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GUEST EDITORIAL

Indian astronomy in the next decade

Young students are always attracted by the night sky. The fact that light from any object in the sky takes some finite time to reach us is very fascinating. While this confirms that no instantaneous communication is possible, it is also allowing us to see how things were looking in the past. Unlike other physics experiments, astronomical observations are restricted to very few basic measurements like flux, shape of objects, line and continuum spectrum, polarization and time-variability of all these quantities. We are still able to get lot more information from these basic set of observations, thanks to high precession measurements interpreted in the framework of some standard physical models (like using Newton's law for measurements related to motion under gravity and Hubble expansion to measure distances to objects based on Doppler shifts, etc.). As our ability to compute physical quantities and measure them accurately increases, we are able to ask and answer more and more fundamental questions related to our universe.

Some of the outstanding questions related to our universe that remain to be answered are: (i) origin and evolution of the universe; (ii) constituents of the universe (normal baryonic matter that our earth and we are made of, dark matter and dark energy); (iii) are basic fundamental interactions that govern physics in earth are also valid at different space and time in the universe? (iv) is general relativity valid at extreme regimes? (v) when did first stars form in our universe? (vi) when our universe transformed from being completely neutral and cold to being highly ionized and warm (i.e. so-called epoch of reionization); (vii) how galaxies form, evolve and cluster around each other? (viii) formation and evolution of super-massive blackholes; (ix) what establishes the connection between central blackhole and stars in a galaxy? (x) how many habitable planets are there in our galaxy? and (xi) can we detect bio-signature of life in space. One can make good progress on these issues using theoretical models and numerical calculations (within the framework of what we know? or what we can guess? or more importantly what we will be able handle?). The final understanding is always driven by high precision observations.

It is important to note that researchers from India and of Indian origin have contributed immensely to our present day knowledge on various issues highlighted above. Important contributions have come from the Indian community on the theoretical understanding of various issues. Individual brilliance and joint programmes of few individuals with researchers abroad have contributed to various observational discoveries. However, given the enormous interest young Indians show towards cosmic observations there is immense potential to increase our direct contribution to cutting edge observational astronomy.

We have several running observatories in the country. However the biggest optical telescopes we operate in India are a factor 3 to 5 times smaller than the world's biggest operating telescopes today. In terms of building high precision instruments, we lag behind the US and Europe by few decades. It is commendable that Indian astronomy community produces interesting results despite these shortcomings. What is more interesting to note is that people trained in our institutes are leading various large science programmes in US and Europe. So in my opinion, things can dramatically change (i.e. more students taking up very top end astronomy as their carrier and extremely skilled Indians work and lead large science programmes from India) if we get access to building and operating the world's best facilities. It appears that such a situation is arising in India in the coming decade.

International community is setting up the next generation observing facilities across the globe and space to answer the questions listed above. These include three extremely large optical near-infrared telescopes (Thirty Meter Telescope (TMT) in Hawaii; Giant Magellan Telescope and European Extremely Large telescope in Chile). These telescopes will have deep imaging and spectroscopic capabilities and will operate at the diffraction limited spatial resolution using Adoptive Optics techniques that compensate the image blurring produce by our atmosphere. These telescopes, with the expected life time of several decades, will start their operations around 2026–2028.

Similarly the radio astronomy community is setting up Square Kilometre Array (SKA) in South Africa and in Australia. While the observatory in South Africa will be operating in the mid-frequency range (~GHz), the Australian observatory will be operating in the low-frequency range (~100 MHz). The SKA is expected to have more than several orders of magnitude higher sensitivity than the existing telescopes. The expected data gathering rates from SKA per day are expected to be as large as the entire planet does in a year. Therefore the challenges are not only related to building an excellent telescope but also in efficiently handling the data at various stages.

Building and running costs of these telescopes (close to 1–2 billion USD for the construction and about 10% of this for the running cost every year) and instruments are beyond the capabilities of few institutions or a single country. The best way forward is to build through international partnerships.

