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SPAGER

INTERVIEW WITH DUNCAN LORIMER

Chasing Islands in the Data: Discover the serendipity behind the discovery of Fast Radio Bursts (FRBs)

GALLERY: THE CAPTURED COSMOS

Collection of professionally clicked and edited astrophotography

Photo: Sujoy and Shahebaj

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EDITOR'S LETTER

Dear Reader,

We are pleased to present the second issue of SPASE Department's magazine, a sequel to a chapter that was tenderly initiated by the students and supported by the faculty. This issue captures the journey of what once was to what it is now, from the story of our universe to IITK campus in the 60's. It portrays the complexities of the universe we live in, and how these very complexities steer our desire to perceive them through poetry, photographs and literature, helping us find solace in the unknown.

Art is an expression of ideas, and life itself is an art. To view life as art is to embrace creativity, individuality, and a space for self-expression. The very notion that everyday life may seem repetitive, yet differs from every other day, is a gentle reminder of life's artistry. But what bounds art? Space, by its very nature, is vast without limits. Boundaries blur, and within that blurring, art continues. In this openness, ideas find freedom, and imagination is allowed to wander, merge, and transform. Within the known and beyond the defined, art is not only lived; it quietly emerges in every moment.

The SPASE magazine renders a space not only to create within academia, juggling codes and concepts, instruments and innovations, but also for venturing further into the details, compositions, and mysteries of the universe through palettes of creativity. It is a collection of those casual "Hey! I made something. Do you want to see it?" moments between friends, where a simple exchange becomes a point of connection.Within these pages, what you will read or see is not merely works, but the very proof that art lives through perspective- the quiet conversations within a mind, and the stories that emerge from a single image. These pages reflect the beauty of the greatest artist, nature itself, while also capturing the depth of the human mind.

We are exceedingly grateful to the artists whose works have filled the pages of this second issue. On behalf of the editorial team, thank you for accompanying us. May this art serve as an inspiration to our dear reader, to never quieten the voice of the artist within you.

VILASANUO
Editor, SPAGER

"The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars.
We are made of starstuff."

CARL SAGAN

The Milky Way and Cygnus Constellation in the night sky over Aleh Negev, Israel, Photo: Ahmad Basem / Pexels

1

INTERVIEW

CHASING ISLANDS IN THE DATA: A CONVERSATION WITH DUNCAN LORIMER

"It's more like being persistent, 'cause I know I'm gonna make mistakes, it's just part of it."

In the world of astronomy, some signals change the way we see the universe forever. We sat down with renowned astrophysicist Duncan Lorimer to discuss the serendipity behind the discovery of Fast Radio Bursts (FRBs), the future of the Square Kilometer Array (SKA), and why the most important tool for a PhD student isn't a telescope—it's persistence.

Duncan Lorimer

The Anatomy of a Discovery

Interviewer: When you first analyzed the data for what would become the first-ever Fast Radio Burst paper, did you immediately know it was groundbreaking, or did you suspect a mistake?

Duncan Lorimer: I knew it was real; I just had a feeling about it. Having looked for pulsars and individual pulses for many years, this was clearly a signal of some kind. It was dispersed and stood out as a "beautiful little island" in the data with no evidence for contamination by sources of radio interferences. However, we weren't actually looking at our intended target. While we were searching for pulses in the Magellanic Clouds, I realized the signal we found was when the telescope was actually pointed two degrees south of the Small Magellanic Cloud. We were looking out into the empty universe! That's when I got confused. I'd never dealt with anything that far away before. It took months of writing, discussions and thinking to realize we had found a prototype for an entirely new class of astronomical source.

Interviewer: Was there a "secret sauce" to this observation that others missed?

Duncan Lorimer: Not exactly. The data were already there; what we did differently was looking for individual pulses rather than continuous signals. But there is a huge element of serendipity in science. We happened to be looking at a random patch of sky at exactly the right time. If there was a lesson to be learned, is that we searched a much larger region of parameter space than we perhaps needed to to find pulsars in the Magellanic Clouds.

Decoding the Fast Radio Burst

Interviewer: We've discovered so many sources till now. Are we close to a "Grand Unified Theory" for FRBs, or are they all unique phenomena?

