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BASE line

A Quarterly Bulletin of the Jawaharlal Nehru Planetarium, Bangalore Association of Science Education

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Contents

100 years of General Theory of Relativity

100 years ago, a paper published by Albert Einstein revolutionised the understanding of space and time. All the cosmologists and physicists are celebrating this turning point. The textbook rendering of gravity becomes only a special case of Einstein's theory.

The long believed concepts of an eternal constant universe, with an absolute time, absolute space had also an absolute frame of reference, the earth. The revolutionary ideas of Copernicus, Galileo and finally Newton questioned these fundamental concepts. Newton's Principia provided the new physics – or 'the natural philosophy', as it was called, and the doctrines therein ruled for over two centuries – till some of the fundamental constants figured in another branch of physics.

One of the articles here puts together some “defocus”ed ideas on gravity.

About this Bulletin

This bulletin is being brought out to communicate the research, education and popularization activities and also to look back at the early steps of our infancy, with a goal to grow beyond the eight pages in a quarter.

Looking forward to feedback and comments on BASE Line.

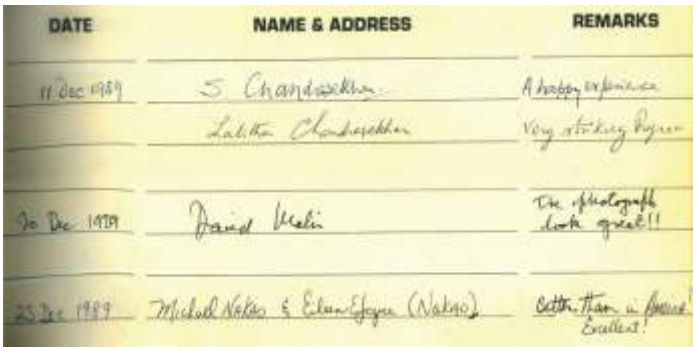
25 years ago

The Planetarium had many distinguished visitors.

Prof S Chandrasekhar, Mrs Lalitha Chandrasekhar, Prof C V Vishveshwara, Prof Saraswathi Vishveshwara, Mr Balakrishnan, and Smt Shyamala Balakrishnan are seen in this photo inside the sky theatre on 11th December 1989.

(Read more about this visit in Current Science, 25th April 2000, vol 78, p 08. www.currentscience.ac.in/Downloads/article_id_078_08_1025_1031_0.pdf)

The visitor’s book has many appreciations recorded - the very first entry is by S Chandrasekhar himself. Here is the first page with the views of David Malin, the famous astro-photographer and Michael Nakao, cardiologist from US, who writes “Better than in America!”



Reprinted from Bulletin of Sciences January-March, 1992

Out of Focus ...

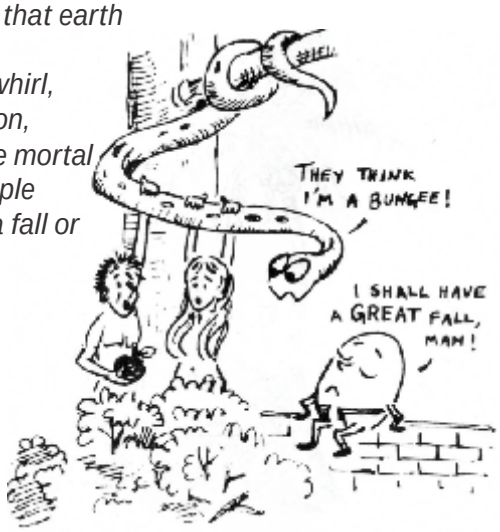
The Apple and The Fall

(Dedicated to the memory of Prof Sanjay Biswas who nurtured the Bulletin of Sciences with his characteristic commitment and zeal)

- C.V. Vishveshwara

THE STRANGE CONNECTION that seems to exist between the fruit and the phenomenon is as old as the beginning of the world itself. After all, it was an apple that caused the Fall of Adam and Eve. Then again, it was the fall of an apple, thousands of years later, that led to the discovery of the law of gravitational attraction by Isaac Newton. Byron wrote about the two events in his *Don Juan :*

When Newton saw an apple fall,
he found ...
A mode of proving that earth
turn'd round
In a most natural whirl,
called gravitation,
And thus is the sole mortal
who could grapple
Since Adam, with a fall or
with an apple.



