September 2023

Issue 8

DOOT

A STUDENTS' INITIATIVE FROM THE INDIAN INSTITUTE OF ASTROPHYSICS

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DOOT
A students' initiative from the Indian Institute of Astrophysics

Issue 08
September 2023
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Invitation for articles

We invite your contributions under the following categories:

Review articles:

Scientific and technical publications (recent publications in academic journals from the IIA family, IIA technical reports, breakthroughs in Astronomy, book review, Journal club discussions, milestones of IIA projects; to be published in simple language) are invited. Project interns and summer school project students can submit an overview of their work. (Word limit: 2000 words)

Individual experiences and field-station stories:

In this section, we invite stories of your personal experience, maybe with a scientific project, an experiment, attending a conference/workshop, a collaborative visit, visit to an observatory, or even a coffee break with a prominent scientist. We also invite interesting stories from our substations at Hanle, Kodaikanal, Kavalur, and Gauribidanur about the ongoing activities and valuable memories. (Word limit: 1400 words)

Science made easy:

For this section, we invite write-ups discussing interesting concepts of Physics in a very simple and enjoyable way, without using much of technical jargons. The main motive is to reach a wider audience by making it easy to understand, relate, or appreciate Physics, without having any technical background in the subject. (Word limit: 1400 words)

Alumni and retired staff/faculty stories:

In this section, we warmly invite our former students and retired staff/faculty to share your invaluable experiences during your time at IIA. We hope that this column offers an opportunity to reflect nostalgically on your journey here. We are also very interested in hearing about your career path after IIA, the challenges you would have faced, and the impact IIA had on your life. (Word limit: 1400 words)

Creativity corner:

Splurge on your creativity here! For this section, we invite all kinds of artworks including but not limited to paintings, poems, short stories, and graffiti. (Word limit: 800 words)

NOTE: Attach a brief bio along with the article. Submissions should be in editable text files (doc/odt).
High resolution images should be given separately with the filename same as figure numbering (eg: Fig1.jpg)
Disclaimer: Any article received will be published only after strict screening. The chief editor's decision will be final.
Submitting your article to DOOT implies your consent to edit and publish the article and that the work is bonafide.

We would like to improve the content of the magazine.
Please send your generous feedback and contibutions to
doot@iiap.res.in

From the Editor

We are delighted to complete three successful years of DOOT magazine with seven issues covering over 100 articles. It would not have been possible without the active indulgence of the ever-growing team members. This year has been a roller-coaster ride for DOOT, with participation in many activities (glimpses seen in the magazine), from the ASI meeting to events/conferences held at various IIA substations. We have received immense support and feedback, improving many aspects and motivating us to improve further.

I take this opportunity to present the latest 8th issue of the magazine. As usual, this issue is filled with many excellent articles in various categories and is further enhanced by beautiful artworks and astrophotographs. I am glad to see a considerable contribution from the community, especially from the young researchers who have just started their journey in Astronomy research. Commendably, our interview team has come so far that they could prepare for and interview a few dignitaries who had visited IIA within days. Bearing these fruits, we have added a new 'Chat with Astronomer' series within the Interview section.

With the changing times, we have also updated our logo to incorporate more Astronomy elements and make it visually appealing. With good times ahead, we wish to expand it to more platforms through audio-video means taking full use of social media. It would require support from everyone to make it a success. With that said, take your time to read various articles, reach out to authors, and give us feedback until we present more such content!

-Rishabh Singh Teja

Chief Editor, DOOT

Contents

Backstory of the magazine cover

I was on my evening stroll after a rainy afternoon at the Gauribidanur Radio Observatory when I saw some waterlogged near the South entrance gate and, in that, the reflection of the antennas of the GRAPH array. I took out my mobile phone and captured this image, keeping the phone near the surface of the water. Gauribidanur Radio Heliograph (GRAPH) is a "T" shaped radio telescope that is used to obtain two-dimensional images of the Solar Corona at 53.3 MHz and 80 MHz. The basic receiving element used in GRAPH is Log-Periodic Dipole (LPD) antenna. In the image, we see the reflection of the South arm of the GRAPH array, and what caught my eye was if the image is rotated, the antennas and their reflection together look like an LPD antenna!

Kshitij Bane

Details: Device- Redmi Note 9 pro

Kshitij Bane is a Senior Research Fellow (SRF) at the Indian Institute of Astrophysics, primarily working in radio astronomy and digital signal processing.

My life in IIA and beyond

Krishnakumar Venkateswaran

One momentous day in 1987, I announced to my parents that I wanted to pursue a career in physics instead of engineering or medicine. As in any typical home at that time, the interest was met with some resistance, followed by the advice that jobs were not easy to come by for a physicist. Nevertheless, in 1987 I started working towards my bachelor's degree in Physics at The American College in Madurai. I continued to earn my master's degree, also in physics. During this time, Prof Riesz, one of my senior professors, called me to his lab. Prof Riesz was well-known in academic circles, so I was thrilled when he asked me to apply to attend a workshop organised by the Indian Institute of Astrophysics (IIA) at the Vainu Bappu Observatory (VBO), Kavalur. After a hectic day at the workshop attending seminars and discussions, the students were having dinner at the Observatory cafeteria, where I had an opportunity to meet Late Prof Surendra Kumar Jain and Prof Tushar Prabhu. Earlier that day, Prof Jain had given a talk on polarimetry. After dinner, the two professors invited a few of us to join them in observing SN1987A (a supernova) using the 40-inch telescope. For all of us, this was our first experience in observational astronomy. While most students were fascinated by the supernova itself, I was very intrigued by and interested in the technology used in the observations. I was thrilled to witness the physics of using a couple of photons to understand the evolution of an object around 160,000 light-years away. I wanted to understand the instrumentation, especially the optics– the cameras which achieved this remarkable feat. The discussions during that time led me to learn more about atmospheric effects, such as seeing, which formed the basis of my PhD thesis a few years later.

Upon completion of my master's degree, I sent in my application for admission into IIA. My first visit to IIA, to write the entrance exam, was very intimidating. Hundreds of students from all over India were milling around, and every conversation I overheard involved words like "entropy" and "Boltzmann constant". We wrote the entrance exam and anxiously waited for the results to be announced. Typical of Indian parents, I saw some parents more anxious than the students themselves. The results were put up at the security office near the gate, and I was ecstatic to see my name among the twenty names listed. The intense two-and-a-half-hour interview that followed set the course for my next eight years at IIA starting in 1992.

The first year of coursework was a fantastic learning experience. I came across many great professors, but my favourites were the great researchers who could translate their findings into classroom experiences. These experiences helped me understand my interests, strengths, and weaknesses. Travelling to IISc (Indian Institute of Science) or RRI (Raman Research Institute) for classes was often tiring, especially after long nights working on assignments. My batchmates and I braved it by incentivizing ourselves with trips to MG Road and Brigade Road. Lectures on fluid mechanics, relativity, and cosmology told me without a doubt that theoretical physics is something I should stay far away from. The options for my doctoral work were crystallising. At the end of the coursework, we were assigned to work on a project as a final requirement. A project to set up a telescope in the Himalayan region had just started, and many tools were being built to assess the sky conditions at potential sites such as Hanle and Tso-Moriri. IIA was buzzing with activities, and everyone was excited about the prospect of a telescope at a high altitude. It was a good time for our batch to finish our coursework and participate in this project. My batchmate Swara and I were tasked with building an all-sky survey camera. The project was supervised by the then IIA director Prof Cowsik (Prof Ramnath Cowsik had served as IIA director from 1992 to 2003). Initial testing of the instrument was done at VBO, Kavalur. I had to understand the science of atmospheric turbulence and its effect on ground-based imaging, which I had first encountered during my workshop. Throughout this project, we also tried identifying the faculty members to work with for our respective thesis work. My interest in optics had been simmering since the start of my master's program. The topic of atmospheric turbulence and its impact on image quality interested me quite a bit. My interest in the surface structure of stars, especially the Sun, was also rapidly growing because of exciting discussions with the solar physics faculty at IIA. The region of intersection between my interests laid the foundation for my doctoral work. I officially started working on high-resolution

Picture 1: At Hanle, during a site survey

Picture 2: Clockwise from top-left: with Prof Cowsik (then director of IIA) inside AN32 getting ready for test flight; formation flying with another AN32 with Agra city in the background - practice flights before the eclipse; inside AN32 during the expedition; after the expedition

imaging techniques under Prof Venkatakrishnan's and Prof Cowsik's guidance. During my PhD, I had great adventures travelling to Tso-Moriri and Hanle for site surveys. Setting up a small telescope and working at those altitudes tested both our physical and mental strength. Being a vegetarian made life more difficult, and I ended up eating Maggi noodles for breakfast, lunch, and dinner for weeks. My disdain towards Maggi noodles remains to this day.

One of the highlights of my life at IIA was the total solar eclipse in 1995. I was thrilled to be chosen along with my senior Dipankar Banerjee to participate in the Indian Air Force expedition to observe the total solar eclipse. The experiment was designed for us to record the solar corona during the totality while we were on board an Indian Air Force plane (AN-32). We were stationed at the Agra Air Force station for a week and flew several test flights for dry runs before the day of the total solar eclipse. The experience taught me many lessons on developing redundancies in designing experiments, especially when the event was a rare occurrence and did not provide a second chance.

My journey in IIA was incredibly fascinating because of the low student-to-faculty ratio. Students had time to meet and discover various topics of research.

Research papers in solar imaging were primarily of interest to me because I could get a peek at the surface of a star. At the time, SOHO and YOHKOH satellite images were making big headlines with images of the Sun in UV and X-ray, respectively. It is a solar physicist's dream to spatially and temporally correlate these images at different wavelengths and probe the depths of the solar atmosphere to learn the physics behind small- and large-scale structures on the Sun. At the time, adaptive optics was an exotic technology for solar telescopes, and observatories were springing up with active and adaptive optics systems for high-resolution ground-based imaging. I was fascinated by the images obtained using these methods. At this time, Prof Venkatakrishnan encouraged me to apply for an internship program at the Center for Astrophysics, Harvard University, USA, where I could work with these images. I spent the summer of 1997 at Harvard working on small-scale magnetic structures on the solar surface imaged using adaptive optics. The analysis fascinated me as I saw, in time sequence, small structures moving around solar granules. My work here formed the basis for a few publications in peer-reviewed journals and a significant part of my doctoral thesis.

Weekday evenings at IIA were busy with volleyball. Weekends were jam-packed with assignments, studying, and a lot of cricket. Much to the annoyance of some of the faculty members, we spent afternoons watering the volleyball courts to keep the dust levels down for our practice later. Many of the IIA staff would join us for volleyball. The best part was the annual tournaments between different IIA sites hosted at the Bangalore campus. It was fun and highly competitive and allowed students to meet

Picture 3: Trip to Hoggenakal Falls - from left: Krishnakumar, Sujan, Sivarani, Annapurni and Arun behind the boatman

the technical staff from the Kavalur and Kodaikanal observatories. These were the people who worked tirelessly maintaining the telescopes and helped the students and faculty when they went for their observations. Mr Nagaraj from the administrative office formed an IIA cricket team. We practised fervently and played matches against the IISc Physics department, St. Johns Medical College, and a few other teams. We were playing T20 matches those days! Sometimes we organised outdoor trips. One of the most memorable trips was with all my seniors to Hogenakkal Falls.

Upon submission of my thesis in the later part of 1998, I left for Italy to join as a postdoctoral fellow at the Royal Observatory in Torino. Here I worked on modelling electron density in the outer solar corona using SOHO-UVCS data. My thirst for instrumentation made me move to Nanyang Technological University in Singapore to pursue research in speckle imaging. In 2000, I joined the National Solar Observatory in Sunspot, New Mexico, USA as a postdoctoral fellow and worked on the solar AO system. It was a tremendous experience. During a Center for Adaptive Optics retreat (organised by the National Science Foundation), I met a vision science researcher who piqued my interest in developing AO systems for applications in human vision. Around this time, applications of AO in ophthalmology were gaining a lot of traction. The technology was costly, but government-funded labs such as the Lawrence Livermore National Laboratory in the US were getting involved in building devices with adaptive optics. Commercial interest was building, and many companies invested in developing AO systems to understand optical aberrations and their effect on human vision. Later, I was faced with an option to either join a university in Southern California as an assistant research professor to work on developing an AO system for retinal imaging or to join as a scientist in a leading company to build their first AO system for research in refractive surgery. With limited experience in obtaining research grants in a short period which was a requisite for the position of research professor, I decided to move into industry. Here I developed the first AO system to understand the effects of higher-order aberrations in human vision and several models to simulate human vision. This area of research is highly challenging as perception is not limited to optics alone but involves the human brain as well.

After 13 years of research experience in the ophthalmic device industry, I was getting impatient and wanted my own ideas implemented in the real world. I decided to go on my own. In 2014, I co-founded Tatvum LLC. Tatvum LLC designs and licenses novel intraocular lens technologies for lens implants in cataract surgeries and also develops optical power calculation methods used by surgeons for cataract surgery. Tatvum's patents

Picture 4: Dr Krishnakumar with members of DOOT, while visiting IIA to give a colloquium (February 02, 2023)

have been licensed to major lens manufacturers and commercialised in the USA, Europe, India, and other countries. We also have the capability to conduct clinical trials to test the efficacy and safety of new lens technologies. Later, in 2021, I founded IMAI LLC, where we work on developing technologies such as optical coherence tomography for ophthalmic applications and also develop augmented reality/ deep learning-based tools for applications in ophthalmology.

On the whole, I would say that a physics major is an excellent preparation for any career. It teaches students to question, hypothesise and analyse complex problems. It gives students a solid quantitative background that can be applied in any technical field. As an illustration, I used the idea of tessellation to study the distribution of cell size in the solar chromosphere and later applied the same technique to identify photoreceptors in retinal images. I was introduced to speckle imaging for high-resolution imaging using ground-based telescopes and later used speckle techniques to study subsurface cracks on aircraft wings. A Physics major gives a student the tools and techniques to handle problems anywhere in the world. The same theory can be used to study the Sun or to help people improve their vision. It is up to us to define boundaries or keep pushing them.

Dr Krishnakumar Venkateswaran completed his PhD at IIA on high-resolution imaging. In 1999, Krishna joined the Royal Observatory of Torino in Italy and worked on modelling electron density in the outer solar corona using data from SOHO-UVCS. In 2000, Krishna joined the Nanyang Technological University in Singapore to work on speckle imaging techniques and applications. Krishna moved to the US in December 2000 and joined National Solar Observatory, New Mexico as a postdoctoral fellow to work on adaptive optics for solar imaging. After a chance meeting with a vision researcher working on retinal imaging using adaptive optics, Krishna joined the University of Houston and worked on the development of adaptive optics systems for in vivo imaging of the human retina. In 2003, he joined Alcon research labs in Florida to work on lasers for refractive surgeries. He later moved to Alcon Labs in Fort Worth, TX as a principal scientist to work in designing intraocular lenses for cataract surgery. In 2013, he joined Bausch and Lomb in Aliso Viejo, CA, before starting his own company Tatvum LLC in 2014, developing new technology intraocular lenses, several of which are now commercially available in many countries, including India. In 2021, Krishna founded IMAI LLC, whose focus is on developing devices and augmented reality-based tools for medical device applications.

Krishna is currently a visiting faculty at The American College, Madurai. Krishna also serves as an academic advisor for Thamarai International School, Thanjavur, Tamil Nadu, conducting workshops for science teachers and encouraging them to adopt new teaching methodologies.

First Days of My Life in the United States

Raveena Khan

It was my first time leaving my home country and traveling thousands of miles away to a new country. The adventure began at the Kempegowda International Airport. During baggage drop, my visa was verified, and it was discovered by the personnel that the visa had a validity of just one more week. I was withheld for around half an hour because they were unsure whether I would be allowed to enter the US. So, they contacted the US Border Security office, where they sent all my documents. I was nervous but tried to keep calm. Fortunately, I was allowed to travel to the US because I had a valid SEVIS for my entire stay period in the US. That was a huge relief. After quite a few haps and mishaps, I was all set to fly to my next destination, the City of Light *(La Ville Lumière)*, Paris.

The plane landed at the Charles De Gaulle airport on a bright sunny morning. Spoiler Alert! The Eiffel Tower is located around 35 kilometers from the Paris Aéroport and, therefore, can't be seen just standing at the airport. My next flight to Detroit commenced after 3 hours of tedious and sleepy layover. But then comes the most exciting part of flying in a plane, that is during take-off when you get to experience the turbulence while transiting from the lower atmosphere (troposphere) to above the clouds (stratosphere). After an hour, the beautiful and elegant air hostesses brought us food and drinks. There were all sorts of delicious French cuisine, varieties of wine, and appetizers. I really enjoyed the food.

After hours of short interval naps, I reached Detroit, my first stop in the US. Here I had a tight layover time of just 1.5 hours for my final flight to Denver. But the immigration process went pretty smoothly and fast. In about an hour, I was at the tram station, which would take me to the terminals for boarding domestic flights. However, it was quite confusing which train to board. There was a girl named Kate who was also waiting for the train. She offered

Picture 1: Pre-snowfall beauty of Flatiron mountains surrounded by colorful trees.

to show me the path to my boarding gate, so she deboarded with me at the North Station (I guess) and walked with me to my boarding gate. We had a friendly conversation. She told me about her plans after college. She was going to her friend's house to take care of her grandmother because that gave her peace since her grandmother, who was very close to her, passed away about a year ago. Kate was very kind and frank. I absolutely enjoyed talking to her. It was time to bid her farewell and board my final flight to Denver.

Denver International Airport was a seriously huge and magnificent one. After collecting my baggage, I booked the Black Eight shuttle, which is like a shared Uber cab. The person in charge of the shuttle was hospitable and helped me in the booking process when he learned that my cell network was not working and that I was new to the country. He took care of loading my luggage into the shuttle and made sure of dropping me at my location.

Wendy (my landlady) was waiting outside to welcome me into her house. Her house is just like the ones I have watched in fairy tales. She has two adorable cats named Pearl and Cally. Wendy helped me with the luggage and showed me my room. She also gave me an extra room to use as the office space. We talked for an hour. She really made me feel at home. I went to bed and was so tired that I fell asleep in a minute. But I woke up at around 3 am as I was hungry. I made some oatmeal but couldn't sleep again because of the jet lag. So I read a book and did some unpacking.

Picture 2: Post-snowfall scenic landscape of Boulder.

In the morning, Wendy gave me a ride to the Foothills Lab (FL) building of the High Altitude Observatory (HAO). My supervisors, Roberto and Sarah, were waiting for me. I was so excited to meet and interact with them that I did not feel jet lagged. They gave me a visit to the FL cafeteria and helped me with my Visitor's badge collection. Sarah had a meeting, so she took off for an hour.

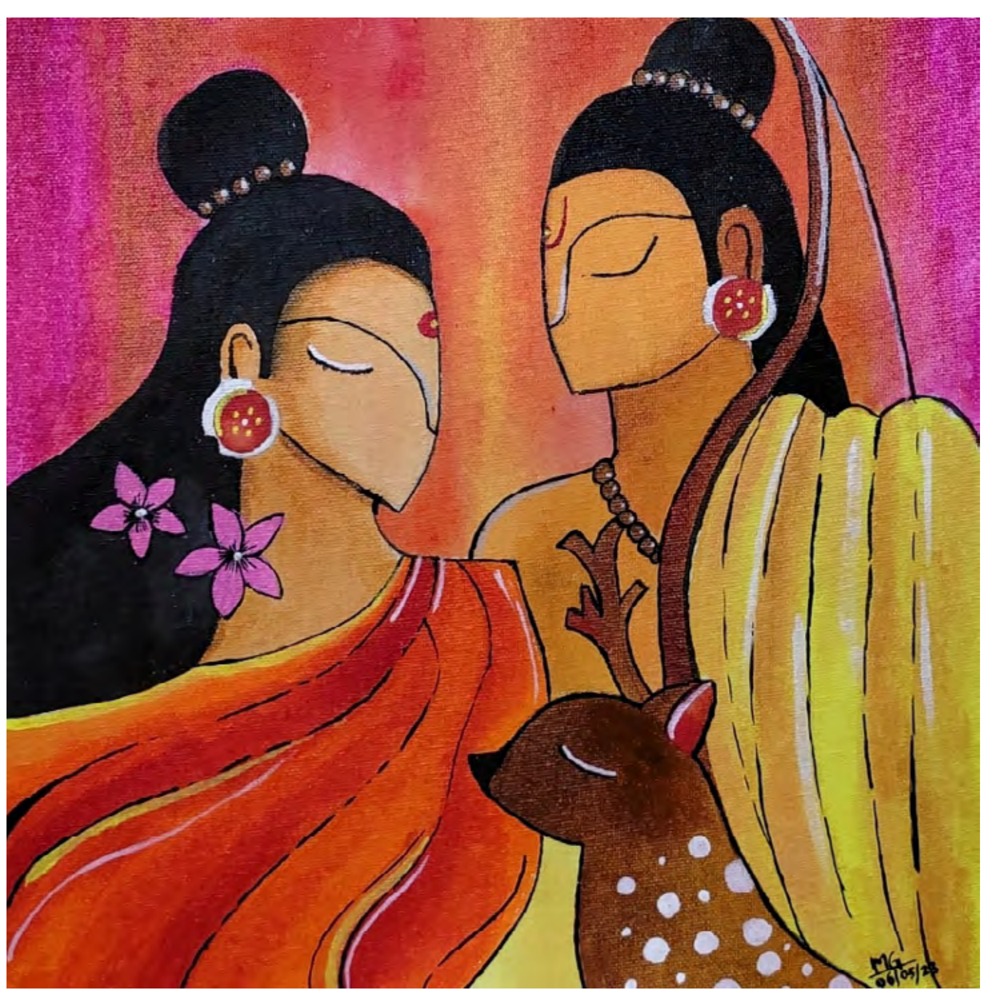
Meanwhile, Roberto and I discussed solar polarimetry and related instrumentation that I am working on as part of my PhD. It was a really intellectual discussion. After some time, we went for lunch, where Sarah and the other group members joined us. Sarah introduced me to the other members, Mauris, Dana, Alin, Ben, and Momo. We talked about science and instruments. After lunch, we walked back to the Center Green (CG) campus, where Sarah and Roberto showed me my office space. After a long day of healthy discussion and adventure, I took the shuttle back to the Table Mesa stop, from where I walked back to my room, enjoying the scenic beauty of nature during the Autumn/Fall season of Boulder.

On the third morning, I went to the office, unaware of the fact that Boulder is famous for its capricious climate. After lunch, when we were walking from the FL cafeteria back to our office, the weather was suddenly freezing cold compared to the warm and sunny morning a few hours ago. One of my colleagues claimed to have observed light snowflakes, which did not seem to be true as it was just the Fall season and too early to have a snowfall. I left the office at around 3 pm. The sky was cloudy, which appeared like a white fleece blanket. Walking towards my room, I could feel tiny particles falling on my cheeks. The particles gradually took the shape of snowflakes. It took me quite some time to believe that I was actually experiencing it. As I reached the foot of the Flatiron mountains, I was thrilled by the beguiling sight of snow falling on the hills and the dense clouds covering the peaks. I was utterly delighted to see the first snow of my life. After reaching home, I learned from Wendy that it was the first snow in Boulder in 2022. I feel blessed to have experienced the beautiful Fall season and the picturesque snowy mountains of Boulder. The memories of my first international trip will be everlasting because, in the end, we won't remember the number of hours spent working in the office or in the lab.

I conclude my story with this heart-touching quote:

> *"Travel isn't always pretty. It isn't always comfortable. Sometimes it hurts. It even breaks your heart. But that's okay. The journey changes you; it should change you. It leaves marks on your memory, on your consciousness, on your heart, and on your body. You take something with you. Hopefully, you leave something good behind."*
>
> *- Anthony Bourdain*

Raveena is a PhD student at the Indian Institute of Astrophysics. She is also a Newkirk Fellow at the High Altitude Observatory, Colorado, USA. Her research work includes numerical modelling of coronal emission lines, spectropolarimetric design and instrumentation, mainly in the EUV wavelengths.



Artist: Meenakshi

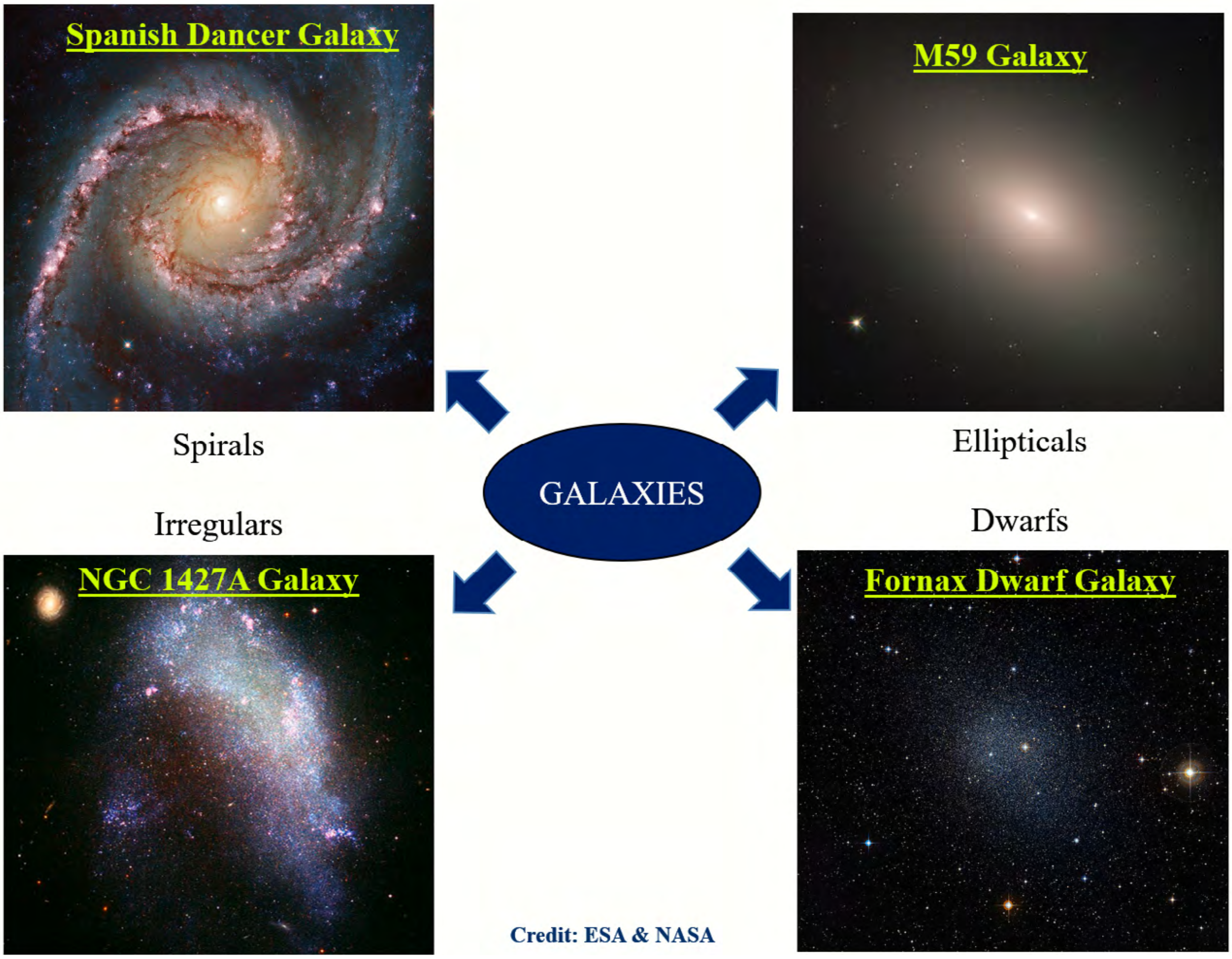


Figure 1: A general classification of galaxies.

Galaxies Saying Hello: To you and to each other

Shashank Gairola

Galaxies are some of the largest known structures in the universe. There are approximately 200 billion galaxies in the universe, and the most massive galaxies are more than a trillion times the mass of the Sun. Galaxies are made up of stars, gas, and dust, and we usually see them in four shapes- elliptical, spiral, irregular, and dwarf (Figure 1). Ellipticals appear like ellipses, while spirals look like flat disks with giant, twisty arms. Our galaxy, the Milky Way, is a spiral galaxy. In contrast, irregular galaxies have distorted shapes that are neither elliptical nor spiral-like. Lastly, dwarf galaxies are comparatively smaller, lighter galaxies with a mass 100-1000 times less than the other three types.