Duncan Lorimer: I think FRBs are an observational combination of different types of sources. We see them in young galaxies, old galaxies, and globular clusters. Some repeat, some show orbital motion, and some don't. To me, the most likely scenario is that they are neutron stars existing in a vast collection of different environments.

Interviewer: Looking ahead, how will the Square Kilometre Array (SKA) change the game?

Duncan Lorimer: It's a massive leap. Our early observations covered about a square degree of the sky; modern instruments like the SKA can see hundreds of square degrees at once. More importantly, they can localize sources within a milliarcsecond—whereas we could only narrow it down to a fraction of a degree. Plus, what used to take us months to process in 2006 can now be done in real-time.

The "Frustrating" Art of Research

For PhD students entering the field, Lorimer offers a perspective that is as grounded as it is inspiring. "*You should only do things if you're really interested in them*" he insists.

Perhaps his most candid advice involves the inevitability of failure. *"I'm always making mistakes. I think it's just part of life,"* Lorimer says. To him, research is inherently frustrating because, by definition, you don't know the answer. The secret isn't being right all the time; it's being persistent enough to go for a walk, clear your head, and try a different avenue when a problem refuses to budge. Sometimes, your best ideas come when you are away from your desk and not trying to force your brain to come up with a solution. He says, *"It's more like being persistent, 'cause I know I'm gonna make mistakes, it's just part of it."*

Beyond the Telescope

"The most successful students are usually the best communicators. You can do the greatest research in the world, but if you can't communicate it, you might as well not have done it." he notes.

ABOUT DUNCAN LORIMER

The Astrophysicist Who Unlocked the Transient Sky

Current Role: Professor of Physics and Astronomy, West Virginia University

Key Recognition: Co-recipient of the 2023 Shaw Prize in Astronomy; Fellow of the Royal Society (2024)

The Discovery That Changed Astronomy:

In 2007, Duncan Lorimer fundamentally altered our understanding of the universe. While working with his student David Narkevic to analyze archival data from Australia's Parkes radio telescope, they uncovered a massive, 5-millisecond flash of radio waves originating from far beyond the Milky Way. This mysterious, high-energy signal—now famously known as the "Lorimer Burst"—was the very first Fast Radio Burst (FRB) ever recorded.

Lorimer's final roadmap for the next generation of astronomers is simple: manage your time and master your language. He still blocks out hours in his own calendar for deep work, shielding himself from a "distractible world" to focus on writing. He believes that the most successful scientists aren't just those who find the data, but those who can communicate it clearly.

2

INTERVIEW

THE ARCHITECT OF EXCELLENCE: A CONVERSATION WITH AMITABHA GHOSH

“Space activity attracts media attention... but you need your faculty and students to bring the map of excellence together.” — Prof. Ghosh

Professor Amitabh Ghosh, a luminaire of IIT Kanpur, reflects on the early days of the institute, the shifting landscape of the campus, and why the next generation of students holds the key to India’s space ambitions.

In this interview, Prof. Ghosh bridges the gap between the "bicycle era" of IIT Kanpur in the 1960s and the high-tech, construction-heavy campus of 2024. His reflections serve as both a nostalgic tribute to the institute's roots and a strategic call to action for the future of Indian space research.

On Beginnings and Motivation

Interviewer: Looking back at your initial days, what motivated you to pursue a career in research? Could you briefly share the different fields you explored during those early years?

Prof. Ghosh: It’s a journey that began quite some time ago. I started teaching at IIT Bombay in 1965. Back then, the professional landscape was very different; getting a job wasn’t easy, and I remember applying for many positions. Eventually, I found my footing in India in 1983, and by 1986, I had established my work center. My motivation has always been tied to the influence we have on our students and the desire to build something lasting in India, rather than seeking opportunities abroad in places like China or Australia.

The Future of Academics in Space Science

Interviewer: You’ve mentioned that the SPASE Department at IIT Kanpur is unique. How do you see it evolving compared to other departments?