HELP ! We are going to fall....

Byron's unusual notion - 'a most natural whirl, called gravitation' - indicates that he was decades ahead of Einstein in identifying gravitation with accelerated frames of reference.

It is a matter of record that Isaac D'- Israeli, Benjamin Disraeli's father, whose word we cannot doubt since he had the same first name as Newton, noted that 'the apple struck him (Newton) a smart blow on the head'. Because of this, generations of physics teachers have tried to inspire their pupils by pounding them on their heads substituting fists for apples. Our faith in the historicity of the incident was further fortified by the movie 'The Story of Mankind" that was made sometime in the nineteen-fifties. In the movie, Harpo, one of the Marx brothers, cast as an unbelievable Newton, sliced the offending apple by running it through the strings of his harp and proceeded to play a sad tune on the instrument. This edifying scene motivated many physicists to pursue research in gravitational physics.

What a shock it is then to find Sir David Brewster, Newton's first biographer, casting doubt on the whole affair of the falling apple! 'I have not been able to find any authority for it', declared Brewster. He did admit, nevertheless, the existence of the apple tree which, he reported, was badly decayed by 1814 and later destroyed by wind. On the other hand, Augustus de Morgan, distinguished for his contributions to logic and mathematics and even more distinguished because of his birth in Madurai, India, had his own thrust to make at Brewster himself. 'One particular tree at Woolsthorpe has been selected as the gallows of the apple shaped goddess: it died in 1820', he wrote, 'But, Sir D. Brewster brought away a bit of root in 1814, and must have had it on his conscience for 43 years that he may have killed the tree'. Mr. Turner, the manor owner, is said to have preserved part of the apple tree in the form of a chair. The chair, with such an inspiring lineage, must have no doubt imparted, to all those who sat on it, knowledge *a posteriori.*

On the positive side, there is indeed sufficient evidence for the apple story. A detailed account is due to William Stukeley, a medical doctor and friend of Newton. Here is his report of his after-dinner conversation with Newton on April 15, 1726 :

"The weather being warm, we went into the garden and drank tea, under shade of some apple-trees, only he and myself. Amidst other discourses, he told me, he was just in the same situation, as when formerly, the notion of gravitation came into his mind. It was occasion'd by the fall of an apple, as he sat in contemplative mood.

Why should that apple always descend perpendicularly to the ground, thought he to himself. Why should it not go sideways or upwards, but constantly to the earth's centre?"

Earlier, Voltaire had written in his Essay on the Civil War in France that Sir Isaac Newton walking in his garden had the first thought of his System of Gravitation upon seeing an Apple falling down from the Tree! Apparently, Voltaire's source of information was Catherine Barton.

Who was Catherine Barton? She was Newton's favourite niece, daughter of his half-sister. Reputed to be charming and intelligent, her beauty had been unmarred by the bout of small pox she once had. During her illness she had received medical advice from her uncle Newton who suggested a remedy consisting of 'warm milk from the cow'! The irreverent poets of Kit-Kat Club of the Whigs

wrote of her:

At Barton's feet the God of Love
His Arrows and his Quiver lays,
Forgets he has a Throne above,
And with this lovely Creature stays.

Catherine Barton's name was amorously linked with Charles Montague, Earl of Halifax, who appointed Newton Master of the Mint. Voltaire remarked on this account, 'I thought....that Newton made his fortune by his merit... No such thing. Isaac Newton had a very charming niece who made a conquest of the minister Halifax. Fluxions and gravitation would have been of no use without a pretty niece'. However, we are assured by historians that this charge is quite baseless, since Montague was not even aware of Catherine's existence when he made the appointment.

On March 22, 1813, Sothcby's held a sale of The Library of the late Mrs. Anne Newton, containing the collection of the Great Sir Isaac Newton etc.' The Library contained books with eyebrow-raising titles such as 'The Mysteries of Love and Eloquence' and 'The Art of Wooing and Complementing'. Were these books added to the collection by someone else or did Newton himself own them? After all, Robert Hooke's library contained a number of works with thought provoking titles such as 'Merry Drollery', and 'The Practical Part of Love'. Newton and Hooke, as is well known, had been involved in a controversy related to the discovery of the law of gravitational attraction. Were they perhaps studying, on the sly, another kind of fall namely falling in love, trying to discover a universal law of biological attraction and its relation to gravity? We do not know. Einstein, on the other hand, is quite clear on the subject. During a visit to England in 1933, he received letter from a gentleman who averred that because of gravity a person on the spherical earth is sometimes upright, sometimes standing on his head, sometimes sticking out at right angles to the earth, and sometimes at "left angles". He went on to enquire whether perhaps it was while upside down, standing on their heads, that people fell in love and did other foolish things. Einstein probably did not answer this letter, but jotted down on it in German the following remark:

