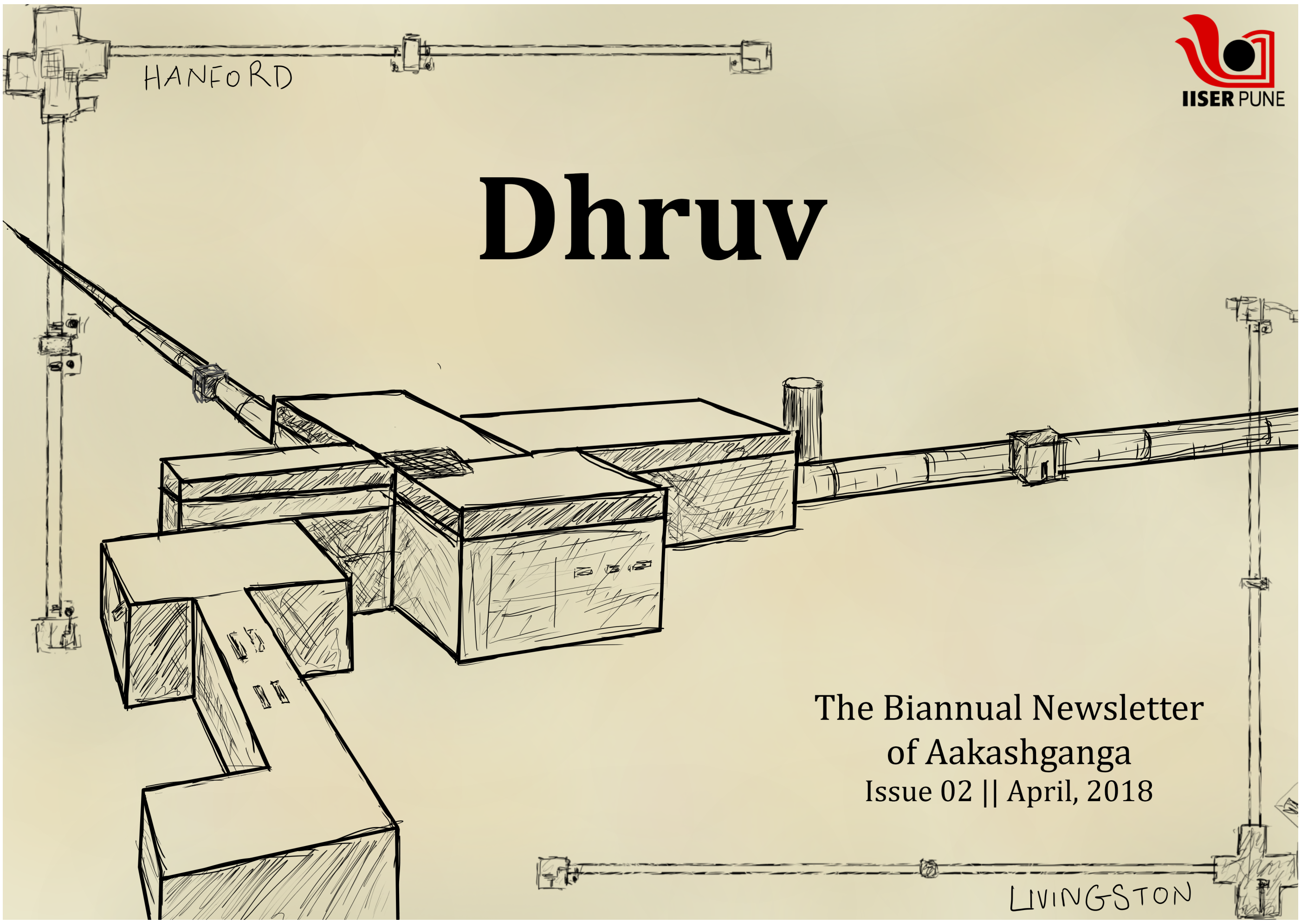
Dhruv



The Biannual Newsletter
of Aakashganga
Issue 02 || April, 2018

Aakashganga is the Astronomy and Astrophysics club at the Indian Institute of Science Education and Research (IISER), Pune. From serene skywatching to deep talks and from lively workshops to intense discussions, Aakashganga organises a plethora of events throughout the academic year. We aim to spark curiosity among the IISER community about the marvels of astronomy and provide astronomy enthusiasts an opportunity to explore their interests. To catalyse this objective, Dhruv was started in January 2015 and now it reports back to the IISER base after a three-year-long interstellar voyage.

In this second issue, we wish to highlight the uproar created by the discovery of gravitational waves in the fabric of science. Generations after generations have been fascinated by the night sky. For a long time, studying astronomy involved discerning the many different patterns that we could only see. As we explored, we discovered various windows to observe our universe, gravitational waves being the latest, which enable us to listen to our universe. For most part of history, humans have made massive telescopes to study celestial phenomena. And LIGO is one of the latest and the most sensitive technologies available to observe our universe. Using gravitational waves to 'hear', we can observe intriguing phenomena like collisions of black holes, neutron stars, and supernovae. Compiling data from different wavelengths and LIGO, we can find new science which has eluded us before. Otherwise invisible objects might be revealed and studied. That a prediction made by a theory over a century ago can be verified now, emphasizes the power of scientific enquiry and is worthy of the Nobel prize along with the immense excitation around it.

The year 2017 also harboured the awe-inspiring discovery of the Saraswati supercluster, made possible by the extraordinary intuition of Prof. Joydeep Bagchi and the joint effort of his group. We are proud to proclaim that this group had Mr. Shishir Sankhyayan, a doctoral student at IISER Pune, as a member. We are grateful to him for elucidating this discovery with a public talk which invoked an enthusiastic discussion from the audience, a reflection of the pride we feel about the sheer magnitude of this finding.