Prof. Ghosh: This department is very special, but it needs to be nurtured carefully. Space activity is going to be a major pillar for India’s future. It has a unique power to attract media attention and public interest. For this department to become a “true masterpiece,” it requires dynamic leadership and a clear vision. If it is guided properly, it will reach a map of excellence that few others can match.

Interviewer: As students, what can we do to contribute to this growth?

Prof. Ghosh: You are the real ambassadors. When you achieve a major breakthrough in your work, you aren’t just doing research—you are bringing the department into the spotlight. Your faculty members are young and talented; many were my own students, like Ishaan, who graduated in 1999. The synergy between young, energetic students and focused leadership is what will make this department a leader in the field.

A Changing Campus: From Cycles to Construction

Interviewer: You have seen IIT Kanpur since December 1974. What are the most striking changes you observe today?

Prof. Ghosh: When I first came, the campus was only four months old. There was just one row of mango trees! In 1964, the only transportation we had was the bicycle. If you wanted to go to school, it took hours. I remember how difficult it was to manage my schedule just to buy a train ticket.
Today, the campus is unrecognizable. Every square inch is being utilized. While the buildings are well-maintained and the facilities have increased significantly, the “openness” of the old campus is gone. It used to have a wonderful, harmonious look. Now, there is so much construction—apartment buildings everywhere. It’s a sign of progress, but the character has shifted.

Preserving the “Bondage” of Alumni

Interviewer: There is talk about rebuilding or replacing older structures like Hall 1 and Hall 2. As a former warden of Hall 1 (1973–1976), how do you feel about this?

Prof. Ghosh: I would be very sorry to see them go. Hall 1 was the first hostel on this campus when we moved from HBTI in 1964. For senior alumni, these halls are not just buildings; they represent a “bondage” or a deep emotional connection.
The first thing an alumnus does when they return is visit their old room. If you destroy the hall, you destroy that link to the past. I believe the institute should think very carefully before constructing high-rises in their place. Even if the structures need work, they should consider rebuilding the same design or doing extensive restoration—much like how the US Embassy maintains its classic look—rather than losing the heritage entirely.

Prof. Amitabha Ghosh

Professor Amitabha Ghosh is one of India’s most eminent mechanical engineers and an academician whose career spans over six decades. A former Director of IIT Kharagpur and a long-standing faculty member at IIT Kanpur and a Senior Scientist for INSA, his influence on Indian engineering education and research is profound.

Research Contributions: His work primarily focuses on Manufacturing Science, Robotics, and Kinematics. He is widely credited with introducing "Manufacturing Science" as a formal academic discipline in India.

Literary & Scientific Impact: He has authored several seminal textbooks used by engineering students worldwide, including Theory of Mechanisms and Machines and Manufacturing Science.

Vision for Space: Beyond traditional mechanics, Prof. Ghosh has a deep interest in celestial mechanics and the fundamental laws of the universe, having published works on Inertial Induction and its implications for cosmology.

Legacy: Known for his sharp wit and dedication to students, he remains a vocal advocate for preserving the heritage of India’s premier institutes while pushing for aggressive modernization in space and satellite technology.

GALLERY

THE CAPTURED COSMOS

These are Orion Nebula and Pleiades star cluster, photographed using the SPASE, IIT Kanpur's 11-inch telescope installed at ARIES, Nainital and provided by Sujoy Nayak and Shahebaj Hasan Shaikh.

