

ASTRONOMY: A PLANETWIDE PERSPECTIVE

by

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1. Introduction

Our planet Earth at the present time is inhabited by some 5000 million human beings distributed amongst 5 main racial types - the Caucasoids, the Mongaloids, the Negroids, the Khoisanoids and the Astraloids - grouped into over a hundred separate nation states. The economic fortunes of humans living in different countries are exceedingly diverse. The GNP data available in 1987 show a wide range from \$90 per capita per annum in the poorest countries to \$17,600 per capita per annum in the richest (Enclopaedia Brittanica Yearbook, 1988). A plot of the distribution of GNP exhibits two broad peaks: one at about \$10,000 p.a and another at about \$250 p.a. The world thus divides sharply into "rich" (developed) countries and "poor" (developing) countries. Only some 25% of the total world population are rich, and this proportion is unfortunately destined to increase with time for the reason that the poorest countries tend to have the shortest doubling times of their populations as shown in Fig.1. A tragic irony of the present world picture is that countries now facing economic genocide and enduring the most abject conditions of poverty include areas in North Africa, the Middle East and Asia which in times past had served as cradles of civilization for the entire world. Some of the world's greatest religions and philosophies were born there, and it is here also that the roots of astronomical science are to be found.

Partly stemming from economic inequalities, partly from

the short-sightedness and arrogance of politicians in command, many nations in the modern world are locked in bitter conflict. Confrontations are most often between neighbouring countries; but, more alarmingly perhaps, groups of nations are at times seen preparing for either combat or defence on a grand scale. In a certain sense such conflicts have a degree of inevitability in that they are part of a much wider biological struggle for survival. Although it is true that such a survival-struggle is common to all life on our planet, the greater intelligence and ingenuity of our own species could surely be deployed to eliminate its less desirable aspects. With proper education in astronomy our politicians could be taught to view our planet in a cosmic perspective - as one insignificant habitat amongst billions where cosmic life has taken root. Considered in such a context, the hatreds and rivalries that currently bedevil nations must pale into insignificance. Strutting our own little stage on Earth will not seem as important as considering the future of Man in global terms, an entity that is worth preserving for as long as it is feasible. Our prime responsibility as members of *Homo sapiens sapiens* must be to push forward the frontiers of knowledge, and to explore the Universe to our fullest capabilities. In the not too distant future one might hope to establish links, including communication, with other intelligent lifeforms that must populate billions of planets in our Galaxy alone. Our extraterrestrial partners may well be horrified to see that we have not been able to manage our affairs more efficiently than is represented in Fig.1.

2. Terrestrial perspective

To set our terrestrial heritage in proper perspective let us summarise briefly the history of our planet and of life upon it. The Earth together with the other planetary bodies of the solar system began its career as a collection of cosmic debris. The material of the Earth was ultimately derived from a cloud of dust particles that collapsed under its own self gravity and then contracted to form a solid object. Initially the Earth would have been too hot at its surface for living systems or even organic molecules to persist.

It is now generally believed that much smaller icy objects from the outer regions of the solar system subsequently collided with the cooling planet and deposited volatile materials including water that went to form the Earth's oceans. Evaporation of water molecules from the oceans, and the dissociation of water molecules by ultraviolet light then gave rise to an atmosphere and cloud cover around our planet. Only after this had happened could the Earth have become a suitable home for life with its surface screened and well protected from the damaging ultraviolet radiation from the sun.

The geological record traces in considerable detail the evolution of terrestrial life over some 3800 million years. The first single-celled lifeforms appear in the oldest Precambrian sediments dated at about 3.8 billion years ago. It is indeed quite remarkable that this was also the first moment of time when conditions on the Earth would have permitted life to survive. The development of life from single cells to highly complex lifeforms eventually leading up to Man was evidently a slow and

somewhat tedious process. To set our timescale in perspective let us imagine that the entire 4.6 billion year age of our planet is contracted to occupy a mere century - 100 years.

At the beginning of our compressed century of Earthly life we find the emergence (or first arrival) of single-celled bacteria. Such humble lifeforms exist on the Earth essentially unchanged and alone for a full 75 years. Flowering plants came in about three years ago, and along with them came also many winged-insect species that served to pollinate the flowers. Our own direct line of descent, *Homo erectus*, a hominid walking upright on two legs made its first tentative appearance three weeks ago. And our immediate ancestor, *Homo sapiens sapiens*, hunter and food gatherer, with a brain equipped eventually to write the plays of Shakespeare as well as to unlock the secrets of the Universe, came in as late as 8 hours ago. Eight hours in a century-long span of terrestrial life! That is the sum total of our proprietary claim on this planet, no more, no less. The ancient Indus Valley civilization and the city of Moenjodaro is scarcely an hour old; the nuclear era only seconds old; the space age is virtually new-born.

