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Contents

ASTROSAT news:

A companion for a star on an extended life

It has always been a challenge to determine the age of a star. It is equally interesting to see how this challenge has been addressed and an amicable solution is found with the help of star clusters. An open cluster consists of hundreds to thousands of stars, which are loosely bound. The globular cluster is a tightly packed cluster. The cluster stars are formed most likely from a single gas cloud, and are therefore roughly of same age.

The color of a star is a measure of its temperature and its mass ; therefore blue stars are hotter and more massive than red ones. The more massive a star is, the faster it burns up its hydrogen, so blue stars are expected to spend less time on the main sequence than red stars. The Hertzsprung – Russell (HR) diagram or the color-magnitude diagram of a cluster shows a smooth transition; stars which are bluer than a certain value (known as the "turnoff" point) will have already left the main sequence (the normal, hydrogen-burning phase of a star's lifetime), while those which are redder will still be on it. Most stars evolve away from the main sequence once their hydrogen burning phase is over. The turn over point on the H-R diagram of an open cluster is indicative of its age. The location of the turnoff point can be used to estimate the age of the cluster.

Open clusters and particularly older clusters therefore are ideal sites to study the stellar evolution for both single and binary stars. The dots above the turn off point correspond to stars which stay on the main sequence longer than they are expected to. They are called Blue Straggler Stars (BS). They are members of old clusters that are brighter and bluer than stars on the upper main sequence. They appear to 'extend' the main sequence in a HR diagram of the cluster and appear as if they are 'younger' stars. They are termed stragglers because they do not move away from the main sequence like the other stars in the same cluster. Their unusual property is explained as the result of stellar collisions or mass transfer from another star. The red, cool (and also old) star can thus get extra mass and turn blue. As explained by the evolution mechanism, the red star burnt hydrogen at a slow rate to still remain on the main sequence. When there is an opportunity to accrete extra mass it appears like a blue star, giving a false implication on the age; it looks younger than it really is.

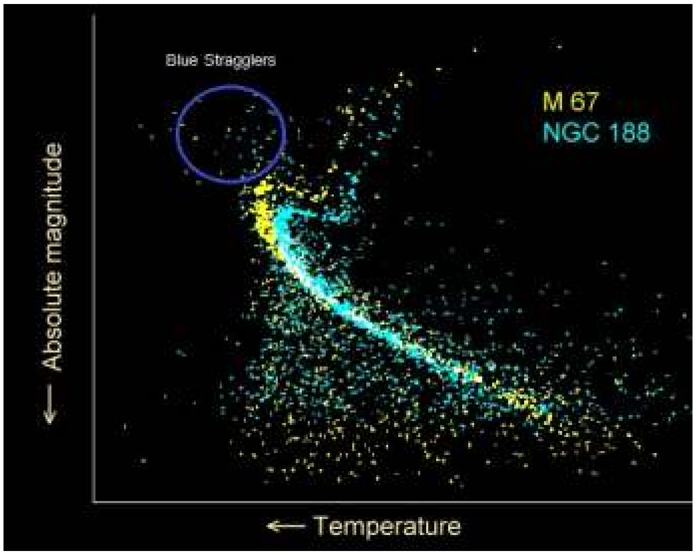
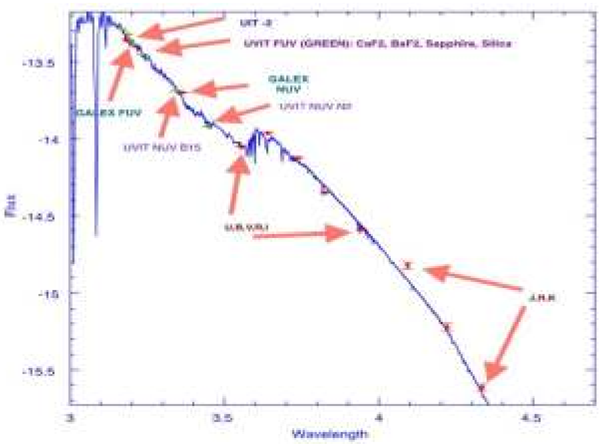


