Celebration of the Birthdays of Profs C V Vishveshwara and U R Rao

The immense contribution of Prof U R Rao and Prof C V Vishveshwara in transforming the planetarium into a unique institution was remembered in another unique way during the first week of March, 2018.

On 6th there was a special meeting which witnessed the narration of the evolution of planetarium program production as guided by CVV from different perspectives. It was inaugurated by Prof Roddam Narasimha who recollected the exchange of ideas between these two visionaries almost 30 years ago in framing the aims and objectives. The uniqueness lay in the fact that CVV ventured to produce planetarium programs when that concept itself was not heard of, here in India. He groomed youngsters who had never seen a planetarium before into creating programs. The talks that followed narrated the choice of the theme and richness in script (Jagdish Raja), specific artworks for the context (Chandranath Acharya), cartoons with fine details of every single object in the scene (B G Gujjar) and the special music (Shylaja) – every one of these aspects had the signature of CVV. There was an exhibition of the artworks and cartoons explaining the context of their origins. Another exhibition was on the contribution of Prof U R Rao to space sciences.

The birth day of Prof U R Rao was celebrated on the 10th March with a workshop for children, who made models of the ASTROSAT, Aryabhata and PSLV. There was a
demonstration of the water rockets prepared by the children. In a meeting held in the afternoon, Dr S K Shivakumar, Former Director, ISRO Satellite Centre, described Prof Rao as the greatest visionary who revolutionised the technology and was instrumental in placing India at the top in space sciences. Dr Charles Lobo, the Chief Post Master General released a special postal cover in honour of Prof Rao. The design highlights his contribution to the evolution of this Planetarium. Col Arvind Verma, Postmaster General, Bengaluru, Mrs Rao and members of the family were the guests of honour.

The exhibitions were open to public during 6-10 March.

**COSMIC PERSPECTIVES - II**

*(Continued from the previous issue)*

We shall now discuss some of the important issues in cosmology with reference to the three possible models we have described. We shall touch upon what is known as well as unanswered open questions.

**The Age of the Universe**

As we have mentioned at the outset, the expansion of the universe leads naturally to the concept of its age. Journeying back in time we arrive at an epoch when all the matter and radiation were condensed into a small region at extraordinarily high density and temperature, the Primordial Fireball as it is called. The universal expansion began explosively from this state. The time measured from this Big Bang to the present gives the age of the universe. A quantitative determination of this age is based on the Hubble law. This law states that the velocity of recession of a galaxy is directly proportional to its distance from us. The constant of proportionality is known as the Hubble constant. The reciprocal of the Hubble constant is a measure of the age of the universe. For the determination of the age therefore one has to measure the velocities of and the distances to the galaxies. Velocities are obtained through the spectral redshifts. But how does one measure the distance to a galaxy? This is done by comparing the apparent or observed brightness of a source of light like a star with its intrinsic brightness. The apparent brightness is given essentially by the intrinsic brightness divided by the square of the distance. By measuring the apparent brightness, therefore, distance can be determined provided the intrinsic brightness is known. But, then, how does one know the intrinsic brightness of a star? Well, there are stars known as Cepheid variables whose brightness varies periodically and the intrinsic brightness is directly correlated to this period. If you can find a Cepheid variable in another galaxy, its intrinsic brightness can be found out from its period. This is precisely how Hubble carried out his original distance measurements. His initial estimate of the age of the universe was about 3 billion years. On the other hand, some of the fossils were known to be as old as 5 billion years. In fact, the solar system has been in existence that long.

**Never forget our ancient family tradition, son. After all, we are older than the universe.**

How could the universe be younger than the solar system which is one of its constituents! This was an awkward situation to say the least. More accurate measurements made later on raised the age of the universe to 15 to 20 billion years which made life easier for the cosmologists.

One cannot be too complacent about the age of the universe as has been determined so far. It depends crucially on the distance measurement. Consequently its value has been taking a dizzy roller-coaster ride. The last word on the cosmic age has not been said yet.