"*Falling in love is not at all the most stupid thing that people do, but gravitation cannot be held responsible for it.*"

All our foregoing considerations pale into insignificance in the light of the following obscure but extraordinary fact which invites further investigation requiring generous grants from suitable funding agencies. Legend has it that a sage belonging to South India discovered the universal law of gravitation some three hundred years before Isaae Newton. It so happens that there are hardly any apple trees in South India, but one can find coconut groves all around. Consequently, the discovery of the law of gravitation by our sage was occasioned by the fall of a coconut as he sat in a contemplative mood beneath the coconut tree. Needless to add the world remained ignorant of his finding. This was indeed the first authentic case in unrecorded history of perishing without publishing.

Our blurred vision was induced by the following works: Derek Gjerston, *'The Newton Handbook";* D. McKie and G. K. de Beer, *"Newton's Apple"* in Notes and Records of the Royal Society of London, Vol. 9 (1952); HA Feisenberger, *"The Libraries of Newton, Hooke and Boyle'* in Notes

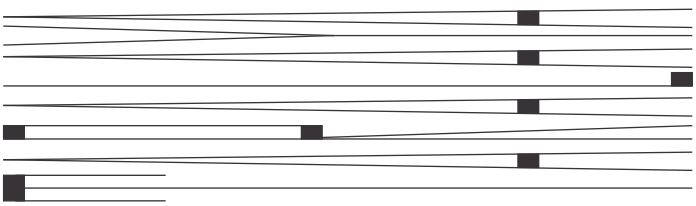
REAPers Speak

REAP (Research Education Advancement Programme) is a three year programme in physics that is offered concurrently with regular under graduate college education complementing the formal curriculum.

Indian Institute of Science, Indian Institute of Astrophysics and Raman Research Institute have played a key role in the success and sustenance of the programme.

More than 100 students have been motivated to take up careers in basic science research by this programme, which has been now extended to life sciences as well.

Here is a glimpse of the research carried out by two REAPers K Vijayakumar and Shivakumar Jolad.



Artwork by K R Srinivas (to be viewed tangentially from the right side)

The physics of living systems

- K Vijay Kumar

Are living systems subject to the same laws of physics as non-living systems? Do the processes of life satisfy the equations of Newton, Maxwell and Schrödinger? At a fundamental level, all living systems are composed of a huge collection of molecules. It is not surprising, therefore, if physical laws should be applicable to biomolecules that interact and move around. However, a living cell is not just a bag of molecules. By using energy from its surroundings, a cell divides, grows, moves around, adapts to its environment and does all things that make it "alive" [1- 4]. At the next stage, by making more of themselves (replication) and specialising for particular tasks (cell differentiation), multicellular aggregates of cells morph into complex three-dimensional shapes [5, 6]. Thus large groups of cells are able to come together and create a complex hierarchy of organisation and do bewildering things. It is shocking to realise that one such group of cells wrote these sentences and another is understanding them right now...! Suddenly, at this level, it becomes less obvious that living systems are subject to the laws of physics. How do we rationalise this dichotomy?

Living systems are "self-organized", i.e., they put themselves together. Unlike in a factory, where an external set of machines make the parts of a product and assemble the parts together, a living system makes itself— the (molecular) machines making the parts of the product, and the product itself are the same. These complex self-organized structures and the processes that occur in cells and tissues (somehow) originate when a large number of biomolecules are put together. How do the processes of living systems "emerge" from the physical interaction of many many biomolecules that are themselves 'not alive'? This question has perplexed us from the time it was realised that both living and non-living systems are composed of the same atoms and molecules.