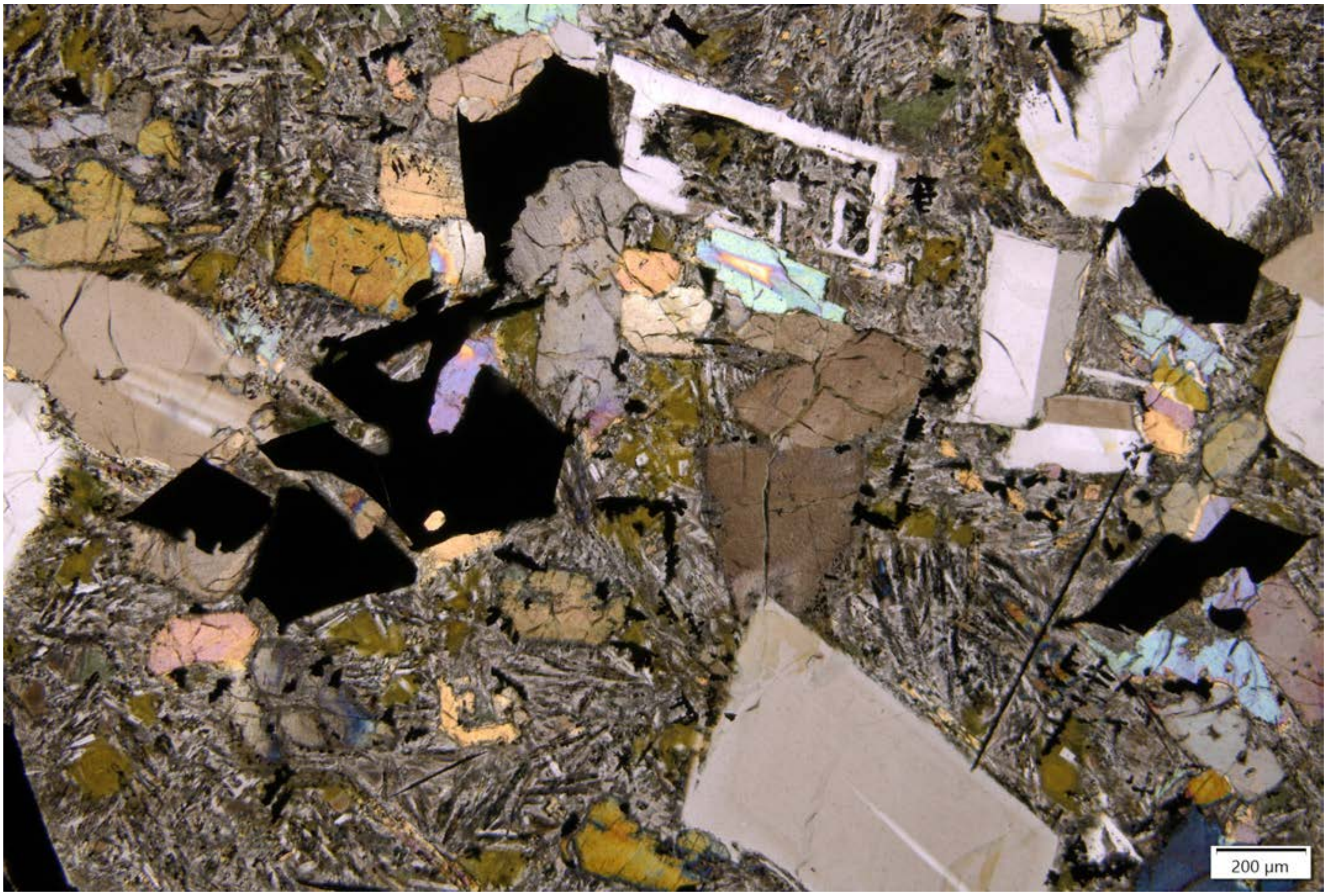
Shahebaj H. Sheikh, Research Scholar, SPASE, IITK

In Orion's sword, the darkness breaks,
Where stars are born from glowing dust.
A cradle carved in silent light,
Teaching the night how to trust.

Young stars glow in borrowed blue,
Dust remembering how to shine.
A cluster learning gravity,
Before it learns the meaning of time.

Sujoy Nayak, Research Scholar,
SPASE, IITK

BASALT A Microscopic Landscape of Habitability



Beneath its vivid interference colours, this basalt thin section reveals more than a volcanic history. It represents a microenvironment central to astrobiology. Interlocking crystals of minerals form during rapid cooling, while vesicles and microfractures create porous niches that can host fluids, nutrients, and potentially microbial life. On Earth, such basaltic habitats sustain diverse subsurface microbial communities. On Mars, similar mineral assemblages and textures are widespread, making basalt a key target in the search for past or present life.

Sample: Crossed polarized light microscopic image of a thin section of basalt (origin: Deccan, India).