Figure 1 - The location of blue stragglers on the HR Diagram

NGC-188 is a well-studied old open cluster with an estimated age of 7 Gyr (Billion year, astronomically known as Giga Year- Gyr) and exhibits high metallicity. It is located about 5000 light years away and has about 1050 stars as its members with 20 BSs confirmed. WOCS-5885, most likely a member of NGC-188 (with a high probability of 53 to 80% quoted in literature), was one of the 3 objects identified with exceptionally blue color. Various classifications, - BS or a sub-dwarf or a binary with a red giant and a pre-white dwarf to name a few - were attributed to this object, because its spectrum did not match with any single identification. This could only be resolved if the hot (UV, blue) and the cool (red, IR) part of the spectrum of this object could be fitted together with spectral models of stars. This had been done with observations from space (GALEX, UIT, UVOT, SPITZER, WISE) and several ground based observatories, spanning the IR, optical and UV bands.

SED of S1 - Binary (12500K+5750k)
Green points UVIT;Red - Literature (GALEX, UIT, Optical, NIR)



FUV (left) and NUV (right) images of NGC188 obtained on 18 February 2016.
WOCS-5885 is marked as red square.

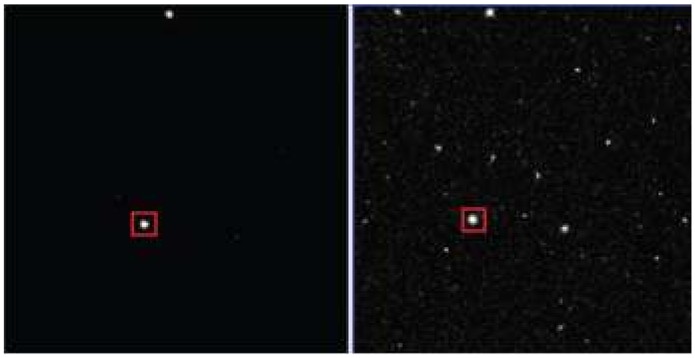


Figure 2 - The Blue stragglers of NGC 188

The UV band observations from the Ultraviolet Imaging Telescope (UVIT) on ASTROSAT have provided additional points in the Spectral Energy Distribution (SED) thus resulting in a much better spectral fit over the wavelength range of 0.15 µm to 7.8 µm. With this data set, WOCS-5885 has been classified as a binary consisting of a BS and a hot star which is either a post Asymptotic Giant Branch or Horizontal branch (post-AGB/HB) star.

The UVIT contains two 38-cm telescopes; one for the far-ultraviolet (FUV) region, the other for the near-ultraviolet (NUV) and visible (VIS) regions. These are divided using a dichroic mirror for beam splitting. UVIT is primarily an imaging instrument, simultaneously generating images in the FUV, NUV and VIS channels over a 28 arcmin diameter circular field. Each channel can be divided into smaller pass bands using a selectable set of filters.

UVIT observed NGC-188 both as a first light object and for regular calibration. The observations have been done in both NUV and FUV filters in the wavelength band of 0.3 to 0.15 µm. With these observations, it is found that the SED can only be fit with spectra consisting of 2 stars. The cooler star is found to be a BS with a temperature of 6,000$\pm$150 K, and the temperature of the hotter star is 17,000$\pm$500 K. The estimated size and luminosity of the hotter star rule out a white-dwarf or a sub-dwarf classification and hence it is proposed that it could be a post AGB/HB star. If the membership of WOCS-5885 to NGC-188 is confirmed, it could be a rare BS + post AGB/HB binary, the first of its kind to be identified (for which probability is high) in an open cluster. This system therefore provides a great opportunity to constrain theories of BSS formation via mass transfer.

Thus, observations from the UVIT were used to solve the puzzle of a star WOCS-5885 which appeared as a single star but whose spectra did not match with this identity.

