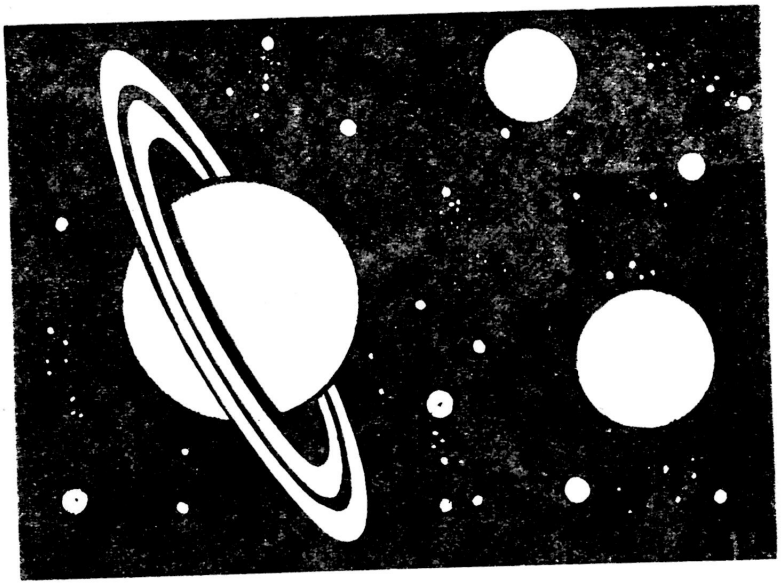

From twinkling stars came the turning point.

Inspiring Moments in the Lives of Great Astronomers

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Newton and Theory of Gravitation

IN 1665 a young graduate from Cambridge, came to Woolsthorpe in Lincolnshire in order to escape from the ravages of the Great plague sweeping across the British Isles. One day, while relaxing in the garden he saw an apple drop from a tree. It was a common enough occurrence but it set him thinking. And out of his thoughts there emerged the law of gravitation.

The above story about *Issac Newton* may or may not be true. Let us assume for the sake of the argument, that it is true. How many of us, on seeing an apple drop to the ground, or on seeing any falling object for that matter, would wonder why it did so? And of those who would, how many will bother to investigate the basic cause of the phenomenon? It is here that we see a glimpse of Newton's greatness. Having wondered why the apple fell, he proceeded to theorize about the cause of the phenomenon and came up with the theory of gravitation. But he did not stop there. Having stated that the Earth and the apple attract each other he went on to postulate the universality of the law of gravitational attraction. He then applied the law to the objects in the Solar System — to the Sun and the planets and to the Earth-Moon system. Even here, he was not satisfied until he had fully resolved the mathematical aspects of the problem which bothered him. In his own words [1]:

[1] From the 'Portsmouth Collection' of Newton Papers believed to have been written about 1714 and found by Adams about 1887.

"And the same year I began to think of gravity extending to the orb of the Moon... All this was in the two plague years of 1665 and 1666, for in those days I was in the prime of my age for invention and minded Mathematics and Philosophy more than at any time since."

Even so, it was the year 1687 which saw the publication of Newton's results — in his book 'Philosophiae Naturalis Principia Mathematica'. The 22-year gap from the falling apple to this momentous volume represents brilliant work in mathematics, dynamics and astronomy.

Should we call the 'falling apple incident' an inspiring moment in Newton's life? Perhaps yes; perhaps no! To call it an inspiring incident is to elevate it too much. It is unlikely that Newton would not have done his great work if he had failed to see the falling apple. The orderly motion of planets round the Sun — expressed by Kepler's laws — did indeed pose a challenge to the theoretician, and a person of Newton's calibre would have risen to the challenge whether or not he saw the falling apple. At best, that incident may have served to trigger off the thought-explosion which led to the law of gravitation.

I think that to look for isolated instances of great inspiration in the lives of great men in any field, is to do injustice to their greatness. Their achievements usually arise by sustained efforts, very often against great odds and in an atmosphere of public hostility. The inspiration which is responsible for this sustained effort must be lasting rather than momentary. Let us look for more such examples in the lives of some other great astronomers.

Copernicus and Heliocentric Theory

Nicolaus Copernicus was nearly forty when in 1513 he began quantitative work in the heliocentric theory. He had a conventional education which included astronomy. The geocentric theory — which placed the Earth firmly at the centre with the heavens revolving round it — was believed to be true by his colleagues and teachers. To believe otherwise would have been heretical. What inspired Copernicus to think of the Sun as the fixed point about which the planets, including the Earth, revolve we do not know. Yet by 1503 he did have a qualitative picture of the heliocentric theory which he set out in a manuscript entitled 'Commentariolous'. But his bread and butter job as a secretary and adviser to his uncle Lucas Watzenrode, the Prince Bishop of Warmia, took much of his time so that it was not until ten years later that he really worked on the heliocentric theory. By then his uncle had passed away and he himself had become a canon of Fraienburg. This transition represented a loss of prestige — which was accompanied by a series of family bereavements. But in spite of this the inner urge led him to work on his epoch making theory; a work which was completed in about ten years. In spite of its hostile reception it 'detonated an overwhelming explosion of human knowledge, an explosion with us in our own day, and whose eventual outcome we cannot yet foresee.'[2]

Copernicus was nineteen when Columbus discovered America — and gave a blow to the concept of the flat Earth! Could this event have influenced Copernicus? He may well have turned to the views of the Greek astronomer Heraclides who suggested that the Earth is a sphere. It is likely that this may have led him to think about astronomy and to question some of the 'well established' edicts of the day. It would indeed be interesting to speculate about what caused Copernicus to think about the heliocentric theory. It will, on the other hand, be more profitable to appreciate the work he in fact did on this

[2] *Nicolaus Copernicus*, by Sir Fred Hoyle (Heinemann, 1973).

theory, and the inner urge that kept him at it for so many years.