3. Cosmic perspective

To discover the place of our own planet in the wider cosmos turns out to be an even more sobering experience. In the contemporary view of the Universe the Earth is relegated to the status of a small planet orbiting around a fairly ordinary star, the Sun. The Sun is one of some hundred billion or so similar stars that make up our Milky Way System or Galaxy, and the Galaxy

itself is just one of a hundred billion galaxies in the Universe.

The current belief, derived from recent infrared observations of stars, is that planets like the Earth cannot be uncommon. Thus many billions of suitable abodes for life must exist on a vast cosmic scale.

The ideas discussed thus far are more or less accepted by astronomers without dissent. But at earlier times bitter arguments and conflicts have raged in order to maintain a cosmic supremacy for both our species and our planet. The Earth was widely regarded as being at the centre of the Universe well into the 16th century; and all species of living things were regarded as eternal and immutable well into the latter half of the 19th century. The Copernican revolution in the 16th century demolished our status as a privileged planet, and the Darwinian revolution in the 19th century diminished our status as a special species. Further humiliations followed from the great explosion of astronomical knowledge in the present century. Our planet, our solar system, our galaxy have all faded away to total insignificance as we came to probe the Universe further and deeper than ever before.

Another scientific revolution that is long overdue and one that is being vehemently resisted at the present time concerns the widely presumed terrestrial nature of life. Ever since the experiments of Louis Pasteur, which already in 1860 put paid to the old ideas of spontaneous generation of life, the suspicion had dawned in the minds of many people that life may well be a phenomenon that has to be understood on a scale much

wider than the Earth. Thus the great Physicist Helmholtz (1876) wrote:

"It appears to me to be fully correct scientific procedure, if all our attempts fail to cause the production of organisms from non-living matter, to raise the question whether life has ever arisen, whether it is not just as old as matter itself, and whether seeds have not been carried from one planet to another and have developed everywhere where they have fallen on fertile soil...."

These ideas were shared by other distinguished scientists of the day, notably by J. Tyndall and Svante Arrhenius. It was to Arrhenius, however, that we owe the first modern exposition of the concept of panspermia. In "Worlds in the Making", Arrhenius (1907) followed essentially the same logic as Helmholtz. He discussed the possibility that bacterial cells (spores, in particular) are lifted out of the gravitational potential wells of their planets by electromagnetic effects, and then came to be dispersed through space by the action of radiation pressure from stars. For particles of bacterial sizes (radii a few tenths of a micrometre) the force of radiation pressure due to a star like the sun exceeds gravity. Particles that are thus freed from planetary gravity are expelled from the entire planetary system. In a very tenuous gas, such as exists in interstellar clouds, such grains can be shown to attain speeds of 100 km/s, and could cross the average distance between interstellar clouds in less than 100,000 years.

A difficult bottle-neck in the Arrhenius scheme was the requirement for expelled grains to re-enter another planetary system. The same force of radiation pressure that expelled grains from one system would tend to repel them as they

Approached the next system. Arrhenius argued that the entry speed of a grain would be checked at some distance from the star, and that if a planet chanced to be at that point at the time a transfer of viable cells would occur. The improbability of this event led to estimates that the number of viable cells reaching a planet like the Earth may be small - perhaps a few dozen a year. Later reassessments of the theory have, however, considered more realistic astronomical scenarios in which the mass of living matter injected into the Earth could be as large as a fraction of a tonne per year.

These ideas never came to be popular for the reason that biologists on the one hand and astronomers and physicists on the other went their own way and adopted totally divergent "world views". The "world view" of the biologist was essentially pre-Copernican: to him the canopy of the Heavens was like a lid over his Earthly laboratory, beyond that his conceptual Universe did not extend. To the astronomer our planet was obviously of trivial importance, but when it came to biological matters his comprehension faltered and in a state of self-confessed ignorance he dared not trespass on territory that was not his own. The gulf between biology and astronomy widened as the years went by. The territorial instinct of the human animal has now invaded science to its detriment it would seem. Today whenever Physicists and Biologist come together their meetings are destined to take place on carefully prepared ground, and the scientific outcome is invariably trivial.

Sir Fred Hoyle and the present author approached the

question of the origins of life through our longstanding interests in astronomy. The link with biology followed naturally and logically from our quest to discover the composition of cosmic dust grains (Hoyle and Wickramasinghe, 1978, 1979, 1981, 1988). As every astronomer knows these microscopic dust particles occur in the form of gigantic clouds that show up as conspicuous dark patches and striations against the background of stars along the Milky Way. For nearly 3 decades Sir Fred Hoyle and the present author have endeavoured to discover the nature of these dust grain by combining rigorous mathematical calculations with astronomical observations. We had explored a wide range of models both organic and inorganic but without success. A solution that we stumbled upon late in the day was that the particles in space might be comprised of freeze-dried biological cells. The cosmic dust particles in our view were the seeds of life in the universe. For several years we have developed these ideas in various directions constantly seeking to compare predictions of our models with experimental data from both astronomy and the life sciences. The correspondences were always precise and beyond dispute. We ourselves could see no acceptable alternative solution to the problem of the the nature of cosmic dust and to that of the origin of terrestrial life. Exactly as Helmholtz had suspected over a hundred years ago life must indeed be a phenomenon that encompasses the entire Universe.