**The Fate of the Universe**

We have earlier described the three basic models of the universe. The closed model is finite in spatial extent
whereas the flat and the hyperbolic models are infinite. All three begin their lives explosively from a big bang origin. What happens ultimately depends upon the particular model. Let us take a simple illustration to highlight the different scenarios of cosmological evolution. Suppose a number of stones are thrown up from the earth. They would mimic the galaxies flying apart and their behaviour would indicate the nature of cosmic expansion. If the velocities of the stones are less than the escape velocity or, in other words, if the gravitational pull is high enough, the stones will slow down, come to a halt and fall back to the earth. If the velocity of ejection is equal to the escape velocity, the stones will just manage to escape to infinity. Finally, if the ejection velocity is greater than the escape velocity, the stones will fly off to infinity more forcefully. These different behaviours depend upon the interplay between the gravitational pull and the ejection velocity. And each case is reflected in the rate at which the flight of the stones slows down, that is its rate of deceleration. The situation is similar in the case of the three cosmological models. The closed universe influenced by its own high gravitational pull slows fast enough to come to a halt and recollapse to a hot, condensed state. The universe that exploded with a Big Bang ends in a Big Crunch as it is called. The flat model coasts along expanding forever. The hyperbolic model too undergoes continued expansion in a more pronounced manner. In these two cases, the universe suffers a long-drawn, cold death. As T.S. Eliot would have put it, the world ends not with a bang but a whimper.

Observationally how can one tell which of the three models our universe actually corresponds to? This is possible if one could measure the rate at which the expansion is slowing down or decelerating. This information is not inherent to the linear Hubble law which indicates only the expansion but not its deceleration. Only the departure from the linear Hubble law would pin down the particular cosmological model one is dealing with.

Such a revelation could come only from measurements made on very distant galaxies. As we go farther into the universe, galaxies become fainter and fainter. Observation of these galaxies becomes an enormously formidable task. We do not yet know what kind of universe we live in and what fate awaits it.

As we have seen, each of the three cosmological models and its behaviour depends upon the gravitation involved. This in turn depends upon the mass-energy content or the average density of the universe that includes all possible types of mass and energy. If the density of the universe is greater than a critical value, the universe would be closed, and open if it is less. The density of the spatially flat universe coincides exactly with the critical value. This brings us to the question of the cosmic contents and the dark matter problem.

The Matter in the Universe

In the beginning, when the universe was in the state of the Primordial Fireball, the temperature was so high that it consisted of only radiation. As the universe expanded and cooled, particles were created, elements formed - predominantly hydrogen mixed with some deuterium and helium - and matter came into existence. In the present epoch, matter in the form of stars and galaxies predominates. When considering the density of the universe at present, we could therefore ignore the contribution from radiation.

From the mathematical models based on general relativity, the critical density corresponding to the flat universe can be computed. This turns out to be about $2 \times 10^{-29}$ grams per cubic centimeter ($\text{g cm}^{-3}$). By the early 1970s, estimates were made of luminous matter contained in the form of galaxies and the tenuous intergalactic medium. The mean density thus computed turned out to be about $10^{-31} \text{g cm}^{-3}$, which is less than the critical density. This indicated that our universe is an ever-expanding open one. This would be a cosmic tragedy indeed. As we have seen, an open universe is fated to undergo a long, agonized death with nothing beyond. On the other hand, a closed universe could, in principle, have eternal, cyclic re-incarnations each starting with a Big Bang and ending in a Big Crunch. It was but natural to believe that the universe in fact contained this ‘missing mass’ that would close the universe. This had to be in the form of non-luminous, invisible, dark matter. And one had to find it.
Sorry Sir. The bottle is partly full, because the rest belongs to the missing mass in the universe

Around the late 1970s, evidence started to grow indicating the existence of invisible dark matter in the universe. As early as in 1933, Fritz Zwicky had conjectured about the hidden matter in clusters of galaxies. There are now essentially two lines of evidence to show the presence of such dark matter.

First, let us consider the dynamics of our own Milky Way galaxy. As we have seen, it is disk shaped consisting of spiral arms. The galaxy rotates in a swirling motion. By measuring the rotational velocity as a function of distance from the center, one can estimate the matter content of the galaxy. This turns out to be more than the observable part that radiates, stretching beyond the visible confines of the Milky Way. This excess is the dark matter in the galaxy that cannot be seen. Other galaxies too must contain such mysterious, unseen material.

Lessons from the History of Science -II
- S Lokanathan

The Lamb Shift

My next example is the famous Lamb-shift experiment in 1947. Let me remind you briefly of the scene. Soon after Dirac published his relativistic theory of the electron precise analytical calculations of the energies of the hydrogen atom showed that the two levels $2S^{1/2}$ and $2P^{1/2}$ both had the same energy, i.e. they were degenerate. Before the war around 1939, there were reports (separately) from Pasternak, Houston and Williams that there were indications that the S level was a bit higher. Here, it is clear that the power and elegance of Dirac theory is what was responsible for the activity of the experimentalists, but one had wait until after the war. Lamb was basically a theorist but used his experience of working with magnetrons during the war for a well planned experiment for settling the issue.