The Ultra-Violet Imaging Telescope, or the UVIT, is a remarkable 3-in-1 imaging telescope. Weighing all of 230 kg, the UVIT can simultaneously observe in the visible, the near-ultraviolet (NUV) and the far-ultraviolet (FUV). UVIT comprises of two separate telescopes. One of them works in the visible (320-550 nm) and the NUV (200-300 nm). The second works only in the FUV (130-180 nm). Remember that the famous Lyman-a line of Hydrogen is at 121.6 nm, at the far end of the FUV, and even beyond that is the X-ray band for which AstroSat has four different telescopes.

Figure 3 - The UVIT on board ASTROSAT

UVIT has a spatial resolution of 1.8 arcseconds and a field of view of 0.5 degree. In comparison, GALEX, an ultraviolet telescope that was launched by NASA had a larger field of view of 1.2 degrees but a resolution of about 5 arcseconds.

Each of the two Ritchey-Chretien type telescopes of UVIT have a primary mirror of 37.5 cm diameter, specially coated with material that very efficiently reflects ultraviolet photons. These mirrors, hyperbolic in shape in order to minimise optical errors, reflect the incoming light to a secondary mirror, which in turn focuses the light onto a filter wheel and the detector.

Just as optical telescopes have filters to image the sky in the red or blue or green range of wavelengths, so also the UVIT has filters to image the NUV and FUV (and the visible) in different narrow wavelength bands. These filters are mounted on wheels which can be spun to bring whichever filter the astronomer wants into the light path.

After the filters, the actual detectors are mounted. These are photon counting detectors and can measure the location and time of incidence of each photon individually. They can also operate in the integration mode (like a CCD camera) and the visible channel will mostly be operated in this mode. These photons are then read out using 'intensified CMOS' readout cameras. Objects are far fainter in the ultraviolet than in the visible and hence each photon is first hugely amplified before it is allowed to fall on the 0.25 Megapixel camera. The UVIT is now sensitive enough to detect a single ultraviolet photon and time of its arrival to within 5 millisecond accuracy! The UVIT can image the field of view 30 times a second (and in special cases, even 200 times a second).

UVIT was a challenging instrument to design and build. It had to deal with the unique problems of ultraviolet astronomy, incorporate modern technology and also withstand the intense mechanical vibrations during launch and the thermal and radiative extremes of outer space.

The intensified CMOS detector works by converting incoming photons to electric charges. Hence, the UVIT can be permanently damaged if it is exposed to very bright light. Sunlight scattered from the satellite, the light reflected from the Earth's surface, emission from molecules (like O_2) in Earth's outer atmosphere when excited by the Sun and even sunlight scattered off the dust in the solar system can threaten the safety of UVIT. Hence, the telescope will observe only at night, and has a number of electronic and mechanical features to safeguard its sensitive insides, to ensure that it produces pathbreaking science.

Indian Institute of Astrophysics (IIA), Bangalore and Inter University Centre for Astronomy & Astrophysics (IUCAA), Pune in collaboration with Canadian Space Agency (CSA) have developed this payload.

For details:

Subramaniam Annapurni et al., A Hot Companion to a Blue Straggler in NGC-188 as Revealed by the Ultra-Violet Imaging Telescope (UVIT) on ASTROSAT-The Astrophysical Journal Letters, Volume 833, No. 2, 19 December 2016.

(with inputs from Dr S Seetha, Program Director, Space Science Program Office, ISRO)

25 years ago

The National Science Day was celebrated on 28th February 1992. It was inaugurated by Sri G Muniyappa, IAS, Secretary Department of Science and Technology, Government of Karnataka. Prof H Narasimhaiah, Former Vice- Chancellor, Bangalore University and Member, Governing Council, was the Chief Guest. Former Director Dr G S D Babu organized the event which had models exhibited by ISRO, IIA, VITM and many more research institutes.

