ASTRONOMY AND HUMAN WELFARE

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Introduction

The title of my talk may suggest to the common reader that I am going to talk about *astrology* which claims that there is a link between the positions of planets in the sky and the fate of humans! Let me right away clear that impression and say that all scientific arguments and controlled tests have denied the existence of such a link. Instead I wish to discuss the subject of astronomy, a well established and perhaps the oldest branch of science, and its role in human welfare.

What can a subject dealing with studies of far away cosmic objects like the Sun, the stars, galaxies and quasars, have to offer in practical terms to the typical human being on this terra firma? A good deal, as I hope to show. The chain connecting astronomy to human welfare is not, however, direct. It may involve several links. There are two different routes it may follow:

(I) Astronomy ---> Physics ---> Technology ---> Human Welfare,

(II) Astronomy ---> Physics ---> Philosophy ---> Human Welfare.

Let us look at these two routes in that order.

Planetary Astronomy to Space and Communications Technology

Let me start with star gazing. From time immemorial humans have looked at stars in the sky and observed their pattern change through the years. Such observations were motivated by idle curiosity about these far away objects. And from amongst those who watched there were some who took notes of what they saw and so began the recorded observational astronomy. And such records revealed the peculiar paths followed by the so-caled planets (-the word means 'wanderers' in Greek) who sometimes moved ahead of their stellar background and sometimes retraced their paths and moved in retrograde fashion.

From the Greeks in the pre-Christian era to Copernicus, Galileo and Kepler in the 16th-17th centuries A.D., the planetary motion posed a challenge to the intellectual to explain its apparent irregularity. It was finally Johann Kepler, who found the correct answer, that the planets

including the Earth, move round the Sun in elliptical orbits. Kepler's three laws of planetary motion detail the way a typical planet moves in its orbit.

Perhaps I should mention that Kepler was able to arrive at these laws because he had the treasure of data from Tycho Brahe, the best astronomer of his times. Kepler had joined Tycho as assistant for the very reason so that he could work on Tycho's data and see if he could unravel the mystery of planetary motion! He stuck with Tycho despite the whimsical nature of the latter which meant that Kepler often had to swallow insults at his master's hands.

As luck would have it, Tycho died after a year or so and with some manoeuvring Kepler managed to acquire all his data. The Keplerian laws represent over two decades of hard work on the part of their author. But the precise nature of these laws was responsible for their leading Isaac Newton to the law of gravitation.

It is often stated in textbooks that Newton thought of law of gravitation when an apple fell on him while sitting under an apple tree in his garden. The story may or may not be true; but it does not do justice to reality in any case. For, the detailed observations of Kepler were really responsible for bringing Newton to the law of gravitation.

Newton applied his newly invented calculus to work out the force on the typical planet that made it move as per Kepler's laws. The answer was the force of attraction towards the Sun, that varied inversely as the square of distance between the planet and the Sun. The point is, that no information on the falling apple could have led Newton to the law of gravitation. Nor could any laboratory experiments in the future have revealed this law as it operates on the solar system scale.

Now let me come to modern times and state the obvious: that today's space technology would not have been possible without the above knowledge. Launching satellites, space probes, spacecrafts to the Moon and the planets, etc., would not have been possible without knowing the way the gravitational force operates on the scale of the Earth and the planetary system.

So when today we reap the benefits of space technology in the form of remote sensing, communications in the form of e-mail, phone and fax, transmission of TV programmes across the globe, missions to the Moon and the planets, etc., we should remember that all this became possible because of the idle curiosity of astronomers like Kepler!

The Clue to Solar Energy

Another idle curiosity about the heavens which promises dividends in the future relates to the mystery of stellar energy. What makes the Sun or any other star shine? Basic physics tells us that the Sun is radiating so much energy and has been doing so for such a long time that it must have a vast reservoir of energy in its interior. What is it?

The answer to this long standing question came through in the twenties of this century. When the Cambridge astrophysicist Arthur Stanley Eddington set up the basic equations describing the internal structure of the typical star, he had them drawn from the well known and laboratory tested physics of his times. Only, in extrapolating the laws to the Sun, for example, he was extending their validity to a system whose size exceeded by far anything tried in the laboratory. Nevertheless, astronomy forces you 'to stick your neck out' and carryout these bold extrapolations. And as Eddington found, this daring approach worked.

While getting a sensible picture of how a star is made up internally to shine as observed, Eddington was stuck at one point. He could see that the source of stellar energy must operate in the central core of star, at temperature upwards of ten million degrees. What mechanism would operate at such temperatures. Here Eddington had a clue from the earlier work of J.Perrin, namely that at such temperatures atomic nuclei could fuse together to make bigger nuclei, releasing energy in the process. In particular in a star like the Sun, four nuclei of hydrogen should combine together and make one nucleus of the next stable atom, helium.

The combined mass of four hydrogen atoms, however, slightly exceeds the mass of helium formed. What becomes of the mass deficiency? Using Einstein's mass-energy equivalence, we can argue that what was lost in mass would be made up in energy. This is known as *thermonuclear fusion.*

Atomic physicists were, however, unconvinced. To bring about fusion, they argued that the star has to bring four positively charged particles together. As there is repulsion between like charges, these particles will not come close enough to be able to fuse. For them to be able to do so, they have to be hurled towards one another with tremendous speeds. Which is possible in a material with high temperatures. Eddington's calculations did give a very high central temperature; but was it high enough?

