

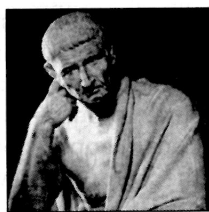
Astronomy: Projections for the Future

DR JAYANT V. NARLIKAR

Dr Jayant Narlikar is a household name today and his contributions to the field of astronomy are widely accepted. His astounding ability to explain terse scientific truths in an absolutely simple manner to the lay reader has made astronomy a popular subject in recent times. His recent popular book is The Seven Wonders of the Cosmos. Dr Narlikar is Director, Inter-University Centre for Astronomy and Astrophysics, Pune. Along with this absorbing article, we publish a pictorial tribute to some of the great celebrities of astronomy.

Introduction

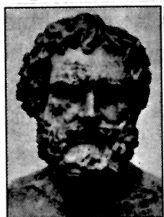
The 20th century has drawn to a close at the end of 31 December 2000, and although



Aristotle

the scale of 10 with the ten digits 0,1,2,3,4,5,6,7,8,9 to write any number, then the Hindu way of writing numbers attaches place values of 1,10, 100, etc as we write digits from right to left. Which is why we celebrate birthdays when our age increases by 1, and talk of decades, centuries and millennia as landmarks in the development of human societies.

My brief here at the turn of the millennium, is to briefly project the future and ask what important developments are going to take place in astronomy in the years to come.



Thales

nothing special is supposed to happen in real terms at this juncture, the moment acquires a significance in our mind largely because of the decimal system that we are used to! If we adopt

Certainly, taking advantage of space technology, electronics and computer revolution, and overall progress in our understanding of physics, astronomers have made rapid pro-

gress in the last three decades. This has raised everybody's expectations as to what more can be achieved in the future. Can we make futuristic projections in astronomy? This is not only a tall order, but my response to it will seem like a reckless exercise! Let us look at history and see what astronomers were thinking of at the turn of the last century.



Anaximander

Some Ancient Indian Astronomers

Agastya
Viswamitra
Aryabhata
Varahamihira
Brahmagupta

Towards the end of the 19th century, astronomers were convinced that our solar system sits at the centre of the Milky Way galaxy. The map prepared by William Herschel a century ago indicating this was still accepted with some modifications. Most astronomers were convinced of

this fact. Yet within two decades of the 20th century, it became clear that *we are not at the galactic centre, but located some 30,000 light years away from it.*

Another shock in store for the astronomical community was about the extent and contents of the Milky Way. There were several cloud-like objects called nebulae, which were found in different directions of the sky.



Nicolaus Copernicus

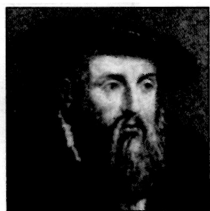


Giordano Bruno

How far were they? Some were definitely believed to belong to our Milky Way; but about some others there were doubts. For example, the Orion nebula is part of our galaxy, being a huge gas cloud containing old and young stars. But what about the Andromeda nebula? While most astronomers felt that this too was part of our galaxy, a small minority suggested that this may be *another galaxy similar to ours, only located far beyond it*. In the early part of the 20th century, this was considered an outlandish idea. See for example, an extract from a popular book *The System of the Stars* by Agnes Clerke written in 1905:

The question whether nebulae are external galaxies hardly any longer needs discussion. It has been answered by the progress of research. No competent thinker, with the whole of the available evidence before him, can now, it is safe to say, maintain any single nebula to be a star system of co-ordinate rank of the Milky Way. A practical certainty has been attained that the entire contents, stellar and nebular, of the sphere belong to one mighty aggregation, and stand in ordered mutual relations within the limits of one all-embracing scheme.

Yet within a couple of decades of this statement, Edwin Hubble working at the Mount Wilson Observatory was announcing the existence of other galaxies similar to ours, and that the Andromeda nebula came to be



Johannes Kepler

recognized as another great galaxy in our neighbourhood, a galaxy similar to ours.

I am quoting these instances to caution against complacency, against the feeling that

today our observations are so precise that we know all the essential details of the universe. For, we may very well be wrong!

With these opening remarks I now make a few prognostications about which way astronomy will go in the coming decades of the new millennium.