India is emerging as a heavyweight in the world of science. Our achievements in the yesteryear are something to be proud of. ISRO scientists set a world record by launching the highest number of satellites in a single launch and the heaviest payload (GSAT-19). This has made heads turn towards India as a cost-effective and reliable option in the commercial launch of satellites. In addition, a large contribution to the Nobel winning discovery of gravitational waves was made by our very own scientists at home. These recent discoveries and the momentum provided by our feats in the last decade has made dream projects like IndIGO and ADITYA-L1 a near reality. Upcoming projects like these will catapult India to the forefront in scientific research.

This newsletter is incomplete without acknowledging the unwavering support of Dr. Prasad Subramanian, our Faculty Coordinator. Our sincere gratitude extends to Dr. P Ajith (ICTS, Bangalore) for writing the enlightening article 'A New Astronomy' and we hope to receive more in the future. We thank Prof. Sanjeev Dhurandhar (IUCAA, Pune) for sharing his views and experiences in an interview. We are also grateful to Prof. Joydeep Bagchi's group (IUCAA, Pune) for contributing an article about their discovery for Dhruv. We also appreciate the time taken by Anup Anand Singh, Ramesh Chandra Ammanamanchi and Shruti Chakravarty (IISER, Pune) for reviewing the content and providing us with their valuable suggestions.

Seat belts checked. Landing site locked. Descending in 3...2...1...and Touchdown!

FROM THE FACULTY CO-ORDINATOR

Greetings on bringing out this edition of Dhruv - the newsletter of the Astronomy and Astrophysics club of IISER Pune. The tradition of enthusiastic participation in astronomical activities is being adeptly carried forward by the new crop of students. We have had informative talks by experts on diverse areas such as Gravitational Wave detection, overview of telescopes, the recent discovery of the Saraswati Supercluster and image processing in Astronomy. The emergence of the Centre of Excellence in Science and Mathematics Education (CoESME) has also provided opportunities for synergistic activities with our club. We look forward to hosting a telescope making workshop, guided by experts from the Science Popularization Centre at IUCAA situated close by. This will pave the way for regular sky watching sessions, which we hope will evolve to become a mainstay of our club. I wish the club much success in their efforts.

With Best Wishes,
Prasad Subramanian

Dhruv is Sanskrit for Polaris, the pole star. Probably the most important star in the Northern Celestial Hemisphere, Polaris for long has been used in navigation and Astrometry because of its apparent motionlessness in the sky. Hence, the name of the newsletter; an inspiration to guide us all along.

The logo of the newsletter recognizes the contributions of Radio Astronomy towards the advancement in the fields of Astronomy and Astrophysics and hence in improving our understanding of the universe.

TEAM DHRUV 2018

EDITORIAL TEAM

Shomik Adhicary

Shriya Hirve

Saismit H Naik

Palash Singh

Onkar Sadekar

Anwesha Maharana

DESIGN TEAM

Harshavardhan B V

Aagam Shah

A NEW ASTRONOMY

DR. PARAMESWARAN AJITH

The existence of gravitational waves is one of the most intriguing predictions of Einstein's General Theory of Relativity. One of the cornerstones of modern physics, this theory describes gravity as the curvature of spacetime. Any massive object (and other forms of energy) would curve the spacetime around it, resulting in a number of observable effects. Gravitational waves were the only prediction of General Relativity that evaded a direct observation until recently, although their existence was confirmed by a strong body of indirect evidence through radio observations of binary pulsars starting from 1970s.

General Relativity predicts that whenever massive objects (or energy concentrations) move with acceleration, the spacetime curvature not only follows them, but also decouples from the source and propagates outwards at the speed of light. Such freely propagating oscillations in spacetime are called gravitational waves. Generation of gravitational waves through the acceleration of masses is analogous to the generation of electromagnetic waves through the acceleration of charges. Although any motions of masses produce gravitational waves, most of the time these are too weak to be detected by any conceivable technology. However, astrophysical phenomena involving massive and compact objects moving with speeds close to that of light can generate enormous amounts of gravitational radiation that can travel through cosmic distances unaffected by the intervening matter.

CATCHING THE WAVE

At large distance from the source gravitational waves can be thought as oscillations in the geometry of space. These oscillations have a characteristic quadrupolar nature. These deformations can be detected by means of sensitive laser interferometers. LIGO consists of four-kilometer long interferometers at the two observatories in Hanford, Washington and Livingston, Louisiana in the USA. Interferometer mirrors act as test masses and the passage of gravitational waves induces tiny changes (less than 10−18 meters) in the arm length. This generates power fluctuations in the interferometer readout port that is measured by photodiodes.

LIGO detectors, which have been operational for a decade, underwent a major upgrade in 2015, graduating to a configuration called Advanced LIGO. As soon as they started operating, they detected the first gravitational-wave signal on 14 September 2015. The signal was produced by the merger of two massive black holes at a distance of a 1.3 billion light years away from the earth. This observation was followed by five other confirmed detections of binary black hole mergers over the last two years by LIGO and its sister observatory Virgo in Europe. These observations not only confirm the century-old prediction of Einstein's theory, but also open up a fundamentally new branch of astronomy. In addition, the recent observation of gravitational waves and multiple wavelengths of electromagnetic radiation from a binary neutron star merger heralds the dawn of multi-messenger astronomy. Quite fittingly, the 2017 Physics Nobel prize was awarded to three prime architects of LIGO – Rainer Weiss, Barry Barish and Kip S Thorne "for decisive contributions to the LIGO detector and the observation of gravitational waves."

A NEW ASTRONOMY

These observations could be compared with Galileo's first observations using the newly invented astronomical telescope, or the detection of the cosmic microwave background radiation in the 1960s — what was originally just a hiss recorded by a microwave antenna eventually turned into an astonishing set of observations that revolutionized our understanding of the origin and structure of the universe.