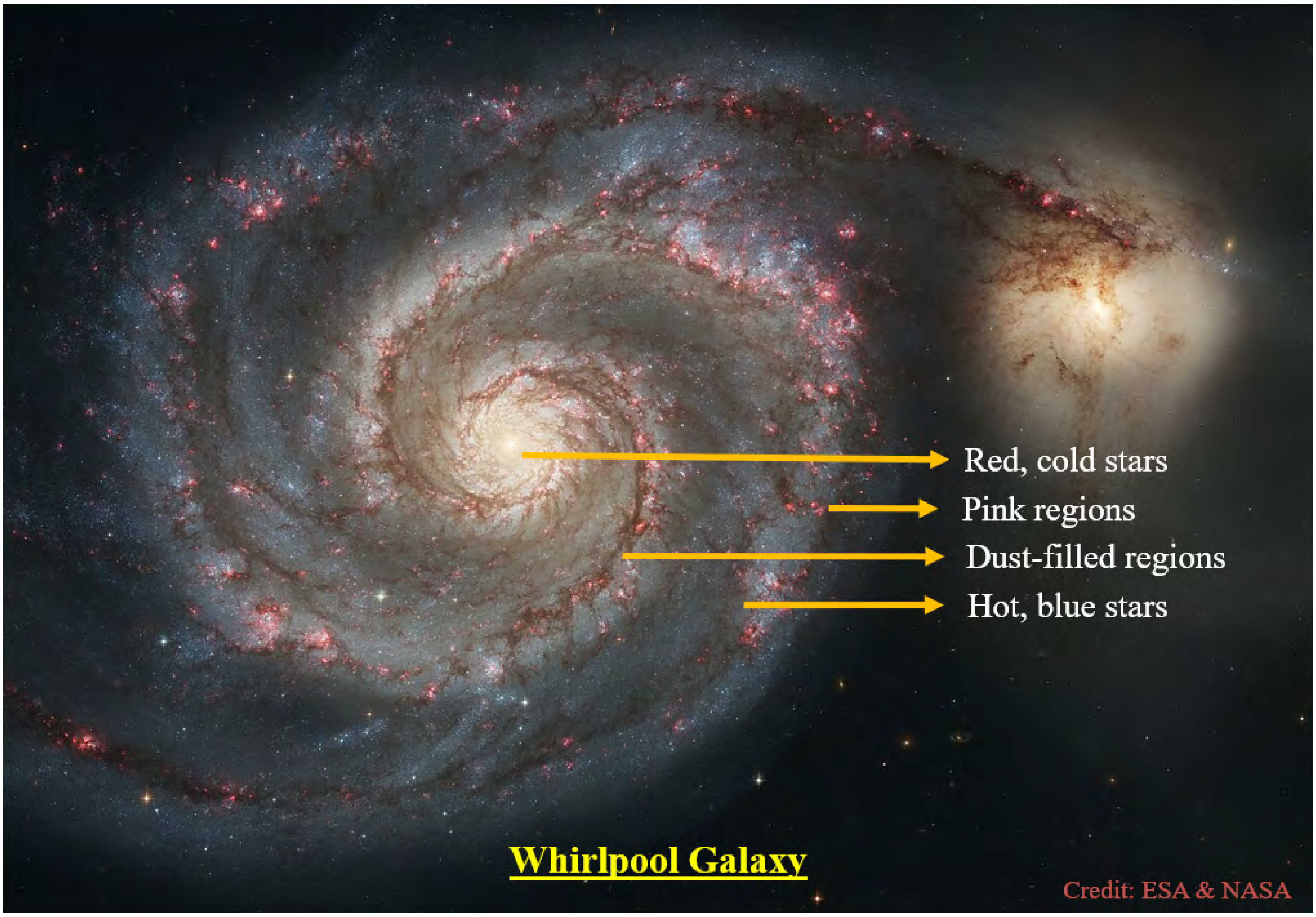


Figure 2: The different colors within galaxies

When it comes to the mass of a galaxy, visible matter makes up only a small fraction of the total mass. Most of the galaxy's mass is invisible to us, but its presence can be inferred from its gravitational impact on the galaxy. This invisible matter, termed dark matter, surrounds the galaxy as an ellipsoidal dark matter halo.

A typical image of a galaxy is very colorful (Figure 2). Each color can give us crucial information about the type of stars present. It is well established that hot stars radiate high-frequency photons, and colder stars radiate photons of lower frequencies (Energy $\propto$ frequency). Therefore, the blue color of a galaxy comes from the extremely hot stars, whereas the red color is due to relatively cooler stars. In the bright pink regions, UV radiation from the most massive and hot stars ionizes the hydrogen gas around them. The ionized hydrogen gets neutralized due to the recombination of electrons and protons emitting this pink light. Additionally, the dark brown features arise not because of any dark stars but due to the dust present in the galaxy, which blocks the light coming from the stars.

There are so many ways to study galaxies. Here are a few examples from my friends working on galaxies at the Indian Institute of Astrophysics (IIA).

Studying dark matter is one of the integral parts of doing research on galaxies. In the present-day universe, the excess gravitational pull of the dark matter halo around any galaxy heavily affects the motion of stars and gas within the galaxy. *Sioree Ansar* (Senior Research Fellow) studies the properties of dark matter halos by looking at their impact on all the visible matter in the galaxies.

As much as it is important to study galaxies apart from the Milky Way, giving attention to our galaxy is also necessary. *Abinaya O. Omkumar* (Junior Research Fellow, IIA & Leibniz Institute for Astrophysics, Potsdam(AIP)) studies satellite dwarf galaxies of the Milky Way called Large and Small Magellanic Clouds and tries to understand the impact they have on the Milky Way and vice versa. She says that by studying other galaxies in the universe, we can better understand our galaxy.

Human life spans roughly 70-90 years, but galaxies live for billions of years, thus making it impossible to see how galaxies evolve throughout their several billion-year lifetime within a human lifespan. *Dr Ankit Kumar* (Post Doctoral Researcher) uses supercomputers to simulate artificial galaxies and see how they evolve during their lifetime.

A galaxy's evolution is affected by both internal and external factors. Gas inflow through the galactic bar, the presence of spiral arms, the formation & evolution of stars, and positive & negative impacts produced by the supermassive black hole at the center of galaxies are some examples of internal factors. Gravitational encounters with other galaxies and different environments are examples of external factors. *Saili Kesri* (Junior Research Fellow) studies the impact of these different factors on star formation in spiral galaxies.

Just like a collection of houses makes up a village, a collection of galaxies makes up a galaxy cluster. These clusters are roughly ellipsoidal, and the position of a galaxy within the cluster determines its properties. How the formation of stars in some galaxies stops or starts, how gas in the galaxy is affected, and what sort of changes a galaxy can have depending upon its environment is where *Renu Devi's* (Junior Research Fellow) work lies.

Galaxies in the universe are not stationary objects. Like all other objects in the universe, they also move relative to each other. This movement sometimes causes interaction between galaxies, which leads to chaotic shapes and an increased rate of star formation within the participating galaxies. The star formation increases because the two galaxies share star-forming material with each other during this interaction. The gravitational force then compresses the shared material and forms new stars. *Chandan Watts* (Junior Research Fellow) works to understand such galactic interactions.

In the remaining article, we will learn about a few interacting galaxies, where metaphorically, galaxies say hello to each other. Interacting galaxies make up for some absolutely beautiful shapes with interesting names. The galaxy shown in Figure 2 is also an interacting system, and because of its appearance, it is called the Whirlpool Galaxy. So, let's explore a few more of them-

Mice galaxies: The name 'mice' originates from the fact that both galaxies have very long tails like two mice would. Such long tails are a common feature in many interacting galaxies and are called tidal tails.

Butterfly galaxies: These galaxies are in a very early phase of interaction and, therefore, appear so clean without much disruption in their shape. The spot where they touch each other gives the appearance of a butterfly's body.

Antennae galaxies: They got their name because

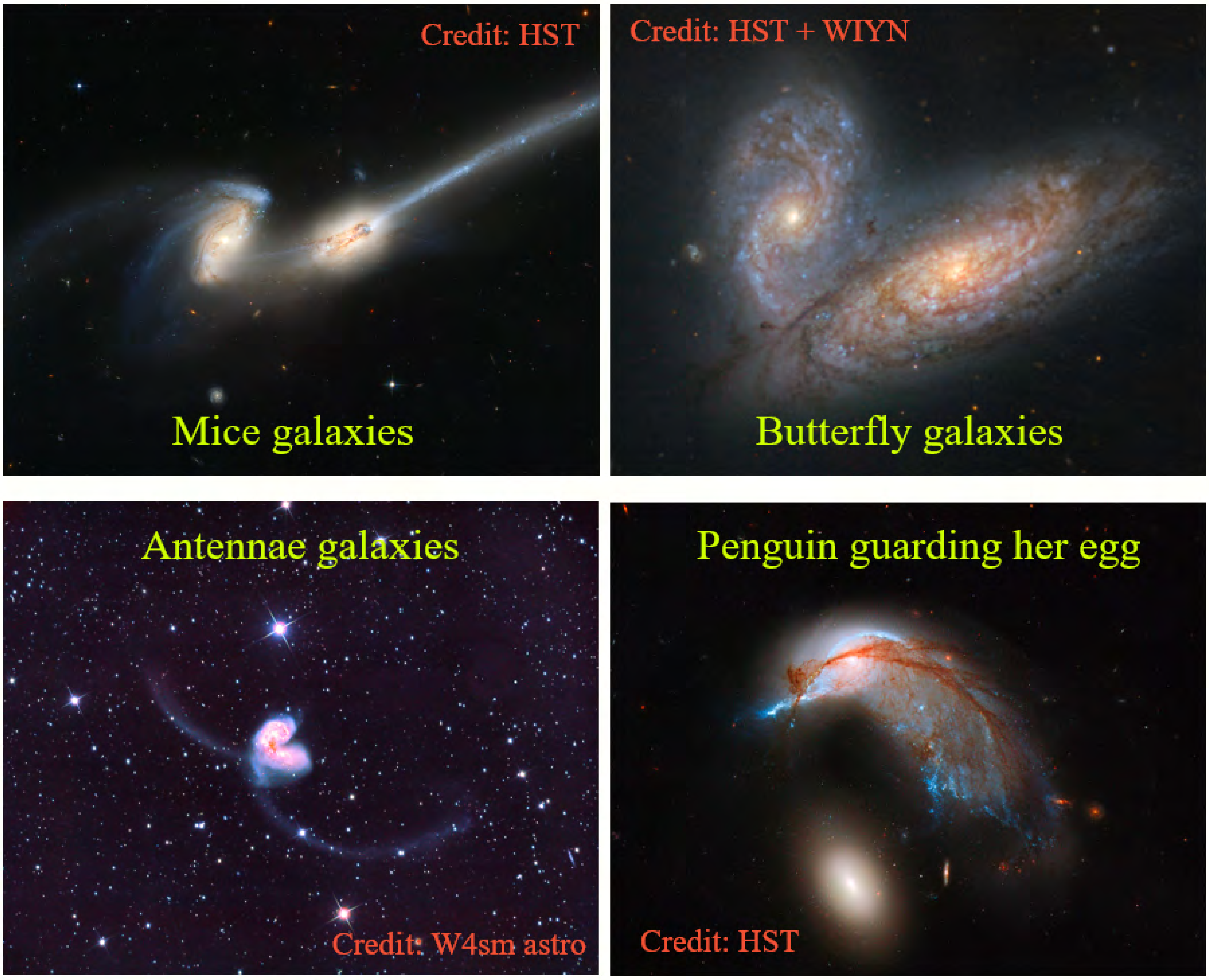


Figure 3: A few examples of interacting galaxies.

the gas and dust left behind by the galaxies look like an insect's antennae. To my eyes, it looks like a pretty little galactic heart.

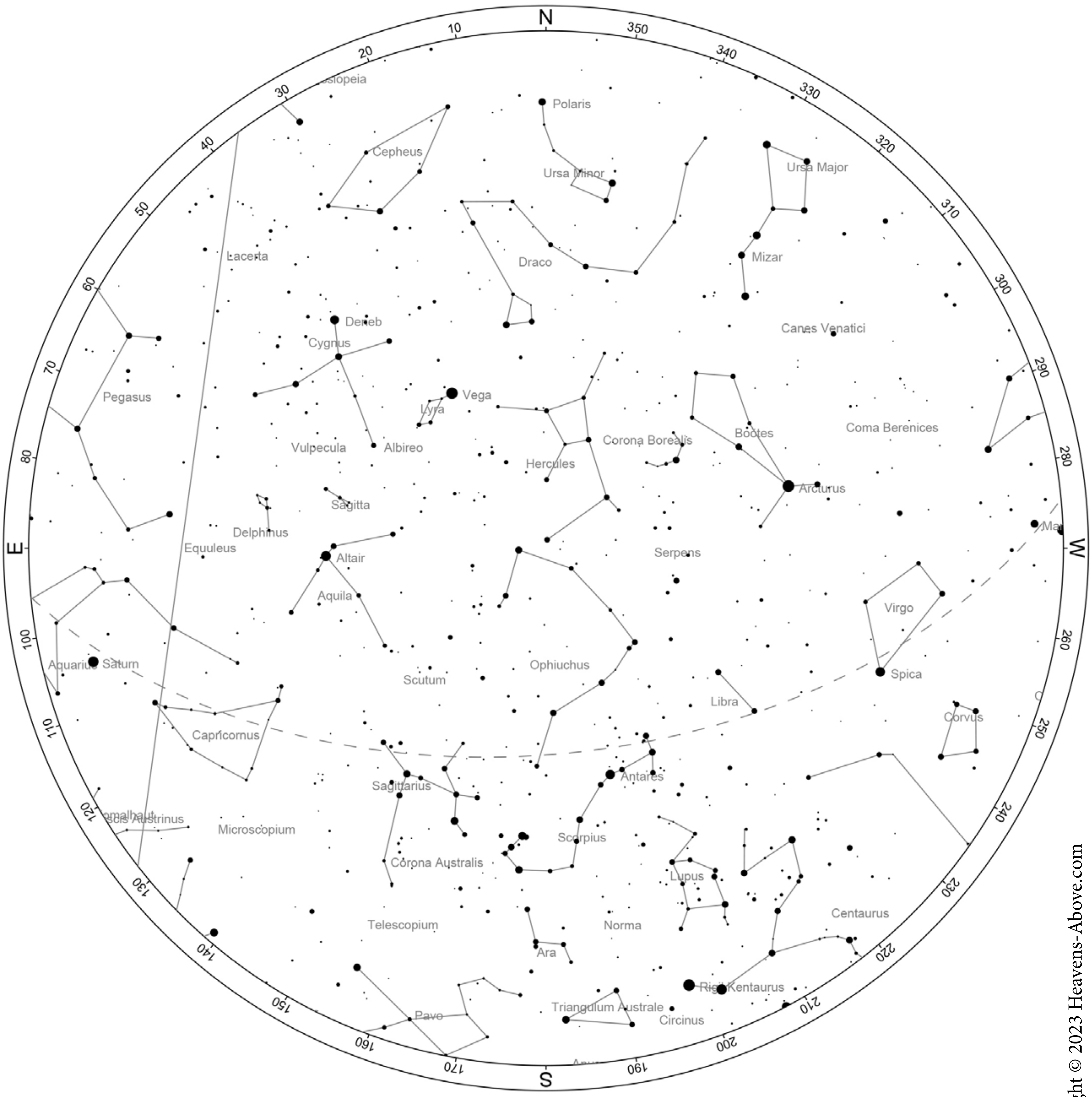
Penguin guarding her egg galaxies: The naming is obvious from the picture (Figure 3). The upper galaxy used to be a disk-like spiral galaxy, but it has been affected drastically due to the strong gravity of the elliptical galaxy below it. Due to this gravitational interaction, the gas in some parts of the upper galaxy has formed young, hot stars, as indicated by the blue color.

"For me, galaxies are the real beauties and wonders of the universe. There is so much to love about galaxies and so much yet to be understood about them. One of the biggest questions - how galaxies form and evolve in a universe this vast and complicated with virtually infinite possibilities is an open question that you, the reader, can help to solve."

Shashank Gairola is a Junior Research Fellow (JRF) at IIA. He is currently working on understanding the hierarchical nature of star formation in galaxies.

Milkyway Galaxy (Credit: Dorje Angchuk)

Andromeda Galaxy (Credit: Avinash Singh)



Skychart September 2023: (As on September 15, 2023. 20:00 hrs Bengaluru)

September 2023

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1 Lunar occultation of Neptune Aurigid meteor shower 2023	2
3	4	5 Conjunction of the Moon and Jupiter	6	7	8	9 September ε-Perseid meteor shower 2023
10	11	12	13 Conjunction of the Moon and Mercury	14	15	16
17	18 Venus at greatest brightness	19	20	21	22 Venus at greatest brightness	23 September equinox
24	25	26	27 Conjunction of the Moon and Saturn	28 Daytime Sextantid meteor shower 2023	29	30

Credit: in-the-sky.org

Background image: Comet C/2022 E1 ZFT
Credit: Anand M N

Journey to the NASI-Young Scientist Platinum Jubilee Award

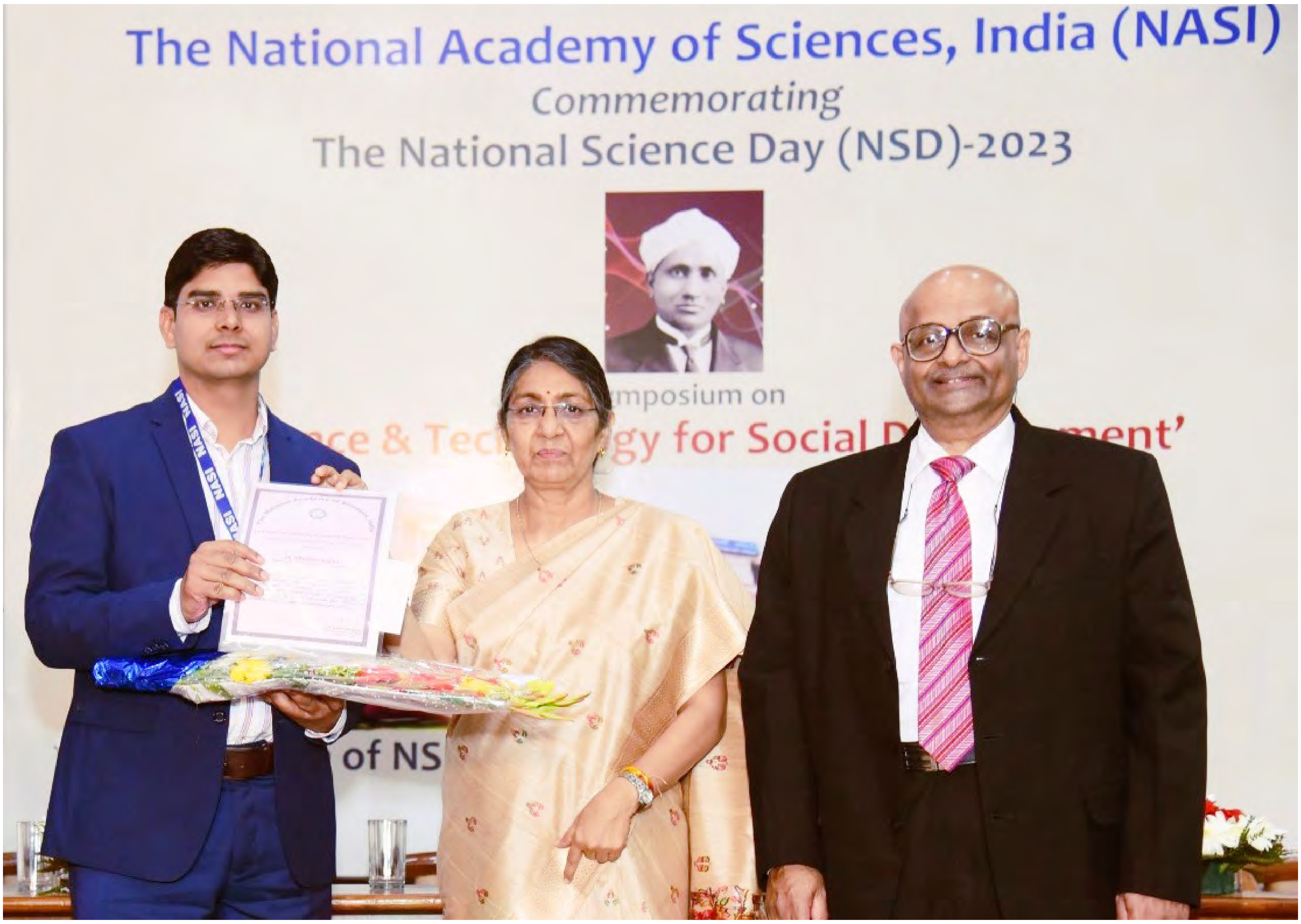
Reflections on Recognition and Responsibility

Wageesh Mishra

Achieving recognition for one's research work is an immensely gratifying milestone in an academic journey. By the esteemed National Academy of Sciences, India (NASI), I was honored with the prestigious NASI-Young Scientist Platinum Jubilee Award recently. Being bestowed this accolade by India's oldest science academy, established by the visionary Indian astrophysicist Prof Meghnad Saha, fills me with immense pride and honor. In this article, I am happy to share my journey towards achieving this prestigious award, the challenges I encountered, and the invaluable lessons I learned.

The journey of this award started after I had secured a faculty position at the Indian Institute of Astrophysics (IIA), Bengaluru. But, this recognition could be made possible because of my earlier scientific research, primarily during my PhD in Physical Research Laboratory (PRL) and postdoc abroad. Upon first hearing about the annual call for "NASI Young Scientist Platinum Jubilee Award-2022," I was intrigued but somewhat intimidated after reading about the exceptional career path of some senior recipients of this award. The annual application welcomes scientists from diverse disciplines to submit their applications for consideration. This prestigious honor recognizes exceptional young scientists under 35 who have significantly contributed to their respective fields of study. Consequently, only a few promising young researchers nationwide get this award. The selection process for the prize is rigorous, thoroughly evaluating applicants based on their research, publications, and overall influence within their domains.

Initially, I hesitated to apply and thought my work needed to be more substantial to compete with other applicants. However, my colleagues and



Dr Wageesh Mishra was honored with the prestigious NASI-Young Scientist Platinum Jubilee Award in Delhi.

mentors encouraged me to apply. The application for this award is nomination based; therefore, I had to request a renowned astrophysicist to recommend me. I am fortunate to get the support of my nominator and thank him/her for showing confidence in me. I knew the competition would be fierce, and I would need to put my best to be considered.

The application process itself for the award was challenging. I had to submit a summary of my bio-data, research papers, significant contribution to the field, impact of research, and a vision for the future. I carefully articulated my substantial contribution to understanding solar coronal mass ejections (CMEs) and their heliospheric consequences and presented them clearly and compellingly. During the application process, I felt that my research articles could have been more impactful if done in extensive collaboration. This was not the case, as I have worked mostly independently. Now I truly realize that science is not a solitary pursuit but rather a team effort that requires the input and feedback of a wide range of individuals.

After submitting the application through my nominator, the first step to success was to be shortlisted for an interview with a committee of experts from different fields in the broad discipline. I was waiting for the announcement of shortlisted applicants, and one day I received an email for the same. The email was sent to all the shortlisted candidates in a loop; therefore, I could get an idea of many deserving candidates who will be giving the interview. My application was considered in Physical Sciences, so I had to face experts from Physics, Astrophysics, Earth Sciences, Mathematics, etc. It was a long interview of around 1 hour, including a 15-minute presentation. The committee asked questions about basic concepts, a broad understanding of the field, state-of-the-art work by other national and international scientists, etc. The most important question was about my significant research findings over a decade, which were unknown to others before. I was satisfied with my performance in the interview, and the committee was positive about my candidacy. A few weeks after my interview, in the first week of January, I received an email from the NASI that I was selected for the NASI Young Scientist Platinum Jubilee Award. After this news, I felt a sense of overwhelming gratitude and accomplishment.

The award journey continued, and I had to prepare for the award ceremony, which was a significant event. The award ceremony was to be held in New Delhi on science day on 28 February 2023. But around the same time (mid-February), I was blessed with a baby boy, so I was hesitant to attend the award ceremony. I would have missed out on such a unique experience had it not been for my wife and mother-in-law. They convinced me to go to Delhi and receive the award in person. I met some of the most accomplished senior scientists at the function, including the Principal Scientific Adviser to the Government of India, Prof Ajay Kumar Sood. After receiving the award, I felt a deep pride in my accomplishments and an even more profound sense of responsibility to continue pushing forward in my research.

I believe that success comes with a responsibility, and if I were to suggest something to PhD students, I would share the lessons I learned from my journey of receiving this award. Firstly, it reminds me that hard work and dedication always pay off. Secondly, my journey taught me the importance of seeking guidance and mentorship. Thirdly, I learned the importance of collaboration and teamwork. Science is a collaborative field; working with others to achieve your bigger goals is essential. And finally, communicating your research findings to a broader audience is necessary, as this will help you build your reputation and establish yourself in the field.

In summary, receiving the NASI Young Scientist Platinum Jubilee Award has been an unforgettable milestone in my scientific career. I believe this would open new doors for me in my academic career. The recognition and appreciation of my scientific contributions profoundly motivate me to continue my research journey with greater zeal and enthusiasm. It also serves as a reminder of the responsibilities accompanying recognition. I must add that pursuing a career in science is not easy, but the rewards are immeasurable if one genuinely understands scientific pursuits' larger purpose in life. I hope this story will inspire other young scientists to pursue their research work enthusiastically and with dedication and contribute to advancing science and technology in their respective fields.

Dr Wageesh Mishra is an Assistant Professor at the Indian Institute of Astrophysics (IIA), Bengaluru. Before taking a faculty position at IIA, he was a Postdoctoral Fellow at the Max Planck Institute for Solar System Research, Germany. His primary research interests are solar CMEs, heliosphere, stellar activity, and space weather.

Launch of the Dec 2022 Issue |

Prof Annapurni Subramaniam, Director IIA

Artist: Meenakshi

In Conversation with David L. Lambert | Research in the 1980s

Parvathy: Currently, you are the co-chair of the Scientific Advisory Committee (SAC) and an Honorary Fellow of the Indian Institute of Astrophysics (IIA). How did your association with IIA get started?

Astronomy is full of interesting personalities. Long ago, I had written a paper with a student and a postdoc on a particular star called R Coronae Borealis, which is a hydrogen-deficient star – these are rare stars whose hydrogen content is a million times less than what is in the Sun. One day, Prof Kameshwara Rao, then a faculty member at IIA, turned up in my Austin office and said we should write a proposal to observe these stars from Cerro Tololo Inter-American Observatory (CTIO) in Chile. Prof Rao had done his PhD thesis at the University of California in Santa Cruz on the R Coronae Borealis stars with the Late Prof George Herbig, an American astronomer who pioneered the spectroscopic studies of R Coronae Borealis. Most of the known R Coronae Borealis stars are in the southern celestial hemisphere. We finally wrote a proposal. It was in 1989 or 90 when Prof Rao and I went to CTIO to observe the R Coronae Borealis stars. I visited IIA that winter and again subsequent times to work on the data.

David L. Lambert dœs research on stellar atmospheres, the chemical composition of stars, and the chemical evolution of the universe. He received his D.Phil. in 1965 from the University of Oxford. Then in 1967, he joined the California Institute of Technology. In 1969, he began a long association with the Department of Astronomy and the W.J. McDonald Observatory at The University of Texas, Austin. From 2003 until 2014 he was the Director of the McDonald Observatory. He is now the Emeritus Isabel McCutcheon Harte Centennial Chair in Astronomy. He has long enjoyed his association with IIA and overlapping productive research interests with IIA faculty and students, including encouraging several students as postdoctoral fellows at the McDonald Observatory.

Prof David L. Lambert (left) and Professor N K Rao (right) at 18,000 feet protecting the India's Northern border! It was during his visit to Leh and Hanle before the latter site had telescopes

And at that time, believe it or not, the only computing facilities at IIA capable of handling the spectra were at Kavalur in the building housing the Vainu Bappu Telescope (VBT). We spent some lovely weeks out in Kavalur, along with Prof Sunetra Giridhar, another professor now long retired from IIA, and a then very young Prof Aruna Goswami. Since then, we have been following R Coronae Borealis and other hydrogen-deficient stars. Even last week (February 2023), we got the referee's report on our study of a related star, where we got infrared spectra of it. So it's a continuing process.

Sipra: When was your first visit to IIA? Would you like to share some memories?

I first visited IIA in 1985 briefly. At that time, the International Astronomical Union (IAU) triennial meeting took place in Delhi, with a related Symposium or Colloquium taking place in Mysore. So to reach Mysore, we flew to the old airport in Bangalore. We were picked up by a representative from IIA and he gave us a tour before we departed for Mysore. We briefly stopped by the institute but then headed to the Flower Show in Bangalore. Later, we came back to the institute to have a cup of tea and meet other people joining the coach to Mysore. But it took forever to complete the paperwork for two cups of tea since three of us were guests and not affiliated with either institute!

Back then, IIA was much smaller, physically occupying the same space but without the CREST campus. Kavalur existed, and there were probably one or two telescopes less than what exists now, and I guess the VBT (Vainu Bappu Telescope) existed too. I've had the opportunity to know or meet every director of the institute, including Bappu (Prof Vainu Bappu), who was a fellow graduate student at Harvard with Harlan J Smith, our McDonald's Director. I met him once in Harlan's office. I also met Bhattacharya (Prof JC Bhattacharya) who reviewed our Harlan J. Smith Telescope (107-inch telescope). It is located at the McDonald Observatory in Texas with a design similar to that of the VBT.

In those days, we used to fly from Austin to a place called Marfa (which is close to the McDonald Observatory) on a little charter plane to visit the Observatory. It would go twice a week. When Bhattacharya visited, I picked him up and showed him the small area near the airport where the charter plane was. He looked at the plane and, referring to the famous fictional pilot, James Bigglesworth (nicknamed 'Biggles'), remarked, 'Is this the kind of plane that Captain Biggles flew?' Anyway, we went out to examine the 107-inch telescope and then discussed the construction of the VBT.

Saraswathi: What are your research interests?

At the highest level, I am interested in the origins of the chemical elements, nuclear synthesis, mainly within stars, how elements get distributed, how many stars get stuff mixed up to their surface, how stuff gets exchanged between the two binary stars and also, the evolution of stars. And then, I have some interest in exploring the interstellar gas in the galaxy. But I'm not doing as much these days.

Akhil: Do you recall any exciting research moments in your life?

I can remember various occasions when we were at the telescope, and we got a result that we hadn't expected. I remember two such instances.

I had a good friend named Jos Tomkin, who came to me for a postdoc from the University of Sussex. It was long ago, in the 70s. We latched on to an interesting problem to explore. When a star turns into a red giant, the outer half of the star gets mixed up; the mixed region is enriched in the isotope Carbon-13. The normal and almost always more abundant isotope is Carbon-12. The atmosphere post-mixing has a changed ratio of Carbon-12 to Carbon-13. The ratio you measure, provided you know what the star started with, gives you an idea of the degree of mixing of the star, which you can then compare with what the theoreticians predict.

We started observing the spectrum of the star. In those days, we got the spectrum in chunks, unlike today, where you may get the whole spectrum in a single exposure. Then, we observed with a novel instrument, a scanner, as we called it. We were observing the star called the Epsilon Pegasi, which is a K supergiant. It was rising early in the morning, and we managed to get one section of the spectrum before the sun came up. And it was clear from this one section that this star was unusually rich in Carbon-13. It was a level of richness that we hadn't seen in any of the stars in our observing program. But we couldn't get a definitive result until we'd done another two sections. We waited, praying that for the next one or two nights, the sky should be clear enough so that we could complete observing this star. And then it turned out that, I think, the ratio of Carbon-12 to Carbon-13 was about 3, which is a high number for a mixed giant and indicative of material severely exposed to hydrogen burning.