The two basic ideas he started with were first, he knew from elementary (by now orthodox) Quantum Mechanics, that atoms in the 2S state were metastable (they could not radiate to reach the 1S) and he wanted to use this to generate a beam of 2S atoms. The next was to use a suitably tuned magnetron to make the 2S to jump to 2P and thereby de-excite quickly to the 1S ground state. The problem was that even in a small stray electric field there could be what is called Stark mixing (this again is elementary stuff – at the most M.S. physics!) and that would vitiate producing a sufficiently long lived 2S beam. Lamb overcame these problems by producing a stream of meta stable hydrogen atoms falling upon a detector sensitive to them so that when a considerable portion of the S beam was induced (by rf absorption) to transit to P state, the detector showed a marked reduction in response. The result, well known, was unambiguous. The 2S level was some 1000 MHz higher than the 2P level.

What is the point in my choice of this story? First, I cannot but feel that this belies Duhem's thesis. It was a crucial experiment and the disagreement with the theory had to be taken seriously – and it was. In fact it even reached the front page of the New York Times! There was an intense period of activity culminating in the development of what is prosaically called QED (quantum electrodynamics). The theory here – Dirac’s – however, was on a different footing. As I had mentioned earlier it was elegant and seemed a more or less finished product at least as far as its application to the H atom was concerned. There is of course, the famous story that Dirac claimed that his equation had solved most of physics and all of Chemistry. Dirac was not the sort of man to parade his genius – he certainly did not have to and I suspect that the story is apocryphal or Dirac merely wanted to be humorously provocative. The second point I want to make is that while the outcome of the Lamb experiment was revolutionary, its design and execution were based entirely upon orthodox physics albeit designed with great ingenuity. I make this point because my philosophy colleagues have sometimes teased me that truths in Science seemed quite ephemeral. The activities of experimentalists rely quite heavily on what Thomas Kuhn would call Normal Science and its life is far from ephemeral.

References
A Tale of Five Eclipses: My Personal Experiences

- P. Venkatakrishnan

A total solar eclipse is an amazing spectacle. The first time I saw it was on February 16, 1980 on the over the Tungabhadra Dam in Hospet in Karnataka, India. I was not part of any team and went with my family to watch it in Hospet, Karnataka. In the morning we visited the famous historical site of Hampi, containing the relics of the Vijayanagar Empire. In the afternoon, we proceeded to the Tungabhadra Dam and chose a grassy slope to watch the eclipse. The weather was fine and we waited for the totality which was slated to occur around 2 p.m. The sun gradually dimmed during the partial phase of the eclipse. The atmosphere cooled down and there was an eerie silence as all the birds went to their nests thinking that the sun has set. As the sun’s corona was unveiled, there was a huge collective sigh from all the spectators. That sound rings in my ears even today. That is when we realise that the sun is not an ordinary boring star, but hosts a lot of exotic physical processes in its atmosphere. Due to superstitious beliefs, no hotel was serving any food and we were forced to fast during the eclipse. It was only late in the night that we could get food. It was a great day to remember on all counts.

My second opportunity was on October 24, 1995. The place was Neem ka Thana in Rajasthan, India. I was assigned some simple tasks related to running a program to switch on the CCD camera at a pre-determined time after which, I was free to watch the eclipse. This time around, the corona appeared like a dagger hanging from the sky. This was because, at the time of totality (around 8 a.m. local time), the solar equator was vertically oriented in the plane of the sky and there was a large streamer projecting out of the equator. The eastern part was long and spectacular forming the blade of the dagger, while the western part was broader and shorter, forming the hilt of the dagger. Also, the panoramic view afforded by the naked eye observation, is nothing like what we are used to seeing in text-books, where the corona is not photographed in its entirety owing to limitations of dynamic range. After the eclipse, we were invited by a local industrialist and philanthropist, a Mr Modi, to his palatial home, profusely garlanded and served a sumptuous meal with typical Rajasthani hospitality. The lapse of 15 years from the 1980 eclipse had indeed brought on a sea-change in the attitude of the public towards eclipses. The media helped too, by helping in the popularisation of such events. I distinctly remember watching the dazzling display of fireworks on my flight back home while my plane hovered above Bengaluru. I had practically missed Diwali (the festival of lights) - but I had seen a cosmic spectacle beyond comparison. One can't have everything, can one?