Based on the rate of observed signals, LIGO and its sister observatories are expected to detect hundreds of binary mergers over the next few years. A large number of such mergers happening at different parts of the universe is expected to produce a stochastic background of gravitational waves which might be detected in the next several years. In addition, we speculate the possible detection of spinning neutron stars and core-collapse supernovae. Indeed, the "holy grail" of gravitational-wave astronomy is to directly detect the stochastic gravitational-wave background from the early universe. Such an observation, analogous to the cosmic microwave background radiation, would provide us a direct access to the so-called inflationary epoch following the Big Bang, which is inaccessible to current astronomical observations. Gravitational-wave astronomy is opening up a unique new window to the cosmos.

Dr. Parameswaran Ajith is a physicist at the International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, Bangalore and a member of the LIGO Scientific Collaboration.

TOTAL LUNAR ECLIPSE AND SUPERMOON

A Sky-watching session, Total Lunar Eclipse.
During the eclipse (top, and bottom left). The Moon with the Orion Belt (bottom right).
Photographs: Sujay Paranjape, Second Year BS-MS.

DIGGING DEEP FOR SILENT TREASURES!

ANUP ANAND SINGH AND DIVYA SINGH

With multiple new gravitational-wave detections that have opened a window into a plethora of new classes of astronomical objects — one of them being a binary neutron star merger, that generated further excitement because of the wonderful opportunity of an electromagnetic follow-up survey — 2017 was one of the most exciting years for gravitational-wave physics. The *Nobel Prize in Physics 2017* went to the three scientists who led this half-a-century-long quest to make these miraculous discoveries. The year also saw LIGO's European counterpart, Virgo, joining the twin US-based detectors in the search, thus paving way for improved localisation of sources in the sky.

The signals we have detected so far belong to the class of *inspiral gravitational waves* — short-lived waves that are produced during the final life stage of binary systems of compact objects ending in a catastrophic coalescence. But you don't really need super-dramatic events like mergers of black holes (or neutron stars) to generate gravitational radiation. Gravitational waves, after all, are distortions in the four-dimensional fabric of spacetime caused by moving masses. Even a rapidly-rotating compact star with some irregularity on its surface will significantly distort spacetime - the gravitational radiation emitted from such sources will, however, be characteristically different. Unlike inspiral gravitational waves whose frequency keeps on increasing till the moment of coalescence, gravitational waves generated by rotating asymmetrical neutron stars, called continuous waves, are typically long-lived and have a fairly constant frequency.

Rapidly-rotating asymmetrical neutron stars are, in fact, particularly strong candidates for being sources of continuous waves that can be detected using ground-based observatories in the near future. These waves are expected to be roughly four orders of magnitude weaker than those from the merger events we have observed till now. But again, these *stronger* signals that we have detected are themselves so feeble that the corresponding change in distance between the detector arms is even smaller than a billionth of the size of an atom. Another challenge one faces while searching for these signals is the huge computational investment required to analyse months and months of data. The entire process of detection and analysis becomes further challenging because of numerous sources of noise — both intrinsic to the detector setup, and those generated due to seismic and environmental disturbances in the vicinity of the detectors, particularly those that are periodic and persist for longer durations.

The ongoing efforts to detect continuous gravitational waves fall into three broad categories: *targeted searches*, where the sky position and the rotation frequency of potential sources are known from electromagnetic observations; *directed searches*, where the sky positions for potential sources are known but most other parameters are largely unknown; and *all-sky searches*, where the entire sky is scanned for any possible signals without assuming any source parameters or parameter ranges.

These searches employ a multi-stage hierarchical method — at each stage candidates that do not meet certain statistical requirements are chucked away, very similar to how you would conduct an excavation if you were an archaeologist — you would have to keep on digging deeper and deeper till you found something interesting. To rummage through the large chunk of data that is collected over a large span of time, one needs hours and hours of computational time and pretty smart algorithms. Building up a significant signal-to-noise ratio to make the signals detectable requires integrating data over long durations of time, a computationally intensive task, part of which is handled by Einstein@Home, a volunteer distributed computing setup where volunteers donate the idle time on their computers for carrying out long and intricate calculations.

The detection of gravitational waves is already an engineering and scientific marvel. The detection of continuous waves from neutron stars will not only be another marvelous achievement, but most importantly be instrumental in improving our understanding of the behaviour of matter at the extremes of pressure and temperature — conditions that are believed to be typical of the interior of neutron stars. Over the last few decades, electromagnetic observations have been successfully used to probe the physics of neutron stars. But like almost everything else in the universe, there is still a lot to be learnt about them. Complementing what we already know, the knowledge that we will obtain from the gravitational radiation generated by neutron stars, will help us form a better picture of what transpires in their deep interiors and will hopefully increase both our comprehension and appreciation of the ways of nature.

Anup Anand Singh and Divya Singh are fifth year BS-MS students at IISER Pune.

A TALK ON GRAVITATIONAL WAVES

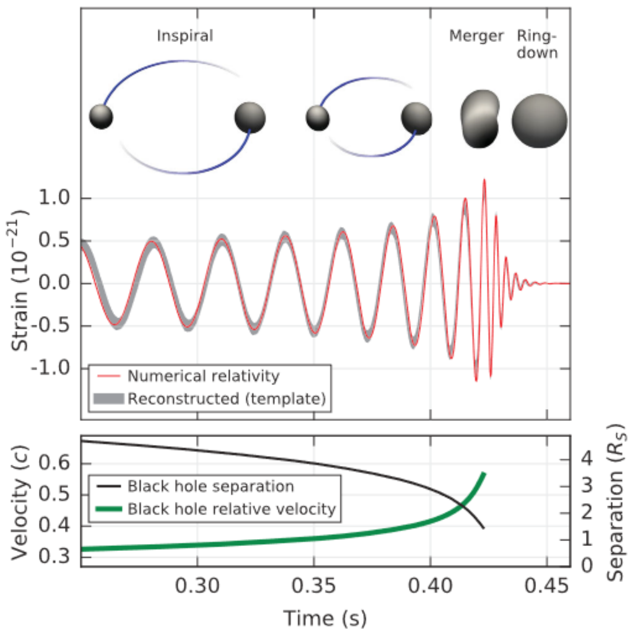
S PAVITHIRAH AND PALASH SINGH

Dr. Sanjit Mitra, an associate professor at the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, delivered a talk for Aakashganga on 29th August 2017. His research lies in the detection and observation of Gravitational Waves. Dr. Mitra is a part of the Indian team which contributed to the detection of these elusive waves by the Laser Interferometer Gravitational-Wave Observatory (LIGO).