Another moment of highlight I can think of is with my student Andrew Bernat. He came from El Paso in the far west of Texas. For graduate students, I liked to give them topics which were a bit or entirely away from my own interests. First of all, it gives them the impression that they are working on challenging subjects. Moreover, it helps me to maintain an active interest in broader fields. I mean I could have told Andy, why don't you look at giants like Epsilon Pegasi? Instead, I said, why don't you study Betelgeuse? Betelgeuse is a massive star above Orion's belt. Andy and I did some initial work which showed that Betelgeuse is losing mass. It has a wind coming off of it. Andy developed a theoretical argument that the wind was of such a density that it should be detectable far out, i.e., if you point a telescope at Betelgeuse, you are observing the star, but if you point the telescope off the star, you're looking on a path through the wind.

Soumyaranjan: Is it something like the solar wind?

Well, it is more powerful than the solar wind; it may have low temperatures and may contain dust in it.

So, I said to Andrew, let's test your theory. We went again to use the scanner and started observing the Betelgeuse, specifically the potassium (K I) resonance line at 7699 Angstroms. Our idea was that when the light comes off the star, it is absorbed by the potassium atom and then it is re-emitted in random directions. If you point the telescope off the star, you're going to pick up light from potassium atoms that have absorbed light from the star and are re-emitting photons in your direction. And, if you observe a Betelgeuse directly, you see a strong absorption line; the potassium atoms along the line of sight to your telescope are absorbing stellar light. We pointed the telescope off the star and saw emission from Potassium atoms in the wind. And then, we pointed it a bit further off and found that the potassium signal got weaker. In this way, we were able to map the wind of Betelgeuse. And then we looked at, maybe one or two, other stars and found similar results. So that was something that hadn't been seen before by anyone! Andrew went on to get a very fine PhD.

Parvathy: Do you have any childhood memories that inspired you to take astrophysics as a career?

Yes, actually there is one instance during my childhood that fired my interest in Astronomy. I attended Ashford grammar school for boys, where the headmaster Mr. E.T. Mortimore was very enlightened when it came to school prize day. He allowed boys who received prizes to choose their own books as a reward. Of course, there was a price limit. I recall receiving a prize for 'Captain of the School', and I selected the book "Frontiers of Astronomy " by Fred Hoyle, which you might find in the IIA library. Hoyle was an exceptional theoretical astronomer, very outspoken, and gave superb talks. In the late 1940s, he advocated for the steady-state theory of cosmology. His book has wonderful chapters on the evolution of stars and the element synthesis expected from them.

Soumyaranjan: Do you like Indian food?

You know, I like Indian food. In my student years, there were few Indian restaurants in England. There were just three or four in Oxford when I was an undergraduate. When I went to Austin in 1969, a few Indian restaurants were there in Austin. But now they are very common, which is wonderful.

ASTEROSEISMOLOGY

Welcome to the cosmic orchestra

Figure 1: Illustration of sound waves trapped inside the star. (Credit: Gabriel Pérez (SMM/IAC))

Anohita Mallick

Nearly four centuries ago, the English poet John Donne contemplated "trepidation of the spheres" in his metaphysical poem - "*A Valediction: Forbidding Mourning.*" The phrase alluded to vibrations of celestial bodies. Modern astronomy has proved that he was not far off the mark. Stars are strewn across the sky, indeed generating a unique symphony. Space telescopes "listening" to these stellar harmonies offer a deluge of information to astronomers, including the composition of stars, their masses or sizes, stellar age, contribution to the Milky Way's evolution, details of their internal structure, and so on.

The study of this celestial music is labeled as "asteroseismology." Similar to geologists using seismic waves to study the Earth's interior, astrophysicists conduct forensic studies of stars by exploiting waves traveling through them. Two persistent questions might occur to any beginner in asteroseismology.

What causes vibrations in stars?

Stars are composed of blobs of gas. If the small displacement of these parcels of gas creates instabilities, stars can oscillate. These vibrations are damped inside stars. There must be some energy feedback to sustain these oscillations for their detection. Three mechanisms have been proposed, namely -

1. **ϵ-mechanism:** Stars are primarily composed of Hydrogen and Helium, which are densely packed in the core, and resultant pressure initiates nuclear fusion reactions. The energy produced from these reactions keeps the star from collapsing in on itself. The nuclear energy generation rate in the stellar cores *(ϵ)* is heavily dependent on temperature. Nuclear energy release compresses cores, resulting in increased temperature. Increased thermal energy can drive stellar pulsations. However, this mechanism is insufficient to explain oscillations in most stars, as mathematical models indicate that ϵ-mechanism driven vibrations are too weak to be detected. They might be observed in convective regions, low-mass stars that are fully convective (M<= 0.35 solar mass), or the most massive ones with convective cores (M> 60 solar mass)

2. **Stochastic processes:** Nuclear reactions in stellar cores produce enormous energy, which results in hot gas traveling up toward the convection zone. Near the surface, the gas cools down and moves at a speed similar to that of sound. Thus, sound waves originate in the outer layers of stars triggered by turbulent convective motion. These sound waves are trapped inside the star by the photosphere and bounce back inside. The increasing sound speed near the core refracts these waves (due to increased temperature) back to the surface, where they are reflected inwards again. The continuous bombardment of the stellar surface causes the star to vibrate. The superposition of these waves creates standing waves making stars vibrate at their resonant frequencies.

3. **K-mechanism:** Consider a zone at some depth inside a spherically symmetric star. Hydrogen is neutral above this zone and completely ionized below it. Within this zone, some hydrogen atoms are ionized, while others are neutral, and minute temperature fluctuations can substantially change the ratio of neutral to ionized atoms. This zone is referred to as a partial ionization zone. Gas opacity in stars usually decreases with increasing temperature. However, for pulsating stars, stellar compression releases energy that ionizes the gas in these zones, increasing opacity in turn. Due to high opacity, ionization zones can absorb radiation. Radiation pressure expands and cools the zone, allowing energy to escape. Further cooling of the zone results in the recombination of ionized material, causing a sudden decrease in opacity combined with a decrease in outward pressure, and the zone drops back. This cycle repeats, and the oscillations are larger in amplitude than stochastic convection-driven oscillations. The K-mechanism explains most categories of pulsating stars well.

How does a star oscillate?

Stars can have both radial and non-radial oscillations. Radial pulsations involve changes in volume only. A star can be considered like an open-at-one-end organ pipe. A node exists at the center of the star, and an antinode exists at the surface. In the case of non-radial oscillations, vibrations do not occur along the stellar radius. Different portions of the stellar surface move in opposite directions, causing the star to wiggle like jelly. However, this motion is very subtle, since the amplitude of these vibrations is weakened at the surface and cannot be detected by the eye.

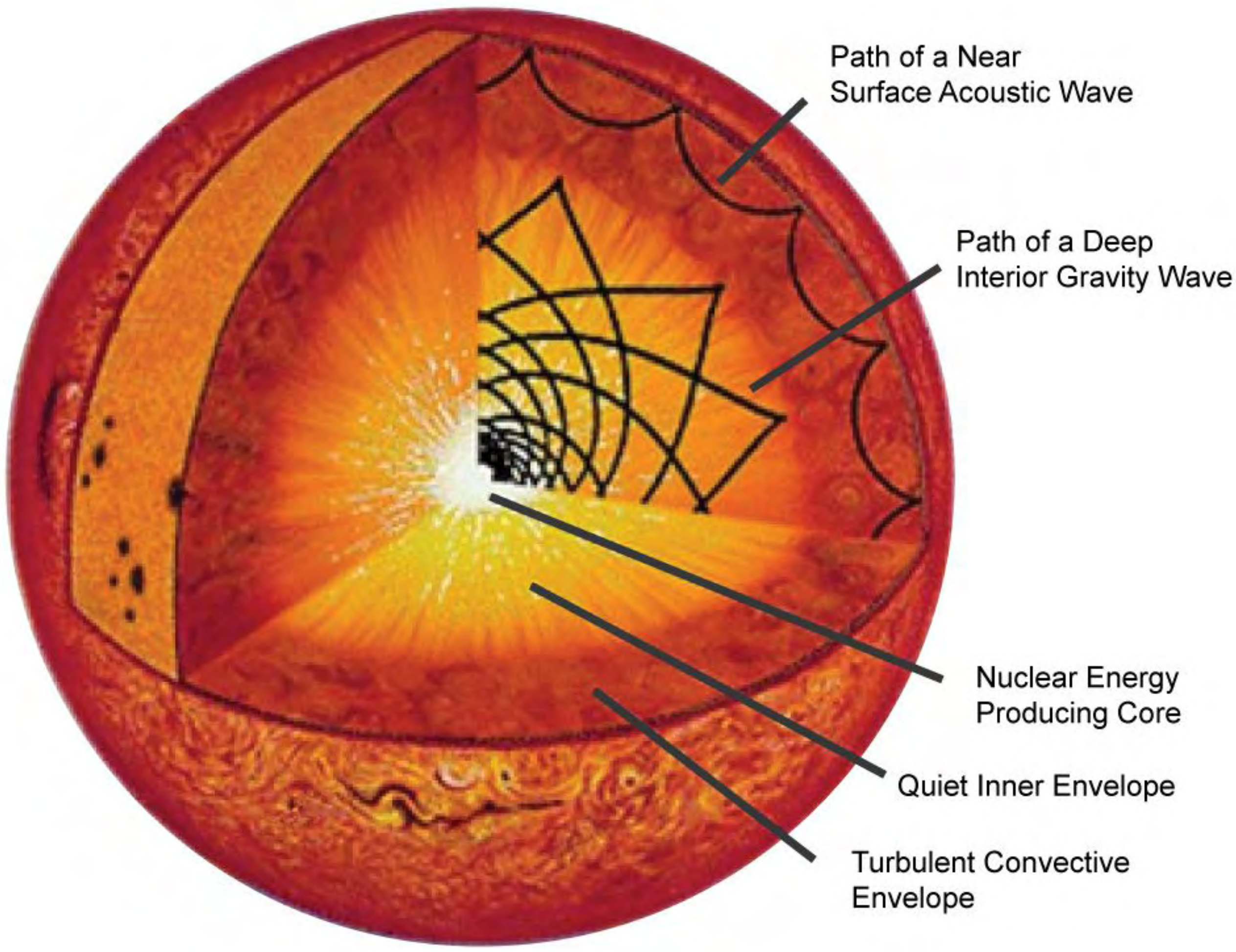


Figure 2: Propagation of p and g-modes in Sun. (Credits: Newton Science Magazine.)

Three types of waves can propagate within stars:

1. **Pressure waves (p-modes)** - In p-modes, the displacement of the gas parcel is in the direction of travel of the wave where pressure acts as the restoring force. These waves are seen only in the outer convective zone of the star.

2. **Gravity waves (g-modes)** - In g-modes, the displacement of the gas parcel is perpendicular to the direction of travel of the wave where buoyancy acts as the restoring force. These waves are seen in the radiative zone of the star.

3. **Surface gravity waves (f-modes)** - Surface gravity waves or fundamental (f) waves are akin to ripples on a pond's surface and are seen on the photosphere of the star.

Stellar oscillations are 3-dimensional in nature and are characterized by spherical coordinates (r, θ, ϕ). The vibrations are labeled by three fundamental numbers - radial order n, angular degree ℓ, and azimuthal order m. The value ℓ represents the total number of nodes on the surface, while m represents the number of modes running through the pole. Modes with $n = 0$ are f modes, $n > 0$ denotes p-modes, and $n < 0$ alludes to g-modes. Modes with $\ell = 0$ are radial modes , $\ell = 1$ are dipole modes, $\ell = 2$ quadrupole modes and so on. While p-modes can be both radial or non-radial, g-modes are only non-radial.

From the telescope to visualization

Sound cannot travel through outer space; therefore, we do not "hear" the ethereal music of stars. Waves propagating through stars will compress and expand regions of gas. Compressed gas becomes hotter and the region gets brighter and expanding gas becomes cooler and a little bit dimmer. Thus sound waves inside stars are translated as localized bright and dim areas on the stellar surface. These

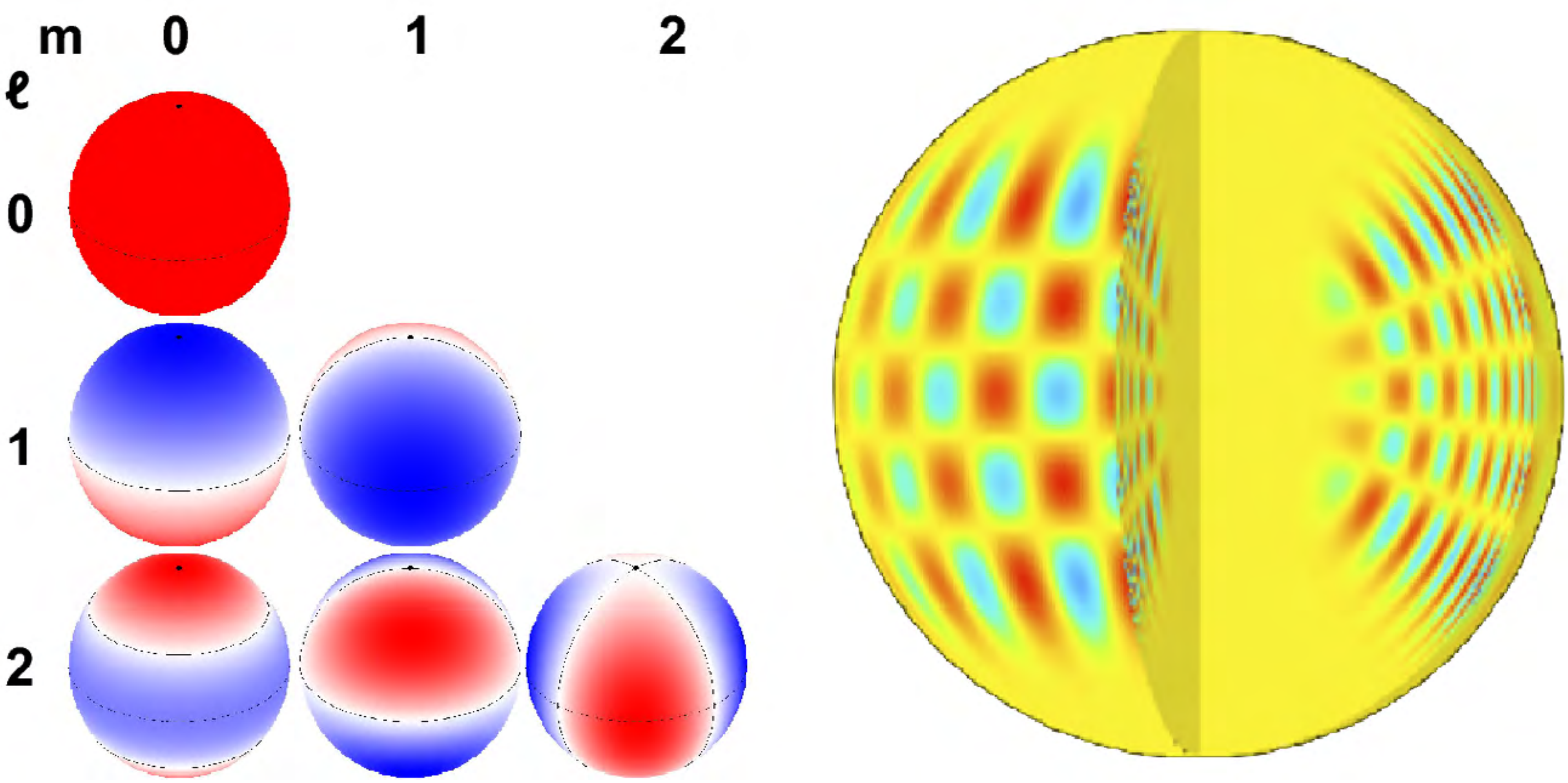


Figure 3: Radial and non-radial stellar oscillations depicted by spherical harmonics. Modes are represented by spherical harmonics. The blue regions are those moving towards the observer, while the red regions represent those that are moving away; half a period later, this is reversed. (Courtesy: Rafael A. García.)

waves might also cause a Doppler shift (change in the wavelength of observed spectral lines due to the relative motion of different portions of the stellar surface with respect to the observer) of lines in stellar spectra resulting in radial velocity variations due to outward and inward movement of the stellar surface. Hence, stellar oscillations can be observed in two ways - spectroscopy of velocity variations and photometry of stellar flux variations.

Space missions or ground-based observations?

Be it a spectroscopic or photometric study of stellar pulsations, in order to identify oscillation modes accurately, it is necessary to have time series data with a high signal-to-noise ratio (SNR) and high duty cycle (i.e., a fraction of time spent successively observing the variability of a given star). The presence of noise and gaps in the observed data can severely affect seismic measurements. Ground-based measurements (these employ the spectroscopic method) are better for our nearest oscillating neighbor, the Sun - since granulation on the surface of sun-like stars causes higher noise on photometric data than in spectroscopic data. But for other classes of stars, space-based data is more efficient. Obtaining continuous data sets for extended periods from the ground is impossible due to the day/night cycle, weather conditions, and other factors. From space, most of these problems are overcome and space missions are both cost-effective and time-efficient as their instrumental requirements overlap with those of exoplanet-finding missions.

Basics of asteroseismic data analysis

Space-based photometric time series data is generally sufficient to study stellar oscillations in most types of pulsators, except in the very low-frequency regime. Both photometric and spectroscopic time series data are converted to the frequency domain. In order to minimize noise, the Lomb-Scargle periodogram technique[1] is employed for such conversions instead of the traditional Fourier transform. This technique fits sinusoids to the signal directly, using a least squares fit. The resulting transform is referred to as the power spectral density (PSD).

The PSD of a time series shows how energy is distributed among frequency components that form the signal in time. PSD will reveal excited modes with amplitude above the noise level at corresponding oscillating frequencies. We can extract two important seismic parameters from the PSD, which can provide information about stellar global properties like mass, radius, and surface gravity.

One of these parameters is ν_{max}. PSD of solar-like stars exhibit a Gaussian-like envelope and ν_{max} corresponds to the peak of this envelope. It represents the frequency of the mode with the highest amplitude. The second global seismic parameter is large frequency separation $\Delta\nu$. Since stars are point sources, oscillation modes are observable for low angular degrees up to ℓ =2, except for the Sun. An asymptotic regime, i.e., $n \geq \ell$, can be followed to characterize such oscillations. Mode frequencies ν with high n and low ℓ values will follow a periodic pattern given as $\Delta\nu \equiv \nu_{n+1,\ell} - \nu_{n,\ell}$. Asteroseismic scaling relations utilize these quantities for precise measurements of stellar parameters.

Applications and Future

Vibrations can be observed in stars across the HR diagram, making seismic analysis a powerful tool for studying Galactic evolution. Asteroseismology has been applied to characterize the evolutionary phases of red giants, internal stellar rotation, magnetic field, and properties of planet-hosting stars. Since oscillation frequencies can be measured with great precision, seismology offers more accurate values of mass, radius, and age of stars compared to conventional methods.

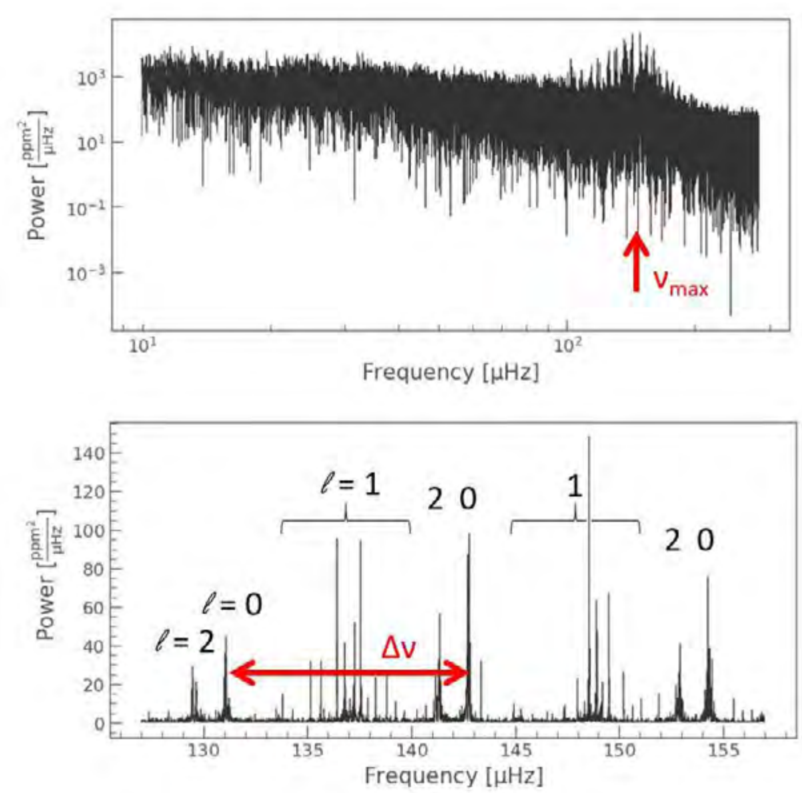


Figure 4: Asteroseismic parameters from the power spectral density (PSD) of a star. The spherical degree of the excited modes is indicated by ℓ. (Courtesy - J. Merc.)

We entered a golden age in asteroseismology with the launch of NASA's Kepler satellite in 2009, which provided seismic data for thousands of stars. This legacy is being carried forward by Transiting Exoplanet Survey Satellite (TESS-launched in 2018), PLAnetary Transits and Oscillations of stars (PLATO-expected launch around 2026), and Wide-Field Infrared Survey Telescope (WFIRST-expected launch around 2027), and the field is only in its teenage years. This is a fascinating time for the stellar physics community as asteroseismology provides possibilities for exploring hidden stellar interiors

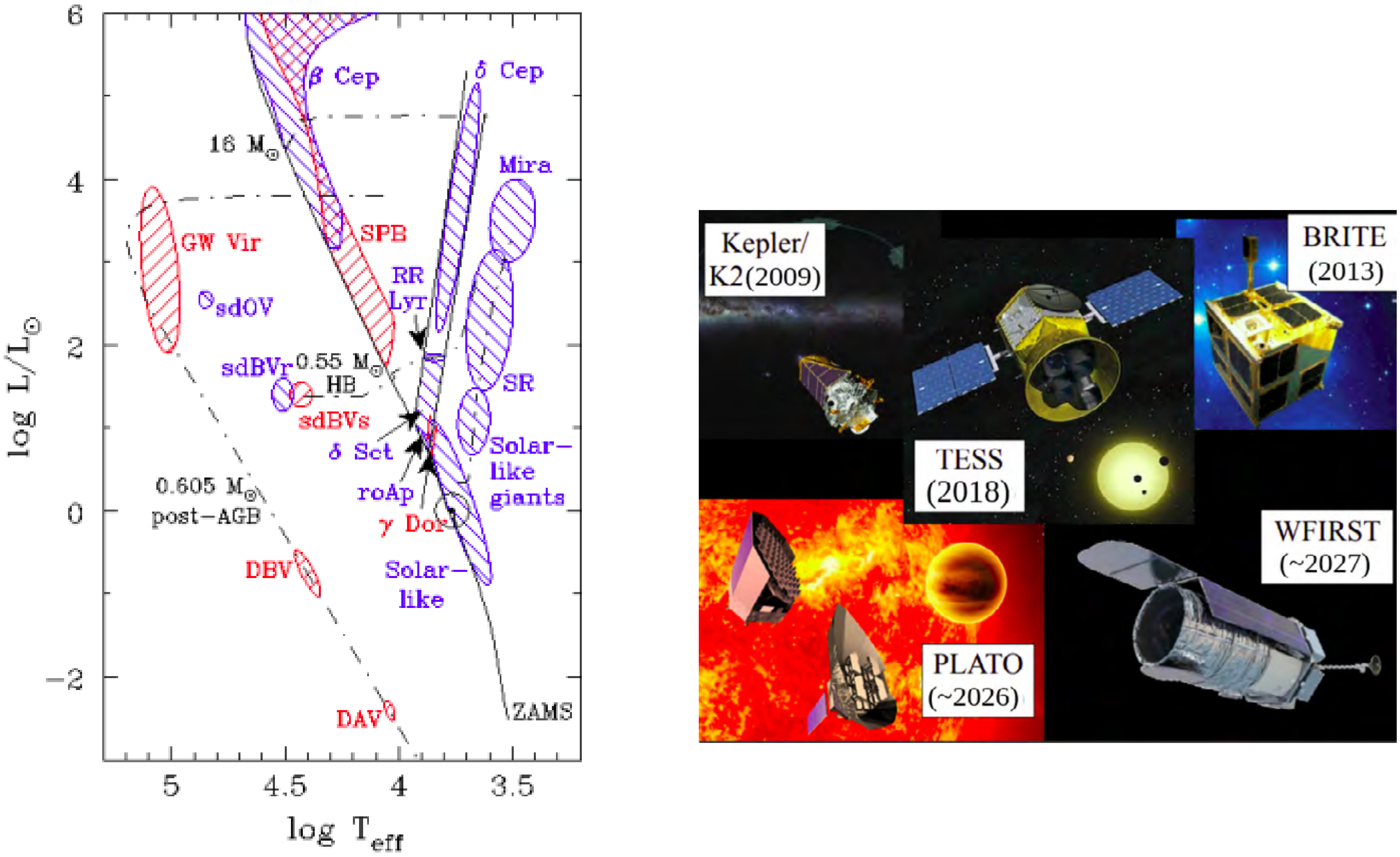


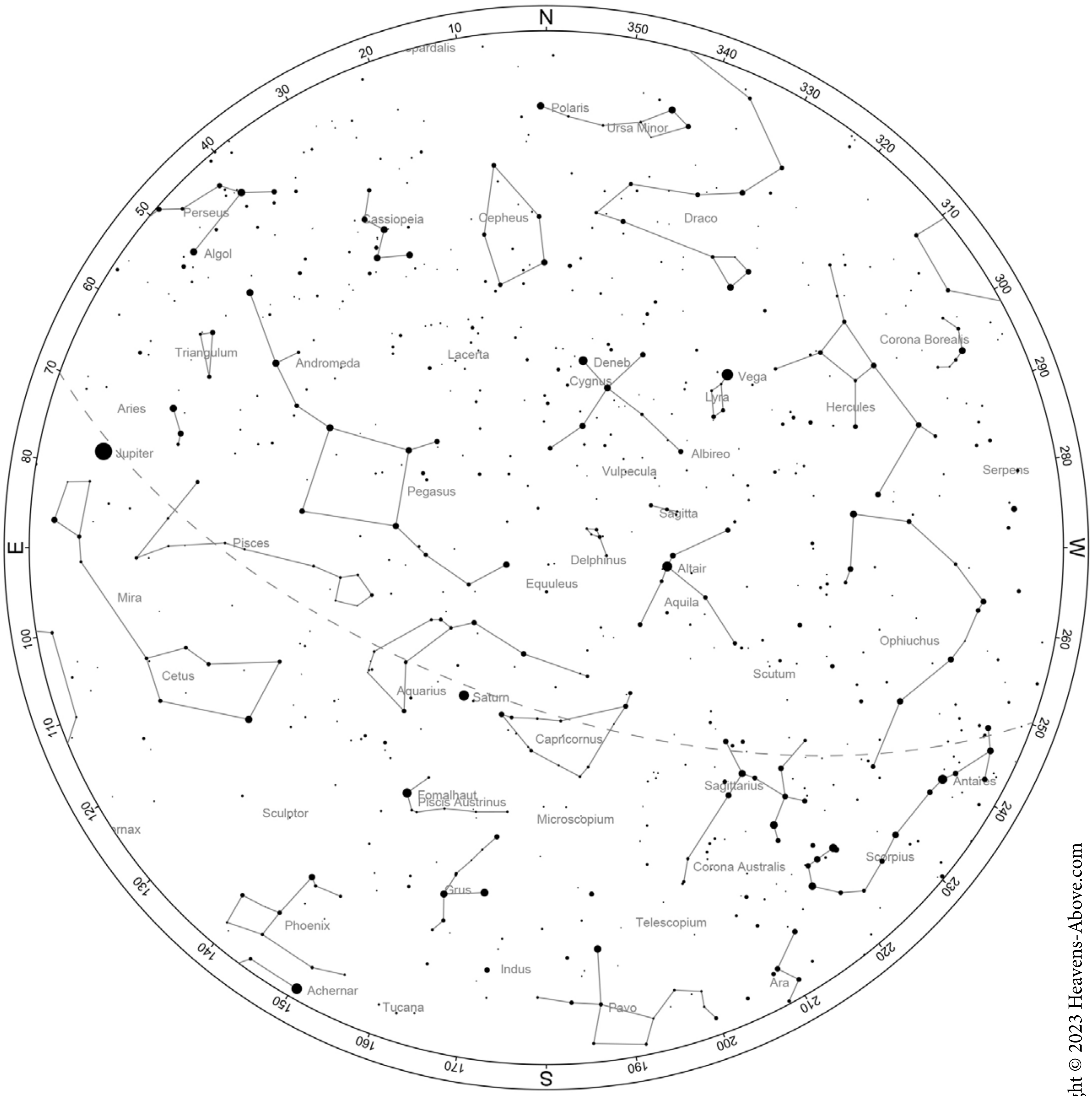
Figure 5: (Left panel) HR diagram showing pulsating stars: Red - known classes of pulsating stars about 40 years ago. Blue - classes of pulsators known to date. (Credit - Handler). *(Right Panel) Space-based asteroseismic missions - past, present, and future.* (Credit - Huber)

and untying several knots of stellar evolutionary theory.

Useful link:

1. *https://ui.adsabs.harvard.edu/abs/2018ApJS..236...16V*

Anohita Mallick is a Senior Research Fellow at IIA. Her research interests are stellar evolution, chemical abundances of evolved stars, lithium anomaly, and seismic studies of red giants.