My third opportunity was in 2009. We were given a chance to view the eclipse at a height of 40000 ft above sea level on board an IAF transport plane. The ramp at the rear of the plane was opened at 40000 ft necessitating the use of oxygen masks. We were asked wear monkey belts to secure us in the aircraft. We had a sortie the previous day and then briefings exactly like for any airforce operation. It was all great fun. However since the pilots were flying away from the sun, pointing was a big problem and only people with hand held cameras could get photographs. Also, there were clouds even at those heights making viewing the corona very difficult. The IAF people were great to work with and they promised to provide suitable support for any airborne astronomy experiment in the future. The scientists are yet to take up the IAF’s generous offer. The whole expedition was led by Dr Vinay Kamble, the then director of Vigyan Prasar. When we touched down after the event we had our brief moments in the spotlight, with various news and tv channels vying with each other to interview us. I vividly remember one question about whether there was really any danger in watching eclipses. My adrenalin was flowing furiously at that time and I promptly replied, “Did we not go right into the mouth of the demon Rahu and get back safely?” I would like to believe that that would have been a big blow against superstition.

My fourth opportunity was in 2012. This was in Queensland Australia. We were attending a conference on helioseismology - the science of measuring the interior properties of the sun using sound waves generated in its interior and measured on its surface. The conference was organised such that the eclipse day was sandwiched in between the program days. But there was a threat of rain predicted on that day. Some of us decided to take no chances and selected a spot about a hundred kilometres north and on the sides of a mountain. A few of us pooled together money for hiring a car and we set off almost at midnight and reached the spot by 3:00 a.m. The other members of the expedition proceeded to snatch a few hours of sleep before sunrise (totality was to be soon after

sunrise). But I chose to watch the stars in the southern hemisphere, a chance which I knew I would get very rarely. The sky was marvellous and I was enjoying myself. But I noticed that there were clouds on the horizon, which was a concern because the sun would be very low above the horizon at the time of totality. Fortunately, the clouds relented and we could watch a marvellous eclipse. I busied myself with a camera on video mode and an objective prism in front to obtain a spectrum of the full sun. The idea was to capture the flash spectrum. The whole thing went off like a breeze and I got some amazing footage which I could display proudly to my colleagues at the conference. Even during this eclipse, the whooping and cheering of the spectators was great to hear and what’s more, I could capture all those sounds on my video! The screams coincided with the appearance of the flash spectrum.

My fifth eclipse experience was a virtual participation. This was in 2017, and was called the Great American Eclipse. There were many websites offering detailed information on the potential observing sites across the USA. I explored many of these sites and chose Casper, in the state of Colorado. I wrote an imaginary story of a little girl who accompanies her grandmother-scientist to this site to watch the eclipse. I predicted the shape of the corona using the coronal image of one solar rotation earlier to the eclipse day and assuming that the large scale features of the solar corona will remain mostly unchanged. I published this story, “Off to an Eclipse” in Amazon just before the eclipse. Later, I found that my predicted shape was reasonably okay.

Thus, even a virtual participation turned out to be very interesting. Of course, modern observers use space telescopes to observe the corona even without an eclipse. India is also going to send a satellite called ADITYA to study the solar corona within a couple of years.
Mid-way through my PhD in Physics at the University of Texas at Austin, Texas, USA, I realized I would probably graduate in time for the solar eclipse of August 2017, that passed over the USA. It was also coincidental that the typical time limit on PhDs at UT Austin would hit me around the same time. Long story short, I managed to have my final results in order and defended my thesis on July 28th 2017, had it submitted by August 11th 2017, and drove off from Austin, Texas to John Day, Oregon for the eclipse. After 3300km of driving spread over several days, I joined my amateur-astronomer friends and mentors in Malheur national forest to the east of John Day, Oregon two days before the eclipse. The weather east of the Cascade mountain range in that time of the year is expected to be very dry, and our only "enemy" was smoke from wild-fires in the nearby forests, which thankfully spared us on the day of the eclipse. There was a lot of traffic on usually empty highways, as people from all over the country and the world had come to Oregon to watch the eclipse. Private ranches were converted into eclipse campgrounds, and were substantially occupied. Parking was expensive. There were eclipse-themed T-Shirts and other merchandise being sold everywhere. Hoping to be somewhat secluded and have a lot of space, my friends had chosen an open meadow in Malheur National Forest to camp at, where we stayed till the day after the eclipse. The path to this meadow was made of gravel roads that were not maintained in any way, and it was a surprise to me that my basic car made the uphill gravel road into the forest and back without trouble. There were no developed amenities or sources of water -- we had carried in enough supplies to last us 3~4 days with us.

However, once we got there, not for a moment did I feel that we were in the middle of a forest, because there were so many people there for the eclipse! Further up on a hill from us was a large group of people including students of physics and astronomy. Having little prior camping experience, I was fortunate to be with my expert-camper friends, who knew how to fix gourmet dinners in the middle of a forest!