The idea of "emergence" is familiar and deeply rooted in condensed matter physics [7], where simple physical interactions between many constituent entities can lead to the emergence of novel collective phenomenon like superconductivity. Physical biology uses the tools of classical statistical mechanics and soft-condensed-matter physics to understand the emergence of the processes of life from simple physical considerations [2, 3]. These physical ideas can be experimentally verified since biological research in recent years has increasingly become more quantitative and precise. This has lead to a flurry of activity in biological research some of which seem to blur the distinction between living and non-living systems.

As such, in recent decades there has been a large influx of people trained in mathematics, physics, chemistry and the engineering disciplines towards problems in biology. In India too, there are many groups spread all over the country working in the physical aspects of living systems.

The physical biology group at ICTS-TIFR[8] is interested in active physical processes that underlie the morphogenesis of developing embryos. Specifically, we are keen to understand the role of mechanical forces and flows in developmental biology. In cells and tissues, mechanical forces are typically generated by the energy consuming activity of molecular motors (such as myosin) as they translocate on polymeric filaments (such as actin) the constitute the cellular cytoskeleton. The cellular cytoskeleton provides a mechanical framework for the cell. The mechanochemical forces generated in the cytoskeleton are responsible for cell deformation, cell division, motility...etc. At the larger scale, these forces can collectively deform and flow entire tissues and shape embryos as they develop. We are interested in how cytoskeletal forces induced deformation are involved in important developmental processes. For example, we have worked on understanding cell polarity and the emergence of the anterior-posterior (head-tail) axis in developing *Caenorhabditis elegans* embryos.

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Vijay studied BSc in MES college, did a PhD in IISc, spent a few years as a postdoc in Dresden, Germany, and returned to India recently to join the International Centre for

Theoretical Sciences (ICTS-TIFR) as a faculty. During his BSc days, the Jawaharlal Nehru planetarium and the REAP programme laid his foundations in physics and mathematics. Vijay hated biology in school and left it as soon as he possibly could. However, a PhD in soft-matter-physics naturally led to asking questions on the physics of life, which he is pursuing right now at ICTS, and plans to do so for the foreseeable future.

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Thinking Electrons – physics of society

- Shivakumar Jolad

In Physics, many of the interesting phenomena such as ferromagnetism, liquid-solid phase traction and superconductivity are a result of the collective interaction among the parts of the systems (spins, atoms, electrons-phonons). Stunning regularities seen in society such as formation a common culture, language or consensus on some issues arise out of free willing, but interacting individuals. This connection between physical and social sciences has motivated people to apply concepts and techniques of statistical physics to social sciences. The concept of entropy, which forms the core of statistical physics and Information theory, is employed in a range of disciplines from economics to linguistics. It is used to measure inequalities in income and life expectancy, and to measure information content of languages. Phase transitions and percolation theory have been applied to understand wide ranging biological and social phenomena such as tipping points in ecosystems, spread of epidemics and emergence of consensus in social networks. The Study of such emergent phenomenon in social, economic and socio-biological systems through the use concepts and methods from physical, computational sciences are classified as complex systems.

I, along with my collaborators have worked on complex systems with focus on two areas: modeling spread of epidemics and opinion dynamics. We have modeled how diseases such as flu spreads on social networks and whether we can suppress such epidemic by changing the network structure through behavioral adaptations. In our group at IIT Gandhinagar, we have worked on spatial spread of vector (such as mosquito) borne diseases Dengue and studied how human mobility can influence the disease dynamics through the use of reaction diffusion equations and cellular-automata formalism.

In history, there are innumerable incidences of small committed minorities influencing the majority and eventually bring a consensus on an issue, ideology or faith. We have worked on a model of what happens when you have competing committed minority and under what conditions one minority group will overpower the other. On a similar note, we are working on how scientific collaborations between authors emerge and how interdisciplinary fields may emerge from working diverse set of people. We are testing our models on the network of authors American Physical Society journals.