Skychart October 2023: (As on October 15, 2023. 20:00 hrs Bengaluru)

October 2023

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2 Conjunction of the Moon and Jupiter The Andromeda Galaxy is well placed	3	4	5	6 October Camelopardalid meteor shower 2023	7
8	9 Draconid meteor shower 2023	10 Conjunction of the Moon and Venus Southern Taurid meteor shower 2023	11 δ-Aurigid meteor shower 2023	12	13	14 Annular solar eclipse (South America)
15	16	17	18 ε-Geminid meteor shower 2023	19	20 Mercury at superior solar conjunction	21
22 Orionid meteor shower 2023 Comet 2P/Encke passes perihelion	23 Venus at dichotomy	24 Conjunction of the Moon and Saturn	25 Leonis Minorid meteor shower 2023	26 Venus at highest altitude in morning sky	27 Conjunction of the Moon and Venus	28 Conjunction of the Moon and Jupiter
29 Conjunction of the Moon and Jupiter	30	31				

Credit: in-the-sky.org

Background image: Super Moon rise, Green Valley view, Kodaikanal

Credit: Anand M N

Phasing of Mirror Segments: The DFS-based Phasing

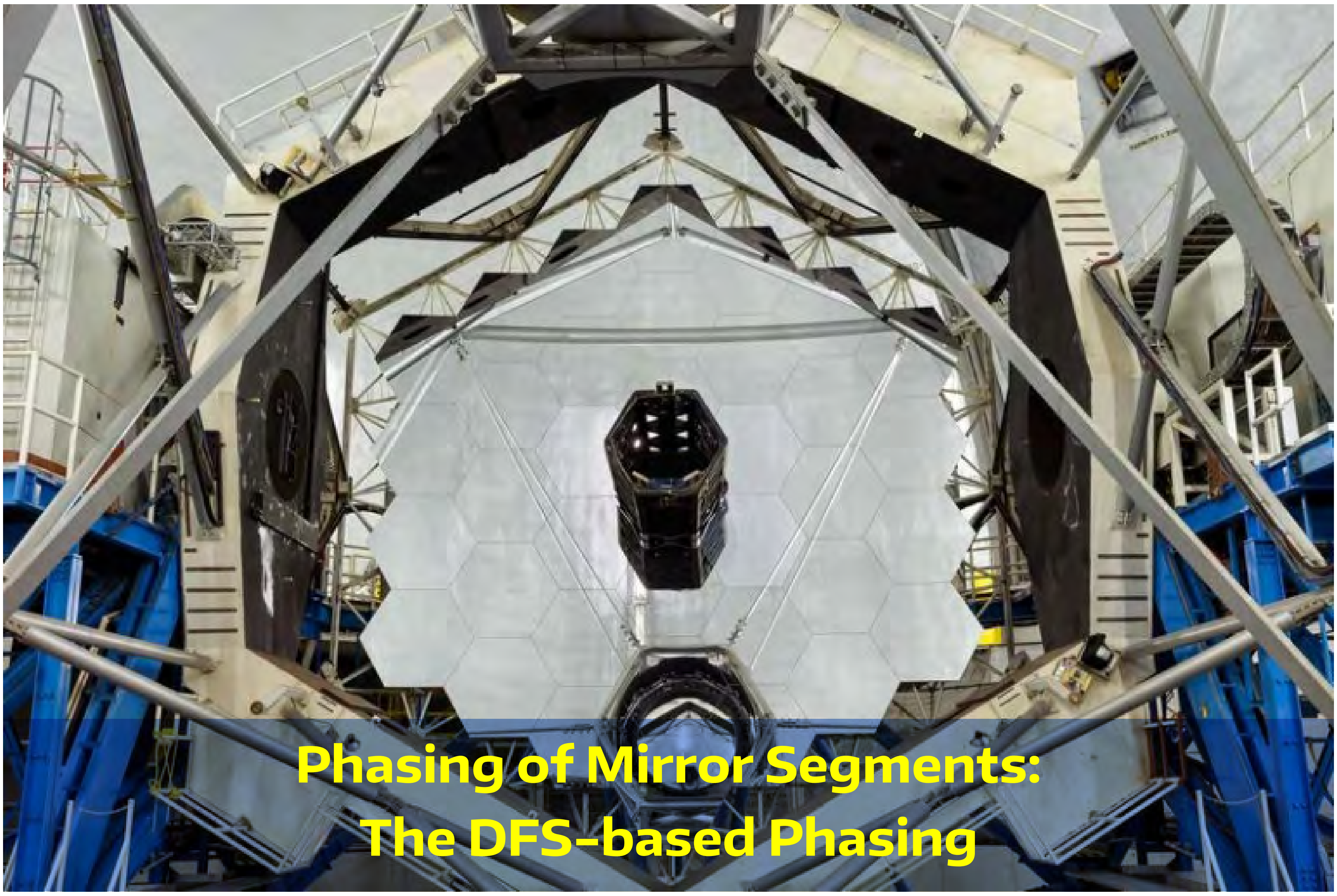


Figure 1: Segmented Primary mirror of the Keck telescope which is 10m in diameter (Credit: keckobservatory.org)

Radhika Dharmadhikari

In order to observe deeper and fainter objects in the sky, we require larger and larger telescopes. However, manufacturing a single primary mirror larger than 8 m in diameter is difficult. Segmented mirror technology is the key to building large telescopes as big as 30 m in diameter. Thus, extremely large telescopes make use of segmented mirror technology, where multiple smaller mirror segments are put together to make the large primary mirror (Fig. 1). The mirror segments must be aligned such that they follow the profile of the parent primary mirror. The alignment of the segments involves tip-tilt, defocus, and phasing. The initial positions of the segment alignment are measured using an optical measurement through an Alignment and Phasing System (APS). Once the alignment values are known for each segment, then the primary mirror control system or M1CS is responsible for maintaining these positions over larger periods of time. Thus, the APS is an important instrument responsible for maintaining the shape of the primary mirror. Typically, the APS measures the tip-tilt and defocus of the segments using a conventional Shack Hartmann Wavefront

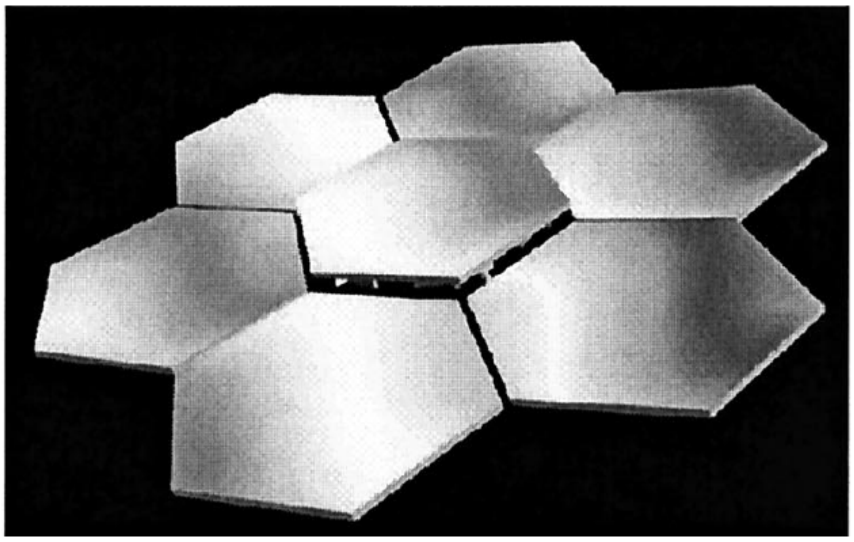


Figure 2: Center segment having a piston error [1]

sensor. The process of detecting the piston error is called phasing, where the piston error refers to the difference in height between adjacent segments (Fig. 2). The phasing of the segments is done by employing a separate optical setup which may use any one or more of the various available phasing techniques.

For diffraction-limited imaging, in order to achieve a resolution equivalent to that of a single monolithic mirror, it is important to phase the mirror segments within a few fractions of the observing wavelength. Various phasing techniques are being developed and used by different telescopes based on their phasing requirements. However, most of the currently available phasing techniques show a strong trade-off between their piston measurement range and accuracy. Thus, the currently operational segmented mirror telescopes use two different phasing techniques for coarse and fine phase measurements. For example, the Keck telescopes use broadband phasing[2] (accuracy = 30 nm) for coarse and narrow band phasing[3] (accuracy = 6 nm) for fine piston measurements. Similarly, the James Webb Space Telescope (JWST) makes use of the Dispersed Fringe Sensor (DFS) for coarse phasing and phase retrieval for fine phasing [4]. The forthcoming section will discuss more about the DFS-based phasing technique.

The Dispersed Fringe Sensor (DFS) based phasing:

The DFS makes use of the broadband light from the telescope's primary mirror, which enters the phasing instrument kept at the telescope focal plane. The broadband light then goes through a collimator lens that gives a collimating beam. In the collimated beam, a mask-prism array is placed that samples light from the intersegment regions. The prisms are then used to deviate the light from each intersegment region into slightly different directions so that it is separated on the image plane. Further, a dispersive element like a grating or grism is used, followed by a camera lens that focuses the light on the detector plane (Fig. 3).

The basic principle of DFS is that in the presence of a piston error δ, we would get the source spectra that would be modulated by fringes. The frequency and

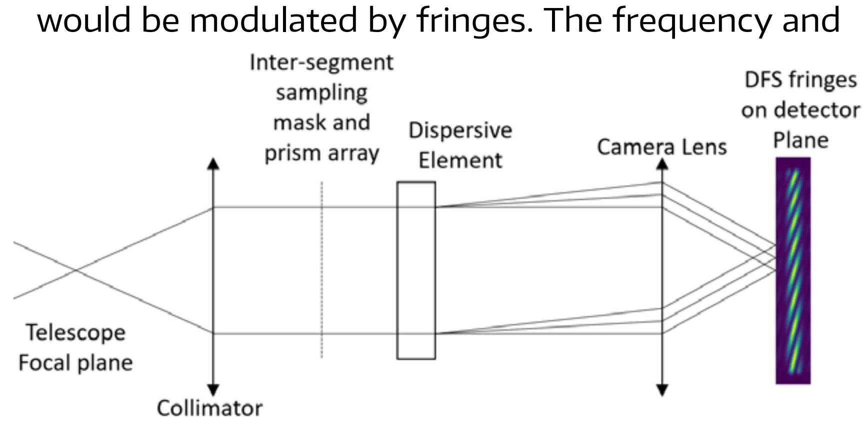


Figure 3: Block diagram for DFS-based phasing instrument [5]

tilt angle of these fringes will be a direct measure of the piston error. Under ideal conditions when the piston error (δ) = 0, in such a case, a continuous source spectrum would be obtained.

Fig. 4 shows a realistic DFS fringe image generated through Python-based realistic simulations for a telescope + APS system. The plot below shows the intensity variation along the dispersion direction.

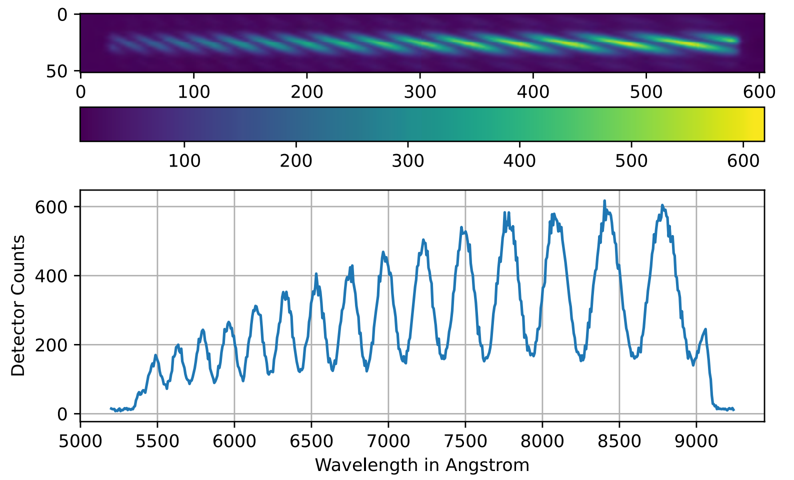


Figure 4: Simulated DFS fringe image for source star of magnitude = 10 with exposure time = 240.0 s and piston error of 10.0 μm [5]

The DFS intensity equation is given by[9],

$$I(\omega)=I_0[1+\gamma\cos\{2k\delta+\phi(y)\}]$$

where I_o is the mean intensity, γ is the fringe visibility (equivalent to contrast), δ is the piston error, $k=2\pi/\lambda$ and $\Phi(y)$ tells the location along the y-axis. This DFS equation is mathematically fitted to the obtained intensity pattern along the dispersion direction to get the piston error δ (Fig. 5). This is one of the most common methods of piston extraction used in DFS. However, the problem with DFS arises under two conditions, i) when the piston error is large and ii) when the piston error $\delta< \lambda/2$ (where λ is the central wavelength of the DFS system).

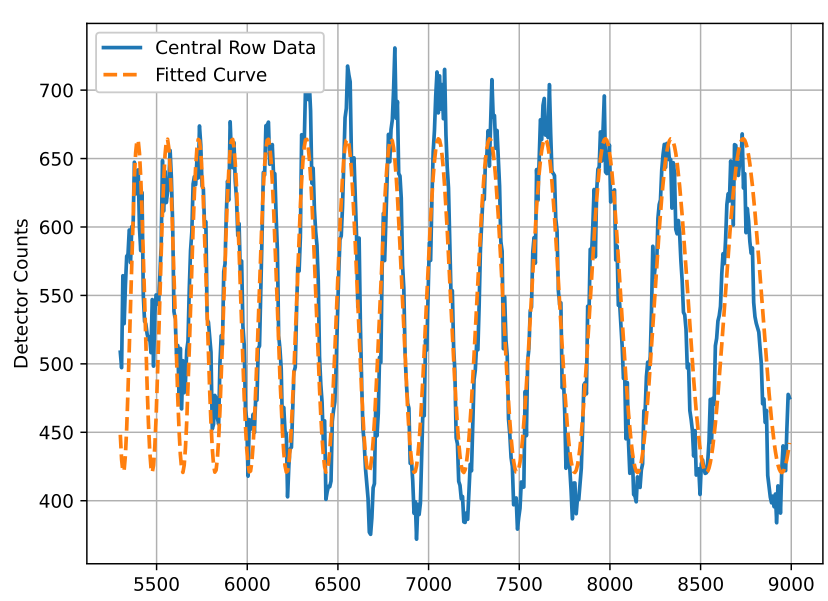


Figure 5: Piston error extraction using curve fitting. Blue curve shows the intensity pattern along the dispersion direction for the simulated fringe. Orange curve shows the fitted data [5]

Under the large piston error condition, the number of fringes is large, which leads to the crowding of more fringes within the same area of the detector. Thus the fringes become unresolvable, leading to lower visibility. This strongly affects the curve fitting, which would further cause large measurement errors. To solve this problem, techniques such as DFS fringe windowing[6] and visibility enhancement[7] can be used to increase the measurement range to some extent.

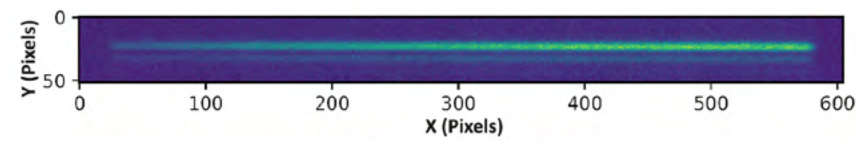


Figure 6: Simulated DFS image for piston error of 69 nm[5]

The second problem arises for the case when $\delta<\lambda/2$. Under this condition, the number of DFS fringes reduces to one, and hence curve fitting fails (Fig. 6). For such cases, the dispersed-fringe-accumulation-based left-subtract-right (DFA-LSR) techniques proposed by Li et al. (2017)[8] can be used. In this technique, the DFS intensity values are summed along the direction perpendicular to dispersion. This would give an intensity pattern having three peaks (left peak, right peak, and main peak). The ratio of the intensity values at these three peaks is then directly relatable to the piston error. Through our realistic simulations, we tested the feasibility of the DFA-LSR technique under practical conditions. From the simulations, we concluded that a phasing accuracy of close to 6nm can be achieved using this method. It was also observed that using a combination of the curve fitting for larger piston errors and DFA-LSR for piston<λ/2, the DFS technique alone can be used for coarse as well as fine piston measurements if an iterative measurement approach is used.

Segmented mirror technology is the current trend for all upcoming large telescopes, and the alignment and phasing system is the heart of this technology. Thus, it is important to explore and develop innovative techniques for segment alignment as well as phasing so that the APS instrument can be made more accurate and less complex. If the DFS technique can be employed for coarse as well as fine phasing, then it would reduce the instrument complexity as well as the phasing time.

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Radhika Dharmadhikari is a Senior Research Fellow at IIA, working with Prof Padmakar Parihar on the Alignment and Phasing of Segmented Mirror Telescopes. Her focus is on exploring phasing techniques, especially DFS, through simulations and lab experiments. She also has an interest in optical design and analysis for telescopes and related instruments.


Credit: Ayushi Chhipa

A Personal Odyssey at Gauribidanur Radio Observatory and Beyond

Anshu Kumari

In the little town named Raxaul in Bihar, where I grew up, I discovered a thirst for knowledge that would shape my entire life. It all began with a monthly digest called Wisdom, which opened my eyes to a world of learning. But it was Wings of Fire, the captivating autobiography of the late Dr A. P. J. Abdul Kalam, that truly ignited my passion. Inspired by his story, I made up my mind at the tender age of twelve - I was going to become a scientist.

Years later, in 2013, I found myself stepping into the Indian Institute of Astrophysics (IIA) in Bengaluru, ready to embark on an exciting journey. Fresh out as an electronics and communications engineering graduate, I had no previous research experience. Little did I know that fate had a surprise in store for me. Within a year, I would find myself immersed in the offbeat but enchanting realm of the Gauribidanur Radio Observatory (GRO), a remote location blessed with awe-inspiring sunsets.

The initial few months at the University of Calcutta, as part of my master's coursework, proved challenging. Optics and optical telescopes were unfamiliar territory for an electronics engineer like me. Yet, fueled by late-night library sessions and the camaraderie of my batchmates, I overcame the hurdles. Then came the internships—an opportunity to explore the wonders of three of IIA's observatories: the Vainu Bappu Observatory at Kavalur, the Kodaikanal Solar Observatory, and the Radio Astronomy Field Station at Gauribidanur. The sight of those magnificent telescopes left me awestruck and filled me with an unparalleled sense of excitement. It was during these formative experiences that I discovered the path I would tread for the next few years.

Upon returning from Calcutta, my classmates and I were presented with a range of projects for our master's dissertations. As an electronics engineer, there was one project that resonated with me deeply - a ground-based radio instrument for studying the solar corona at GRO. Encouraged by

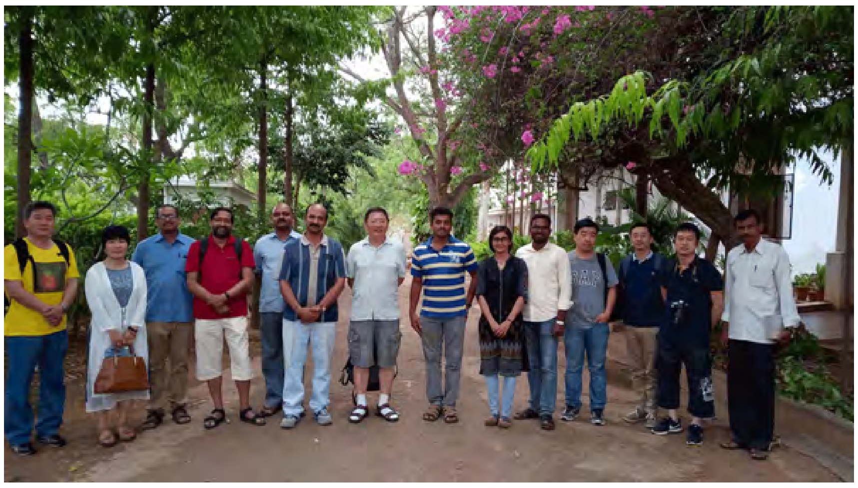
Picture 1: Integrated M.Tech-PhD students of IIA-CU batch 2013 with the University of Calcutta professors after the completion of their first year (2014)

Prof R. Ramesh, the scientist in charge of GRO, I visited the observatory and immersed myself in its captivating aura. Guided by my supportive seniors, I delved into the world of radio telescopes, eventually designing an instrument to monitor the Sun in radio wavelengths. Those early days at the observatory were a mix of challenges and camaraderie as I bonded with my colleagues over countless nights spent in the field, testing and calibrating antennas and systems.

After completing my M.Tech, I chose to continue my journey at GRO for my PhD under the guidance of Prof R. Ramesh and Dr C. Kathiravan. My project focused on improving the radio telescopes' observing capabilities, involving extensive field-work. I was the only female student in the group and the first female PhD student from IIA to work at GRO. Despite arriving with preconceived notions about potential gender-based discrimination, I was pleasantly surprised to discover an inclusive and egalitarian environment within my research group. From the very beginning, my colleagues and supervisors treated me as an equal, never allowing my gender to define my role or limit my potential. I was neither favoured nor discriminated against based on being a woman. Instead, I received the same level of recognition, praise, and constructive criticism as any other member of the team. In fact, Prof Ramesh affectionately dubbed me the Jocelyn Bell of the observatory, adding a touch of uniqueness to my presence.

As my PhD journey progressed, the first year was relatively relaxed. I dedicated most of my time to conducting a thorough literature survey and designing the instruments for my research. However, the second and third years brought a surge of activity as I delved into my first scientific paper while simultaneously refining the design of my instruments. By the third year, my instruments were fully operational, and I found myself immersed in exciting new research projects. I embarked on long internships, attended conferences, and actively expanded my professional network through networking events.

The final year of my PhD was primarily focused on writing my thesis. Additionally, I had the privilege of guiding a few internship students, sharing my knowledge and experience with them. I continued to attend conferences and workshops, eager to stay updated with the latest advancements in my field. Publishing papers during my PhD journey gave me a sense of validation, as it demonstrated the relevance of my work in the scientific community. I vividly recall the exhilaration I felt when I attended the Astronomical Society of India meeting at the University of Kashmir in May 2016 and won the Best Poster Award for my presentation on astronomical instrumentation. It was an incredibly rewarding experience that left me on cloud nine.



Picture 2: The Gauribidanur radio astronomy group with visitors from the Chinese Academy of Sciences (2016)

In the summer of 2018, I had a remarkable opportunity for a three-month internship at the Netherlands Institute for Radio Astronomy (ASTRON). There, I worked on analysing solar data from one of the largest low-frequency radio telescopes, the LOw Frequency ARray (LOFAR). It was an invaluable experience, and I had the privilege of being guided by Dr Pietro Zucca, a truly exceptional supervisor. Through his mentorship, I had the chance to meet numerous researchers in the European solar community, expanding my professional connections and broadening my horizons. This internship coincided with a period of mid-PhD crisis, and to rejuvenate my spirits, I would occasionally pack my bags and embark on exploratory journeys across central Europe. These moments served as a reminder that all the hard work and dedication put into being a PhD student also came with its own rewards.

Amidst the rigorous demands of my research, I learned the importance of maintaining a balanced life outside of academia. Preserving my personal and professional well-being became paramount. Living in a remote area like Gauribidanur posed its own challenges, but I was fortunate to have Mugundhan, a senior colleague, by my side. We would often organise movie nights and indulge in delightful conversations over snacks. During moments of mid-PhD crisis, we would take solace in walking through the fields and witnessing the breathtaking sunsets, providing a much-needed respite. The joy multiplied when our friend Saurabh from Raman Research Institute joined us at the observatory for his experiments every few months.

In a quest to establish a life beyond my research, I began writing on a question-and-answer platform called Quora. Over a span of two years, I garnered a following of more than a hundred thousand people. It was a gratifying experience to provide guidance and support to individuals aspiring to pursue a career in astronomy, offering the guidance that I wished I had received during my own formative years.

During the later half of my fifth year at the observatory, along with writing my PhD thesis, I started applying for a postdoctoral position. Fortunately, the observatory provided a serene and calm environment, allowing me to navigate the arduous process of thesis writing without succumbing to burnout. After submitting my thesis, during my first postdoctoral position at the Space Physics research group at the University of Helsinki, Finland, I went on to work on numerical simulations of solar eruptions, a domain that was entirely new to me. It was an exhilarating challenge, and I owe a debt of gratitude to my advisor, Prof Emilia Kilpua, who believed in my abilities and entrusted me with this exciting project. My first postdoctoral period in Helsinki coincided with the challenging times of the COVID-19 pandemic. Despite the uncertainties, I was surrounded by a supportive community of researchers and friends who made the journey bearable. The University of Helsinki became my haven, a place where I could immerse myself in my research and explore the wonders of computer simulations.

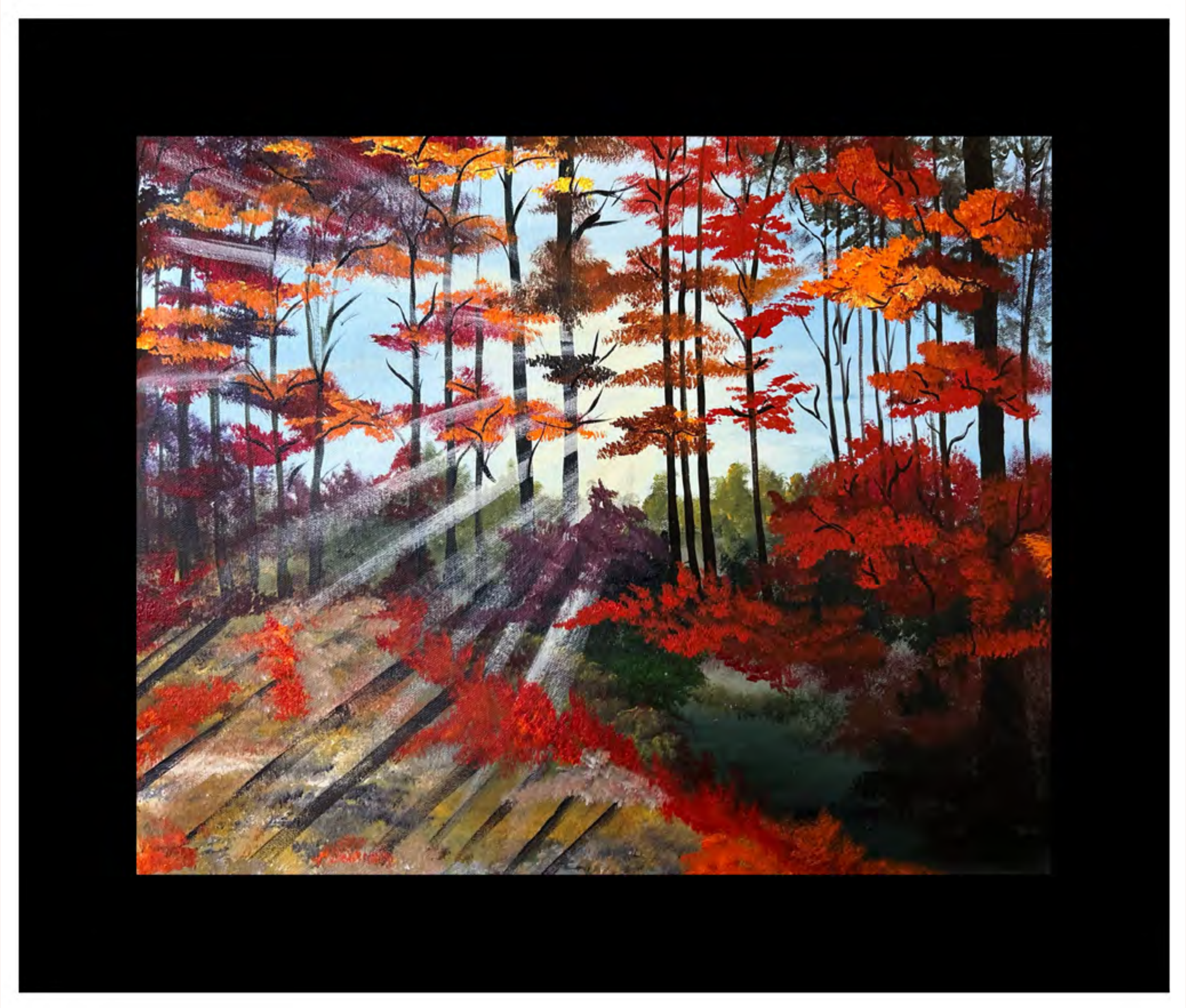
Although I was content in Helsinki, a longing for field and laboratory work tugged at my heart. The call to return to my roots in instrumentation grew stronger within me. It was during this moment of contemplation that a prestigious opportunity presented itself: the NASA Postdoctoral Program (NPP) fellowship. I accepted the offer without a second thought, ready to embark on a new adventure. At NASA Goddard Space Flight Center (GSFC), my research focuses on the proof of concept study of the Faraday Effect Tracker of Coronal and Heliospheric Structures (FETCH) onboard the next-generation multi-spacecraft comprehensive mission concept. Here I get to use all my expertise: I design the antenna and its back-end in the antenna laboratory, perform numerical simulations to understand the behaviour of the system (FETCH) in space, and use solar radio observations from novel radio telescopes

Picture 3: NASA Fellow days: Working in the RADAR and antenna lab at NASA/GSFC

and remote sensing observations.

These diverse experiences, collaborations, and research environments have broadened my horizons and enriched my perspective. Each chapter of this story has been filled with challenges, growth, and moments of pure inspiration. Reflecting on my PhD journey, I've come to realise that it is a profound experience of self-learning and self-development. It's during this process that researchers truly grasp the essence of their chosen field. While coursework provides a foundation, the bulk of knowledge is acquired through independent exploration. I can confidently say that my PhD journey was an incremental improvement, a transformative period that I will forever cherish. I am immensely grateful for the opportunity to be associated with the esteemed IIA, an institution that has played an instrumental role in shaping my path and nurturing my passion for research. I am glad that I was able to have a foundation built at GRO/IIA for an exciting and diverse journey in my academic and research career.

Dr Anshu Kumari is currently a NASA Postdoctoral Program (NPP) Fellow at the NASA Goddard Space Flight Center (GSFC), Maryland, USA, working on space-based radio instrumentation for solar and space weather observations. Her research interests include radio observations, numerical simulations of solar eruptions, and radio instrumentation. She completed her M.Tech-PhD in astronomical instrumentation from IIA in December 2020.