First Celebration of National Science Day

The tides and earth's rotation

- Shylaja B S

It was believed that the Earth's orbital /spin motions are quite stable, to the extent determinable by the best instruments. The mechanism can be understood by basic laws of gravitation. The earth and moon both rotate around the common center of mass. Figure 1 represents the centers of the earth and the moon as E and M. We may consider point N nearer to the moon and the point F farthest from moon for calculating the differential acceleration. E goes round the center of mass C and so do the points N and F. We can calculate the acceleration at N and E due to moon as

$A_{NM} = GM_M / (R-r)^2$

and

$A_{EM} = GM_M / R^2$

where R is the earth-moon distance, M_M is the mass of the moon and r is the radius of earth.

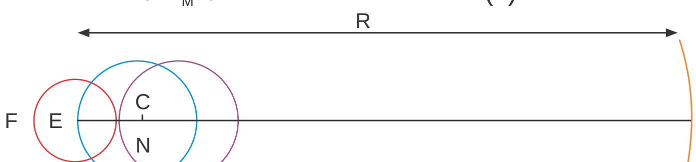
The acceleration of N relative to E will be

$A_{NE} = A_{NM} - A_{EM} = \{GM_M / (R-r)^2\} - \{GM_M / R^2\}$

Since r << R, we can simplify this as

$A_{NE} = GM_M / R^2 \{1 + 2r/R\} - GM_M / R^2$

$= 2 GM_M r / R^3$ (1)



E-Earth, M-Moon, C-Centre of Mass
N-the point nearer to Moon, F-th point farther from Moon

This is directed towards the moon.

Similarly we can calculate the acceleration at F also as

$A_{FE} = 2 GM_M r / R^3$

This is directed away from the moon.

We now consider the effect in the perpendicular direction as shown in Figure 2 at a point P. The Acceleration is directed along PM.

$A_{PM} = GM_M / PM^2 = GM_M / (R^2 + r^2)$

This can be resolved along PE and EM.

$A_{EM} = GM_M / \{R^2 + r^2\} * R / \{R^2 + r^2\}^{1/2}$

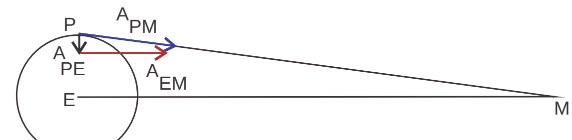
neglecting higher orders of r/R

$A_{EM} = GM_M / R^2$

For the other component,

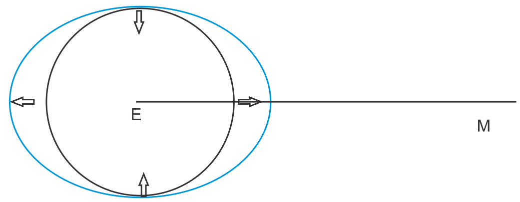
$A_{EM} = GM_M / \{R^2 + r^2\} * r / \{R^2 + r^2\}^{1/2}$

$= GM_M r / R^3$ (2)

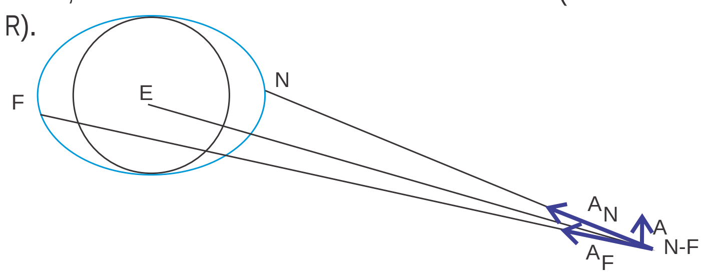


A_{PM} Accelerate at P due to Moon

Notice that this is exactly half of (1). This implies that along with stretching along the earth-moon line, there is also a compression in the perpendicular direction. These may be called land-tides amounting to values of the order of a cm. (Figure 3). However the same force on fluids can lead to dramatic results. The ocean can be treated as a uniform shell surrounding the landmass. The height of the tide can be estimated ignoring differences in surface features.