Shivakumar Jolad is an Assistant Professor of Physics at Indian Institute of Technology Gandhinagar, Ahmedabad, Gujarat. Prior to that he worked as a postdoctoral research associate at Virginia Tech, USA- where he worked on application of statistical mechanics to problems in dynamical process on complex networks. He holds a PhD in Physics (condensed matter theory) from The Pennsylvania State University, USA. His doctoral work was on physics of quantum Hall systems. Prior to that he did his MS in Physics from Texas A&M University, USA and a BE in Electronics and Communication Engineering from M S

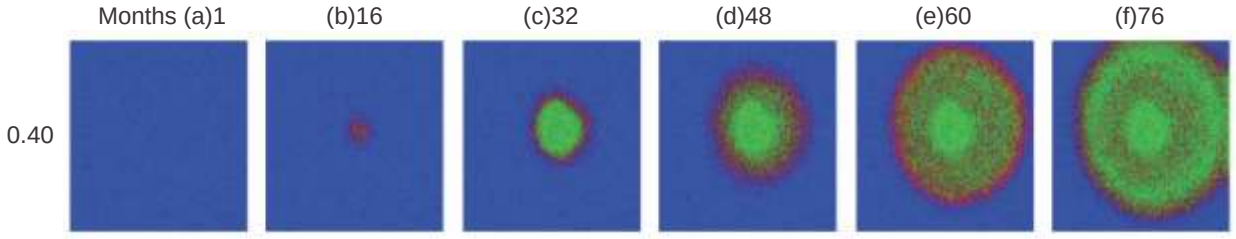


Fig. Spatial spread of Dengue fever in a city modeled with data from Ahmedabad.

Ramaiah Institute of Technology, Bangalore. During his pre university and Engineering days, he was part of the weekend science lecture program (which later turned into REAP). The years spent at BASE laid the foundation for pursuing scientific career.

Small set up and large responsibilities

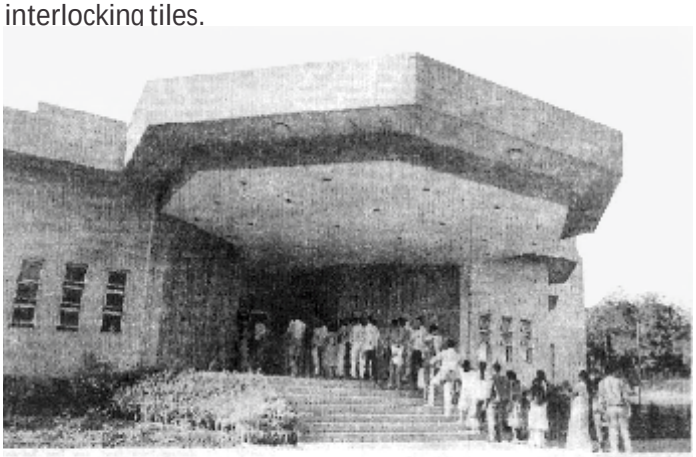
- K K Kutty

Planetarium is a very small organization; however the administration and maintenance are not small jobs. While the production of the sky theatre shows is the main activity, delivering it to the public in the best possible way is an equally challenging task.

Way back in 1989, when the Planetarium opened up for general public, it had only very minimal facilities. The growth potential of the Planetarium was yet to be explored; therefore as the Planetarium grew it was found that the facilities needed some augmentation. Actions were initiated towards this improvement and the results showed up gradually.

Parking Area

In the early days, the parking lot was a mere facility. Few years ago the road were freshly done and parking instructions were laid down. Further on, with increasing demand, extra area had to be carved out in the campus especially for the school buses brought in by schools and picnickers. That brought in an order which was very well received and appreciated by the visitors. The necessary civil works were carried out with the help of BBMP. The small lane (which earlier pits and ditches) leading to the transformer (exclusively used by the BESCOM vehicle) now looks very attractive with the interesting design of the interlocking tiles.



People queuing up at the Jawaharlal Nehru Planetarium at Bangalore which was thrown open to the public on Saturday. The programme "Our Sun and his Family" had to be shown twice as a large crowd turned up for the inaugural show.

DECCAN HERALD, Sunday, December 3, 1989

Science Park

The Science Park was introduced as a novel idea, to make science as a joyful experience for children. The visitors had something to see outside apart from the 45 minutes inside the sky-theatre. The families were happy to keep the children engaged in the park during the waiting time. However, though envisaged quite early, the park actually happened only in the year 1997 with a handful of exhibits and ever since several new models are being added. It has been serving a resource for others who caught on the idea and implemented in their own premises all over the state and outside. Now the Science Park has over 40 models with appropriate scientific write ups. Recently the pathways have also been laid and the entire park has been beautified. Now visitors can walk through these pathways without any hindrance and enjoy watching the models. The write-ups were also redone to suit the new arrangement.