Artist: Maya Prabhakar

Team DOOT @ ASI 2023, IIT Indore

Laden with Ladakh

Bird's eye view of one of the valleys in Ladakh

Judhajeet Basu

It was on one of those summer days in May that I was in a meeting with colleagues from the Indian Institute of Astrophysics (IIA) and Indian Institute of Technology Bombay (IITB), who operated the GROWTH-India Telescope (GIT) at Hanle in Ladakh. The discussions were on the annual maintenance of the telescope during the monsoon season when most nights are cloudy, which provides the optimal opportunity to stop operations and maintain the telescope so that it can be ready for the next year to gaze into the ever-changing night sky. Faculty members discussed sending students to Hanle this year, and I was asked if I would be interested in participating. I assumed it was a joke because no one else had travelled to Hanle for a similar purpose before and answered, "Sure! Why not?" Only when my supervisor called me into his office and instructed me to gather some warm clothing and pack my luggage did reality hit me!

Fast forward to a couple of months later, my colleague Vishwajeet and I were travelling from New Delhi to Leh by plane. We were excited to land on the highest plateau in India. We had 30 mins before touching down, yet all we could see outside the windows were clouds. Even though time passed by but the aeroplane was unable to land. We continued getting delayed by reports of thunderstorms in Leh. The pilot had no choice but to return to Delhi because the plane was running out of fuel. We were disheartened when we came to know that bad weather can persist for several days in Ladakh, and in such a scenario, we would have to cancel our trip! Fortunately, after a few hours of waiting inside the plane in Delhi, we were informed that the weather had cleared and we would be flying to Leh. Who doesn't like getting two trips for the price of one? We finally arrived at Leh more than 6 hours late, but the wait was well worth it. The view just took our breath away!

We acclimatised for two days in Leh (3500 m above sea level) before hitting the road toward Hanle. The view along the route was picturesque. I must have irritated the driver by insisting that he make several stops to photograph the serene cold-desert valley. The journey was long yet beautiful. A wide expanse of nothingness, with occasional brooks and streams by the road and mountains at a distance. The valleys, together with crystal blue skies and cotton clouds, were mesmerising.

We arrived at Hanle village after almost a 10 hours journey from Leh. It was around 10℃, but the chilly wind made it feel even colder. Mr Dorje Angchuk welcomed us into the guest house located at the base of Mt Saraswati.

Hanle is at an altitude of 4250 m, and we were advised to get acclimatised for at least a day before we could start our work. The road trip from Leh to Hanle and the change in altitude can take a toll on one's body. If Leh was attractive, Hanle was appealing. We went atop Mt Saraswati (4500 m), home of the Indian Astronomical Observatory (IAO), which operates two telescopes - the Himalayan Chandra Telescope (HCT) and the GIT. HCT is a 2.01 m telescope with four instruments mounted on it. The Himalaya Faint

Typical terrain of Ladakh. On the way to Hanle from Leh

That's me! At the summit of Mt Saraswati, looking at IAO's telescopes HCT and GIT. Mountains at the backdrop with the clearly visible snow line

Object Spectrograph (HFOSC) is used for optical imaging and low-resolution spectroscopy, the Hanle Echelle Spectrograph (HESP) is for high-resolution optical spectroscopy, the TIFR Near Infrared Spectrometer and Imager (TIRSPEC) is for NIR imaging and spectroscopy, and a Shack-Hartmann sensor is to align the mirrors. The GIT, on the other hand, is a 0.7 m telescope equipped with optical imaging capabilities dedicated to monitoring transients in the night sky. The dry climate and more than 250 clear nights per year make IAO one of the best observing facilities in the world. Our job was to ensure the GIT maintenance and communicate with the engineers about the issues we faced during observations. We also carried a spectrometer which was used to determine the response function of all the filters in the GIT. The incandescent bulb and the clear sky served as our two sources for the studies, and we collected the data throughout the day to be analysed at night. It is important to note that faculty members (Prof GC Anupama, Dr Sudhanshu Barway, and Dr Varun Bhalerao) kept in regular contact with us and asked how we were doing both at work and in terms of our health. We conducted the trials with the assistance of Dorje, Stanzin, Padma, and other technicians and engineers, who were always on hand to help. We also saw the mirrors of both telescopes being cleaned as a part of the maintenance procedures.

Apart from work, we took a drive around Mt Saraswati and had a wonderful session of birding in the marshy areas. We could spot birds such as the Black Winged Stilt, Gray Wagtail, terns, gadwall, etc.

We celebrated Independence Day with the people in the observatory. Riding at the back of a truck with the "Tricolour" in our hands from the guest house to the mountaintop was enjoyable.

Some days, we chose to trek down the mountain instead of taking the car. It was tiring but adventurous, and occasionally we saw the sundown

National flag being hoisted near the MACE and HAGAR telescopes, Hanle

painting the mountains orange as if the hills were on fire. One of those days, we came upon a Red Fox, which is a native to Ladakh.

The most memorable moment in Hanle was perhaps the night when we went to fix the pointing model of the GIT. We felt a different kind of rush! The sky was full of stars, and the Milky Way arch loomed above us, reaching from one end of the sky to the other. The grand structure reminded me of a few lines from Adam Levine's *Lost Stars*.

But are we all lost stars

Trying to light up the dark?

Who are we?

Just a speck of dust within the galaxy

I didn't want to miss this opportunity to learn astrophotography. Gusty winds made it difficult to stabilise the camera, but thanks to Stanzin, we focused the camera using Jupiter and managed to image the Milky Way at the backdrop of the GIT.

After a week of a wonderful stay at Hanle, we were

Milky Way looming over the GIT

The beautiful Pangong Tso (Left). Compatriot Vishwajeet chilling in the cold waters of Pangong Tso (Right)

on our way back via Rezang La, a pass at the Line of Actual Control (LAC). We stopped briefly at the Rezang La Memorial, which has witnessed numerous Indo-China battles and from where the China border is visible. Thereafter we headed towards Merak. The first sight of Pangong Tso thrilled us. I wondered if Matplotlib already has that colour predefined; if so, I could have been able to describe it. Its freshness relieved us from all the travel fatigue. The lake is narrow and so long that it gives the impression of a river. The water was ice-cold. We just sat there on the bank, staring into the distance where the lake made its way to the mountain. I wished I could relish the moment longer, but the sun was already setting behind the hills. The following morning we woke up with the blues of heading back to Leh, which marked the beginning of the end of our trip. The return trip was through the desert, followed by snowy peaks. Ladakh is one of those rare places, if not the only one, where you get to see both. From sheep, wild horses, and wild asses galloping across the stretches of the desert to yaks strolling in the mountains, Ladakh never stops amazing you.

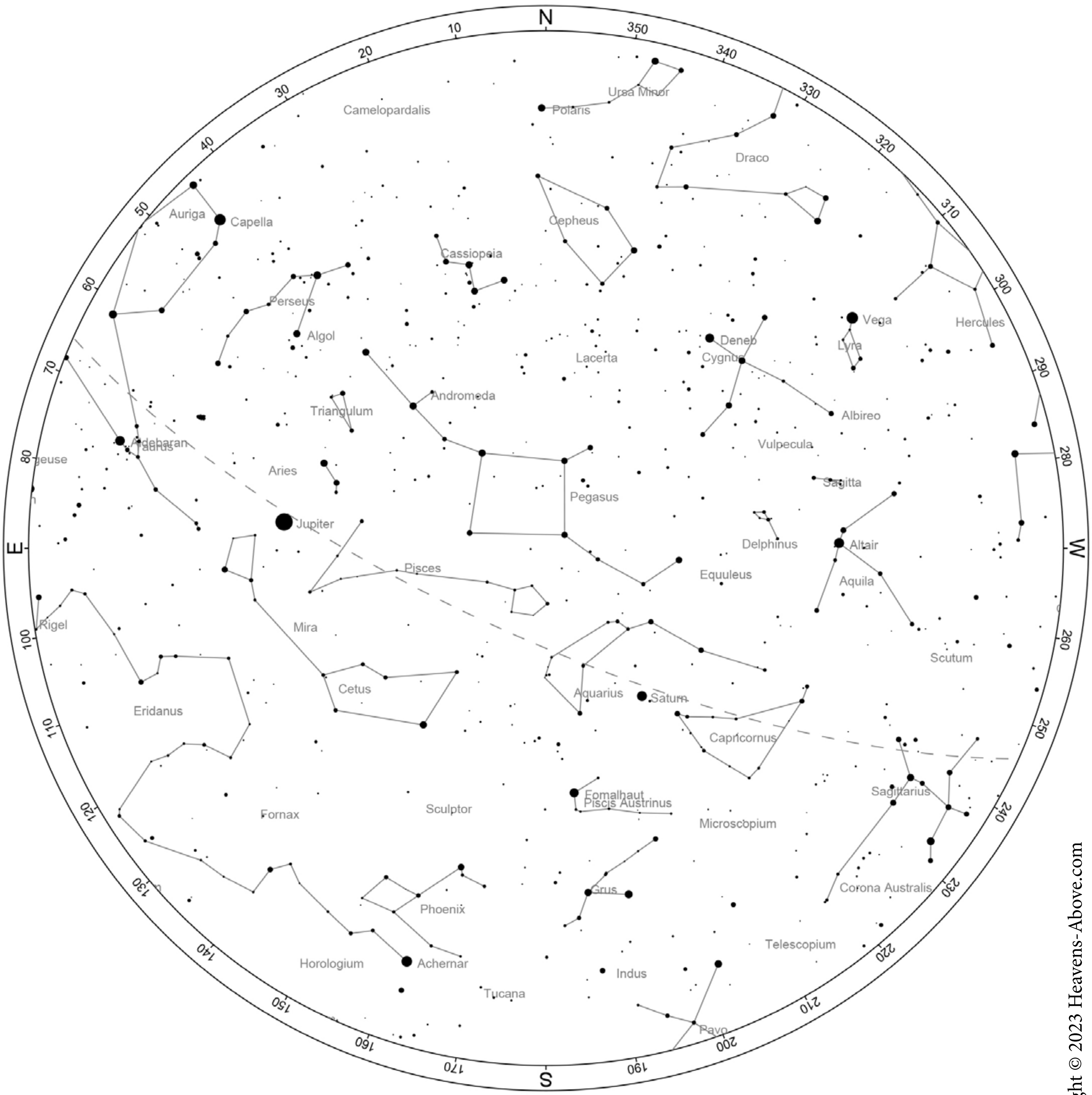
Leh is majorly populated by Tibetans, with a Kashmiri minority. The presence of different groups of people is reflected in the local cultures. The markets are flocked by tourists. We indulged in local cuisines: from momos to kebabs, local thali to sweets; everything was delicious. We also tried the famous apricots of Leh! The local people were exceptionally friendly and didn't hesitate to help us find our way back when we got lost in the city.

Overall, it was a fantastic trip. The unique landscape and the hospitality we received made it a journey to remember for ages. If circumstances allow, I would love to revisit Ladakh.

Judhajeet Basu is a Senior Research Fellow at the Indian Institute of Astrophysics. He is a Transient Astronomer who is fascinated by stars in the universe going kaboom.

Credit: Dorje Angchuk

Credit: Ayushi Chhipa



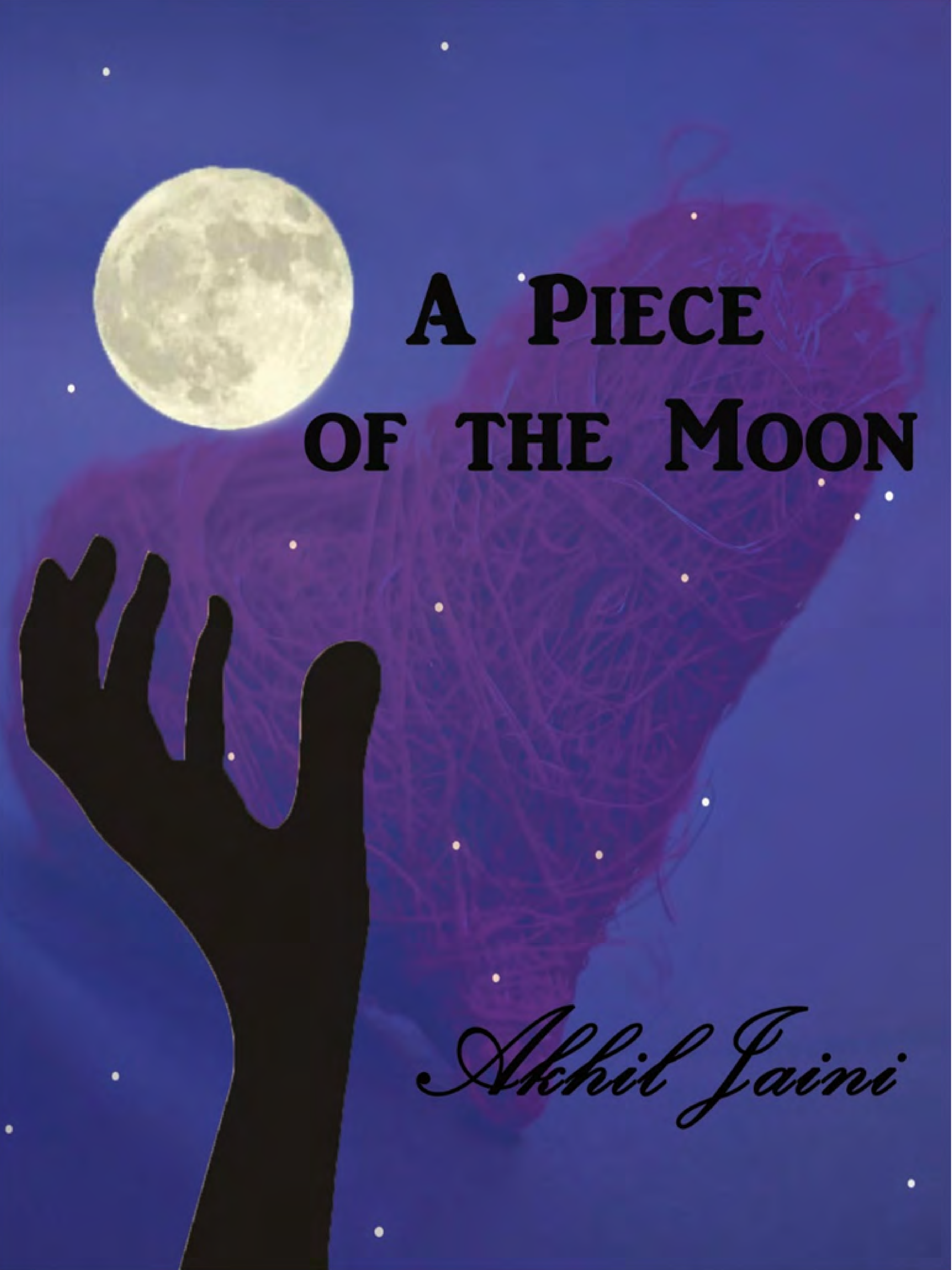
Skychart November 2023: (As on November 15, 2023. 20:00 hrs Bengaluru)

November 2023

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1	2	3 Jupiter at opposition	4
5	6	7	8	9 Conjunction of the Moon and Venus Lunar occultation of Venus	10	11
12	13	14 Conjunction of the Moon and Mercury	15	16	17	18 Mars at solar conjunction Leonid meteor shower 2023
19	20 Conjunction of the Moon and Saturn	21	22 α-Monocerotid meteor shower 2023	23	24	25 Conjunction of the Moon and Jupiter
26	27	28 November Orionid meteor shower 2023	29	30		

Background image: Jupiter Venus Conjunction

Credit: Anand M N


A Piece
of the Moon
Akhil Jaini

A Piece of the Moon

Akhil Jaini

" The following fictional story is a product of the author's imagination and dœs not reflect real events, individuals, or beliefs."

"How dare you ignore me! What do you think about yourself? Shah Rukh Khan or what? I will never speak with you again," her cute cheeks had assumed a deep red color, uncontrollable drops of tears rolled down her beautiful black eyes, her neatly done jet black hair swayed in all possible directions as she shouted her curses upon me. I saw her eyes. Through the tears, I could see the pain she was experiencing.

It was not such big an issue for me but she had made a hell out of it. There was not much I could do in the present situation so I played safe and opted for a subordinate position. I stood in front of her, kept my head low, folded my hands behind me and tried my best to keep as mournful an expression as possible. I hoped she would gain her normal temperament soon.

Minutes passed and then more minutes passed but she was as bitter as the time when our fight had begun. Neither had she shut her mouth since. Her anger had almost fried me top to bottom. I could not take it anymore. So I interrupted her and broke my hush, "I'm sorry...sorry for everything I have done. Please forgive me. I am ready to do anything you want me to."

"Oh, are you, Aryan?"

"Yes. I am true to my word, darling."

"Then bring me a piece of the moon...and don't show me your face till you succeed in your mission."

Wrong timing.

She turned and started walking away from me. Her stride showed determination and anger. But I did not understand what made her so determined, whether she was confident that I would win her trust back or whether she was satisfied with what she had just done and thought all of it served me right.

I knew she was not going to turn back to look at me. But I did not have the guts to run and stop her and then fall on her feet for mercy. I was shocked at her sudden demand. Was she serious? Should I wait until she cools down and then apologize to her once again? I was confused.

Days passed. Months too. But nothing changed. All my attempts to win her back went in vain. I did not know how else to. She refrained from seeing me or even talking to me. My days without her were hollow, nights sinister. A train of thoughts, memories of us, kept running in my mind all the time. It became difficult for me to concentrate on anything, leave alone my studies and schooling. Life became grim.

Then came the day I never expected. The morning was (un)fine. I was standing outside my house, in the verandah. The weather was quite gloomy. There was no wind at all. The atmosphere was damp and the trees were filled with yellow and orange leaves. I looked towards her house. In the beginning I saw nothing unusual but then I saw...I saw a truck filled with goods parked in front of her house. Beside it was a car, her car. My eyes widened in stupor. I ran towards her not even caring to see how I was dressed.

I saw her in her car. She was sitting in the rear seat. Then she saw me too. A faint smile crossed her face, probably due to the fact that I was standing bare-chested in the middle of the street. Soon her smile was lost. I saw into her eyes. I stared into them. But I couldn't decipher them. Something inside me told that they had some kind of an expectation in them. I kept looking at her. She kept looking at me. A drop, a single drop of tear fell from her left eye and then it was gone. She was gone, just like the drop of tear. My Shraddha was gone. I did not see her again.

At that moment I could have broken down, I could have given up. But I did not. Rather I grew stronger and bolder. I was determined...determined to get what she had asked for.

11 years later

I had achieved what only an exceptional few personalities in the world could. At the age of 28, I was going to be the youngest astronaut cum astrophysicist to be flying to the moon. In less than three months, I would be heading a team of 4 to the moon in the "modified" Chandrayaan-22 mission. We would be launched on a GSLV Mark-XI, from the Satish Dhawan Space Center on Sriharikota Island. Our goal, to examine and bring back samples of the water like substance that mysteriously appeared on the surface of the moon fairly recently. My goal, to bring back a piece of the moon.

After passing the physical and mental tests put by the organization with flying colors and learning all the space flight basics, in a training which took place for a span of sixteen months, I was opted to lead a team of two astronauts and a biologist for the mission.

As the event neared, everything became tight. No stone was being left unturned. The space vehicle's functionality was double and triple checked until every possible human error could be rectified to the maximum possible extent. We were made to run simulated training vehicles dozens of times until everything seemed more than perfect. We were being briefed about everything needed, every day, till we almost remembered all tens of thousands of facts, figures and rules on the tips of our fingers. Everything was like a military training, only much worse.

Somehow the days of diligence had ended. The

D-day had arrived! It was 8:00 am in the morning. Our spacecraft was to leave the launch pad at 4:47 pm. I was at my house, meditating. I was excited, more than being tensed. I was least worried about the technical difficulties of the mission. Rather my mind was busy thinking about her, speculating what could happen once the mission was successful and I returned back to the earth. My thoughts were flowing, very soon I would have a piece of the real moon in my hands. Very soon I would be meeting her, I would be giving her the piece of the moon, which I had earned after so much of hard work. Very soon, we would be together, I would be holding Shraddha in my arms and we would fall back in love with each other. Very soon, we would be hugging each other and very soon, we would be married, we would have our own children who would also grow up to become astronauts and astrophysicists. Very soon...

There was a knock on my door. In a flash, all my thoughts and plans of me and her and our future came to a halt. I came out of my meditation and went to answer the door. It was the courier man. Couriers those days were very rare. But that day was one of those. After the person left, I looked at the package in my hands. It was very neatly packed and my name and address were written on it with superb handwriting. I tore it open. Within was a wedding invitation. I opened it.

Inside, printed with a beautiful font and golden types, was, "We cordially invite you to the marriage of Shraddha and Vivek on the 27th of this month..."

Akhil Jaini is a PhD student at the Centre for Astrophysics and Supercomputing, Swinburne University of Technology in Australia. He's working on the search and characterization of Fast Radio Bursts. He did his MTech in Astronomical Instrumentation from IIA, and his research interests lie in radio astronomy and instrumentation.

Artist: Shivani Gupta

Is it the plus (+) or the minus (–) charges that carry current?
A peek into the Hall Effect

Sankalp Srivastava

In every secondary school's science class, one is always told that electric charge comes in two varieties in nature - the positive and the negative. Also, one learns that inside a solid material through which current is flowing - say a metal wire hooked up to a battery - there are some negatively charged particles called "electrons" that are actually flowing around, and it is these electrons whose flow makes up the current. But is there some way to actually find out what the sign of primary current carriers in a solid material is? It turns out that there is, and the trick is to utilize a curious phenomenon known as the ***Hall effect***.

Before I actually describe it, let me explain why the Hall effect is a "curious" case. As one might well be aware, a current in a material is the charge that passes a given point per unit time. Now, whether it's a given amount of positive charge moving to the right or the same amount of negative charge moving to the left, it produces the same effect, i.e., the same current. In general, almost all phenomena involving moving charges depend only on the combination of charge and velocity; if one reverses the sign of both, the same effect is produced, so it's immaterial what kind of charge one had in the first place. But the Hall effect is a different case altogether. It offers an opportunity to observe opposite outcomes for opposite charges. (Velocity of something is just the speed along with its direction, and since there are only two possible directions of motion in a wire, we can simply put a "+" or a "-" sign with the speed to indicate the velocity.)

The current carriers (electrons or whatever) in a solid are in constant motion due to their thermal energy (the hotter the material is, the more energy they possess) even when there is no battery to drive them. However, this motion is completely random. If we consider a large number of these carriers, there will be no preferred direction of motion for the group and no net current flow. But when we connect an external battery, it tends to create a net "drift" of these carriers, and the direction of drift is such

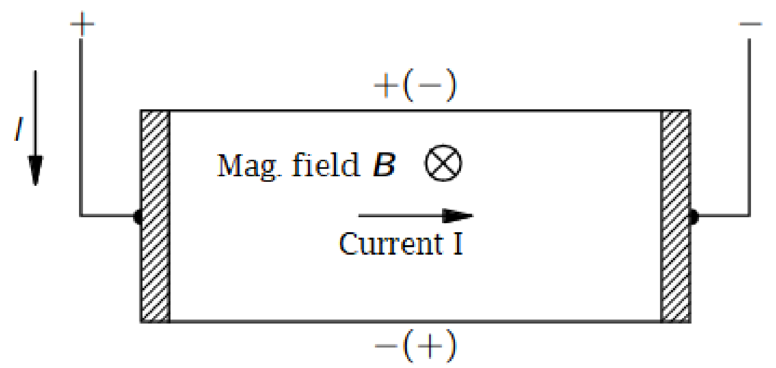


Figure 1: A current-carrying solid block placed in a magnetic field (*Source: The Feynman Lectures on Physics, Vol.3, R.P. Feynman, R.B. Leighton, M. Sands*)

that a current flows from the plus terminal to the minus terminal of the battery (remember, negative charges flow opposite to the conventional direction of current). The stronger the battery is, or the more conductive the material is, the stronger the current will be.

Now, suppose we put a magnetic field (by using some magnet) on a solid block that is already running, say, a horizontal current (as shown in Figure 1), and the direction of the field is pointing at right angles to the current into the plane of the figure (note: the direction of the field of a magnet is from its north pole to its south pole). It's a general fact that if a charge is moving in a magnetic field, it experiences a magnetic force. The direction of this force on a positive charge, in this simple case under consideration, can be found as follows. Hold out your left hand with the forefinger, middle finger, and thumb at right angles to one another (Figure 2). If the forefinger represents the direction of the magnetic field and the middle finger that of the motion of charge, then the thumb gives the direction of the force. For a negative charge, the force will be directed exactly opposite to this for the same direction of magnetic field and that of motion of charge.

Now, here comes the catch. In our case, for the same direction of current (rightwards), the net motion of positive charges will be directed from the plus terminal towards the minus terminal of the battery, and for negative charges, it will be directed exactly opposite to that. Hence, for the same direction of magnetic field (into the plane), whether it's the positive or the negative charges flowing, they will experience a net force in the same direction (in this case, upward) due to their net drift in the magnetic field. The reversal in force direction due to the opposite sign of charge is reversed again due to the opposite direction of motion.

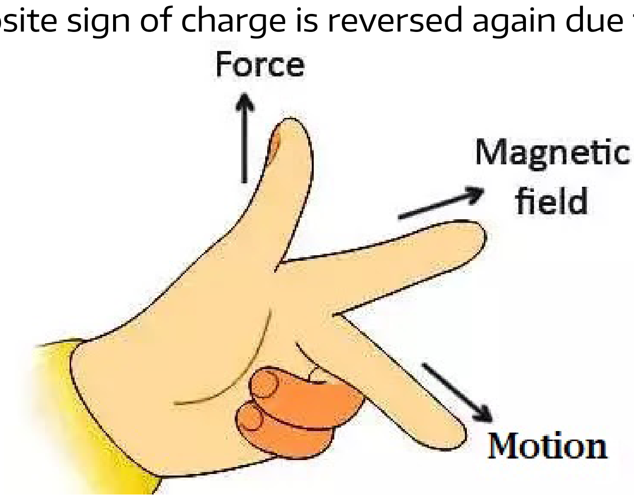


Figure 2: The rule for finding out the direction of the magnetic force on moving positive charge (*Source: https://www.electrical-technology.com*)

Due to this force, a few of the carriers initially flow upward, producing a net build-up of charge along the upper surface of the block, creating an equal and opposite charge along the bottom surface since the block as a whole remains neutral. But this upward motion of the carriers cannot continue forever. As more and more carriers pile up at the top surface, they will increasingly repel the new ones coming from below, and further, these new carriers will be increasingly attracted towards the bottom surface (since like charges repel, and unlike charges attract). The piling up of carriers will continue until the electric force they produce on the moving carriers just exactly cancels the magnetic force (on average) so that a condition is reached where only a steady current flows from left to right.

The resultant build-up of charge on the top and bottom surfaces of the block manifests itself in the form of a "potential difference" or "voltage" between the top and bottom surfaces (much like the voltage of a battery). Voltage is just an indicator of how much "work" needs to be done to push an imaginary unit charge from one point to the another (intuitively, one can understand that an imaginary positive charge will experience a repulsive force if we try to push it towards a build-up of positive charges, say on the upper surface of the block, and therefore, we need some external agent to supply energy to move it upward, i.e., the agent has to do some "work" on it. Similarly, if we have a build-up of negative charges on the upper surface, then we need to do work to push an imaginary negative charge upwards. It is possible to measure this voltage produced vertically across the block with a device called a voltmeter. The sign of this voltage registered by the voltmeter is going to depend on the sign of the charges that have piled up at the top surface. Hence it becomes possible to discern the sign of the current carriers in a solid material using this effect wherein a transverse voltage is generated across the solid block, known as the Hall effect. *(This effect was discovered by the American physicist Edwin Hall in 1879 while he was still a graduate student.)*

What kind of solid material can one try this effect on? One could use metals or semiconductors. When such experiments were first done on metals, it was expected that the sign of voltage would just be what is expected for the case of negatively charged electrons carrying current. People were, therefore, quite surprised to find that for some metals, the sign of the voltage was the opposite, i.e. the current carrier appeared to be a positively charged particle. The original discovery of this anomalous sign of Hall voltage was for Beryllium. Afterward, several other such metals were discovered. It is now understood that although it is ultimately the free electrons in the material that flow, the response to an external battery is exactly what one would expect for an electric current carried by positive particles called "holes." With the emergence of semiconductors, it became clear that the "p-type doped" semiconductors have these positively charged holes as primary current carriers.

So, the next time somebody asks you whether it's the plus or the minus charges that carry current (in a metal or semiconductor, of course), you can answer: it all depends on the sign of the Hall voltage!

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Sankalp Srivastava is a Junior Research Fellow at IIA. His topic of interest includes solar astrophysics and plasma astrophysics.

How do magnetic fields affect the line polarization in the inhomogeneous solar atmosphere?

L. S. Anusha

The Sun's atmosphere comprises a high-density photosphere which slowly transits to a low-density chromosphere where the scattering of radiation on atoms becomes important. Below the photosphere, convection acts as the means of energy transport, above which radiation takes over. In the lower layers of the atmosphere, where density is high, thermal radiation dominates over scattered radiation. Here one can assume localized thermodynamic equilibrium (LTE) while preparing the radiation transport equation. In the higher layers, as the density decreases, scattering becomes the dominant source. In this layer, one cannot assume LTE. The radiation transport equation, in this case, is known as the non-LTE transport equation. Scattering is a complex phenomenon that makes the non-LTE transport equation non-linear. Therefore a numerical solution is apt for this equation.

Polarization acts as a probe to unravel the mysterious entanglement of magnetic fields to matter and radiation. Scattering of isotropic radiation does not produce any polarization. However, since the outgoing photospheric radiation is anisotropic due to limb darkening, the radiation we receive, which is scattered by the atoms in the atmosphere, is polarized. This is known as Rayleigh scattering. The inhomogeneities in the solar atmosphere also affect the amount of polarization produced. The radiation scattered by matter produces different amounts of polarization when a weak magnetic field acts on it. This is known as the Hanle effect. Mathematically, the scattering process is represented using scattering phase matrices whose elements are functions of the incident and scattering angles. When the magnetic field is included, these functions also depend on the magnetic field geometry.