14th September 2015 was an unforgettable date in the history of science. On this day, LIGO received the signal which led to the observational evidence of one of the most sought after predictions of general relativity, the gravitational waves, proposed by Albert Einstein in 1916. This discovery served as an appropriate celebration of the centenary of this remarkable theory. The predictions of general relativity and the existence of gravitational waves in the strong field regime were confirmed.

Dr. Mitra explained a few basics of general relativity and properties of gravitational waves in a lucid way and how this in turn leads to a completely new field of gravitational wave astronomy, thus heralding the age of multi-messenger astronomy.

Dr. Mitra explained to us, all the difficulties faced in this endeavour - right from the pioneer, Joseph Weber who developed the first gravitational wave detectors (Weber bars) in 1960s, until the laser interferometers of the LIGO detectors in Hanford, Washington and the other in Livingston, Louisiana. This mammoth task required so many years to come to fruition, primarily because gravity is a weaker force as compared to other forces of nature. Hence, highly sensitive instruments were required for the amplification and detection of these waves.



Top: Estimated gravitational-wave strain amplitude from GW150914 projected onto H1 (Hanford). Bottom: The Keplerian effective black hole separation in units of Schwarzschild radii and the effective relative velocity.

Source: Observation of Gravitational Waves from a Binary Black Hole Merger, B. P. Abbott et al.

Arguably, the most interesting part of the talk was about LIGO-India - Indian Initiative in Gravitational-Wave Observations (IndIGO). He outlined the scientific benefits of LIGO-India and how the addition of a new detector to the existing network will increase the expected event rates, boost the detection confidence of new sources and serve as an opportunity for young enthusiastic Indian scientists who would want to work in the field of gravitational wave astronomy.

IN CONVERSATION

WITH PROF. SANJEEV DHURANDHAR

TRANSCRIBED BY ONKAR SADEKAR AND ANWESHA MAHARANA

Prof. Sanjeev Dhurandhar is a physicist and Emeritus Professor at the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune. Over a career spanning more than three decades, he has made seminal contributions to gravitational-wave physics, particularly to the data analysis techniques for the detection of gravitational waves. Presently, he also serves as the Science Advisor to the Indian Initiative in Gravitational-Wave Observations (IndIGO) Consortium Council.

1. What got you motivated into science as a student? And as a young researcher what got you interested particularly in general relativity and gravitational wave physics?

Science was always my primary interest, so nothing got me motivated into science. Kids of my age were more interested in other things, like playing and socialising. However, I was always curious to find out new things and try them out and understand them. I was always interested in science since birth (laughs).

As for the interest in gravitational waves, things sort of led to it, in a way. I was interested in both mathematics and physics in my childhood. I liked engineering as well; I used to build electromagnets and other things like that in childhood. But I was equally interested in mathematics. Once I was trying to trisect an angle with a compass and a ruler, and I'm happy my teachers didn't know that it can't be done; it kept my curiosity and interest in mathematics alive. Back then, general relativity was taught as a mathematics course. Since I had taken mathematics, I got to learn general relativity and I found it very interesting.

I did my PhD on black holes and also worked for a year with Prof. Govind Swarup at the GMRT (Giant Metrewave Radio Telescope). In 1986, I heard a talk on gravitational-wave detectors by Prof. Kip Thorne (Nobel laureate in Physics, 2017). That was the first time. Later, I talked to Prof. Bernard Schutz who told me that it (the gravitational-wave detector) involves general relativity as well as antennas. I was interested in both and took up gravitational-wave physics. I realised that it was a major challenge. I did not care about success at that time and well, it (the theory) did succeed.

2. What differences do you see in the gravitational-wave physics community between when you started and now? What are the revolutions/major insights you think the recent detections have resulted in?

Well, there was no gravitational-wave community back then! There were a few prototype detectors; prototype, because they couldn't detect anything. There were a few small detectors of size of the order of tens of metres.

Prof. Ronald Drever was very instrumental in coming up with innovative ideas for this project. He would come up with a new idea for the detector everyday. He would have been one of the Nobel Prize recipients had he not died this March (2017). At this time (Prof. Bernard) Schutz and (Prof. Kip) Thorne were concerned about how we could analyze data from gravitational wave detectors and what sources could be detected. It was Thorne who realised that compact coalescing binaries are the most promising sources for laser interferometric detectors and all the events detected so far have been of this type. Initially, very few groups were working in this area. As for the recent detections, the findings about the masses of black holes were surprising. Earlier, we used to think that stellar mass black holes are about 10 solar masses, but the first detection itself were black holes of about 30 solar masses. This was an addition to our knowledge. And now people have to come up with mechanisms to explain how such big black holes can be formed. This was also the first direct detection of gravitational waves, black holes, and black hole binaries.

Also, these events are completely consistent with the general theory of relativity, which add one more feather to Einstein's cap!

3. What are the questions you are particularly hopeful about and wish to get solved in the field?

Gravitational-wave detections have opened a new window to the universe in astronomy. The first window in astronomy was opened by Galileo 400 years ago when he pointed his telescope at Jupiter and observed its moons. Then, radio astronomy started 70 years ago and immediately made many discoveries like the CMB (Cosmic Microwave Background), pulsars, radio galaxies, quasars, which couldn't have been made by optical astronomy. Then we have infrared astronomy, which has shown us exoplanets and other stellar systems like ours. So as soon as a new window opens, it enables us to discover new things in our universe. It complements our previous knowledge. I think gravitational-wave astronomy will do the same thing. The recent neutron star coalescence event has told us so many things. For example, it has confirmed that the speed of gravitational waves is not different from the electromagnetic waves, as the gamma rays were also detected around the same time after the merger.

