 faces resembles a round drop of *Water*. The dodecahedron is assigned to the fifth element, the quintessence of the universe, the aether, being capacious and celestial in form, having 12 faces, one for each sign of the Zodiac.

The familiar names of the four elements were given by Empedocles, who derived them from those originally designated by Pythagoras himself. For him they were the Sun, the Earth, the Wind and the Rain, whereby all life had its being and sustenance. They were invoked in the grace which the Pythagoreans chanted at meals.

The Pythagoreans were by tradition supposed to keep their inner knowledge secret, and Kepler thought that behind the assignment of the

"Jeans accounts for the observed facts at the expense of introducing hypotheses which are extrapolations of the laws of physics, and to be perfectly frank I don't suppose anyone really believes his story."

Sir James Jeans replies:

"As Professor Milne has been so frank in the expression of his views as to my theory, I feel that I can be equally frank about his work. In brief, I do not think it gets anywhere; I think he has found a mare's nest. It seems to me he is not studying stars at all, but only solutions of a differential equation in a very special, very misleading and physically impossible case."

Sir Arthur Stanley Eddington joins in the discussion, saying at one point:

"Milne, I understand, objects to my calling his paper a hypothesis, and claims that it is an inevitable conclusion. Like most inevitable conclusions, it is only inevitable if you grant the premises, and I have been combating these premises for the last fourteen years."

A very candid and perhaps by no means unshared view among some astrophysicists is offered by Professor Hardy:

"I have been interested in the discussion, but as a mathematician I don't care two straws what the stars are really like."

There has been criticism in much wider terms of the work of modern cosmologists facing the same problems as did the Pythagoreans, but confronted with a vastly greater field of observational activity. What is entirely different, of course, is the motivation for their work. In his Presidential Address to the Royal Astronomical Society entitled *Science and Modern Cosmology*, published in *Monthly Notices*, 113 (1953), Professor Herbert Dingle said of the Steady State theory of the universe:

"I cannot give a true account of this new cosmology without appearing to ridicule it. I am doing nothing of the kind. I am simply divesting it of the symbolic clothing in which it has been wrapped for formal presentation, and the substance beneath appears ridiculous because it is ridiculous. One naturally inclines to think that the idea of the continuous creation of matter has somehow emerged from mathematical discussion based on scientific observation. It is nothing of the kind. It has no other basis than the fancy of a few mathematicians who think how nice it would be if the world were made that way. The mathematics *follows* the fancy, not precedes it; the fancy is credited because it gives scope for mathematical exercise, not because there is any reason to believe it is true."

In 1960 Professor Herman Bondi, in a broadcast discussion of Rival Theories of Cosmology, must have considerably disconcerted those who had hitherto looked to science as the unassailable champion in their rejection of all beliefs about the origin and purpose of the universe which were not based upon what they called scientific proof. He said:

"A scientific theory is one that it is in principle possible to disprove by empirical means. It is this supremacy of empirical disproof that distinguishes science from other human activities."

About two years ago Professor Martin Rees in *Nature* introduced a highly mathematical paper by himself and two colleagues with the opening paragraph:

"There could be one hundred thousand million million million 'mini-holes' within our Galaxy; on the other hand there may not be any at all."

Such brilliant exercises are, of course, not to be disparaged: they are simply not to be mistaken for descriptions of the real world, if indeed that 'real' world can ever be known, by those not involved in such work. They certainly are not intended as such by the authors, as is indicated by the preliminary caveat.

There is a perennial case of phenomena saving which has persisted throughout the centuries right into the present time, and that is the attempt to reconcile the biblical story of the Star of Bethlehem with plausible astronomical explanations, the most recent impressively detailed papers being those of Dr D. W. Hughes in *Nature* and of Mr John Farquharson in our own *Journal*. As they stand they represent lengthy, painstaking research in the history and geography of the New Testament, and also into a wide range of ephemeral astronomical phenomena, and are thus comparable with the scholarly works on the authenticity of Pythagorean writings to which I have already alluded. There are among us some at least who like to think that the motivation behind these and similar investigations is something more than scholarship for scholarship's sake, that what is accomplished is much more than an academic exercise.

On June 30 this year about 200 people attended the opening of the Croydon Astronomical Society's observatory at Kenley. This excellent building with its fine telescope was the culmination of the efforts of some of the most enterprising of the members in overcoming unexpected difficulties and disappointments. It is not without relevance to the theme of this address that the Bishop of Croydon, rather than someone in the astronomical world, or indeed any lay person, however eminent, had been invited to perform the ceremony of dedication to the memory of Mr Fred Best. The need for some recognition of man's latent feeling of relationship with worlds beyond his own, however slight, or even disavowed by some, was thus in these particular circumstances most suitably acknowledged.

It was Pythagoras more than anyone before or since who produced a cosmology which most deeply and satisfyingly incorporates man's spiritual aspirations with his understanding of the physical universe. Now, perhaps more than ever before, cosmology is an exercise of the mind on the ever-expanding vistas of astronomical knowledge, an opinion which is shared

by many who have no direct acquaintance with the subject and was stated so succinctly by the Unitarian minister Benjamin Downing in his Essex Lecture a few years ago:

"The universe has largely to be regarded as our own mental construction. Cosmologically, we live now in a universe of the mind, pulsating or otherwise, or we do not live at all."

Something of this belief was suggested by Professor Herbert Dingle, not at a meeting of the Royal Astronomical Society but in the Meeting House of the Religious Society of Friends at Purley:

"The universe is probably bound together into an ordered whole by the stuff of which men's minds are made."

The ultimate supremacy of mind over the physical environment is wonderfully stated by Gilbert Murray, who brought so much of ancient Greek thought to modern English readers:

"The things of the spirit depend upon will, on effort, on aspiration, on the quality, of the individual soul; and not on discoveries and material advances which can be accumulated and added up. Material things are superseded, but spiritual things are not."

Whether one probes for an evermore comprehensive catalogue of the universe purely in descriptive terms of the vastly complex interaction of physical processes in the light of constantly revised concepts of the nature of matter and the extreme states it assumes in the enormously varying conditions of explorable space, or whether, like Giordano Bruno, one seeks the universe within oneself, there is always for everyone the starlit sky which originally prompted the interest. I am perfectly sure that Pythagoras would not have been confounded by any of the marvellous developments in modern astronomy; he would have integrated them into his own cosmology just as Johannes Kepler integrated his own discoveries into Pythagorean cosmology.

I would remind you that those whom I am especially addressing this evening are they who gaze with wonder into the night sky, a wonder which is not diminished by the progress of astronomy but which kindles the desire for a direct understanding of the universe, a desire which promotes the seeking of apprehension rather than of comprehension. Pythagoras still offers today as in the sixth century BC the means of satisfying that desire. For some in this hall at this moment, as for others throughout the world, he is not merely the historical figure of Greek philosophy and science, but a living force from which they receive inspiration. They find the fulfilment of their need for a religious expression of their response to the celestial scene in the celebration of a liturgy in which the doctrines of the Master concerning the whole of life and death and the universe are reiterated at appropriate seasons in the beauty of ritual, poetry and music.

I will conclude by quoting something which must surely have special appeal to members of an astronomical society—

γὰρ παῖς εἶμι καὶ οὐρανοῦ ἀστέρωντος
 "I am a child of Earth and Starry Heaven."

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