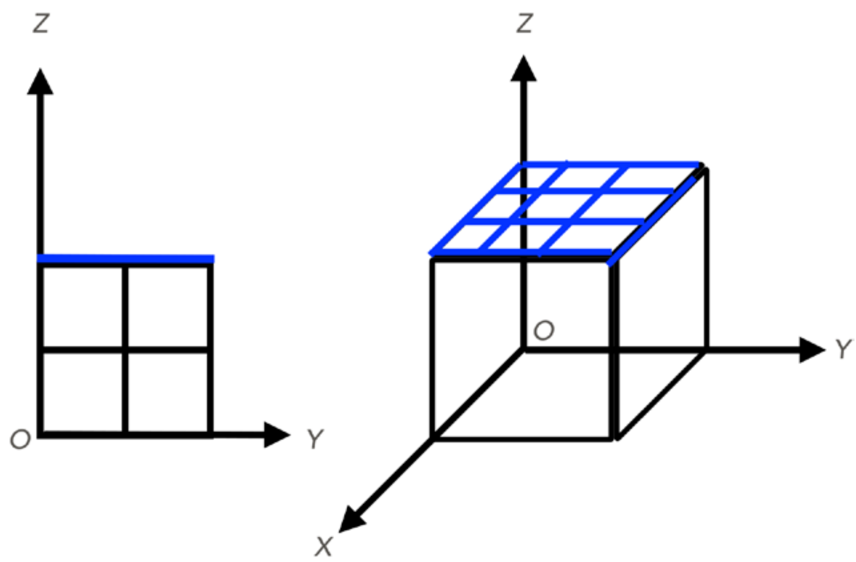


Figure 1: Cartoon diagrams of a 2D slab (left) and a 3D box (right) atmospheres. *(Credits: L. S. Anusha, 2023, ApJ, 949, 84)*

When sunlight is observed using a combination of a polarimeter and a spectrograph we can observe polarization in spectral lines such as Ca I 422.7 nm line. In order to study polarized radiation one needs to solve the polarized transport equation, which is even more complex. The solution of such a polarized transport equation can generate synthetic polarized spectral line profiles. One can then infer magnetic fields on the Sun by comparing the observed and synthetic spectra.

Theories on the mechanism of scattering of radiation in the stellar atmosphere have a varied level of complexity. While it is easy to use approximate theories for a first-hand understanding of the observations, exploring how much impact the most complex theory has on the results obtained from approximations is interesting. The scattering theories on line polarization can be categorized as 1) complete frequency redistribution, 2) angle-averaged partial frequency redistribution, and 3) angle-dependent partial frequency redistribution.

The complete frequency redistribution means that there is no correlation between the frequencies of incident and scattered photons. This approximation is valid only for certain spectral lines. A more general theory is that of the partial redistribution in which correlations between frequencies of incident and scattered photons are taken into account. In the case of angle-averaged partial redistribution theory, the redistribution functions are averaged over all the incoming angles.

Polarized radiation is represented using four Stokes parameters *I, Q, U,* and *V.* While *I* represents the intensity profile, *Q* and *U* represent the linear polarization, and *V* represents the circular polarization. The solution of the polarized transport equation with partial redistribution scattering process involves solving a non-linear integral equation, the integrand of which contains a combination of redistribution functions and scattering phase matrices. The solution will then be a spectrum for each of the Stokes parameters, known together as the polarized spectra.

In a recent study, we analyzed how different types of inhomogeneity affect polarization in spectral lines. We considered only linear polarization here to study the Hanle effect. The aim of the study was to understand the relative effects of different types of inhomogeneous atmospheres. Therefore we considered a hypothetical spectral line formed in idealized atmospheric conditions such as an isothermal atmosphere. We used two different types of atmospheres - a two-dimensional (2D) plane and a three-dimensional (3D) box - and two scattering theories - angle-averaged partial redistribution (approximate theory) and angle-dependent partial redistribution (complex, more accurate theory) (see Figure 1).

The polarization profiles denoted as Q/I are shown

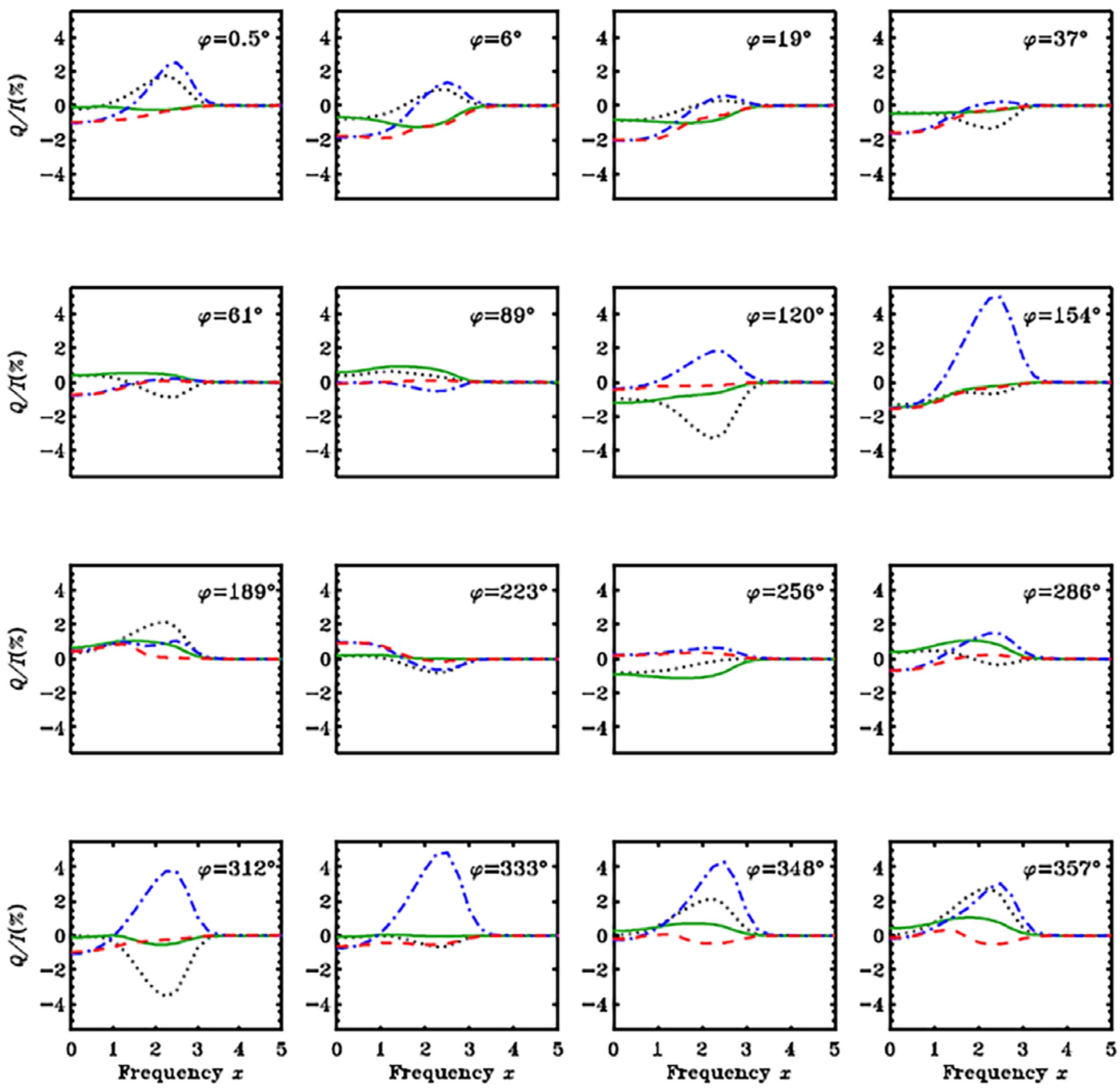


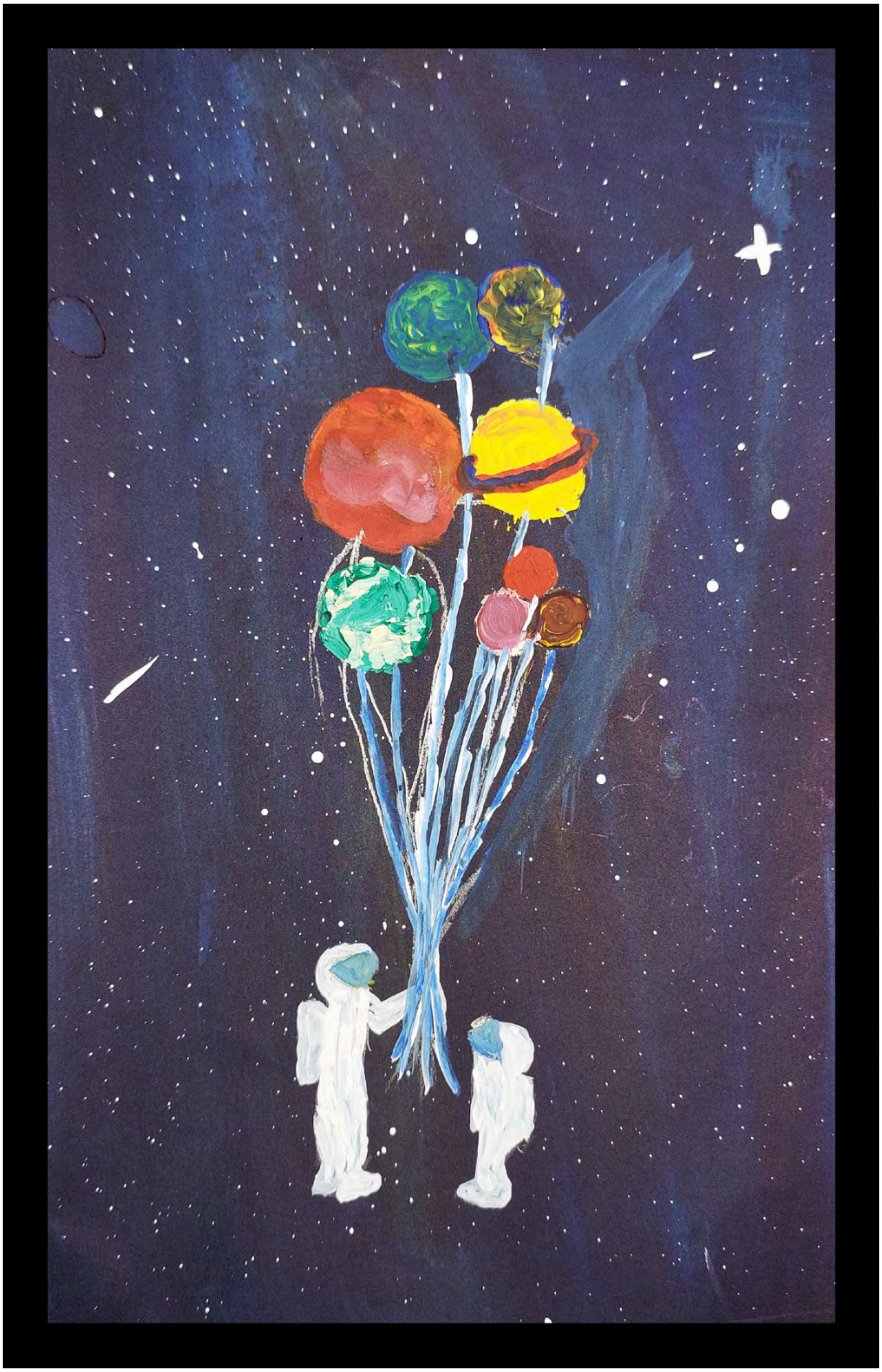
Figure 2: The Q/I profiles with angle-averaged partial redistribution in 2D (dashed lines) and 3D (solid lines) geometry and angle-dependent partial redistribution in 2D (dot-dashed) and 3D (dotted lines) geometry. (Credits: L. S. Anusha, 2023, ApJ, 949, 84)

in Figure 2 for the two scattering theories and two different atmospheres. We found that the 3D geometry is important as it produces completely different polarization profiles compared to 2D geometry. We also found that the most complex scattering theory of angle-dependent partial redistribution does make a significant impact since the use of this theory leads to a larger polarization when compared to the polarization produced by the approximate theory.

Reference:

1. *L. S. Anusha, 2023, ApJ, 949, 84 (https://iopscience.iop.org/article/10.3847/1538-4357/acc9a8)*

Dr L. S. Anusha is an Assistant Professor at the Indian Institute of Astrophysics Bengaluru. Her research interest includes Radiative Transfer, Scattering, Polarization, Numerical Methods, and Stellar/Solar Atmosphere.



Artist: Sipra Hota

From dust grains to exoplanets | A journey to detect the cooler worlds!

– Interview with Prof Andy Skemer

1. Neeraj- When did you start getting interested in space, and when did you realize you wanted to be an astronomer?

For me, seeing the images from Voyager, some of which came before I was born and some after, was really interesting. I remember having a visiting scientist who showed us some of the pictures of the different planets and different moons seen by Voyager, and I thought that was really interesting.

I didn't grow up always thinking I wanted to be an astronomer. I think I knew I liked science. More than that, I knew I liked Natural Sciences, by which I mean studies of things and nature in the process, like ecology, ocean sciences, atmospheric sciences, astronomy, etc. I think I would have been equally happy in any of those fields. When I started college, I took a physics class, and then the natural science that spawns off is astronomy. So I didn't necessarily choose between all of those fields. I just ended up in astronomy. Sometimes I think I chose the wrong one because I don't like staying up all night. Maybe I should have done Ocean Sciences, but I get seasick.

2. Parvathy- We would like to know what was the topic of your PhD. Also, how was your experience when you shifted your focus to exoplanets and instrumentation?

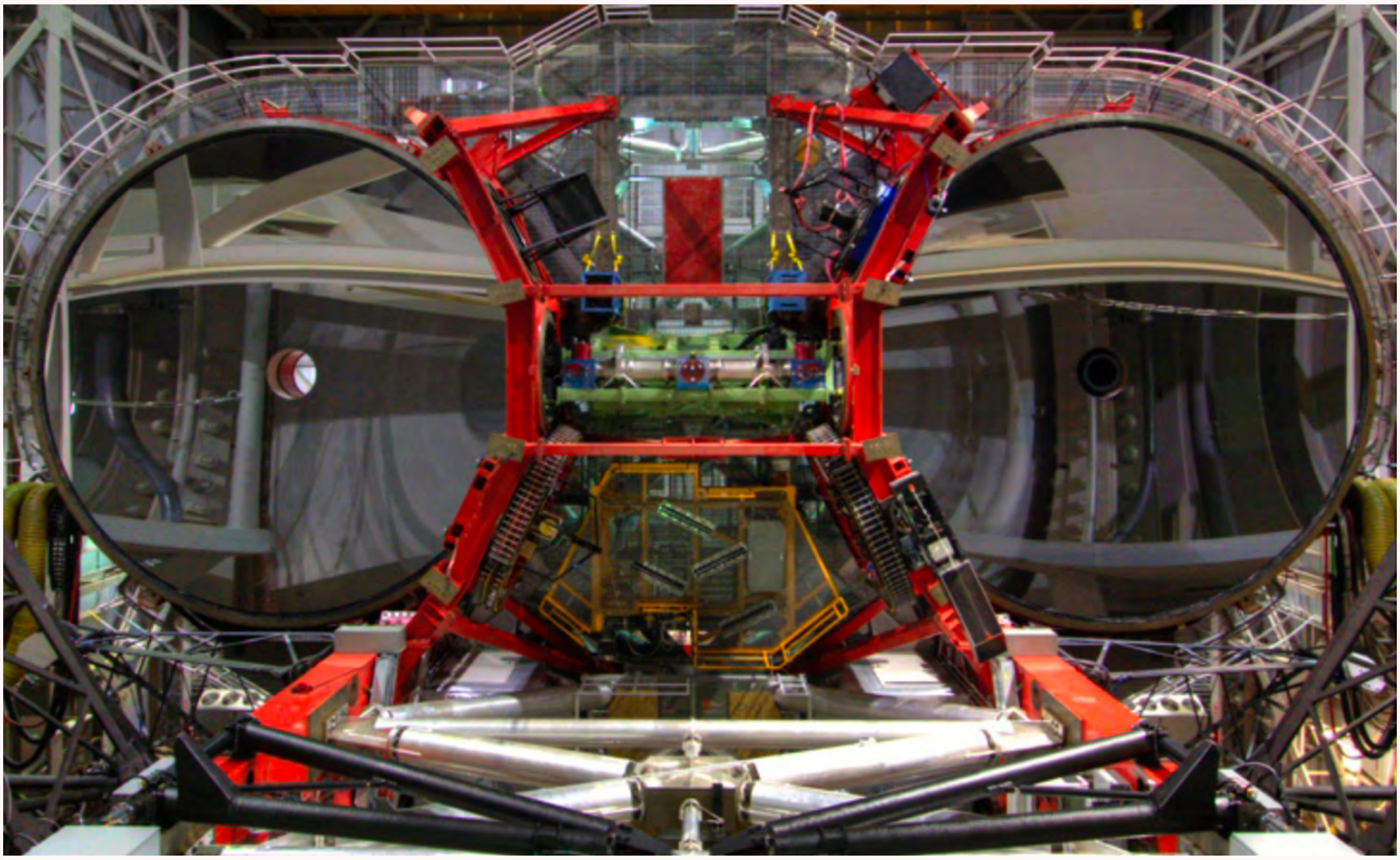
I went to a small college before PhD, where we had two astronomy professors. One of them worked on low-mass stars, and one on high-mass stars. So I didn't have a lot of exposure to all of the different

Dr Andy Skemer, an Associate Professor of Astronomy and Astrophysics at the University of California, Santa Cruz (US Santa Cruz), is a distinguished figure in exoplanetary exploration. His research focuses on searching for and characterizing directly imaged exoplanets from ground-based and space observatories. He secured a Ph.D. in Astronomy from the University of Arizona in 2011, building upon a foundation laid with a Master's degree in Astronomy from the same esteemed institution in 2008. His quest for knowledge saw him as a Hubble Postdoctoral Fellow at the University of Arizona during 2014-2015. His accolades, including the Outstanding Mentorship of Undergraduate Students award (2022) and the prestigious NASA Group Achievement Award (2020), stand as a testament to his profound impact on the scientific community and the aspiring minds he guides.

Prof Skemer's expertise shines through his pivotal role as Co-Principal Investigator (Co-PI) of the James Webb Space Telescope (JWST) Early Release Science program, a testament to his commitment to advancing our understanding of exoplanets through cutting-edge imaging. His pioneering work includes obtaining the first spectrum of the coldest known brown dwarf, WISE 0855, at temperatures around 250 Kelvin, revealing evidence of water clouds outside of our Solar System. He is also the PI of SCALES (Slicer Combined with Array of Lenslets for Exoplanet Spectroscopy), a new instrument under development for Keck Observatory. SCALES will push the boundaries of our ability to study colder and lower-mass planets. Prof Skemer's expertise extends to the development of advanced instruments optimized for exoplanetary studies, including Large Binocular Telescope Interferometer (LBTI), Arizona Lenslets (ALES), Planetary Systems Imager (PSI), Planet as Exoplanet Analog Spectrograph (PEAS), and Keck Planet Imager and Characterizer (KPIC).

fields, and then I went to the University of Arizona in the United States for PhD. I remember Don McCarthy, one of the senior astronomers who was giving us a tour took us outside of the front door and said, "Ok, this building that we're in is the Astronomy Department of Steward Observatory. That one over there is the planetary Sciences Department called the Lunar and Planetary lab, that over there is the mirror lab where they build giant mirrors for the LBT and the GMT, that one over there is the Optics Department, that one over there is Space Sciences and Planetarium Museum, and that one over there is NOAO." The latter is now NOIRLab, which is the organization that runs the national ground-based telescopes in the U.S. It was like, oh my God! And so I really wanted to go there for school.

My advisor in grad school did instrumentation and was interested in exoplanets, and I thought both of those were interesting, particularly the exoplanets part. He was working on a survey, which was on Gemini, kind of the predecessor to the Gemini Planet Imager. I was really excited about that. So I went and worked for him. But I didn't work on exoplanets. I worked on T-Tauri Stars – young low-mass stars, their circumstellar disks, and their silicate features. We had a new Adaptive Optics system on a telescope called the MMT, which used to stand for Multiple Mirror Telescope. It was the first Adaptive Optics system that was designed to work at very long wavelengths, in this case, 10 microns. MMT was the first deformable secondary AO system in the world. So, instead of having a small deformable mirror

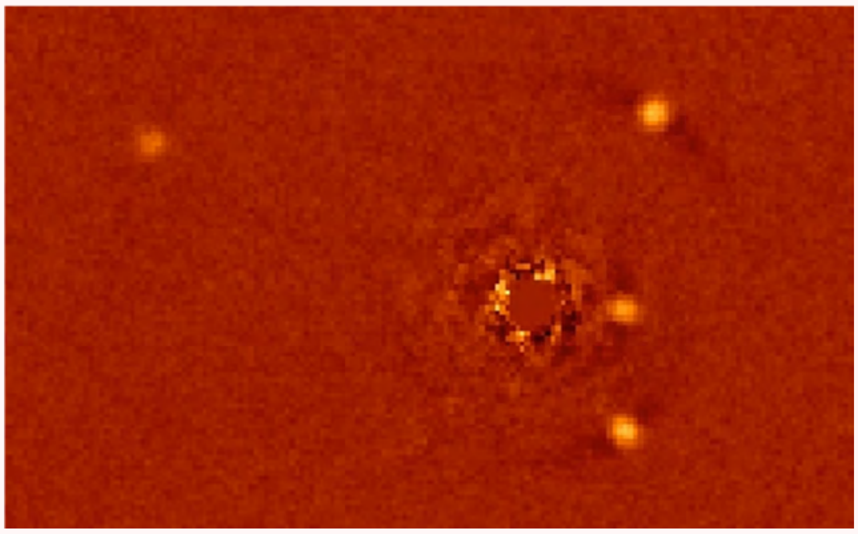


Picture 1: The Large Binocular Telescope and the Large Binocular Telescope Interferometer (green structure in the image center) [Source: https://nexsci.caltech.edu/missions/LBTI/]

in your AO system, the secondary mirror itself is the deformable adaptive mirror. And the reason that's useful for what I was doing is that Adaptive Optics systems have a lot of mirrors in them. Each one contributes to the thermal background of the system. If your secondary mirror is the adaptive mirror, you have a much smaller number of mirrors in your system, so the thermal background is lower. That's why this Adaptive Optics system could work at 10 microns, where conventional adaptive optics doesn't work well. My advisor thought I should do a project on that. So, I was doing 10-micron Adaptive Optics of binary stars.

The circumstellar disks have small dust grains that eventually coagulate into bigger and bigger things and eventually form planets. There's a feature from silicate dust. And when you look at this silicate feature, its shape tells you the size of the smallest grains in the system. One shape of the feature tells you that it has half-micron grains. Another silicate feature would tell you the smallest grain in the system is two microns, so it has already evolved a little. There are all these different silicate features in different stars, and nobody can really make sense of which stars are forming planets. So I thought about it for binary stars that formed simultaneously and from the same materials. I removed those two variables to see whether they were the same or different. Turned out that they both looked the same, so that was sort of an interesting result.

At that time, the University of Arizona was a partner in the telescope called the Large Binocular Telescope, which was going to get two Adaptive Optics systems. They were built in Italy, and the performance testing in Italy looked like these would be incredible, way better than the one on the MMT. Another professor in my department, who later moved to Santa Cruz, was the PI of the Large Binocular Telescope Interferometer. The purpose of this instrument was to measure dust around very nearby stars because NASA is interested in imaging Earth-like planets around nearby stars. A possible limiting noise source Earth-imaging is dust-scattered light, which can be brighter than the Earth-like planets you're looking for. And so, they funded the Large Binocular Telescope Interferometer to measure the dust around nearby stars. That topic was close enough to my PhD thesis, and I knew that this instrument was going to work really well, or at least, the Adaptive Optics systems were working really well because of these early lab tests. And so, I applied for that job and ended up getting that job. In the US, that was a very unusual thing to do, that is, to do a postdoc at your PhD institution. But I changed advisors between grad school and postdoc and stayed in the same place.



Picture 2: HR 8799 (Source: https://ui.adsabs.harvard.edu/abs/2014SPIE.9148E..0LS/abstract)

After that, I was basically ingrained in that instrument; I couldn't leave anyway. A normal post-doc in the U.S. is three years, but I was going to stay longer than even that. I was working on exoplanets, and I used this system to study HR 8799, which has been discovered previously. But with this new instrument, I could image it to longer wavelengths than other people. Because the Adaptive Optics system was so high-performance, I was able to add some new photometry points that other people didn't have, and then you can fit all the photometry points and try to learn about the composition of the exoplanets. I did this with two filters and then I wanted to do it with even more filters because I wanted to see if there was a methane feature. I sort of had a broad filter, and I wanted to use the narrow filters. So I bought some narrow filters and added them to the instrument, and then instead of doing two filters, I did six filters and learned some interesting things from doing that. I really wished there was integral field spectroscopy for doing this kind of work so that I didn't have to sit there and go through every filter and get only six wavelengths. Before that, I had worked on commissioning instruments. I used new instruments that had a lot of problems that needed to be fixed before I could do science with them. But I was more of an observer at that point. I'd never built instruments. But, my advisor supported this idea, so I built the world's first integral field spectrograph to work at the wavelength range of 3-4 microns, which was called ALES, Arizona Lenslets for Exoplanets Spectroscopy.

Then I applied for faculty jobs and was fortunate to get one at UC Santa Cruz. UC Santa Cruz has great instrumentation. There's a focus on adaptive optics, which I worked on, so it was a very logical place for me to go.

3. Soumyaranjan- What are the works you are involved in currently?

When I moved to Santa Cruz, even though I had been trained more as an observer and was getting into instrumentation, they viewed me as an instrumentalist. So, I agreed to work on instrumentation for Keck. Since I had built the Arizona Lens for Exoplanet Spectroscopy (ALES), I wanted to work on an instrument called SCALES, Slicer Combined with Array of Lenslets for Exoplanet Spectroscopy. Building an instrument is a big project requiring a lot of time and learning. So, I had less time for observational research than I used to do previously. But I still wanted to do some of it, and in particular, I really wanted to use the James Webb Space Telescope (JWST). When I was a PhD student, and I was working on 10-micron adaptive optics, my advisor told me: "We've got this MMT, which is a 6.5-meter telescope working at 10 microns. That's what James Webb is also going to do. So if you're doing science from the ground at 6.5 meters, then you'll be really well positioned to do the science with the 6.5 meters, 10 microns in space." I think that was good advice, and it turned out to be true, but I ended up switching science fields in between. I sort of kept some of the techniques of working at the longer wavelengths and some of the things you can learn there, but instead of working on T Tauri stars, I was working on exoplanets.

About six years ago, one of my collaborators, Sasha Hinkley, who's at the University of Exeter, decided that everybody in the world who worked on direct imaging needed to team up and do one big proposal for the early release science programs of JWST. We all thought that was a good idea, and then he asked me if I would be co-PI with him, along with Beth Biller. The three of us have been leading that program for a long time. Because the launch was delayed, that proposal was accepted probably four or five years ago. The nice thing was that even though James Webb was delayed, I knew I had time. I knew I was going to get to use it.

I have another proposal with James Webb that's coming up. Again, on this theme of working on longer wavelengths, I got interested in this brown dwarf called W0855. When it was discovered, it was the coldest thing and still the coldest thing outside our solar system. It's 250 Kelvin. And it's really nearby, around 2.2 parsecs from the Sun. From the ground, I was able to get a very crude spectrum of it. When we published it, we said the spectrum showed evidence of water clouds. And at 250 Kelvin, you would expect this object to have water clouds. At this point, I think it might have been a different chemical process that was going on. It's hard to get a spectrum of something that's 250 Kelvin from the ground since your telescope is 300 Kelvin. So this was a 30-hour integration with Gemini, which is an 8-meter telescope. So a really, really deep spectrum. And you can look it up; it is not a beautiful spectrum. But again, this kind of gave me a step up when I was ready for James Webb. So I wrote the Cycle 1 proposal with some of my collaborators from the previous paper, talking about looking for the water clouds. It's very hard to see clouds. They have these smooth features. They don't have sharp atomic or molecular features. There's this band of molecular lines, and on top of that, you have to see this sort of continuum shape. Even if you see the continuum shape, it could be any type of cloud in some ways. We thought they did have this slight triangular shape, which I think would be hard to pick out with all the molecular features. But we're planning to watch it for 13 hours. And in 13 hours, it should go up and down, and the shape of it going up and down should look like that triangular shape. So that's what we think we'll see, or at least we're hoping to see. And those observations are scheduled.