Eddington thought so but the atomic physicists did not agree. So in his classic book, *Internal Constitution of the Stars*, Eddington had this rejoinder: *We do not argue with the critic who urges that the stars are not hot enough for this process, we tell him to go and find a hotter place!*

A decade had to elapse before the controversy was resolved, in Eddington's favour. By the late thirties, nuclear physics as a subject had advanced to a stage where the nature of the nuclear force had come into focus. The force is attractive and of short range within which it dominates over the electrostatic force of repulsion between like charges. Using the available knowledge Hans Bethe was able to work out stellar and solar models by solving the Eddington equations, now supplemented by the energy equation.

The fact that stellar models are by now well understood, has confirmed the existence of thermonuclear fusion energy source in nature. Man has already tapped it in an explosive fashion in the form of a hydrogen bomb. But stars tell us that controlled thermonuclear fusion is also possible and if achieved in the laboratory, it can solve our energy problem for the foreseeable future. Using heavy water available in plenty in the oceans, we should be able to tap vast energy sources in this way, which are cleaner than the conventional petrochemical ones.

Thus astronomy is pointing the way to a lasting solution to the energy problem facing our civilization.

Collisions in the Solar System

The instance of comet Shoemaker-Levy colliding with Jupiter and the possibility of comet Swift-Tuttle colliding with the Earth on August 14, 2126 brought home not only to the astronomical community, but to the population at large the possibility of collisions in the Solar System. Indeed, the giant dinosaurs on the Earth most likely became extinct due to the catastrophic impact on Earth by a large asteroid or a comet.

How likely is the possibility of a major collison in space with Earth as one party? The most likely objects to hit the Earth are the asteroids which normally move round the Sun in a belt between Mars and Jupiter. Occasionally one of them may stray inwards and come closer to the Earth. That is when the chance of a hit becomes serious.

The impact of an asteroid can be devastating in terms of the force, the heat released and the distrubances created in the atmosphere. One way of measuring the effect is to quantify in terms of

the energy released with the energy from the atomic bomb dropped on Hiroshima as a unit. (The energy released by the impact of an asteroid is not, however, radioactive as in the atomic bomb; nevertheless it is very destructive by its very magnitude.) Thus we can say that the impact of an asteroid of 10 kilometre diameter will release energy of a *billion* Hiroshimas. The impact of a one kilometre object will release a million Hiroshimas while that of a 100 metre body will release a thousand Hiroshimas.

Fortunately, the bigger objects are rarer, and the expected frequency of a hit by the biggest of the three classes mentioned above is once in a hundred million years, that of the next (1 km diameter) is once in a million years while that of the 100 metre object is once in ten thousand years. Nevertheless, as in a random event, this could happen *anytime*. Thus we should like to be forewarned, just in case there is one heading straight for us in the next century.

With this objective, astronomers have started the *Spacewatch programme* in which all moderate to big size objects in the Solar System lying within a reasonable distance from the Earth are looked for and their trajectories determined. The programme may take some twenty-five years to create the database from which we can work out the chance of an impact on the Earth in the near future. Thanks to advanced computers, once the trajectories of all such objects are determined, the answer will not be difficult to obtain.

How can we save ourselves from a major catastrophe if we do not find that, say, in the next 50 years a one - kilometre asteroid will hit us? The answer is that we can explode a nuclear device sufficiently close to the incoming asteroid in such a way that the shock waves generated by the explosion give a gentle nudge to the object and change its path. It will then pass by harmlessly. Of course this explosion is to be carried out well in advance of the collision so that it is at a safe distance away from the Earth. (I may mention that in 1976 I wrote a science fiction story called *The Comet* which had exactly this scenario!)

This last example illustrates the vital role astronomy can play in saving the Earth and its inhabitants from a major catastrophe.

Some Philosophical Issues

I now move on to some philosophical issues. One major fact that astronomy brings home to us humans is that we are so small and negligible against the backdrop of the cosmos. Eddington has compared man in his search for the understanding of the vast universe, to a potato bug in a potato

inside a sack lying in the basement of a ship, trying to fathom the nature of the sea! Another scientist, Fred Hoyle has argued that with its biological make up the human brain may be inherently incapable of understanding the complexity of the universe in its totality.

These ideas are indicative of the difficulty of the cosmic quest and forces us to be introspective and perhaps learn some humility!

A second point relates to the oft-asked question, as to are we alone in the universe. The SETI (Search for Extra-Terrestrial Intelligence) efforts are aimed at finding signals from intelligent civilizations from other parts of our Galaxy. Given the vastness of the cosmos, with over 100 billion stars in the Galaxy, even if we scale down the number to allow for a living system to evolve on a suitable planet around a suitable star, the expected number of civilizations more advanced than ours may still be around a million. It is anybody's guess; I am only quoting my personal number! When we do succeed in establishing a contact it will be the most important discovery in the annals of recorded human history.

One may speculate as to whether the extraterrestrials would be benignly disposed towards us, or they will come down and colonize us. One may also wonder if they would answer our outstanding questions about nature, life, existence, consciousness, etc. and thereby advance our intellectual level at a stroke. All these are exciting possibilities, which astronomy presents to the human psyche.

But suppose, there are no extraterrestrials at all. Suppose, as many scientists do, that we are alone in the universe. Or, alternatively, till the SETI programme bears fruit we may consider ours as the only known habitat for life in the universe. Apart from making us feel very lonely, the idea also places added responsibilities on the homo-sapiens. For, we have the responsibility to maintain our planet as a hospitable place for life. We have to nurture it and respect its ecology, rather than take liberties with it in the name of progress.

I think, this awareness is the greatest gift of astronomy to human civilization.