And then the day of the eclipse arrived -- Monday, August 21st, 2017. We were not far from the center line, to catch a bit over 2 minutes of totality. The moments just before totality felt like an odd kind of sunset, that had the same level of illumination, but no orange tint. But if one saw through filtered binoculars, one would see what it was a thin sliver of the photosphere that was producing so much illumination -- much thinner than a one-day-old moon! It is amazing how bright the sun i! Birds moved around confused. There was a noticable drop in temperature. I did not see the "wavy shadow" knife-edge diffraction pattern, because I was looking up at the sun through filtered binoculars for Bailey’s beads, which lasted for a fleeting fraction of a second. It is unfortunate that the visual view of the Bailey’s beads will never match the photograph, because one must use a solar filter during this time. The diamond ring was my favorite moment, and another favorite view was the pink prominences shooting out of the sun seen during totality, through a 10x50 binoculars that a friend hurriedly fetched for me! (I am very, very grateful to her for this act of selflessness during totality!) The thought of having unfiltered binoculars handy had skipped our minds! The pink H-alpha added so much colour contrast to the black of the moon, the white of the corona, and the deep blue of the sky. We did not see a very strong corona during this eclipse. The visually observable corona was somewhat compact compared to what I had expected from photographs of other eclipses. The 2 minutes of totality passed so quickly! It obviously left us wanting more! To observe all of the phenomena during an eclipse, I believe, would take multiple opportunities to witness this amazing phenomenon. I’m getting ready in anticipation for 2024, back in Texas where I spent the last 7 years.

**Akarsh Simha** recently graduated from the PhD program in Physics at the University of Texas at Austin. His PhD work involved experimental and theoretical explorations of short time-scale aspects of Brownian motion in liquid media, and the associated fluid mechanics. He is an alumnus of IIT Madras and the REAP program, attending the latter during his weekend visits to his hometown of Bangalore. Apart from physics, he enjoys working with computers and is an avid amateur astronomer.
Workshop: *Importance of Eclipses in the History of Astronomy*

Was held on March 3, 2018. Prof B V Sreekanthan, Former Director, TIFR, highlighted the importance of maintaining observational records in his opening remarks.

Prof Kiyotaka Tanikawa from National Astronomical Observatory of Japan, gave the introductory lecture explaining the importance of records from ancient observatories, which help us understand climate change in historical time scales. During ice ages, the earth rotated faster and conversely when the sea level rises the rotation is bit sluggish. The imprint of perturbations in Earth’s rotation, called delta T, can be deciphered from ancient eclipses. Scientists infer the changes in the sea level from geochemical measurements of radioisotopes derived from ice cores, sediment/rock cores, coral growth rings, tree rings, etc. Study of ancient eclipses take us back to thousand five hundred years.

Based on an extensive survey of Kannada inscriptions, Dr BS Shylaja showed that the stone inscriptions in India also have contributed to the understanding of the small changes in the rotation speed of earth. The inscriptions record solar and lunar eclipses as well as astronomical phenomena like solstices, equinoxes and occultation of Moon with bright stars like Rohini. By comparing the predicted path with the observed sites we can infer the minute differences in the motion of Earth.

Prof Balachandra Rao, Hon Director of Centre for Gandhian Studies and Human Values, described the records from many texts of the medieval period. He also explained the difficulty in the interpretations since different parts of the country followed different types of calendars.

Prof Mitsura Soma, also from National Astronomical Observatory of Japan, discussed the small changes in the motion of the moon as deduced by special types of eclipses called occultations. The moon is moving away from the earth at a rate of about 3.8 cm per year. We are also studying whether or not the Moon’s tidal acceleration has been constant from ancient times. Our study of ancient records of solar eclipses between 198 and 181 BC in China and in Rome show that the lunar tidal acceleration that is consistent with the current rate. The records of lunar occultations of Venus and Saturn in AD 503 and 513 in China are useful for our studies of the Earth’s rotation.

**Sundial Cannon for Zero Shadow Day**

In the past it was a very important task to announce the noon by an audible signal. The conventional method was ringing of a bell. By 18th century it was replaced by a small device which used a lens to focus the sun’s rays on to a small hole filled with gun powder which would explode at sharp noon. Such a device was used by the Maharaja Swathi Thirunal Rama Varma (1813-1846), who was a music composer and also an astronomer. It is on display in the museum of Tiruvananthapuram. This principle was demonstrated on the Zero Shadow Day (24 April 2018) by bursting a cracker at the instant of zero shadow.