4. How vital a role is LIGO-India going to play in the coming decades in your view? What role do you see young students in science playing in the project, if any?

Speaking in terms of astronomy, LIGO-India has got a strategic location. Combined with the other detectors in the US and Europe, this will give a much longer baseline. These detectors are omni-directional. So a longer baseline will help us determine the location of the event more precisely. These detectors play a similar role to gravitational waves as dipoles earlier did to electromagnetic waves. Further apart the detectors are, the better it is to determine location of transient sources. Also, the orientation of LIGO-India will be different from the rest (of the observatories), which will help in getting more information about the polarisation of gravitational waves.The polarisation contains information about the orientation of the source. In case of the binary (neutron stars or black holes) it is the angle of inclination of the orbit. LIGO-India will improve the determination of location by one or two orders of magnitude compared to the just the LIGO detectors.

Also, being in India, it will attract significantly more advanced technology. Young students in science will have a big role to play in this. We will need good engineers and physicists. The problems encountered here will be different, and we will need creative minds to solve them. Our aim is to make the detectors even better than the present ones in terms of technology and other aspects.

5. The Laser Interferometer Space Antenna (LISA) is a very ambitious upcoming project. You have yourself been involved in calculations related to the time-delay interferometry for LISA. Can you elaborate on the work? Also, what are the major expectations from LISA?

It is difficult to detect waves with frequency below 10 Hz using ground-based detectors. Variations in local gravitational fields shake the mirrors – this is called Newtonian noise and is difficult to eliminate. Moreover, to detect some specific objects like supermassive black holes or things falling into massive black holes, we need to go below the current bandwidth, to the millihertz (mHz) range. Space detectors will allow us to make such detections. Just like radio astronomy complements optical astronomy, space detectors will complement ground-based detectors and will help us find new sources in a different frequency band.
However, LISA has interferometers with unequal arm lengths as it is difficult to keep the spacecrafts equidistant. (LISA will have a constellation of three spacecrafts, arranged in an equilateral triangle with sides 5 million km long, orbiting the sun in a manner similar to earth.) But laser frequency noise is a problem for LISA because it is an unequal arm interferometer – it is impossible to make the arms equal in length. This noise is many orders of magnitude more than other noises. In ground-based detectors, this noise is common to both arms which are equal in length and hence, it cancels out. In LISA we have six different data streams between the three spacecrafts, and we must build the interferometer in software. We must appropriately delay the data streams so that the laser frequency noise is cancelled. This is called time delay interferometry. I recognised that this problem can be mapped to a problem in algebraic geometry, more specifically in commutative algebra. This problem has already been solved by mathematicians. We could then apply their results to the problem in LISA.

THE SARASWATI SUPERCLUSTER

A TALK ON DISCOVERY OF SARASWATI SUPERCLUSTER

AASHNA ZADE AND SHREEJA GHUGAL

On 12th September 2017, Aakashganga got the privilege of hosting a talk on the topic of the hour - 'The Saraswati Supercluster'. The talk was delivered by none other than one of the discoverers of this bizarre supercluster, Shishir Sankhyayan, a PhD scholar at IISER Pune. He was a part of a team consisting of Prof.Somak Raychaudhury, Prof. Joydeep Bagchi, Joe Jacob, Pratik Dabhade and Prakash Sarkar, which made the discovery.

Shishir started his talk by making the audience visualise and ponder over the magnificence of our galaxy, The Milky Way by introducing the light year as a scale to measure distances. After laying down the types of galaxies, Shishir began assembling these stellar objects into a hierarchy initiating from a galaxy to groups of galaxies (few tens of galaxies gravitationally bound) to clusters of galaxies (few hundred galaxies). Thereafter, he discussed the various structures of the cosmic web.

Shishir then touched upon the topic of expanding universe and its promising evidence - the redshifts. In addition to this, he elegantly dealt with dark matter and dark energy, which still remain a mystery to us, by explaining how they dominate the universe and shape its future. We even saw an elaborate video on how they play a role in the formation of stellar objects. After giving insights into the basics, he dived into the details of his work.

Ironically, identifying something as humongous as a supercluster proved to be a Herculean task since it required accurate redshift data over a vast region of the sky. The Saraswati Supercluster extends over at least 650 million light years and spreads over an angle of approximately 10 degrees spread equivalent to 20 moons! It has a mass greater than that of 20 million billion suns combined. and is known to consist of tens of thousands of galaxies (43 clusters). It is the second farthest known supercluster from Earth. Interestingly, the supercluster was discovered in the data of the Sloan Digital Sky Survey (SDSS) which was made publicly available. After enlightening us with these astonishing facts, he showed us some spectacular images of the supercluster and about 3000 neighbouring galaxies.

He also gave a brief history of its discovery by stating how Professor Joydeep Bagchi's intuition of a cluster being at a specific location on the SDSS lead to their uncovering of the ZWCL2341.1+0000 cluster. The shape of this discovered cluster, which depicted it being stressed, finally led to the discovery of the Saraswati Supercluster. Such superclusters are of paramount value since only four other superclusters are known (with two of them discovered by Indians) and the probability of finding them is extremely low.

Shishir concluded the talk by putting forth some compelling questions for the audience to ponder over, which left them with a sense of admiration for the imagination, perseverance, immense patience (since a year and a half was spent in analysing the incorrect data) and teamwork put in by Professor Bagchi's team which led to this phenomenal discovery.

SARASWATI SUPERCLUSTER : A GIGANTIC STRUCTURE

PROF. JOYDEEP BAGCHI, PROF. SOMAK RAYCHAUDHURY AND SHISHIR SANKHYAYAN

Superclusters are among the largest coherent structures in the universe. A supercluster is a chain of galaxies and galaxy clusters bound by gravity, often stretching to several hundred times the size of clusters, which consist of tens of thousands of galaxies. Our own Milky Way is a part of the Laniakea Supercluster. The newly discovered *Saraswati* supercluster extends over a scale of 600 million light-years and has a mass greater than that of 20 million billion suns combined. The *Saraswati* supercluster is now observed as it was when the universe was 10 billion years old.