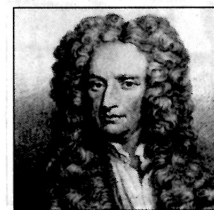
The Discovery of New Planetary Systems

Is the Sun the only star with its own planetary system? Till 1983 there was no positive indication of other stars having planetary systems. In 1983, the Infra-Red Astronomy Satellite (IRAS) demonstrated the existence of proto-planetary discs. It is believed that when a star forms from a primordial gas cloud, it develops a disc around it which spins in the same general direction as the star. The planets condense out of this disc. A typical disc is likely to be dim in visible light but would radiate in the infrared (as planets in our solar system do). Such proto-planetary discs are seen around several stars now, thus indicating that a planetary system is likely to be a common feature of a star.

However, since 1991, planets are being found around stars by another means. The existence of a fairly massive (Jupiter-like) planet moving in an orbit close to a star would make the star wobble because of its gravitational influence on the star. Such wobbles can be detected in the spectrum of the star. From such studies, the first extra-solar planetary system was discovered around the pulsar PSR 1257+12. Three planets go round this pulsar. Amongst ordinary stars, 51 Pegasi was the first to be found with a planet.



Galileo Galilei

Omar Khayyam,
the first Islamic astronomer

Isaac Newton



Robert Goddard
tem.

The Mystery of Solar Neutrinos

One of the outstanding mysteries of the 20th century has been linked with our Sun. Since it is well accepted now that the Sun generates its radiation through nuclear fusion in its core, the fusion reaction is expected to release some neutrinos as well. The neutrinos are particles with very weak interaction with the rest of the matter in the Sun, they are ideally of zero rest-mass, which means that they travel with the speed of light, and they therefore carry 'recent' information about the centre of the Sun. Theoreticians can estimate how many neutrinos we should expect in a given period, in a terrestrial detector set up deep underground (to avoid any confusion with other particles which come through cosmic rays). Although three detectors have been looking for these elusive particles from the Sun, the records to date reveal that not more than a third to a half of the expected number are being detected.

This has led to several speculations. Are our calculations of the physical conditions in the central region of the Sun in error? Are the data on nuclear reactions, on which the calculations are based, in error? Are we missing some subtlety of the chemistry of the detector that makes it less efficient than supposed? Or, are we unaware of some intrinsic property of the neutrino that makes it difficult to detect in its original form?



Percival Lowell

So my guess is that several examples of extrasolar planets will be found in the next few decades and probably we may find some planet-star pair similar to the Earth-Sun system.

I expect that this

puzzle will be resolved in the years to come.

Gaps in the Biography of a Star

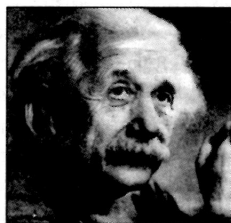
The science of stellar evolution is a success story of the 20th century. Right from the time of its birth in a dark interstellar cloud to its death in a violent explosion or in a slow fade out, different physical effects play a role. These effects have been studied and most of them understood satisfactorily. Yet there are a few important gaps. For example, one would like to know when and how, in a proto-star stage, it will lead to the formation of its proto-planetary disc. How does the star change its external physical characteristics as it reaches the end of the giant stage? The star may be relatively undisturbed as it puffs out shells of its outer envelope in gaseous form, while it progresses along a track when its temperature rises and mass reduces. Ultimately the star will 'rest' as a white dwarf when its radiation would be very little. Will we see such very old white dwarfs that may have been around for, say, 20 billion years or more?

Some massive stars may have more violent ends: known as supernovae, these stars explode with a short-term (a few days) ejection of huge quantity of radiation and matter. Although we understand the causes that trigger off these explosions, the details await the usage of high-capacity and high-speed computers. I expect that in the coming years, this problem will finally be laid to rest.

Stars produce heavier and heavier nuclei as they shine with the energy produced by the thermonuclear reactions. Our Milky Way galaxy will show an evolution of its chemical composition as it ages, thus giving infor-



Christiaan Huygens



Albert Einstein



Erwin Schrödinger



S. Chandrasekhar

important area in which the coming century is bound to shed new light.

Understanding of Structures of Galaxies

Our galaxy is disc-shaped and has spiral arms. Why? Many galaxies have this spiral structure and they, like ours, also show a central bulge on top of the disc. Why? A large fraction of galaxies are elliptical, not showing the disc + bulge + spiral shape at all. Why? If the generic shapes are spirals and ellipticals, then why are some galaxies with irregular shapes? Then there are a large number of small 'dwarf' galaxies too. What is their role in the scheme of things?

A related issue is of radio galaxies and quasars which are powerful sources of radiation. The former, as their name implies, emit radio waves while the latter radiate in many different wavelengths including radio, optical, infrared, ultraviolet and X-rays. And that too from a comparatively very compact region. What is the energy mechanism that leads to these extraordinary manifestations?