All these expressions have not included the rotation of the earth, which results in two important effects. The water body of the ocean will not react to the force instantaneously and hence there is a time lag. This is taken care of since the change in the moon's position is slow as compared to the spin of earth. The second effect pertains to the friction between the solid earth and water. The difference in the near side and far side accelerations results in a net acceleration on the moon (Figure 4). This is a very small change but the long term effects cannot be ignored. There is a net increase in the angular momentum, though small, and results in the recession of the moon (increase in R).



Let us consider the total angular momentum of the earth – moon system and visualize the effect. There are three components contributing to it – rotation of the earth and moon, revolution of moon.

$W = p M_E r^2 w + p' M_M r_M^2 w_M + (GM_E R)^{1/2} M_M$

where M_E and M_M are the masses, r and r_M are the radii, w (= 2p/P) and w_M are the angular speeds of the earth and the moon respectively. p and p' are constants. The second term corresponding to the spin of moon can be ignored for differentiation to get the rate of change of spin period P of earth and R the distance as,

$$dR/dt = 4ppr^2/P\, M_M * (rM_E/G)^{1/2}\, dP/dt \qquad (3)$$

If we determine dP/dt, the rate of change of R can be found.

The above derivation is a very simplified version. The center of mass lies within the earth at a distance of about 4680km from the center of earth. The variation of distance resulting from the elliptical orbit, the tidal force due to the sun, differences in surface features and non uniform distribution of water – all these have to be taken in to consideration. For estimating the height of tide the latitude of the place also is important.

Now we have methods and tools to detect the variations in both angular speed and direction of Earth spin.

Before the advent of quartz clocks, rotation of the Earth was regarded as the most reliable clock. The observations of star transit across meridian achieved accuracy better than 1 millisecond in the 1950s which led to the detection of periodic variations in the length of day (LOD). There were annual, semi-annual, and fortnightly perturbations. The Universal Time (UT), which is based on rotation of earth, has been replaced by the International Atomic Time (TAI) based on atomic clocks.

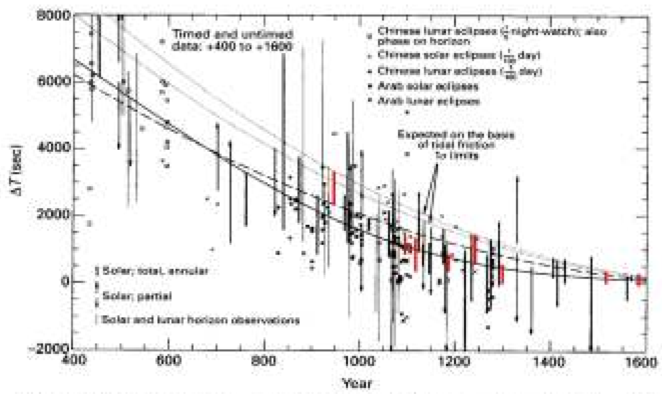
Based on the understanding of the tidal friction in the oceans and solid earth during tides, Immanuel Kant (1724-1804) and George Darwin (1845-1912) suspected a decrease in the speed of rotation of earth. They concluded that the lunar orbit should be modified accordingly.

Satellites play a very important role in the measurement. Their orbits are continuously monitored for effects other than earth's gravitation for example from the moon, the sun and solar radiation pressure. Lunar laser ranging initiated by Apollo 11 provides a direct estimate of the present lunar recession as 3.82 cm/yr.

Paleontological evidences like the tree rings have supported the tidal effects. The differential growth of shells of corals record high and low ocean tides. Ring Laser Gyroscope measures very accurately the earth's spin rotational angular velocity. VLBI (Very Long Baseline Interferometry), Global Positioning System (GPS), Satellite Laser Ranging (SLR) have been of great use.

Historical eclipse records have contributed to the study of the variation of the rotation period. A stone tablet records a total solar eclipse in Babylon on 15th April 136 BCE. The computations based on the assumption of a uniform rotation speed put the shadow path about 500km away from this place. Now the rotation speed can to be adjusted to match the observational record. A small change in the length of day by 64ms would result in a shift of 13 hours of the eclipse time. Without applying this correction we will be wondering how they recorded a solar eclipse in the night!