The popular *Lambda Cold Dark Matter Model* explaining the evolution of the universe predicts that small structures like galaxies form first, which congregate into larger structures. Most formations suggested by this model do not predict the existence of large structures such as the *Saraswati* Supercluster within the current age of the universe. The discovery of these extremely large structures has thus forced astronomers into rethinking the popular theories on how the universe got its current form, starting from just post Big Bang with a more or less uniform distribution of energy.

It is believed that galaxies are formed mostly on the filaments and sheets that are part of the cosmic web. Most galaxies travel along these filaments and end up in the rich clusters, where the crowded environment switches off their star formation processes and aids in their transformation from disky blue and spiral to red and elliptical. The galaxies face various environments during their lifetime in the supercluster, whose effect on them needs to be closely studied to understand the formation and evolution of superclusters. This discovery will greatly enhance this field of research on evolution of superclusters.

Previously only a few relatively large superclusters like the *Shapley Concentration* or the *Sloan Great Wall* have been reported in the nearby universe, while the Saraswati supercluster is a far more distant one. Thus, the discovery of Saraswati supercluster will help shed light on the perplexing question - how did such extremely large scale and prominent matter-density enhancements form billions of years ago, at a time when the mysterious dark energy had just started to dominate structure formation?

Two most massive clusters of galaxies in the Saraswati supercluster
"ABELL 2631" cluster (left) and "ZwCl 2341.1+0000" cluster (right).
"ABELL 2631" resides in the core of the Saraswati
supercluster. The Saraswati supercluster has a total of 43 clusters of galaxies.

The authors are the discoverers of the Saraswati supercluster. Prof. Joydeep Bagchi and Prof. Somak Raychaudhary are Professors at Inter-University Centre for Astronomy and Astrophysics (IUCAA) and Shishir Sankhyayan is doctoral student at IISER Pune working in collaboration at IUCAA.

A TALK ON

THE WORLD OF TELESCOPES

SHRIYA HIRVE AND RIJYUTA KAABAADEE

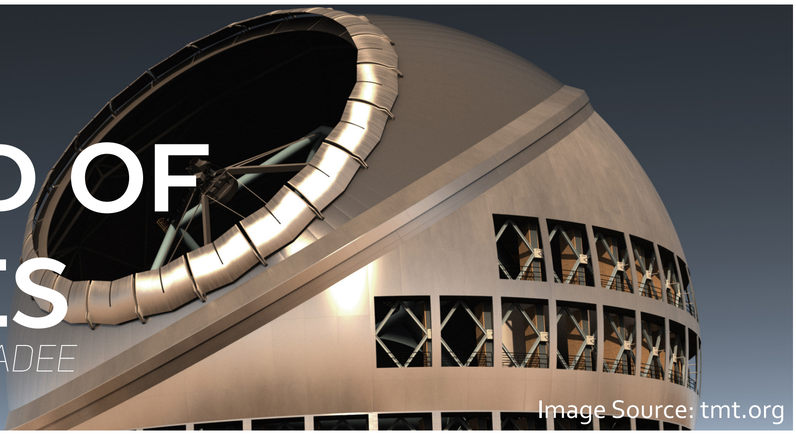


Image Source: tmt.org

The semester activities of Aakashganga kick-started with an orientation talk for the first-year students, titled 'The World of Telescopes', on 10th August 2017. The talk was delivered by Mr. Samir Dhurde, head of the public outreach Science Popularisation Program (SciPOP) at the Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune.

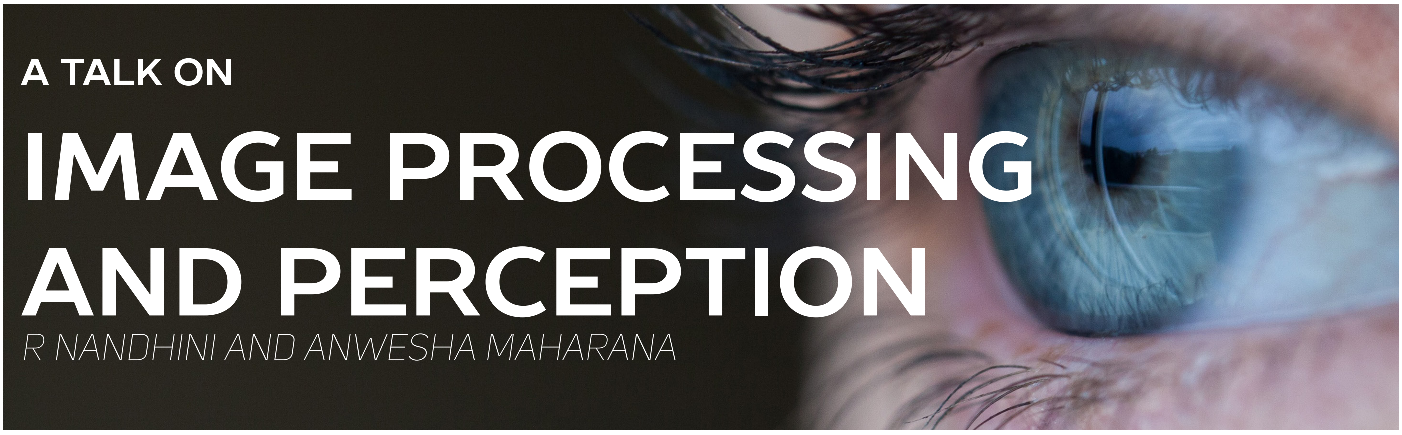
Unit 4 of VLT Shooting a Laser Beam
Image Source : ESO

He began his talk with astrophotography and the immense amount of information we can extract by collecting light from objects. He revealed star clusters, the Milky Way, aurorae, Magellanic clouds and bioluminescent bacteria at sunset in just a single image and made us appreciate the sheer amount of knowledge that an image can provide. He explained that data from telescopes is more detailed than that from cameras. He went on to elaborate on various types of telescopes and their working mechanisms. He elucidated how refractors, the oldest ones, use lenses to collect light, how reflectors use mirrors and how radio telescopes collect radio waves. He emphasised on the fact that the material of the lens in a refractor is crucial in determining the aperture of the telescope, since the lens tends to bend under its own weight. Another important requirement is leveled ground, an example of which is the Very Large Telescope (VLT), an array of four 8.2 m telescopes built on a leveled hill.