There are several such questions. Indeed, it will not be unfair to draw a parallel with the situation prevailing at the beginning of the 20th century, when a lot of observations of stars were available but did not fit into a comprehensive scheme of stellar evolution. It was only when the energy source in stars was identified with nuclear fusion that such a scheme

emerged. Are we missing such a comprehensive scheme for galaxies? Only time will tell...hopefully the coming decades will bring a resolution of this puzzle.



Carl Sagan

The Evolution of Large-Scale Structure

The galaxies are just one manifestation of structure in the universe. History of astronomy to date tells us that as the observing techniques improved and man could view the cosmos on larger and larger scales, he began to discover structures on larger scales too. Thus, from galaxies there emerged *groups* of galaxies, then *clusters* of galaxies followed by *superclusters* of galaxies (separated by giant voids)...much like the division of populations into cities, districts, states and nations. Have we reached the end of hierarchy? Many astronomers think so. But then thirty years ago most astronomers refused to believe that superclusters existed!

So the searches will continue with bigger and better instruments and we may get a better perspective of the *present* structural hierarchy. But then we need to understand how that hierarchy came about. The answer will have to fit into the theory of evolution of the universe as a whole. Or the other way round: the theory of the universe must be consistent with the structural hierarchy that we see at present.

At present there are many investigations into this past-to-present development of large-scale structure. There are additional lines of evidence that need to be taken into account. Like matter, there is also the all-pervading radiation. How homogeneously is it distributed? What can its observed inhomogeneities tell us about the large-scale structure of the universe? Can we spot young and old galaxies and use them as milestones in this structural evolution? Can the change of chemical composition reveal how structures evolved? These are the issues that will dominate astronomy and cosmology in the years to come.



Satyendranath Bose



George Gamow



Fred Hoyle

Theories of the Universe

This short list will not be complete without the mention of the fundamental question in cosmology: *What do we know about the origin and evolu-*

tion of the universe? Despite the popularity that the big bang cosmology currently enjoys I feel that our perception of the universe will undergo a radical revision during the coming century. I think more and more evidence will come to light telling us that the universe is much older than we think it is, that it is far more inhomogeneous than we think it is, and that our perception of the laws that govern its behaviour is more incomplete than we imagine. This is my gut feeling, not based on any current evidence, but by looking at the way our perception of the universe has expanded with time. Right from the days of the geocentric theory when man thought his Earth to be at the centre of the universe, the human tendency has been to simplify the universe so that it can be grasped with his current abilities and knowledge. The universe has never obliged in this way! Rather, at each stage of development of science and astronomy new evidence has come to light whenever the complacency that we have now understand everything has set in.

In this context, the following comment of Fred Hoyle comes to my mind:

...I think it is very unlikely that a creature evolving on this planet, the human being, is likely to possess a brain that is fully capable of understanding physics in its totality. I think it is inherently improbable in the first place, but, even if it should be so, it is surely wildly improbable that this situation should just have been reached in the year 1970...

Hoyle made this remark at the Vatican Conference of 1970, when several cosmolo-

gists were making very categorical remarks about the universe. Indeed, a number of issues came up in cosmology in the post-1970 era, such as dark matter, superclusters and voids, the inhomogeneities of the microwave background, etc, which altered the ideas of 1970.



Jayant Narlikar

Our perception of the universe is continually growing with the new information that our observing instruments have brought in the past and will no doubt do so in the future. No doubt there will be new generations of space telescopes circling the Earth, some of them even doing so with location on the Moon. More spacecrafts are planned to Mars. Dare we hope that they will bring evidence of fossilized life (or even existing life) on our neighbouring planet? Several modest attempts are being made under the SETI (Search for ExtraTerrestrial Intelligence) programme to search and establish the existence of alien cultures in this vast universe. If these attempts bear fruit it will surely be the greatest ever finding in the history of human civilization. In the 1930s when the Palomar 200-inch telescope was being planned, it was considered a major step forward in observational astronomy. At a press conference given by the promoter of the project Edwin Hubble and the distinguished astronomer Arthur Stanley Eddington, the question was asked to these scientists: 'What do you expect to find with this telescope?' Their rejoinder was: 'If we knew the answer, there was no purpose in building it.'

So let us hope that the next century will bring us fresh surprises and challenges: for the human intellect feeds, progresses and prospers only if it gets taxing challenges. □