These ideas, which fly in the face of received scientific wisdom in 1988, have been vigorously resisted in many quarters. The resistance is invariably of a shallow polemical nature, and needless to say we have lost friends from both

astronomy and biology alike. The implications of the cosmic life theory are obviously far-reaching. In our view the evolution of terrestrial life is primarily driven by the addition of cosmic genes onto the Earth (Hoyle and Wickramasinghe, 1981).

4. A Synthesis of the Sciences

Our traditional concept of the venue for carrying out scientific experiments is the scientist's laboratory; and the material for conducting such experiments is usually thought to be derived from material that is necessarily collected on the surface of this planet. The scientist constantly strives to widen the scope of his experiments with a view to further his understanding of the basic laws which govern the physical world.

It is quite obvious, nowadays, that the Universe almost by definition provides the widest possible laboratory for the scientist. The astronomer who uses this cosmic laboratory suffers a minor handicap in that he is unable to conduct controlled experiments. But this disadvantage is more than amply offset by the sheer scale of the Universe, the highly favourable statistics in terms of numbers of possible observations, and the widest possible range of physical conditions that prevail there.

The role of astronomical systems, particularly the solar system, in the evolution of physical theory is well known. Observations of planetary motions made in the 16th century led to the Newtonian theory of gravitation, and indirectly to the birth of modern physics. The first great triumph of Newton's theory

was the accurate predictions of cometary orbits (including Halley's Comet), and later the discovery of new planets Neptune and Pluto which were based on calculations using this theory. Before the dawn of the present century studies of the spectrum of the Sun made a significant contribution to the development of atomic spectroscopy. Fraunhofer's investigations of the dark lines in the solar spectrum in 1815 led 47 years later to Kirchhoff's formulation of the well-known law that the ratio of emissivity to absorptivity of a body at a given wavelength depended only upon its temperature. The discovery of helium by Sir Norman Lockyer in 1874 is also worthy of note. A bright yellow line was discovered by Lockyer in the spectrum of the Sun during a solar eclipse. At the time the line could not be identified with any known terrestrial element. The presence of helium on the Earth was unequivocally established by Sir William Ramsay some twenty seven years later in 1895.

More recently astronomical observations have been shown to connect with theories of nuclear physics in the interiors of stars and with plasma physics in both interplanetary and interstellar regions. Astronomical scenarios which include the most exotic ranges of physical conditions continue to present stringent tests for physical theories. Astronomical observations have presented a variety of checks on Einstein's General Theory of Relativity, starting with the advance of the perihelion of Mercury which was correctly calculated by Albert Einstein in 1915. Through cosmic ray studies and from observations of X-ray and Gamma-ray sources various aspects of fundamental high energy physics have come under close scrutiny.

With the discovery of large numbers of interstellar molecules, ions and radicals in the past two decades, chemistry has come under the ambit of astronomical science. The giant molecular clouds that populate our galaxy are proving to be gigantic chemical factories producing all manner of molecular species through complex networks of reactions that can occur only on a cosmic scale.

The most interesting interdisciplinary aspect of astronomy that is only now beginning to unfold lies in the interface with biology to which we have already referred. Whether biology engulfs astronomy in the long term, or vice versa, is a matter that remains to be determined in the decades that lie ahead.

5. International Roots

The study of astronomy as a scientific discipline has its historical antecedents in diverse cultures throughout the world. The humblest beginnings of astronomy must surely date back to the very dawn of civilization. The careful systematisation of data which is a prerequisite to astronomical theory would perhaps have occurred at the stage when the transition was made from a hunting and food-gathering mode of life to an agricultural one. This transition is believed to have occurred somewhere in the middle East possibly in Iraq around 7000 BC. With the constant threat of starvation that had plagued human beings over millenia lifted for the first time they probably found enough leisure to contemplate the Universe.

Moreover there was an immediate need to understand certain astronomical phenomena such as the seasons in order to plan agriculture and farming in a sensible manner. The way was then paved for astronomy to flourish.

Attempts to order astronomical observations into the framework of a scientific theory, to evolve a world view from such observations, must have constituted the earliest type of human intellectual activity. It is precisely our ability to engage in this kind of abstract contemplation of the Universe that sets us apart from all other creatures that inhabit our planet. The pursuit of astronomy was perhaps the first intellectual activity of Man that was not primarily linked to the struggle for survival.