Keck Telescopes

Next, Mr. Dhurde shared information on the Gran Telescopio Canarias, the world's largest reflecting telescope, with just one mirror of an aperture of an astounding 10.4 m. Then came the Keck Telescopes, which are twin telescopes with segmented mirrors, an advantage that reflecting telescopes have over the refracting ones. This helps in reducing the aperture size required for collecting an image. This very technology is also used in the Honeycomb mirrors installed in the Hubble Space Telescope.

Mr. Dhurde then shared information on various interesting projects coming up in the foreseeable future. The Thirty Meter Telescope (TMT) is a reflecting telescope being built by a collaboration of countries with India as one of its members. The Extremely Large Telescope (ELT) is larger, with an aperture of 39.3 m! The Square Kilometre Array (SKA), which is under construction will have a collection of many antennas spread over a collection area of one square kilometre. According to the plan, it will be 50 times more sensitive than existing telescopes and will provide insights into the realms of general relativity, dark matter, dark energy and even extraterrestrial life. The talk ended with Mr. Dhurde talking about the promises that these new projects offer and how they can change our present perception of our magnificent universe and it's innumerable elements.



A TALK ON

IMAGE PROCESSING AND PERCEPTION

R NANDHINI AND ANWESHA MAHARANA

“Don’t you trust those eyes every time.”

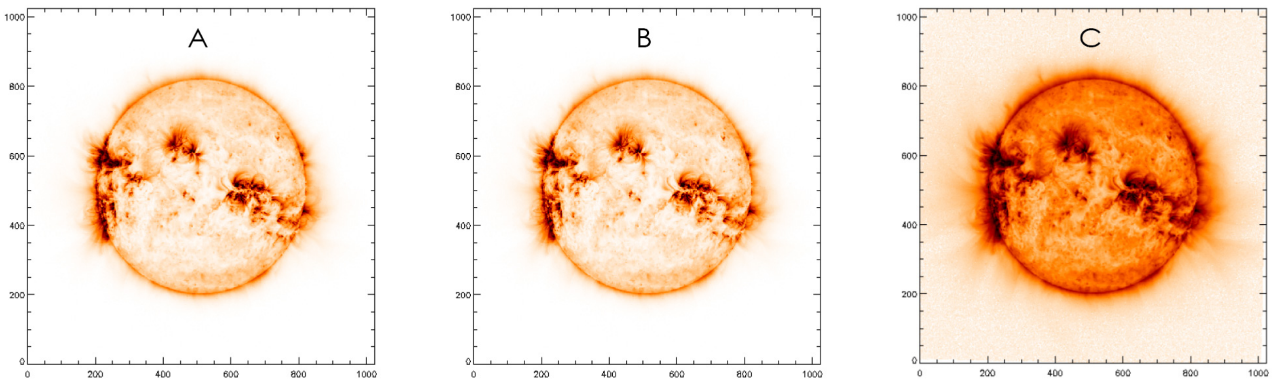
Thus began Vaibhav Pant’s engrossing talk on image processing. Vaibhav Pant is a PhD student at Indian Institute of Astrophysics whose research lies in Solar Physics. At the beginning of the talk, this neuroscience enthusiast played a few intriguing visual games with the audience to emphasise his opening quote.

The first stop was the scaling of images and its techniques along with an explanation of the ineffectiveness of arithmetic operations and linear combinations on the intensity of the image. The speaker threw light upon the usage of gamma transformations in bringing out the finer details in the picture. Various scaling techniques were explained with illustrations.

Keeping the young members of the audience in mind, he briefly discussed how the brain responds to light, how the rods and cones respond to the contrast observed in objects, followed by how we perceive it. Concepts on stimuli were touched upon too. He then drew our attention to many interesting neuroscience experiments on animals that give clues to similar transformations happening in their brains as well.

With the basics covered, he went on to elaborately discuss Edge Detection, by demonstrating the use of various operators like the Sobel operator, the Laplacian operator and the Canny Edge operator and differentiating between them by analysing their advantages and disadvantages. The next stop was filters. He explained what spatial filters are by differentiating between low pass and high pass filters. Gaussian filters with their applications and necessary precautions to be taken during their usage were discussed as well.

As it is with every good talk, the time flew by without our notice. He quickly covered wavelet transformations and their algorithms followed by difference imaging and its features. In the Q & A session, popped a question, “*Is seeing believing?*”, and this memorable talk concluded with an equally memorable response, “*Rather we see what we believe.*”



B is 10000x brighter than A , C is of same brightness as A
B - Linear Transformed , C - Gamma Transformed

RADIO ASTRONOMY WINTER SCHOOL

ONKAR SADEKAR AND PRASANNA JOSHI

Amazing! Awesome! Wonderful! Even these words aren't enough to describe our experience at the 10th Radio Astronomy Winter School (RAWSC), jointly organised by the National Centre for Radio Astrophysics - Tata Institute of Fundamental Research (NCRA - TIFR) and the Inter University Centre For Astronomy and Astrophysics (IUCAA). We were already excited by the news of our selection, and our excitement only increased as the date drew near.