Most importantly, Indian astronomers will be directly involved in these projects from the inception. Through DST–DAE programmes, India is now part of the TMT project (at 10% level partnership). Up to 70% of the Indian contributions will be spent in India for (i) polishing ~80 mirrors that will be part of the array of primary mirrors; (ii) providing mirror support systems and actuators that will keep different segments aligned to produce a single large 30 m aperture mirror and held it intact during observations; (iii) provide software support for controlling the telescope and the observatory; (iv) participating in the development of first generation instruments, and (v) leading the construction of 2nd generation instruments. These efforts will be lead by Indian astronomers and engineers in collaboration with Indian industries. Various facilities that are being set up now for this purpose will be useful for our future experiments in land and in space. Indian astronomers are part of all the international working groups for developing science cases and drafting required specifications for the telescopes and instruments. As part of human resource development efforts are being made to train young people in various sophisticated astronomical techniques.

Similarly India will be one of the partners with approximately 6% share in SKA project. Like in TMT considerable amount of Indian contributions will be spent in India. As of now India is engaged in developing the telescope control system for SKA and involved in the development of various sub-systems like receivers and developing special techniques for detecting signals from pulsars to the epoch of reionization, etc. The Giant Metrewave Radio Telescope operated by National Centre for Radio Astrophysics is now recognized as one of the SKA path finders where some of the advanced technologies for SKA will be prototyped and tested. The Indian community is developing large science programmes to be carried out with SKA and is represented in all science and technical working groups of SKA.

When these telescopes become operational, complementary information could come from other upcoming facilities like: (i) James Webb Space Telescope, to be launched in space around 2021, will provide data of unprecedented quality over the optical and infrared wavelengths. Though India is not a partner in this project, Indian astronomers will be able to get time through competitive proposal processes. (ii) Advance Laser Interferometer Gravitational-wave Observatory (LIGO) searching for gravitational wave events. One of them will be operating in INDIA (LIGO-INDIA) in the next decade. Indian community is part of LIGO project from the very beginning. Having access to TMT and SKA will give a boost to Indian community in leading the efforts in identifying distant counterparts of the gravitational wave events. (iii) Large all-sky surveys like 'The Large Synoptic Survey Telescope' (LSST) will monitor all the visible sky continuously. LSST is expected to provide a list of variable sources that may probe very interesting transient events occurring in space every day and also provide deep multi-band images of the universe to an unprecedented depth by adding data over a period of time. Some Indian institutes are members of the LSST consortium and will have access to these data that can provide interesting targets for follow-up studies using TMT and SKA.

All this means, from early next decade our science and engineering students will get a chance to directly work on cutting edge science and technology projects related to building and operating these telescopes. In particular, students with varied background in physics and engineering can have a role to play in this large scale high technology developments. By the end of next decade, when these telescopes will be operational, Indian researchers and in particular young Ph D students will have direct access to world's largest facilities in the optical to radio wavelength ranges. This will encourage them to take up the more challenging and exciting observational programmes that will probe our universe to unprecedented depths.

It is now well documented that a successful observatory will be able to allocate only about one sixth of the requested observing time. In other words if typically 6 experiments are proposed only one will get a chance to perform the observations. Moreover, the more the subscription factor the more will be the quality of the scientific outcome. This is because, in order to be successful a proposal should have a solid observing plan with a demonstrable ability to analyse and interpret the data using high quantity analysis tools and simulations. Therefore, in order to maximize our scientific returns from our investments in TMT and SKA, it is imperative that we develop a competent and competitive user community. This means more than doubling the number of practising astronomers with enhanced skill sets. In parallel we should also be developing more sophisticated data analysis and simulation tools so that the high quality data we obtain can be interpreted appropriately. These things also take the same amount of time and efforts as building the large facilities.

Thus the next decade looks very exciting, promising and challenging for Indian astronomy.

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