Rainwater harvesting storage tanks

The rose garden in the Planetarium was once very attractive and grabbed a couple of prizes in the competitions of flower shows. As the water table lowered, the bore wells dried out one by one and the garden vanished. The idea of harvesting rain water was implemented in 2009 with two small tanks each of capacity 20000 and 10000 li. Other methods of harvesting introduced in various corners served as demonstrations of the different techniques and attracted attention of a large number of visitors. In order to further improve the availability of water, two very big RWH storage tanks were constructed with the financial assistance of BBMP. These have capacities of 1.5 lakh litres and 1 lakh litre each. The stored water has been serving the toilet and garden requirements of the campus partially during summer months apart from increasing the height of the water table.

Peripheral Fencing

The short peripheral fencing which served for over several decades hardly provided any security from two legged and four legged unwelcome intruders. The change in the fencing was needed from the aesthetics point of view also. The gates and the entire stretch of about 920 meters are now replaced with tall and more attractive design; thanks BBMP who fully supported this work. While nothing can be declared about the thieves right now, the menace of the four legged has come to a total stop.

A concern for the physically challenged

The building has a ramp to facilitate the physically challenged. In the early days a couple of wheel chairs were

donated by well known social activist, (late) Mrs Lakshmi Nizamuddin. Now few more of them have been made available. In the last couple of years the sky-theatre shows have on Fridays are shown with subtitles for benefit of the hearing impaired. However, the much needed requirement for the physically challenged was the toilet facility. At the same time, the existing public toilets were grossly insufficient to meet the needs of the large number visitors. Therefore toilets on one floor above the existing are being constructed to serve the physically challenged and ladies. Once they are operational, the existing toilets in the ground floor will be exclusively for gents. This work is being done entirely with the special grant from the Government of Karnataka through the Department of Science and Technology.

New ticket counter

Twenty five years ago, the security gate of the previous office was converted in to a ticket booth as a stop gap arrangement. Thus the ticket counter, situated far from the main building, is putting visitors into some difficulties. Apart from this, this small building with poor ventilation, has become very old and not worth repairing. It did not have adequate shelter for visitors who stood in the queue. They were at the mercy of sun and rains. Therefore a new building was envisaged for the ticket booth, where visitors can queue up and sit comfortably. The construction is in progress. When fully done, this building with a good aesthetic touch and an appealing atmosphere, with a few informative materials for the public to read while waiting for buying the tickets will offer a good experience.

Moon in the class room

- B S Shylaja

It was a gathering of about 70 children in the sky theatre of our planetarium. Some of them were seeing the theatre for the first time. The first question that opened up the session was - "How many of you have seen the moon?" All the hands went up. "How many of you have seen stars?" Again all the hands went up. "How many of you have seen planets in the real sky?" was the next question. Hesitatingly a couple of hands went up. One said " I had seen one planet last year"; the other said, "My grandfather had shown me Venus when I was a small girl".

The next question was on what they knew about the moon - everyone was ready with a different answer - that the moon is a satellite of the earth, that the moon has no air, that man has landed on the moon, that "somebody" had found water on the moon..... The next question - "When did you see the moon?" - there was a long pause, as expected, then the question continues - "Was it yesterday,... the day before, ...last month or ....last year?" After a long pause came one answer, "Last week".

That is a typical live session, as part of a workshop entitled “universe in the classroom”.

The assignment was very simple to look up for the moon at least once in an hour in the night. The session continued with the introduction to stars and constellations, with the glory of the night sky at our disposal.

The next day they were back quite disappointed - they could not see the moon. Only one came up with an answer - he had seen the moon in the morning well after daybreak. When he announced it there was a big roar of laughter. The others thought he was bluffing. That led to a heated up discussion on whether one could see the moon in the morning at all.

Now I had to use one of them as the earth, the other as the moon, the planetarium projector itself as the sun. The "earth" would revolve around the "sun" and rotate on its axis. The concept of day and night was driven home. Now the "moon" joined the earth. His job was to simply go round the earth. The rotation and revolution of the moon were thus clarified. (Later I was told that this is called the role play)

Switching over to a make shift "white board" arrangement, I explained the same concept in two dimensions. How would that be seen in the sky? That demanded an introduction to the stars. This job was relatively easy once the projector resumed its activity. Many of them had recognised some constellations the previous night; a few had identified the pole star as well.