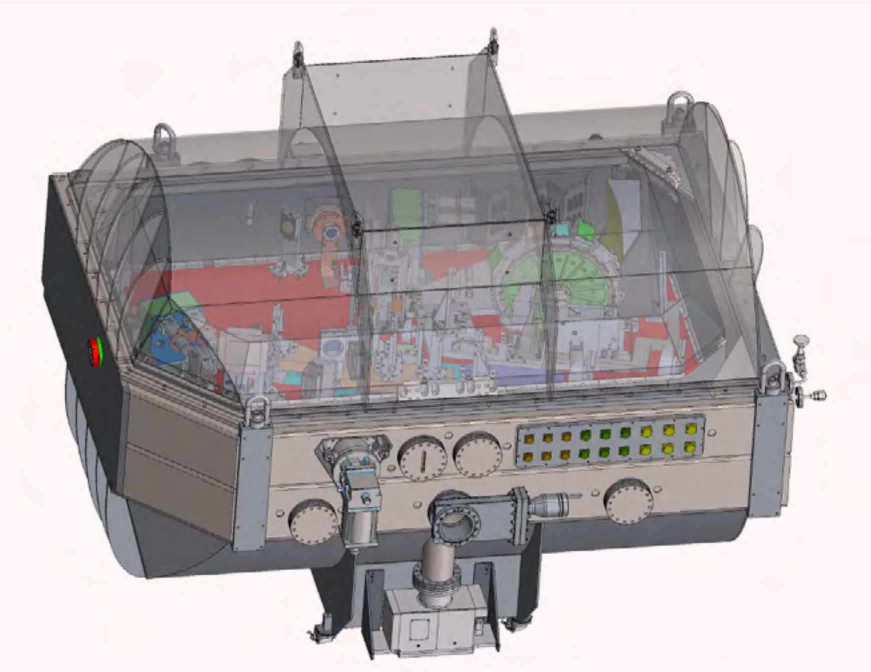
I have one more project related to this. After that proposal was accepted, another astronomer, Mary Anne Limbach, wrote a paper saying, "Hey, maybe James Webb could be sensitive enough to see a moon transiting in front of a free-floating planet." This object that's 250 Kelvin, we think it's massive, about 5-Jupiters. So you could either call it a brown dwarf or a free-floating planet. Assuming these things all have moons like the Galilean moons of Jupiter, you have to stare at one of these things for about 12 hours to see it transit. It has to be inclined in a favorable direction, edge-on so that you can see it. So, we actually are looking at one of these things for about 12 hours, which is good. But we don't know its inclination. So Mary Anne's paper suggested, well, there's about an 8 to 10% chance, geometrically, that this thing will be favorably aligned and that a transit will happen during that time. So, that's a new area I'm interested in and haven't worked in before, i.e., looking for exomoons transiting free-floating brown dwarfs. I'm lucky to have a great data set for it totally by accident because I didn't think of this when I wrote the proposal, but now I'm working with Mary Anne on it.

So that's sort of what I'm working on now, and then I have to stay disciplined and not work on other things. I will keep applying for James Webb time because it's such a great opportunity, and no matter how busy I am, I have to apply for that. The acceptance rate this time is expected to be 1/7, so I probably won't get any time anyway. But if you submit these every year, you never know! As a Co-Investigator, I was on 12 proposals this time. So I probably will get time for one; if I'm lucky, I'll get two. And so I'll sort of have this steady state of James Webb projects going on, which is my plan.

4. Raveena- For our young and new aspirants of astronomy, could you briefly describe the project of SCALES and its future prospects?

The primary purpose of SCALES is to take spectra of directly imaged planets. In order to image a planet, you need to see something very faint that's next to something very bright. And there are a couple of ingredients for that. One is adaptive optics which sharpens the image of the star so that you can see the planet next to it. But even after you do that, there's residual glare from the star. And so, you have to remove that residual glare. And the way that you do it is usually by taking advantage of correlations. The glare is mostly symmetric, and it has both spatial correlations and time correlations. Because the sky is rotating, the planet will move around the star's glare, but the star's glare will kind of stay fixed. So what that means is that the only way to image an exoplanet is to take an image of a field with a star and a planet in it and then work really hard to move the starlight. There are other ways of doing it, like taking a spectrum directly of the pixel you know the planet is on. But there are advantages to being able to remove the starlight so that you can more easily see the planet. So, you have to do imaging, and at the same time, you want to get a spectrum. And that's where integral field spectroscopy comes in. Because in integral field spectroscopy, you get a spectrum of every pixel. So whatever pixel the planet is on, you get a spectrum of it. And all of the other pixels are also useful because they help you remove the star's glare. SCALES is an integral field spectrograph, but it's specifically designed to work at longer wavelengths than most of the other exoplanet imaging spectrographs or integral field spectrographs, including instruments like GPI, SPHERE, CHARIS, and others. All of them work from one to two microns. SCALES works from two to five microns. And because that's where gas giants could peak in brightness, they're easier to see at the longer wavelengths.

But it is less good at integral field spectroscopy of galaxies because galaxies are fainter, and the sky background is high at SCALES wavelengths, which makes the galaxies invisible. Exoplanets are actually fairly bright. They're drowned out by the light of their host star, but plenty of photons come from an exoplanet. That's still not a huge number of science cases, and it might not be an instrument that gets used by everybody in astronomy. But then the Keck



Picture 3: Left: Computer-aided design (CAD) of SCALES. Right: SCALES Lyot Stop mechanism (Credits: Author)

Science Steering Committee asked if we could put an imaging channel in as well. Keck already has an imager that works at these wavelengths. It's called NIRC2. But it's over 20 years old. So they asked if we could put this in as well. And I said, sure, but we don't have any funding or engineers for this. Fundraising and collaboration building are a huge part of your job when you build an instrument. So, during the pandemic, when we were sort of thinking about how we could partner with people and get more engineers working on this project, I asked Sivrani if she would be interested. Sivrani and then Ravinder were interested and thought it would be nice if IIA could lead one of the modules. So, the design of

Most of the planets we imaged are around 1,000 Kelvin, but Jupiter is only 130 Kelvin. Most of the gas giant planets that are far enough from their star so that we can directly image them are quite a bit colder than 1,000 Kelvin. SCALES might be able to see things as cold as 300 Kelvin. It's a new type of planet and a temperature that I find quite interesting because of the water clouds we discussed earlier. So that's the scientific idea behind SCALES.

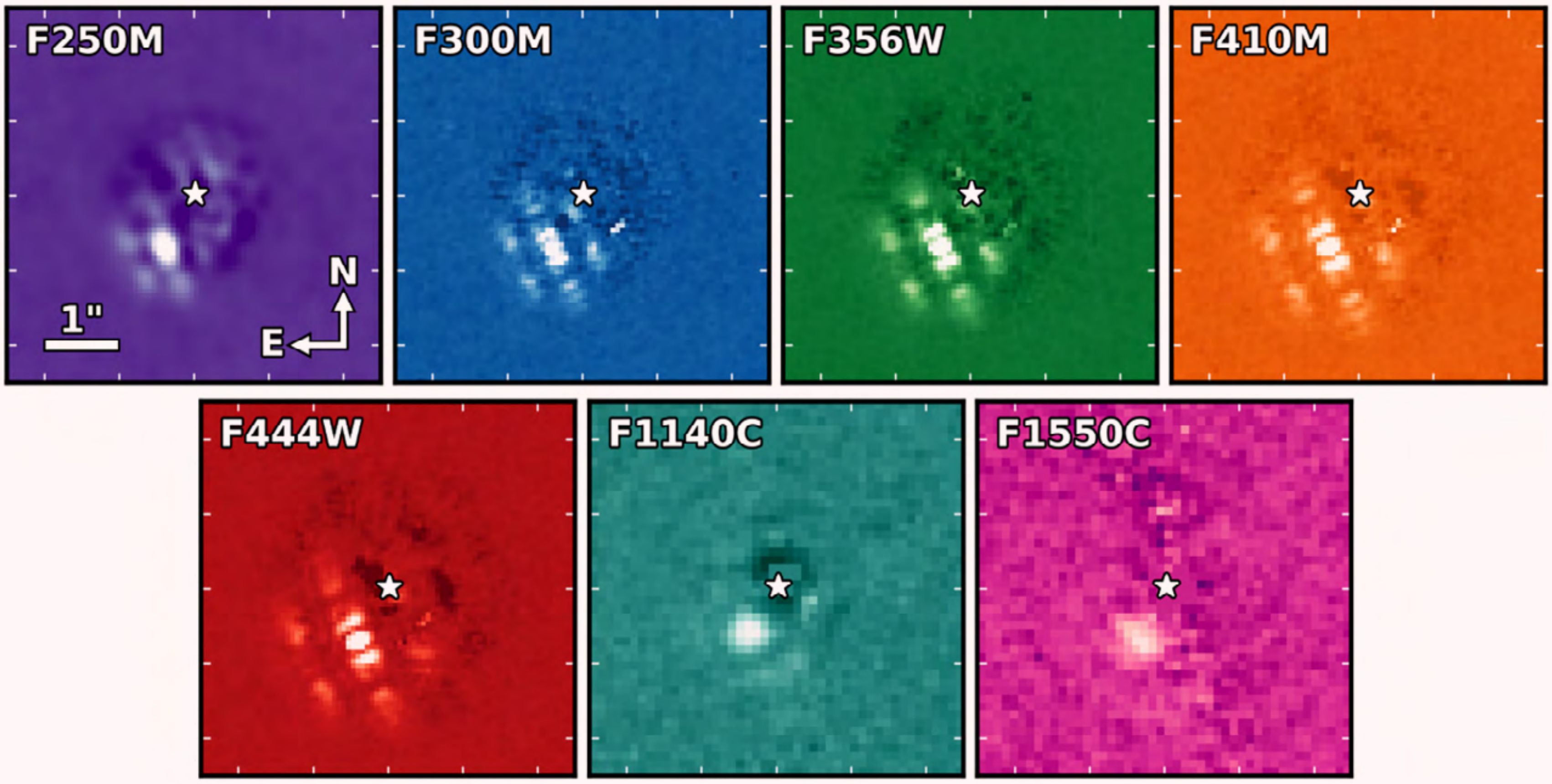
It also needs to be able to do other things because when you build an instrument for Keck, you can't just do it for one science project. It should be broader than that. Another area that it'll be really good in is integral field spectroscopy of solar system objects.

the imaging channel was all done by IIA. Now, IIA is fabricating the mechanisms for the imaging channel and other parts of the instruments.

5. Akhil- You are an integral part of the JWST science team and the Co-PI of the JWST Early Release Science Program for exoplanet imaging. Could you explain to us the improvement in JWST compared to the current technology that we have for direct imaging?

There are a few advantages for James Webb. A big one is that it can work at longer wavelengths than you can do from the ground. The longest wavelength image of an exoplanet from the ground is at 5 microns. I know I talked about 10 microns earlier, but we haven't been sensitive enough there yet. With James Webb, we wanted 15 microns. That was one of the first images. James Webb is extremely sensitive. It can see things that are really, really, really faint. Fainter than we'll ever be able to do from the ground. Fainter than TMT will be able to do at those wavelengths. And that means it can image really, really faint and, therefore, cold exoplanets. So, James Webb could imagine a planet resembling Uranus or Neptune. We've never been able to do that from the ground. But, one issue with James Webb is that it's smaller than our largest ground-based telescopes. And certainly much smaller than the largest ground-based telescopes we're planning to build, like the 30-meter telescope. So you can't see planets that are as close to the star as you can from the ground. That's true today, and it will be even more true with the 30-meter telescope. And unfortunately, planets tend to be really close to their stars. James Webb being a 6-meter telescope and TMT being a 30-meter telescope, you should be able to see a planet five times closer to the star with a 30-meter telescope. That means on a given star, if you're looking at, let's say, 20 AU away from the star with James Webb, you'll be able to look 4 AU away from the star with a 30-meter telescope. And if you look at our solar system, there aren't any planets at 20 AU, but there are large planets at 4 AU. So, James Webb is more sensitive, but it can't always look at the regions where planets most commonly form. The ground-based telescopes have the advantage that they can look closer in, but they're not quite as sensitive. So, ground and space are complementary. I'm excited about the exoplanet imaging science

Picture 4: Waiting for the JWST data release with the Early Release Science team at UCSC (Credits: Author)



Picture 5: First JWST images of exoplanets (Source: https://ui.adsabs.harvard.edu/abs/2023ApJ...951L..20C/abstract)

that James Webb can do. Of course, people will have all sorts of creative ideas, but one that I think is particularly interesting is looking for Neptune-mass planets at very, very wide separations. In particular, at those wide separations, we do see some evidence for planet formation from the ALMA disks. ALMA has seen these rings at very, very large separations, and they can be formed by lower-mass planets than we're sensitive to today. So if our ground-based telescopes can't yet image a Neptune at those separations, James Webb can.

6. Akhil- When do you think we can detect Earth-size planets within the Goldilocks zone? Following that, do you think that life exists outside of Earth?

With the transit method, we can detect Earth-sized planets. Kepler has discovered a few Earth-sized planets. Then some other surveys specifically look for Earth-sized planets around M stars because there is less light from the host star, and it is easier to see the transiting signal. For example, the Trappist-1 systems have rocky or Earth-sized planets within the temperature range where liquid water would form on the surface. But, these planets around M stars might be tidally locked. So I don't know if they're compatible for life or not. In terms of imaging the Earth-sized planets, we won't be able to do that until we have telescopes like the Thirty Meter Telescope.

Regarding your second question, when I give talks to the general public, I get that question a lot. And my answer is always; it doesn't matter what I think; I'm a scientist. It doesn't matter what I believe; I'm a scientist. My job is to design the experiment and do it. All that said, if you asked me my best guess, everything we know about probabilities suggests that there is probably life throughout the universe. My more controversial statement here is going to be - if we find life in our lifetimes, it's going to be in one of the subsurface oceans of one of the moons in the outer Solar system.

7. Neeraj- The next question is regarding outreach efforts. UCSC is well known for its outreach efforts and inclusivity. Please tell us briefly about the programs and your role in them.

Yeah, various professors in the UCSC do different sorts of outreach, and we all have to decide how to spend our time. I think a major initiative at UC Santa Cruz is to use the Lick Observatory for outreach. It's a beautiful sight on Mt. Hamilton, just outside San Jose. It's not as remote as the Vainu Bappu Observatory (VBO) that I visited a few days ago. The Lick Observatory gets over 30,000 visitors yearly, which is a great opportunity for people to look through various telescopes. They can look through the 1888 telescope of the 36-inch Lick Refractor. They can also look through a more modern 1-meter Nickel Reflector, which has been really interesting. And then there are a lot of other programs to help both inward-facing astronomy students and the more outward-facing ones - people who aren't in astronomy.

Then there is this project I inherited from a previous Professor called Project for Inmate Education. It is to teach math and maybe some astronomy at a jail in Santa Cruz. So, some students in this jail tend to be pretty young, probably college-aged, and many would like an opportunity to, while they're in there, sort of better themselves through education. So, this class is called college-level algebra; that's sort of the lowest-level math class that we can grant college credit. They get credit from UC Santa Cruz if they complete this class, which is free of cost. Not a huge number of students finish this. But for those who

Picture 6: Public talks at Lick Observatory (Source: https://www.lickobservatory.org/)

do, I think it would be very rewarding for them and probably their families. Some of the students in our department participate in this program and teach a lot of the classes. So it's not just me going in twice a week. It's usually the grad students doing it, and they've also been interested in teaching astronomy classes.

Many different faculty have different Outreach programs. I think the person at UC Santa Cruz who has the most going on is Raja Guha Thakurta, and he has a huge program called Creating Equity in STEAM (CrEST) with all sorts of different Outreach programs. The one I find most interesting is called Shadow the Scientists (StS). During the pandemic, all these telescopes switched from in-person to zoom observing. So he said, "I am just going to invite people from all over the world to watch me observe," and then it has turned into other people observing while he narrates. He is doing this constantly now, and it works great in India because you get to observe during the day, and it will be a reasonable hour. So that's my favorite outreach program UC Santa Cruz is doing right now. Something like that could be done here as well. While you are observing through the Vainu Bappu telescope, you could start a Zoom session.

8. Parvathy- We would also like to know if you noticed any significant difference in the research culture in India compared to the US.

I've certainly noticed some similarities. The VBO felt just like the Lick Observatory. It is in a jungle instead of being on top of a mountain in California. It was full of monkeys, which I'd never seen before, but the rest of the site was very similar. I went there with

Picture 7: Andy Skemer (third counting from left) with the IIA engineers and Prof Ravinder Banyal (fourth from either side) at the Vainu Bappu Observatory (VBO)

Ravinder and others. And you know, it's clear that people who go there love going there, and they know all the staff and everybody seems happy to see each other. The telescope looks the same. They're about the same size as the Lick Observatory telescopes. The food at the canteen at VBO is so much better. That's the best food I've had since being here. The chefs were incredible. The VBO also has similar challenges that we have at the Lick Observatory. They're not the biggest telescopes in the world, but they have certain features, you know, they're local and available for students. It's easier to do smaller instrumentation projects that a student can do that will take less time than a whole PhD. I think it's clear that it's important to people here, just like the Lick is important to the people at Santa Cruz. The topics of study are a little different here. A lot more solar astronomy is going on at IIA than we have in my department. Similarly, not as much exoplanet research is going on here as we have in our department. You know, I guess I didn't get a chance to witness the day-to-day life of a researcher because I was mostly traveling around and talking to people.

9. Raveena- How was your experience in India so far?

Well, I had a great visit, and I got to see a lot more on this trip than when I came for the TMT science forum. I enjoyed staying here at the guest house and having the chance to interact with you more because of that. If I had just stayed at a hotel, we wouldn't have had a chance to interact like this or get breakfast in the morning and walk over to IIA. I think visiting the observatory was a real highlight for me for a couple of reasons. One is because I love visiting observatories and seeing all the cool instruments and telescopes, and the other reason is because, you know, I have never left the city before. It is only my second time in India, and so, seeing India was really different for me and very interesting. Getting to see the natural landscape was very interesting; the drive was really great. I also got to see the mirror polishing facilities for the TMT segments, which is extremely impressive, and I got to visit the clean room for the Aditya mission. Getting to see all that was really cool. It's an incredibly impressive facility. I spent a lot of time with the students. I spent a lot of time with the SCALES team and the engineers, got to meet with many of the professors, and got to give the talk. The food was excellent at the CREST campus. One thing is, if there's some food that looks very raw, I avoid it, even though some of it looks really good. I'm probably being overly cautious, and I only eat food that is hot. That's worked pretty well. But the downside is that I haven't had any of the juices. Yeah, there are many things that look really good, but I haven't tried, and the things I've tried all have been good. So the whole visit was perfect.

10. Soumyaranjan- Could you say a few words for our readers or some young researchers interested in this field?

It's clear that there's a really good astrophysics program here at IIA. I think the students should take pride in the program, be ambitious in their projects, and take full advantage of everything here. It's good to try different things. Don't be intimidated to try something just because other people are

Picture 8: Andy Skemer (sixth counting from left) in the TMT mirror polishing facility at the CREST Campus, Hoskote

also doing it. There are a lot of resources worldwide for astronomy data, and I think people here could take advantage of that. James Webb is available to everybody in the world. It's hard to get time on it, but you just submit a lot of proposals, and maybe you'll get one through. The same is with the Hubble and many ground-based telescopes too. So I think, you know, you don't have to have an amazing idea to use one of these telescopes. I think sometimes students are intimidated because they think they have to have a brilliant idea, but they don't have to. Sometimes there's obvious science, and you just have to be one of the people who go for it.

Picture 9: Andy Skemer with our director Prof Annapurni Subramaniam during his visit to IIA

Picture 10: Andy Skemer with members of DOOT after the interview

Planetary Motion and the Venus

Ayushi Chhipa

Solar System is a family of 8 planets and, of course, the Sun. Of these planets, we can see Venus, Mars, Jupiter, and Saturn in the night sky with the naked eyes from Earth. We know that every planet has a fixed orbit, and the orbital speeds for all the planets are different. Venus and Mercury have an orbit that lies inside the Earth's orbit; hence, these are called Inferior Planets. The rest of the planets have their orbits outside Earth's orbit, called Superior Planets. All the planets change their position with respect to the Sun as well as Earth (or us: *as observers on Earth*) while orbiting the Sun. Given its distance from the Earth and Sun, Venus appears to be the brightest planet in the sky. Due to its orbit, Venus can be seen only in the morning or the evening sky. Thus it is called the 'Morning and Evening Star.' We will discuss the properties of Venus later in this article. Before that, we should look at some useful terms.

Conjunction: Conjunction occurs when any two astronomical objects in the sky appear with a small angular separation. As we know, planets continuously change their position in the sky. Hence, we can observe their conjunction with the Sun, Moon, and each other. This is termed as **planetary conjunction**. A good example of this was the great conjunction of Jupiter and Saturn in 2020, as shown in Figure 1. The arrow indicates the line of sight direction as seen from the Earth.

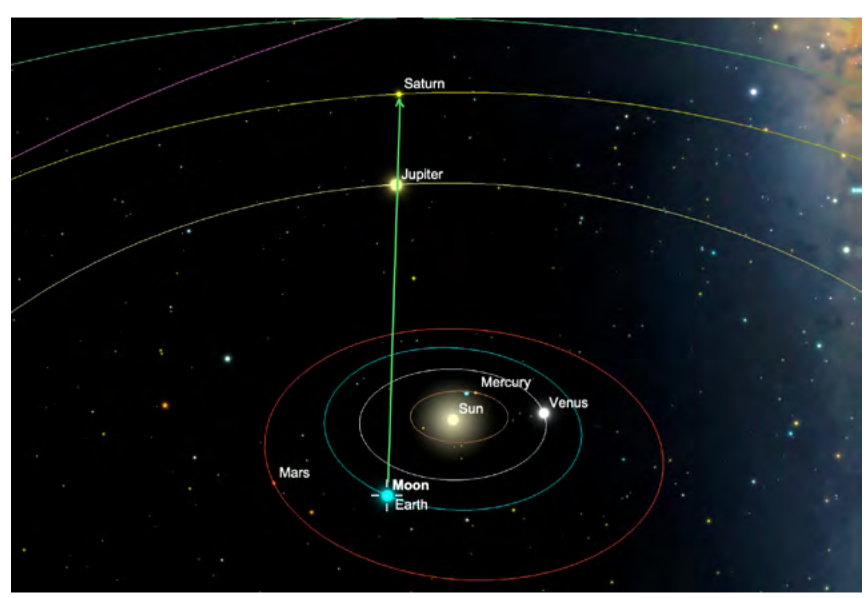


Figure 1: The Great Conjunction of Jupiter and Saturn 2020 *(Source: SMO Hiram College Ohio)*

In the following sections, we will concentrate on the changes in the position of planets with respect to the Sun for an observer on the Earth and how this affects the planet's visibility.

Elongation: The angle observed from the Earth between the direction of the Sun and the direction of a planet is called elongation. This also represents the angular separation between the planet and the Sun in our sky. A planet can be at an eastern or western elongation, depending on whether the planet lies east or west of the Sun as seen from the Earth. The elongation of a superior planet can vary from 0° to 180°. For Inferior planets, the range of elongation lies between 0° and the angle of **greatest elongation**, the largest elongation, or the largest angular separation the planet and the Sun can have, as seen from the Earth. The range of greatest

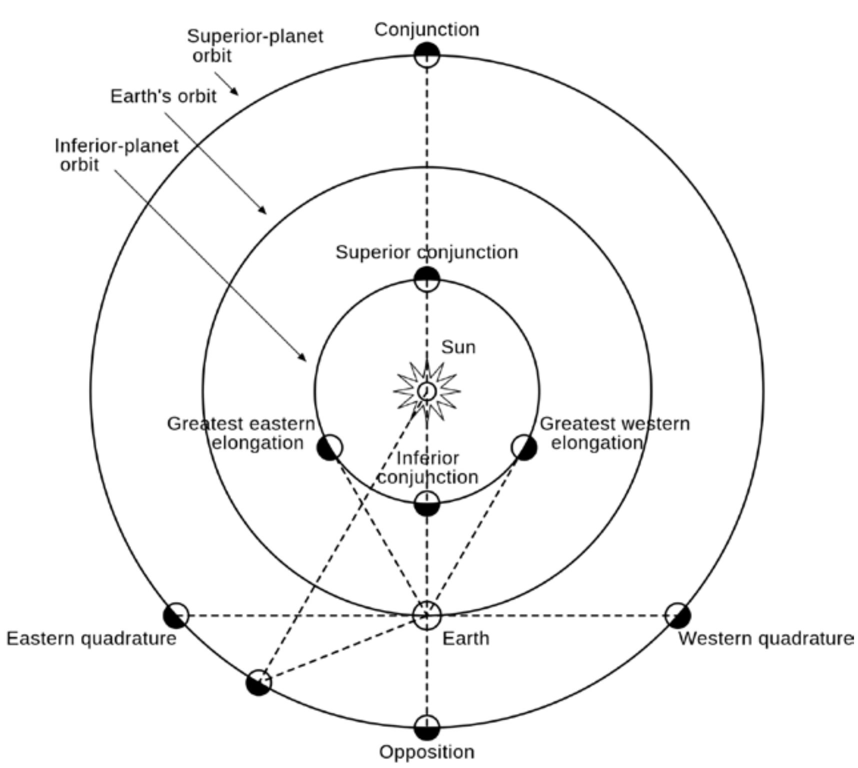


Figure 2: Superior and Inferior planet orbits (Source: Wikimedia Commons)

elongation for Mercury is ~18° to 28°, and for Venus, it is ~45° to 48°. This variation in angles is due to the elliptical orbits of planets.

Superior Planets: These planets can appear to be in conjunction (alignment) with the Sun once while orbiting around it. This happens when it is on the opposite side of the Sun, as seen from Earth. At this point, the planet will be farthest from us, and in our sky, it will be close to the Sun's position, so it cannot be seen. When the planet and the Sun are on opposite sides with respect to the Earth, we call it **opposition**. At this point, the planet appears to be

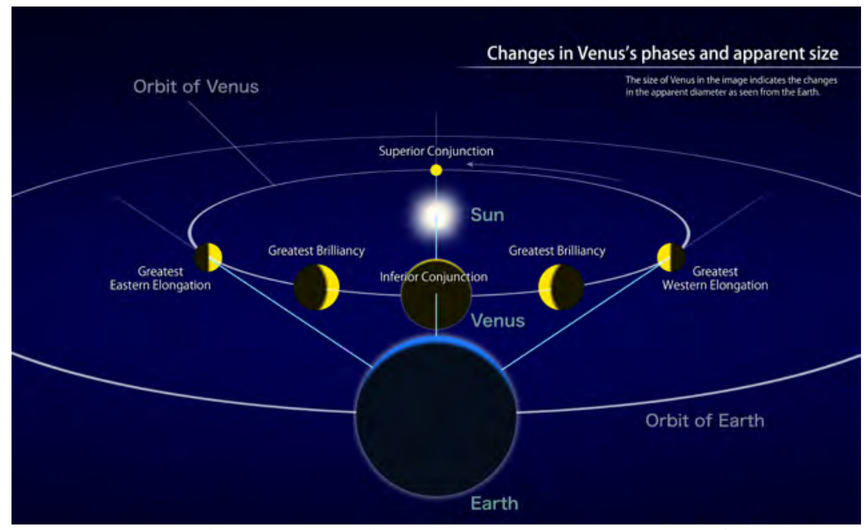


Figure 3: Changes in phase and apparent size of Venus. The size of Venus in the image indicates the changes in the apparent diameter as seen from the Earth (Source: NAOJ)

the largest and the brightest in the night sky. There are two more points for consideration: the eastern and western quadratures. At these positions, the planet is at an elongation of 90°.

Inferior Planets: In this section, we will try to understand the orbit of Venus in detail, given that it is the only inferior planet visible to the naked eye. Venus appears closer to the sun in the sky because of its smaller orbit. When the planet is at a position which is between the Earth and the Sun, it is in alignment with the Sun as seen by an observer on the Earth. This is called the **inferior conjunction**. At this point, the planet's darker side is towards us, and the Sun and Venus rise and set together. Hence Venus cannot be observed for this period. When the planet is on the far side of the Sun, we call this **superior conjunction**. Again for this period, Venus is not observable even though its bright side is towards us. So, when can we see this planet? Answer is when it is at the intermediate positions between two conjunctions.

Here we should consider some facts:

- *The Earth rotates from West to East.*
- *Venus takes approximately 225 days to complete one orbit around the Sun (Sidereal year of Venus); the same for Earth is about 365.26 days. This means the synodic Year (the time Venus takes to be seen again from the Earth in the same position relative to the Sun) of Venus is about 584 days.*

When the planet is to the west side of the Sun, it will rise before the Sun for an observer on Earth. As it has already risen before the Sun, it will also set before the Sun. So it will be visible in the morning, in the eastern sky for the observer, and behave as the **Morning Star.** When the planet is to the East of the Sun, it will remain above the observer's horizon after the sunset, in the western sky for the observer, and behave as the **Evening Star**. Venus remains visible as either the evening or morning star for a period of about 8 to 9 months. For the remaining times, it is not visible as it will be very near to the Sun or during the conjunction period. The transition of the planet from being the morning star to the evening star happens about every 19 months when it crosses either of the conjunction points.