The first session began at 9:30 a.m. on 18th December, 2017. All the participants introduced themselves and met their group members. The motive of the school was briefly introduced by Dr. Neeraj Gupta and Dr. Subhasis Roy. The founders of the RAWSC, Dr. Joydeep Bagchi and Dr. B. C. Joshi were also present to welcome us. Over the next few days, we attended lectures on techniques in radio astronomy, galaxies, clusters, pulsars and more, delivered by eminent researchers at IUCAA and NCRA. We performed four experiments specially designed to help us understand the basic techniques employed in radio astronomy. Not only did we learn a lot from them, but working in a group also helped us develop team spirit. We also got a chance to attend a colloquium and a public lecture by the famous astrophysicist Prof. Frank Shu and interact with him during his visit to IUCAA. We were fortunate to meet Prof. Govind Swarup, one of the pioneers of Indian Radio Astronomy, in a specially organised session.

Giant Meterwave Radio Telescope
Photograph : Onkar Sadekar

The cherry on the cake was our visit to the Giant Metrewave Radio Telescope (GMRT). We got a peek into the insides of one of the dishes in the array and the control room. A special lecture was delivered on the working mechanism of the GMRT. Although we couldn't persuade Dr. Subhasis to let us stay at the GMRT for the night, the visit was truly memorable. Later, they organised a small sky watching session and had a hands-on demonstration on positional astronomy. Since Christmas was a holiday, most of us spent it in preparing for our group presentations. Next day, we delivered our presentations and then were quizzed on what we had learned. It was the last day of the school and we were sad about it coming to an end. However, we were happy about the entire experience and the new friendships formed.

The school officially ended with distribution of certificates, mementos, and books on astrophysics. We bid farewell and promised to meet again in future. The school ended, but not without igniting our curiosity about radio astronomy and illuminating a new path to discover. We shall always relish the fun we had, the lectures we attended, the experiments we performed, the visit to the GMRT, and most importantly, the new insight that the school provided.

Onkar Sadekar is a BS-MS second year student and Prasanna Joshi is a third year student. They attended the 10th Radio Astronomy Winter School (RAWSC) at NCRA.

SKY WATCHING SESSION

ANWESHA MAHARANA

Aakashganga organised a sky-watching-cum-interaction session for the students of the Innovation in Science Pursuit for Inspired Research (INSPIRE) Camp conducted by Department of Science and Technology (DST) and Centre of Excellence in Science and Mathematics Education (CoESME) at IISER Pune in December. The session started with observing the International Space Station (ISS) and the Hubble Space Telescope (HST) traversing the early evening sky. It was fun to watch the kids ponder over why the satellites disappeared on their way to the horizon and then see them coming up with explanations. Unfortunately, the clouds came over the star-studded sky and we had to wait until they cleared. Meanwhile, we discussed about the celestial sphere, stars, galaxies, clusters and the Big Bang theory. They were all ears to learn more about the Gravitational Waves discoveries and the working of the LIGO. As the clouds gave way to the gateway of heavenly bodies, we familiarised them with the working of telescopes and then showed them a few clusters and nebulae through the reflectors we possessed. In parallel to that, we discussed about the different types of telescopes and various regimes of Astronomy. It was indeed a great experience to see the kids unleashing their curiosity and actively indulging in discussions. We are glad that we got an opportunity to organise such an outreach event and share our knowledge about the Cosmos with the society. We hope to continue this in the future.




MARMALADE SKIES

HOW THE URBAN SKYGLOW IS KILLING AMATEUR ASTRONOMY

ANUP ANAND SINGH

Marmalade, or at least the modern version of the tangy orange spread — as the story goes — was born in eighteenth century Scotland when a storm-struck Spanish ship had to take refuge in a harbour in the City of Dundee. The Seville oranges in the cargo made their way into the kitchen of a local merchant where his wife turned them into a preserve. Marmalade, in all its red and orange hues, has been a part of British identity ever since. These shades and tints of marmalade feature in the 1967 Beatles song *Lucy in the Sky with Diamonds* as well — tangerine trees and marmalade skies — an imagery inspired by the *Alice in Wonderland* stories. But marmalade skies that shroud our cities on so many nights are no sweet imageries.

Growing up in an Indian *city*, the night sky was always something full of delight and mysteries, but it was never something to feel really proud of, particularly after the occasional visits to more pristine pastures away from the city. Years later, attempts to share a sense of beauty and wonder with school kids during the sky watching sessions within the confines of the city always ended with feelings of both joy and guilt. One could explain to them how looking at the night sky is like looking back into the past, or how just analysing the light from stars while still being earthbound can reveal so much about them. But one could not share the delight of feeling dazzled by a star-studded Milky Way stretching across the sky, or the intrigue of discovering that what looks like a fuzzy little star is actually Andromeda, a galaxy very much like ours. Because you cannot see any of them! Our night skies, all red and orange with the skyglow, are not just good enough any more.

While this may not exactly be true globally, at least in an Indian context the urban skyglow has pushed the amateur astronomy scene to a state of almost complete irrelevance. Kids across the country with their decent homemade reflectors have to wait patiently for the nights when the sky is, well, *not that bad*. The same pretty much holds true for college-level astronomy clubs in the country that have predominantly survived on night-sky observations made from hostel rooftops and secluded parts of the campus (and on relatively less frequent trips to nearby farms and hills). To place this issue in its proper context, one can easily factor in how important contributions from amateur astronomers have historically been — and there are more than a handful of them to lend support to the argument. One can even keep aside this entire discussion about how useful such contributions have been. Just think about all those scientists and painters and poets and writers who have looked up at the starry night skies and have drawn inspiration to make their marks on the world.

Like the solutions to most problems, the first step — as cliché as it may sound — is to realise and acknowledge that the urban skyglow is actually a serious concern and one that is primarily an outcome of our blatant ignorance of our impact on the environment. In the fight for clear night skies, where we are both the perpetrators and the victims, the outcome quite heavily depends on the level of awareness at all levels. And even though night-time lighting in itself is a complicated issue, switching to more responsible options and getting rid of redundant lighting — both indoors and outdoors — are some very simple solutions that can bring about a significant favourable change.

Anup Anand Singh is a fifth year BS-MS student at IISER Pune.

We would like to receive your feedback and suggestions at **astro@sac.iiserpune.ac.in.**