Thus accurate records of the timings of solar eclipses of the past can help in tracing the variation of the speed of earth. Chinese and Arab records have greatly contributed to this. After the advent of telescopes, there is a systematic record of the timings based on which the small time difference between a standard 24 hour clock and the actual rotation period has been maintained. The variation does not appear to be smooth. (Figure 5)



Combined timed and untimed data for the period from +400 to +1600. (Courtesy: Dr L. V. Morrison.)

All over India, we see stone inscriptions almost in every village. There are more than 30000 inscriptions in Karnataka alone. The grant of donations, gifts and even self immolations for attaining salvation were performed on important celestial events like eclipses. Thus they serve as unconventional record of eclipses and other celestial events.

It is amazing that stone inscriptions from non-descriptive villages like Otturu in Soraba Taluk (eclipse of CE 938, Feb 3), Pattadakallu in Badami (eclipse of 754 CE, June25) and Soundatti in Belgaum (eclipse of 1087 CE August 1) have contributed to the understanding of the variation in the speed of rotation of earth. (the red lines in Figure 5).

The calculations of equation (3) can be extended to reveal another interesting aspect. dP/dt value of 0.0016s results in dR /dt of 0.029m/year. This means that in a billion year from now the moon would have moved away by 29000 km. Its angular size decreases to 28'. This may not be noticeable to the naked eye. But this is marginally smaller than the angular size of the sun. So, there will be no more total solar eclipses!

Counterintuitive Experiments in Physics

- H R Madhusudan

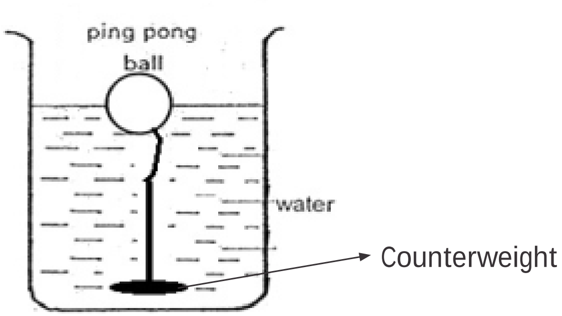
Experiments play a pivotal role in the teaching and learning process in science. Right from the elementary classes to the postgraduate courses, experiments occupy a central position. Yet, we see students at all levels fumble with even elementary ideas. This is partly due to the fact that experiments are either not carried out or they are not carried out in the right way. Here, we are not talking of the mandatory experiments that students perform as a part of their course. We are talking of the experiments that help one develop concepts in the right perspective. Consequently, we see a number of students, including the 'bright' students make mistakes in their analysis of certain situations that are not at all unfamiliar to us. Let us have a glimpse of some of the concepts that are often misinterpreted.

Suppose we have a cylindrical pipe of length 'L'. Measured from the top, three holes of same dimensions are made at 'L/3' 'L/2' and '3L/4' lenghts. Now the pipe is filled with water and the water level is maintained. The question for the student is:

"Water coming out of which of the three holes covers a maximum horizontal distance or range as in a projectile motion?"

This experiment can be demonstrated and shown while discussing projectile motion and also Toricelli Theorem for fluids.

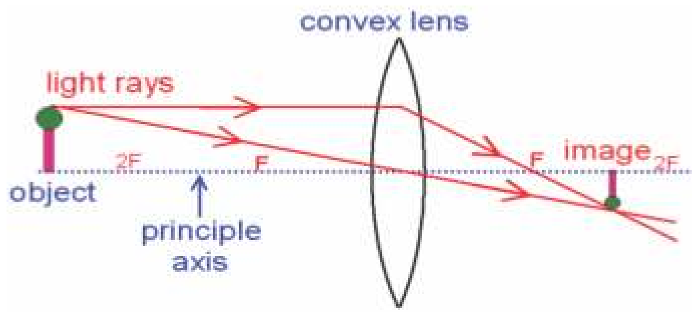
While on fluids, here is another nice little experiment. Fill a beaker with water. Float a table tennis ball as shown in the figure. Suppose one accelerated it a certain direction, say to your left. In which direction does the ball initially move? In the same direction as the beaker or in the opposite direction?