In its very earliest manifestations astronomy was closely linked to primitive superstitions including astrology. Indeed developments in astronomy in many countries owed no small debt to astrology and to the assiduous practitioners of this art.

The emergence of sophisticated astronomical theories may be seen to mark the beginnings of high levels of civilization in widely separated parts of the globe. Where records of such activities have survived the degree of sophistication reflected in astronomical theories could often be used as an index of advancement of a particular culture.

The Mesopotamians, who inhabited the plains between the rivers Euphrates and Tigris, had developed a long and distinguished tradition of astronomy over many centuries leading upto the destruction of Nineveh in 607BC. Detailed observations of constellations and planets are recorded in the famous clay tablets known as "astrolabes" - records which are of interest to astronomers even in the present day. The Mesopotamians developed a lunar calendar; the Babylonians were able to predict eclipses to a remarkable degree of accuracy.

Almost contemporaneously with the Mesopotamians and Babylonians, the Mayan civilization flourished in Central America and has left impressive evidence of astronomical achievements. These include their skills in precise time keeping and in the prediction of both lunar and solar eclipses. Likewise the Egyptians, the Jews and the Phoenicians had in their own ways made valuable contributions to astronomical science. It appears likely that the astronomical interests of the Phoenicians were mainly connected with navigational applications.

The ancient Indians and Chinese had both developed sophisticated traditions in astronomy and they each left their mark in history as meticulous observers of celestial phenomena. In India cosmological theories were largely connected with Hindu and Buddhist traditions often incorporating the concepts of creation and destruction of an infinite world. It is believed that the ancient Chinese calculated a series of eclipses extending as far back as 4000BC. Well preserved Chinese records

of comets, including that of Halley's Comet, and of supernovae remain of considerable interest to modern astronomers.

In Western Europe Astronomy as indeed all other forms of scientific and philosophical endeavour began with the ancient Greeks in the period 700-200BC. The progress that was maintained in Greek astronomy over several centuries was in large measure due to their development of geometry and trigonometry as rigorous logical disciplines, following upon the pioneering work of Pythagoras (b.550 BC) and his followers. Aristarchus of Samos in the 3rd Century BC argued correctly that stars were a great distance away. He maintained that the Sun was just another star which he thought was just 7 times larger than the Earth. Most remarkably of all, Aristarchus argued that the Earth circled around the Sun. Aristarchus clearly emerged as an astronomer and philosopher who was many centuries ahead of his times; and for holding such views as he did he was predictably accused of impiety. The Greek tradition was continued for a while through the work of Erastheneas (230BC), Hipparchus (180BC) and Ptolemy (100AD).

The decline of Western Culture from the fall of the Roman Empire through into the Middle Ages led to a steady decline, even reversal of much of the earlier progress in astronomy. Except for a few isolated attempts to revive the ancient culture the decline continued unchecked until about the 15th century AD. Rapid progress recommenced only with the work of the Polish astronomer Nicholas Copernicus (b.1473) who revived the old heliocentric ideas of Aristarchus. This was followed by

the pioneering contributions of Galileo (b.1564), Johannes Kepler (b.1571) and Isaac Newton that eventually led to the Copernican revolution to which we have already referred.

Modern Traditions

The major developments in astronomy from the time of Newton upto the end of the Second World War have come almost exclusively from countries in Western Europe and North America. From 1945 onwards the Soviet Union, Australia, Japan and latterly India and China came to the fore to join the list of countries with a serious commitment to astronomical research.

In the modern world which is dominated by materialistic considerations the question is often asked: why astronomy, and of what practical use can it be? To the latter question it is customary to give an apologetic negative reply. But such an answer is in fundamentally inadequate. Although in the sense of getting more food or clothing or energy astronomy would not directly help it is undoubtedly an important part of Man's cultural heritage. Even in a poor country like India to reject astronomy would be to sever its links with history and with an intellectual tradition that stretches back over thousands of years. The same would undoubtedly be true of China and of the Middle East as well. The basic motivating force of the astronomer is one that is shared by all humans to lesser or greater degree: to penetrate the unknown irrespective of immediate gain. The excitement of astronomical discovery is akin to the excitement felt by a young child embarking on a train ride

for the first time, or like the thrill of explorers in conquering unknown lands.

Astronomy is a truly international academic discipline.

The fund of knowledge acquired through the collective efforts of many countries cannot be regarded as belonging to any one nation alone. It is the property and the inheritance of Mankind - just as the Mesopotamian "astrolabes" or the ancient Chinese records of eclipses are now a property of the entire astronomical community. In recent years many astronomical research programmes have been conceived and developed as joint ventures between several countries. Most recently the International Halley Watch programme coordinated measurements of Comet Halley from very many different countries. The USA and the Soviet Union are now showing signs of coming together in a forthcoming mission to the planet Mars.

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