The following were the assignments for the evening:

1. Noting down the time of moon set or moon rise, whichever is convenient.
2. Position of the point of moon rise (or set) near the horizon.
3. Position of the point of sunrise or sunset.

By the end of the month, they were ready with the tabulated timings of the moon rise for some days and moon set for some other days. Interestingly now they were in a position to "predict" the moon rise and set timings for a couple of days.

This did not require any great skill in mathematics. The 10 to 12 years olds could not prepare a plot.

However, the senior students who came later with a great

enthusiasm to learn astronomy and astrophysics were better equipped. Apart from the text book calculations of the apple – moon in the context of gravitation, I made them repeat the observations done by the juniors. These were in the age group 14+ and prepared plots of their observations. The following inferences were immediately apparent.

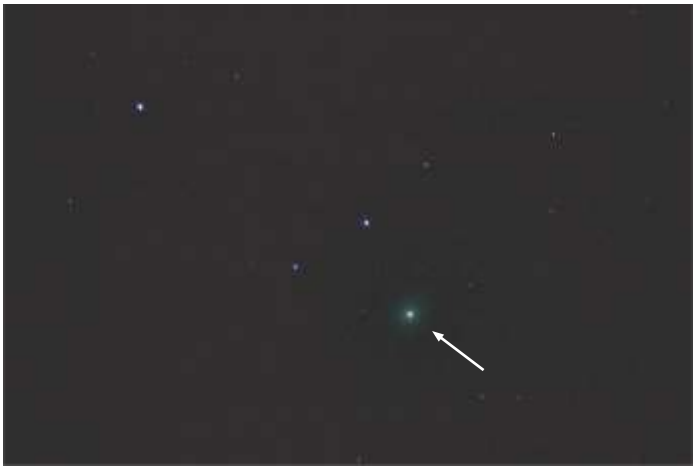
1. The moon rise (set) timings are delayed by about 50 minutes every day.
2. The graph shows a saw tooth pattern, which can be extrapolated with only with some common sense.
3. The positions of the moon rise and the sun rise (moon set and sun set) at the horizon do not coincide.
4. The duration of the "moon day" i.e. the time for which moon is above the horizon, varies over a mean.

I asked the students to select the full moon days and compare the duration and the position of the rise (set) points with reference to that of the sun rise (set) points throughout the year. The plots they produced contain important concepts of spherical astronomy.

These may be summarised as

- The sun and the moon move along lines parallel to the equator, i.e. perpendicular to the pole every day.
- Their position is on a different circle called the ecliptic, which is inclined to the equator.
- As a consequence the position of rise and set varies from day to day for the moon; while it varies from month to month for the sun.
- The delay of about 50 minutes in the time of moonrise explains its movement around the earth. (At this point, there was a very interesting discussion on what would have happened if the moon went round the earth in the opposite direction)
- It is impossible explain the movement of earth round the sun by these observations.
- The point of moonrise and sunrise (or moonset and sunset) gradually separate and approach twice in a month. This is a consequence of the inclination of the ecliptic. Mathematically, this is reflection of the change of declination of the moon within a day.
- The moon and the sun occupy diagonally opposite points on the ecliptic on the full moon day. For example, if the sun is at winter solstice, the full moon in that month will be in the northernmost constellation of the zodiac. On the other hand, when the sun is at summer solstice, the full moon of the month will be at the southernmost constellation of the zodiac. On equinoxes, the full moon also will rise at a point very close to the cardinal point E.
- The moons position every night (sometimes) need not necessarily be on the zodiac. That is how it can be in Orion or Ophiucus. This is because its orbit is inclined to the ecliptic by about 5 degrees.
- The duration of the full moon "day", the time for which moon is above the horizon, is longer in winter than in summer. The durations for the equinox full moons also are not same.
- While the motion of the sun can be represented by a circle, the ecliptic, (sometimes the word is used for the plane as well) the motion of the moon cannot. The zodiac would have to a have a width of at least 5 degrees. The fact that orbits of the planets are still more inclined, needs the zodiacal belt to be still wider.

Here in Bangalore, (latitude ~ 13 degrees) the difference between the duration of the day in summer and winter is not as exaggerated as in the higher latitudes. Thus the actual calculations only can reveal the differences. Here moon again helps us. .....*(to be continued)*



Comet Love Joy (Photograph from the 6" Coude refractor by A.P. Lokesh)

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