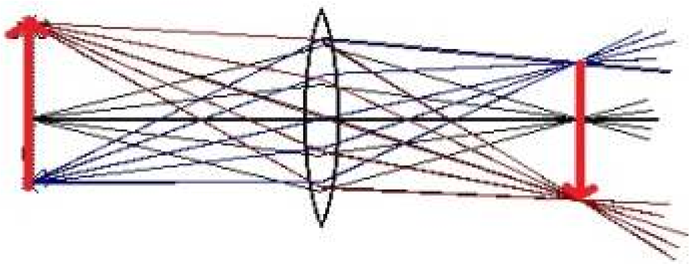
It will be very illustrative if this demonstration is preceded by suspending a simple pendulum in water. Compare the directions in which the bob of the pendulum and the table tennis ball move. Again we have seen that students make incorrect guess – that the ball moves in the direction opposite to the direction in which the beaker accelerates.

Here is another demonstration that students find rather difficult to analyse correctly. Suppose we consider an arc of a circle for a horizontal track in which a steel ball moves along the inner periphery. The question is: "Predict the path of the ball after it leaves the track". Again we find that a majority of the students predict a circular path – in continuation of the path traversed by the ball before leaving the track. They seem to look upon this instance as a sort persistence of motion. They do not consider the track as a constraint that made the ball move in a circular path. And, that at the exit point the ball does not experience any constraint. As such, the ball leaves the track and moves along a straight line drawn tangential at the exit point of the circular track. This experiment, indeed, requires a whole session or two of discussion before students appreciate the finer aspects of applying Newton's Laws of motion.

Image formation by lenses and mirrors is another grey area of learning. Mostly because the ray diagrams drawn in text books as well as in classes induce misconceptions. Take, for instance, a double convex lens.



Suppose you show to a class of students the image formed by a convex lens. Usually the situation is explained by drawing ray diagrams that include specific rays from the object. Typically, we have one ray travelling from the top most point of the object towards the lens. Another from the bottom most point. On refraction, the bottom ray moves up and the top ray moves down intersecting at the point of focus. Then, the inverted image is shown. So far fine. The problem comes the moment you ask them, " What changes do we notice in the image if top half of the lens were to be covered with a cardboard?" The answer most often heard is that the top half of the object will be missing in the image. When the experiment is actually demonstrated, there is a gasp among them. The whole object is represented in the image. Only, the intensity of the image has diminished! Why do students commit this blunder? Mainly because, teachers and the text books don't emphasise on the fact that a number of rays travel from every point on the object through the lens.



There are several other questions that can go with this experiment. Suppose the dimensions of the object is greater than that of the lens, will the image contain every point of the object? Then again, suppose one half of the lens is covered with a red cellophane paper and the other half with green. Will there be a colour inversion in the image? Or will the whole image have a uniform colour that is neither red nor green but a mixture of the two? The topic of image formation demands more attention than what has been discussed here.

So we see that concepts that we think to have been understood offer lot of surprises in the light of carefully designed but simple experiments. There is a need for classroom teachers at all levels to plan out conceptual experiments and allow the students to probe a vast number of parameters that have a bearing on the outcome of the experiments. It is only then that concrete concepts are crystallized.

REAPers Speak

The Fascinating Night sky

- Deepak Dembla

I used to spend my weekends with my grandmother when I was in school. My bed was under the moon lit sky or a starry night in the garden in summer and in winter with a thick blanket. Loved watching stars and occasionally see shooting stars. Fascinated by the beauty of night sky I bought my first book in Astronomy, Phillip's Star Chart and started to identify stars and constellations. My physics teacher, Ravinder Kumar Panday knew about my interest in Astronomy and took me to Jawaharlal Nehru Planetarium for an Astrophysics course. Under the guidance of Dr.Shylaja my interest in Astronomy deepened. We were introduced to Co-ordinates Systems, Spherical Astronomy and many more concepts on stellar evolution. Occasional talks from well know Astronomers from Indian Institute of Astrophysics like Dr. Vishveshwara fascinated us. Science experiments and exhibitions organized by Madhusudhan Sir revealed how science is seen and used in real life using simple tools.