Making best use of opportunity

By the middle of the nineteenth century, the Newtonian Law of gravitation had become well established, and a good many problems of the Solar system were explained by this law. Yet, there were occasional problems. A relatively major one arose in connection with the motion of planet Uranus. This planet showed unmistakable irregularities in its motion. What could these be due to? Two explanations suggested themselves. One, the obvious one, was that something was wrong with Newton's law. The other explanation depended on the possible existence of a hitherto undiscovered planet, whose gravitational pull on Uranus might have distorted its orbit. Perhaps this latter explanation occurred to many astronomers. In fact only two followed it to a successful conclusion. One was *Adams* in Cambridge, England, and the other *Leverrier* in France. Adams was the first to calculate the probable position of the new planet and he sent it to the astronomer Royal Airy and the Director of Cambridge Observatory, Challis. Both Challis and Airy, however, did not take Adams seriously; and scarcely made any attempt to look for the new planet. Leverrier was more fortunate in his work. His calculations took less time and when he sent his results to the Berlin Observatory, the astronomer there, *Galle*, immediately instituted a search for the planet and found it, on September 23, 1846. The planet, named Neptune by Leverrier, was announced to the scientific community and only then Airy and Challis realised what a great opportunity was missed by them. Later due credit was given to Adams as the co-discoverer of Neptune.

Astronomical discoveries are very often made by chance, or as a result of fortuitous setting of astronomical objects. This is because, unlike the laboratory scientist, man cannot control the heavens. He has to make the best use of whatever observational opportunities are offered to him. In the case of Neptune, if Adams and Leverrier had tackled the problem 75 years earlier or 75 years later, they would not have arrived at the correct solution. It so happened that Neptune happened to be in the one part of its orbit that made the solution of the problem possible. The method of Adams and Leverrier would not have worked if Neptune had been elsewhere in its orbit! Here is an example of 'striking the iron while it is hot' in the astronomical setting! The greatness of Adams and Leverrier lies in that they made the best use of this 'heaven sent' opportunity.

In their inspired moments the astronomers have taught a thing or two to the laboratory scientist. A notable example of this occurred in the theory of stellar structure. The problem of what keeps a star shining had baffled the scientists for many decades. The suggestion of the nineteenth century physicists *Kelvin* and *Helmholtz*, that the Sun may be shining because of its huge store of gravitational energy, proved to be successful. For, it meant that the brightness of the Sun could not last for more than a few million years. Yet the Sun, which is believed to be at least as old as the Earth, should have been shining for well over a few *thousand* million years! What then was the source of its power?

A. S. Eddington

In the early 1920's, the Cambridge astronomer *Sir Arthur Eddington* had calculated models of stars like the Sun. His calculations led him to temperatures of several tens of millions of degrees at the centres of stars. On the basis of these he speculated that at such high temperatures the energy stored in the nuclei of atoms in the stellar core will be released. It is this sub-atomic energy, argued Eddington, which makes the Sun

shine. The atomic physicists of those days disagreed with Eddington. They did not think that even these high temperatures were high enough for the release of sub-atomic energy. To their criticism Eddington coolly replied :[3]

" 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.*"

Eventually Eddington was proved right ! Around 1940, the pioneering work of *Bethe* demonstrated that Eddington's temperatures were sufficiently high to trigger off thermo-nuclear reactions which fuse four hydrogen nuclei into one helium nucleus. It was possible to construct models of the Sun and other stars based on this nuclear fuel as the source of energy.

Team work behind a Discovery

Modern observational astronomy has become very much a team-work job with highly sophisticated instruments. Behind a modern astronomical discovery, it is often difficult to locate a single genius. The discovery of the first Quasars in 1962-63 is an example. It started with accurate determination of positions of certain sources of radio emission from outer space. The positions were determined by occulting the radio sources by the Moon and for this purpose the big radio telescope in Australia was used. Next the position was compared with those of stars and galaxies in that part of the sky. In this way the radio source with the catalogue number 3C-273 was identified with a bright star. But this is not the end of the story. Further careful observations revealed the star to be moving away from us at nearly 1/6 the speed of light ! The only reasonable explanations lead us to the view that even though the object is star-like, it is in fact a million times or more massive than a star and located well beyond our Galaxy. Such objects, called quasars, are now known by the hundreds. But their nature still poses a challenge to the astronomer.

The discovery of the quasar, and the discovery of another astronomical object called the ' pulsar ' in 1969, are remarkable discoveries in the annals of astronomy. Yet they were unexpected and unsought for. So were the detection of the first cosmic X-ray sources. All were the results of team-work. Perhaps in observational astronomy the days of the isolated observer are gone.

Yet the challanges presented by the recent discoveries to the theoretician are immense, and call for some inspiration for their solution. For, in many cases the conventional frame-work of science is insufficient for understanding the weird behaviour of astronomical phenomena.

Boldness on the part of the theoretician in coming with imaginative new concepts and opportunism on the part of the observer in making the best use of available technology are needed to produce further inspiring moments in the annals of astronomy.

Let us hope that there will be many more instances of Copernicus, Newton, Adams, Leverrier and Eddington in the future of astronomy.

[3] *The Internal Constitution of the Stars*, by A. S. Eddington (Cambridge, 1926).

Bound by one hope, one purpose, one devotion
Towards a great, divinely-destined goal.

— SAROJINI NAIDU.