Here the points of greatest elongation are of particular interest. At these points, the planet will either prominently appears as the morning star (greatest western elongation) or the evening star (greatest eastern elongation), with the highest altitude in the observer's sky reaching up to 40° (while remaining visible to the naked eye). Therefore, it is present above the observer's horizon for the longest period of the day. Near the points of conjunction, when the planet is at a sufficient distance from the Sun so that it is visible, we can see

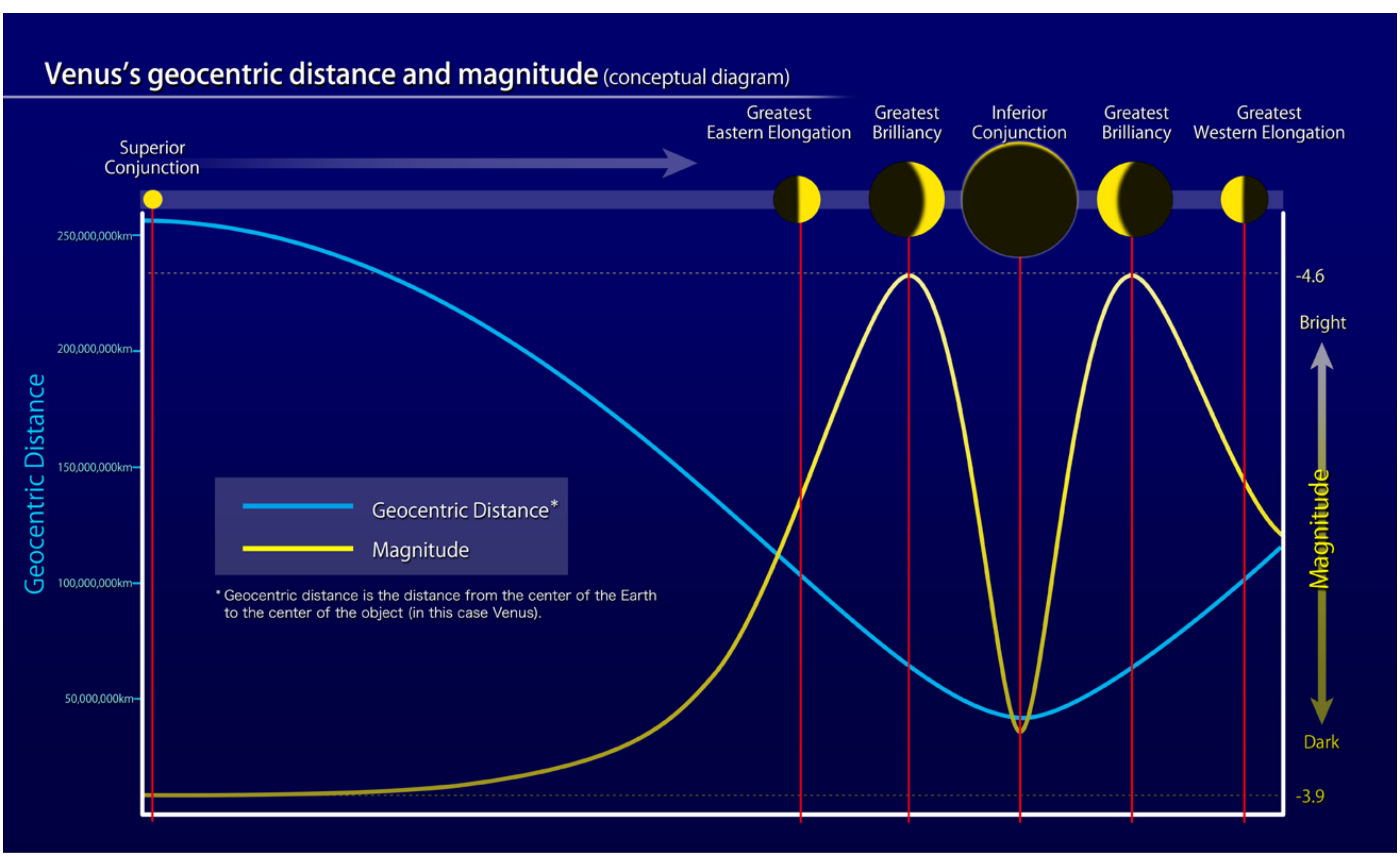


Figure 4: Phases of Venus (Source: NAOJ)

it during dusk or dawn, depending on its elongation. Thus the relationship between orbits is the reason why Venus appears as the morning or evening star.

A careful observer can also see a change in the brightness of Venus. This is because Venus changes its phases throughout its complete cycle, like our Moon. When Venus is at the point of greatest elongation, whether the greatest eastern or western elongation, its half-illuminated surface can be observed through a small telescope. As the planet moves towards the superior conjunction from the points of greatest elongation, the observed brightness decreases because the distance of Venus from Earth increases. During this phase, the illuminated surface of Venus will be towards us. However, as it moves towards the inferior conjunction, we observe an increase in its brightness until it reaches the position of greatest brilliancy (as shown in Figure 4), where the planet is in the crescent phase. As Venus further moves towards the inferior conjunction, we observe a decrease in its brightness because its darker side is then towards us. The planet reaches its peak brightness (approx. -4.6 magnitude) during this crescent phase since it is closer to Earth now. You can refer to Figures 3 and 4.

The occurrence of periods of different phases of Venus in a year changes over time due to its relative motion with respect to the Earth. In 2023, the greatest eastern elongation will occur in June, and the greatest western elongation will occur in October and November (refer to Figures 5 and 6).

This we can check using software facilities like Stellarium and Mobile Observatory. On these platforms, one can search for any celestial objects, including Venus, and by changing the time and

Figure 5: Venus during greatest eastern elongation in 2023 (Source: Stellarium)

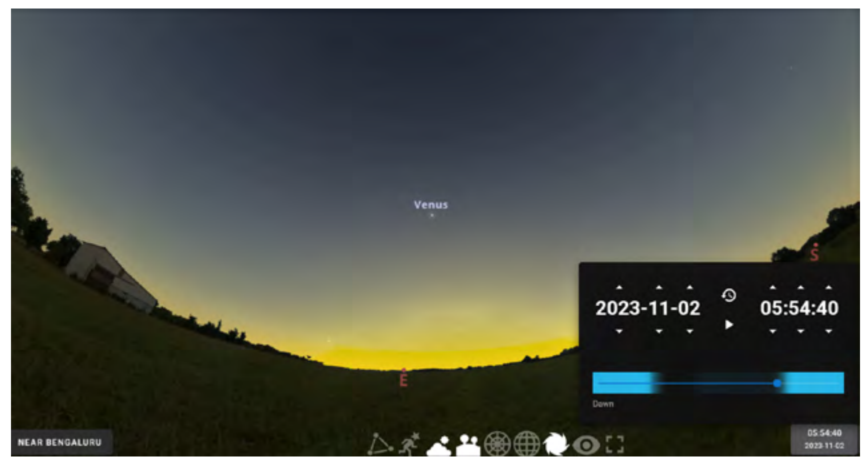


Figure 6: Venus during greatest western elongation in 2023 (Source: Stellarium)

dates, one can check for the object's visibility and altitude in their respective sky.

Thus we have seen how the solar system works and the interesting behaviour of planets in our night sky. Readers are encouraged to check the maximum altitude Venus reaches for different locations on Earth and if some changes are observed in the Northern and Southern hemispheres. One can also observe other planets like Mars, Jupiter, and Saturn as well and learn about their behaviour in the sky.

Happy learning.

Ayushi Chhipa is a Junior Research Fellow (JRF) at IIA. Her research interests are in the fields of Galaxies and AGNs.

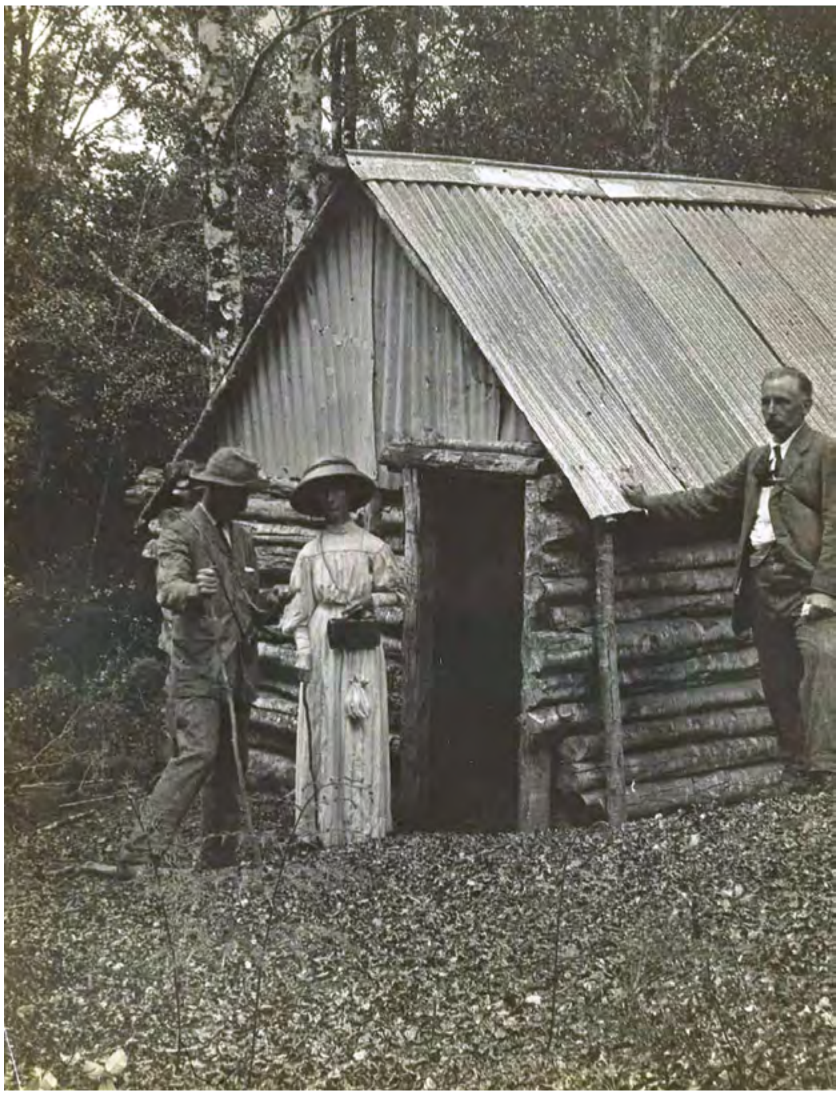
Artist: Maya Prabhakar

The Indian Eclipse Expedition, 1922 | Records from IIA Archives

Contributions from IIA Library

Last year, in 2022, the scientific community celebrated the Centenary celebration of the 1922 Indian expedition to Wallal, Australia, to observe a solar eclipse. A group of renowned astronomers conducted an expedition on a remote shore in Wallal, Western Australia, in September 1922 to test Albert Einstein's Theory of General Relativity, arguing that gravitational objects with gravitational influence warped spacetime around them. Observing the deviation of starlight caused by the Sun during total solar eclipses was an opportunity to corroborate the experimental proof of Einstein's theory. This expedition group included W.W. Campbell, J. Evershed (Kodaikanal Solar Observatory), C.A. Chant, a group from Perth Observatory led by C. Nossiter, A.D. Ross, C.E. Adams, J.B.O. Hosking, and a private party from England.

The objective of the Indian expedition led by John Evershed, former director of the Kodaikanal Solar Observatory, was to photograph the star field encompassing the eclipsed Sun to determine the light deflection near the Sun. Initially, the crew intended to occupy the Maldives Islands; however, transportation and funding issues necessitated a move to Australia. Initially, the Indian expedition crew consisted only of Evershed and his wife, Mary Acworth Orr. Then, Professor Ross of the University



John Evershed and his wife Mary Acworth Orr Evershed at Wallal Expedition, 1922 (Credits: IIA Archives)

of Western Australia coordinated with university officials to assign Mr Everson of the Physics Department to the Indian expedition team. A year prior to the eclipse, the Observatory workshop underwent extensive construction and testing of the instruments. It consists of a large camera case, 12×12½ -inch plates, and a wooden frame. The Royal Society and Astronomical Society lent a 16-inch coelostat for use with the Einstein camera. Eclipse utilized high-dispersion auto-collimating prism spectrographs with two spectrographs for the simultaneous acquisition of east and west coronal spectra, thereby reducing friction and permitting a 45-minute descent.

The expedition sailed from Madras on July 28, 1922, and arrived in Broome, Western Australia, on August 18 via Singapore. They created five dark transparencies for the Einstein camera and pier to photograph Canopus's high dispersion spectrum. The expedition arrived at Wallal on August 30 and met with numerous eclipse teams, including those from the United States and Canada. With a concrete pier for lens mounting and coelostat, the 35-ton instruments were assembled in 18 days. A precise adjustment was challenging, so the coelostat was adjusted. There were irregularities in the driving clock, and star images remained stationary for 20 seconds before beginning to wander. They used a 16-inch coelostat and a 12-inch lens for the high-dispersion Canopus spectrum. After making all the necessary preparations, they observed the solar eclipse at Wallal on September 21, 1922. The Indian expedition party returned from Broome on October 24, 1922, and arrived in Kodaikanal on November 20, 1922.

(Left) Hut of the Indian expedition team, Wallal, 1922 and (right) Setting up of the instrument by the Indian expedition team, Wallal, 1922 (Credits: IIA Archives)

About IIA Archives

The archives of the Indian Institute of Astrophysics (IIA) contain a wealth of historical documents pertinent to the institution's past. John Evershed was the second director of the Kodaikanal Solar Observatory after the Madras Observatory's operations were relocated there in 1899. The IIA Archives comprise an extensive collection of archival materials pertaining to John Evershed. It includes correspondence, letters from prominent scientists, observation notes, photographs, CDs, transparencies, and other official documents. We are preserving archival materials associated with the Wallal, Western Australia expedition. The photographs from the expedition are significant evidence of this historical event.

The article was submitted by Dr Arumugam Pitchai on behalf of the IIA Library. He is currently the librarian at the Indian Institute of Astrophysics. Feel welcome to contact the IIA Library team (archives@iiap.res.in) for more information about this historical event.

Credits: Seth Shostak, SETI Institute https://www.seti.org/we-keep-looking-space-aliens-are-they-looking-us

Naman wants to meet ALIENS!

Manika Singla

Naman has come to *Nani's* (grandmother's) house to celebrate his birthday, and *Nana* (grandfather) has bought a surprise present. Naman cuts his birthday cake in the evening. Nana teases him by showing him the gift and saying, "I won't give it to you! It's mine!" Naman pleads, "Please give me na! This is mine!" As soon as Nana gives him, he starts opening it and exclaims with joy, "Wow! These are sunglasses!" He wears them at the very instant and starts roaming around everywhere. As it is dusk time, he is hardly able to see anything. But he keeps wandering around in the house. He is very anxious for the morning to come so he can see through his "sunglasses."

The next morning, he wakes up eagerly before sunrise, wears his new gift, and goes out. The blood-red sun is rising slowly on a hazy morning.

Still, he sees significantly less brightness as he looks directly above his head while wearing his gift, although the day is bright enough to see with the naked eye.

He checks by removing the goggles and can see clearly with his naked eyes. He gets surprised! Why is it happening? He returns to Nana a little downheartedly and says, "These glasses are defective! I am unable to see through them!" Nana blandly asks him to see through it another day. He does not understand the reason.

He goes out the next day as well in the early morning. Fortunately, there are no clouds, dust, or haze due to yesterday night's rain. It is a clear sky, and the day seems to be bright and sunny.

This time he is able to see clearly through his gift. Also, there is not much difference in the light as he sees through his "sunglasses" or naked eyes. He jumps with joy just because he can see through it. Innocent Naman!

In the evening, Nana asks him, "Naman! What did you see today morning?". Naman gets excited again and says, "Nanu! I saw it clearly today. I saw the sky, the Sun, the Peepal tree, some birds, and much more."

"What difference did you notice between these two days?" asked Nana.

"Yesterday, I could hardly see anything, but today, I could see almost clearly. Why is it so Nanu?"

"You remember? Yesterday was a hazy day. So the sunlight gets scattered by the dust particles."

Naman seems puzzled.

Nana further adds, "Suppose you look directly above your head through your glasses. You will see darker than you see in other directions."

"But why is it dark above my head? Is there any ghost above me?"

Nana smiles and says, " No, Ghost! But science is there! Do you know what light is? It is made up of two parts. One is horizontal, and the other is vertical. If we block one part, we will see only the other part, known as polarized light. A polarizer is a device that blocks one part, and thus we can see only the

Figure 1: Rising blood-red Sun (Credits: Maxwell's Equestrian Centre Facebook page)

polarized light through the polarizer. Let's assume that you see the horizontally polarized light through a polarizer that blocks the vertical part of the light. Then, you will not be able to see anything. But if you start rotating the polarizer slowly, you see the fine brightness coming. And that brightness is maximum when the polarizer is rotated at right angles."

Naman curiously asks, "But where can I get that polarizer?"

"You already have that!" Nana says laughingly, pointing at those glasses. Naman is looking at his gift with his eyes wide open.

Nana continues, "When the Sunlight passes through the Earth's atmosphere, it gets scattered in many directions and polarized in a particular direction. If we see at that specific angle, we can see the polarized light."

Naman is listening carefully and introspecting. He confirms, "On that hazy day, the dust polarized the sunlight. Thus, I could hardly see anything through the "sunglasses" above my head!

Two days later, he goes again at the same time to explore more. He sits at the shore of the nearby lake peacefully. He is thinking about the exoplanets that revolve around other stars in the sky. Nana told about them when he was getting stubborn to meet Aliens after watching the film "Koi Mil Gaya" a few years back. He goes deeper into his fantasy world and imagines his own dreamy world. He wonders what these exoplanets are made of! How would we know what it is made of? If they have grass or not? What if they have only water? Or only ice? He has a lot of questions, not a single answer!

He again disturbs Nanu! Nana explains with joy, "Let there be two planets, *"Baraf"* made of ice, and *"Paani"* which has only water. As the planet orbits the star, the light from the star gets reflected by the planet and then reaches us. That light is reflected by the atmosphere of the planet as well as by the surface of the planet. Hence, if we observe this light from the telescope, we can learn about the atmosphere and the surface. As ice reflects more than water, the light reflected by "Baraf" will be more than "Paani". Thus we can infer about the surface of the planet."

Naman asks, "What if the planets are made of grass or anything else?".

Nana replies, "Similarly, we can find out how much the other materials reflect. And then tell about their surface!".

"But what about their atmospheres? How can we tell if there are clouds or dust like our Earth has?"

"Beta, suppose there are atmospheric gases like oxygen, carbon dioxide, methane, water vapors, etc., that we, lucky people, have on our Earth. Then, those gases will eat some of the light of particular energies, like worms eat plant leaves from here and there (see Fig. 2). And thus, there will be dips in the remaining light, the same as in the case of a leaf. The starlight comes to us after getting reflected from the planet and being eaten up by the gases. Those dips are like the fingerprints of the gases. By studying those dips, we can get to know about the planetary atmospheres."

"Okay! But what about the haze, dust, or the clouds?"

"The reflectivity increases due to the presence of such things. It is because they scatter or reflect more. It is the same as if you see yourself in a glass. You see yourself very faint. But if you polish the

Figure 2: Intricate traces left by worms on a once-complete leaf (Credits: Bioadvanced.com)

other side of the glass, the reflection will increase, and you will see a clear picture of yourself."

Nana continues, "You can also tell about the dust by polarization. You have experienced more polarization when there is dust or haze. This is true for the exoplanets also. " Naman gets lost in his deep imagination. He is sitting still and smiling, surprisingly. "This is a wonderful gift!" he thinks.

He smartly asks, "Can I see those planets with these "sunglasses"? Nana laughs his heart out and says, "Beta! We can see those planets with the help of telescopes. "James Webb Space Telescope (JWST)" has been launched recently. And we can get to know more about these planets soon. Our nearest neighboring exoplanet is "Proxima Centauri b," which is Earth-like and orbits around its own star. Maybe in the future, we will find ALIENS on this planet!"

"Wow! That's so amazing, Nana!"

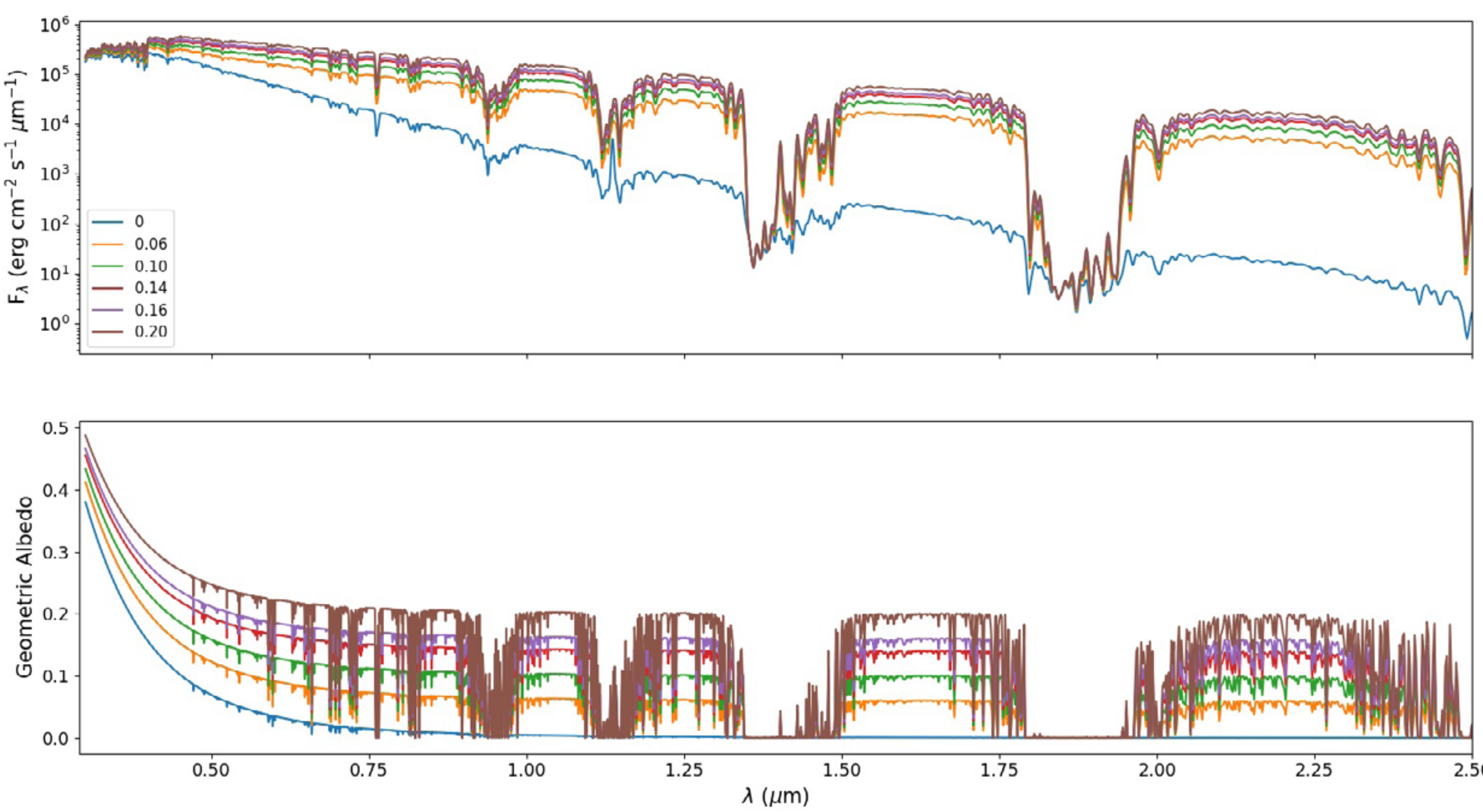


Figure 3: Reflected flux and Geometric Albedo versus wavelength for an Earth-like exoplanet for different surface compositions. The absorption lines of oxygen, water, ozone, etc.(biomolecules) are visible in the plot.
Colors: zero surface albedo, 100% ocean cover (surface albedo = 0.06), 50% ocean cover and the remaining 50% covered with trees and grass (0.1), present Earth-like surface composition (0.14), prebiotic Earth-like surface composition (0.16) and 83% ocean and the remaining is snow (0.2) [2]

He continues, "I have a question! As the planet revolves, it will come in front of the star at one time. Then the starlight should transfer through the planet's atmosphere. Can we see that light"?

Nana satisfactorily answers, "You are thinking right, Beta! The light will transmit through the planet's atmosphere and reach us. And it will also contain the information of the atmospheric gases and the clouds just like the reflected light."

"How will the clouds change the transmitted light?"

"The clouds will reduce or suppress the light. Also, the observed light will reduce even more if the clouds are denser."

Nana continues, "So basically, I have told you three different ways to know about the atmospheres of the extrasolar planets. First is by polarization, second by reflection, and third by transmission. Soon, many upcoming telescopes, like Habitable Exoplanet Observatory (HabEx), Thirty Meter Telescope (TMT), The Large UV/Optical/IR Surveyor (LUVOIR), etc., will unravel life's mysteries on the other planets. We can sneak more and more into their atmospheres and tell if life is possible on those planets or not! Until then, we only have movies like "Avatar, Koi Mil Gaya, and many more to tell about the aliens."

Naman gets enthusiastic and eagerly waits to meet the ALIENS and visit another planet!

Naman has learned how scientists work hard to know about life outside our Earth. The day is not very far when we can live with aliens, play with aliens, and eat with aliens. When we can go to exoplanets, they can also come to our home planet. But till then, we have only one world and one life to live, love, and cherish! We must take care of mother nature so that future life on Earth can survive, at least until we meet the ALIENS!

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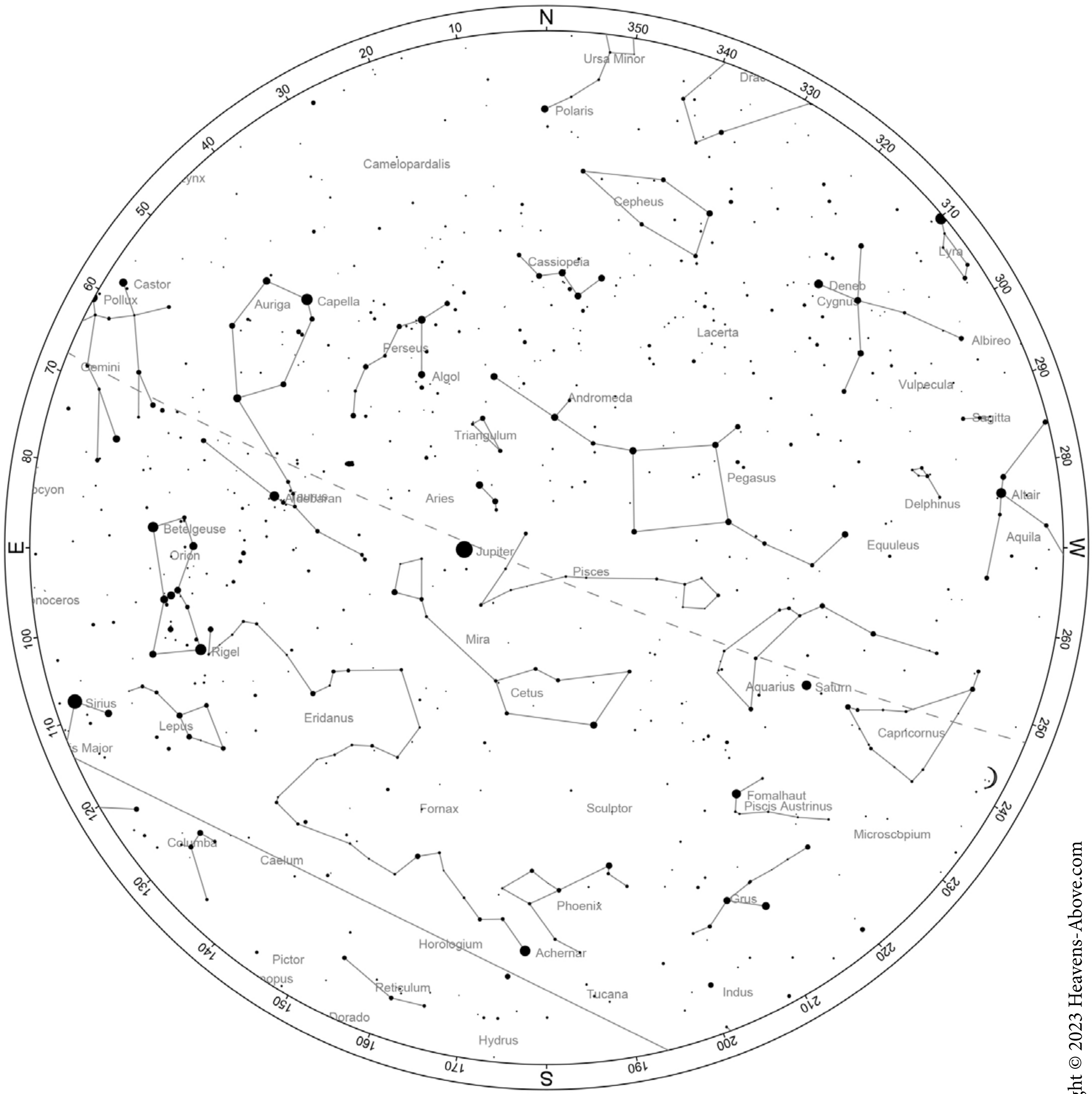

Skychart December 2023: (As on December 15, 2023. 20:00 hrs Bengaluru)

December 2023

Sun	Mon	Tue	Wed	Thu	Fri	Sat
31					1	2 Pheonicid meteor shower 2023
3	4	5 	6 December φ-Cassiopeid meteor shower 2023	7 Puppid-Velid meteor shower 2023	8	9 Monocerotid meteor shower 2023 Conjunction of the Moon and Venus
10	11	12 Comet 144P/ Kushida passes perigee σ-Hydrid meteor shower 2023	13 	14 Conjunction of the Moon and Mercury Geminid meteor shower 2023	15	16 Comae Berenicid meteor shower 2023
17	18 Conjunction of the Moon and Saturn	19 Lunar occultation of Neptune	20 December Leonis Minorid meteor shower 2023 	21	22 December solstice Conjunction of the Moon and Jupiter	23 Ursid meteor shower 2023
24	25 Comet 62P/ Tsuchinshan passes perihelion	26	27 	28	29	30

Background image: Jupiter Venus Conjunction

Credit: Anand M N

Newly designed DOOT logo: Encompassing the ethos of inclusive science and communication

With the continuous overwhelming progress in modern Astronomy, marked by many breakthrough results in recent years, many members of the DOOT resonated with the idea of revamping the doot logo to make it more inclusive of various fields and give the name a new meaning, where DOOT does not just act as a messenger of information to readers but brings together a large section of people involved in the process not limited to researchers but from various staff to the people who provide different kinds of support for a smooth research environment.

Although "Doot" (Sanskrit: दूत *[dūta]) in a literal sense means "a messenger" in various Indic languages, the magazine does not act as a mere messenger but caters to multiple things with an inclusive vision of bringing together different factions under one umbrella. Hence, with the new graphical representation of the name, we have tried to give a broader meaning to the word DOOT.*

DOOT

A students' initiative from the Indian Institute of Astrophysics

'D' signifies the diverse nature of the content presented in the magazine, from simple art to technical articles, including interviews, research reviews, personal experiences, and a whole lot more.

The first 'O' is an ode to the Milky Way, our home, a spiral galaxy, but is generalized for galaxies as a whole, representing many disciplines of astrophysical research included in it

The second 'O' symbolizes a black hole, one of the many intriguing mysteries yet at the heart of almost all the large galaxies.

Finally, the 'T' represents various Telescopes, which have given birth to many curiosities and are further used to probe these by collecting the astrophysical messengers (the photons from various sources). Eventually, 'T' brings all these things 'Together' under one umbrella.

The logo is a result of various dialogues and discussions with all the members of the DOOT. Shubhangi Jain designed it with consultation from Lupamudra, Renu, and Rishabh.

Background image: Comet C/2022 E1 ZFT
Credit: Dorje Angchuk