We went to Kavalur, a journey which was not smooth. The train which we were to board was cancelled and we had to stand and travel in the subsequent one. Alighting at Jolarpettai we discovered that there was a total bundh (arrest of Madam Jayalalitha). Finally we changed a couple of private buses and managed to reach Kavalur by evening. The beautiful sky there made us forget all the trouble we had on the way.

Dr. Shylaja knew about my interest in Observational Astronomy and introduced me to Mr. Dilip Kumar who was the president at that time of Association of Bangalore Amateur Astronomers (ABAA) club.

I still remember my first observation trip to village called Shivanahalli. It rained the whole afternoon. I was disappointed. We all went for a tea and while walking back, we saw band of clouds obstructing our view. I said too many clouds to do some observations. Dilip smiled and said “that's Milky Way I Say”. It's the galaxy we live in. I was surprised and overjoyed to see that beautiful view. That was one of the most unforgettable moments in my life.

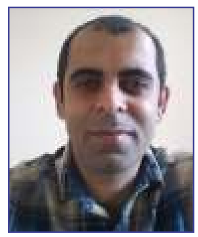
With the help from Dilip and all others in the club, my skills in observation and use of telescope got better and I also made my own telescope. My main interests were deepsky galaxy hunting and looking for comets. I still remember hunting for 14th to 15th mag galaxies in the Virgo cluster and watching 4-5 galaxies in the same field of view using the 12” telescope. There were times when everyone in the club was busy, and I would go alone to a village and do some observations on my own. I was also introduced to astrophotography by Dilip and took pictures of Milky Way and comets.

I moved to London in 2006 and been busy with work and other activities. But astronomical events (Comets, Eclipse and of course my quest for galaxies) always catch my interest. Coping with the London light pollution and clouds and with a lot of running around, I managed to capture comet Lovejoy (2014 Q2) and the Total Lunar Eclipse in the year 2015. With interests in observations and astrophotohraphy, I'm now able to put my 8” telescope to good use. I use Digital SLR camera, stacking and various image processing techniques to get a better view of our observable universe. I'm still challenged with the London weather, only 40% of the sky visible from where I live, and light pollution. But still manage to view the heavens above.

Total Lunar Eclipse - 12th Sept 2015.

Whirlpool Galaxy - 57 X 10s, ISO: 1600

Comet Lovejoy Q2 taken on 18 Jan 2015. ISO 400 19X30s

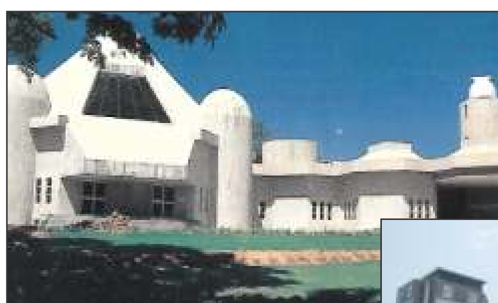


Deepak Dembla attended the sessions in astronomy at the Planetarium to evolve in to an amateur astronomer. He works as a Computer Software Developer in London. He still pursues Astronomy and photography as his hobby in London and keeps interacting with his friends in Bangalore. Apart from observing the sky and astro-photography, Deepak loves body movement and sports. He's trained in Martial Arts for a couple of years. He's now focused on Parkour or Free Running. Deepak also dances and occasionally teaches Salsa.

The changing "sky"scape.

The Planetarium has been organizing sky watch events for over 27 years. The only comets that had the privilege of getting the attention in this program were Swift Tuttle (1992), Hyakutake (1996) and Hale Bopp (1997). The changing sky line can be clearly seen in the pair of images and the effect of the associated light pollution deprives the view of even Orion nebula today. (The one with the blue sky was taken in 1992.)

The evolution of the science park is also noticeable.



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