- Image and Caption credit: Vinay Nayak

Junior Research Fellow

SPASE,IITK

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HUMOR

THE INVISIBLE ARCHITECT & THE LOUD TENANT

Characters :

Dark Matter (DM) – Mysterious & calm but egoistic

Baryonic Matter (BM) – Expressive & dramatic

BM : Hey! Look how beautiful the universe is today. You can thank me for that. 😎

DM : You tell stories through light. I make sure those stories don't scatter into intergalactic fan fiction. 😏

BM : Oh please, without me there would be no stars, no planets, no life, no PhD scholar stressing about structure formation.😂

DM : Without me you don't even know where to ignite 😂. You are basically furniture. I built the house 😎.

BM : Excuse me ? 😒 I set myself on fire and light up the galaxies. That sounds easy work to you? 😑

DM : Work, huh?🤔 Remember your toxic relationship with photon. You couldn't even collapse properly.

BM : Yeah that was a tough period. 😢 But at least I interact, you don't talk to anyone. You have no friends except me.

DM : I prefer the term gravitationally selective. While you were busy flirting with photons, I was preparing the backbone of the universe, literally setting the stage for you to shine.

BM : So you are saying you are the CEO of structure formation?

DM : Exactly! You're just the PR department. 😉

BM : Fine. You made halos. Big deal.

DM : Big deal? After your break up with photon, you literally fell into my halos like a confused tourist. 😆

BM : I needed time to collapse properly!

DM : Yeah , yeah. After 380,000 years of cosmic procrastination.

BM : Still I am the reason there is life in the universe.

DM : And yet you only make up about 5% of the cosmic budget. I am roughly 26 %. Numbers matter.

BM : You are just salty because nobody has directly detected you.

DM : Yeah, that hurts. 💔

BM : So tell me honestly… Do you ever wish to interact with light and be seen?

DM : Sometimes. But if I did, structure formation would have been different. Collisional damping, radiation coupling…chaos. 🙂

BM : So your invisibility is necessary?

DM : Every great architect remains behind the walls.

BM : You are an unsung hero 🧬 & you know maybe we are partners then.

DM : Agreed. You bring stars, planets and poetry. I hold them together silently.

BM : So technically… We co-authored the universe?

DM : Yes. But you keep taking credits.

BM : Well..glowing helps.

DM : Fair enough.

BM : Friends?

DM : Gravitationally… Always.🤝

Wasim Mondal, Research Scholar, Dept. of SPASE, IITK

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ARTICLE

MILKY WAY DYNAMICS: DARK MATTER, BARS & THE EARLY UNIVERSE WITH JWST

For generations, the “white patch” stretching across the night sky has fascinated observers. With the advent of telescopic astronomy, we identified this feature as the Milky Way—a collection of billions of stars, including our Sun, rotating within a flattened disk. However, the kinematics of these stars reveal a fundamental puzzle. As observed in the pioneering work of Vera Rubin on the Andromeda Galaxy (M31) in the 1970s, the rotation speeds of stars in galactic disks do not drop off with distance as expected from visible matter alone. The gravitational force generated by baryonic matter (stars and gas) is insufficient to account for the observed rotation curves.

Sandeep Kumar Kataria,
DST Inspire Faculty,
Dept. of SPASE, IITK

This discrepancy provides primary evidence for Dark Matter. Under the standard Lambda Cold Dark Matter (ΛCDM) theory of galaxy formation, a massive, invisible halo of dark matter envelops the galaxy, providing the missing gravitational potential required to explain stellar velocities. While ΛCDM successfully explains large-scale structure, challenges persist at smaller, galactic scales that demand deeper investigation and refined models.

State-of-the-art surveys like LAMOST and Gaia are currently mapping the substructures of the Milky Way, providing an empirical testbed to understand the distribution of this invisible matter. Furthermore, the James Webb Space Telescope (JWST) has begun imaging massive galaxies in the early universe, challenging our timelines of galaxy formation within the ΛCDM regime. These observations reveal that galaxy formation may have occurred more rapidly and efficiently than standard models predict, raising important questions about the processes driving early galactic assembly.

The Milky Way is classified as a barred spiral galaxy, distinguished by its non-axisymmetric structures—specifically a central bar and spiral arms. Unlike a smooth,

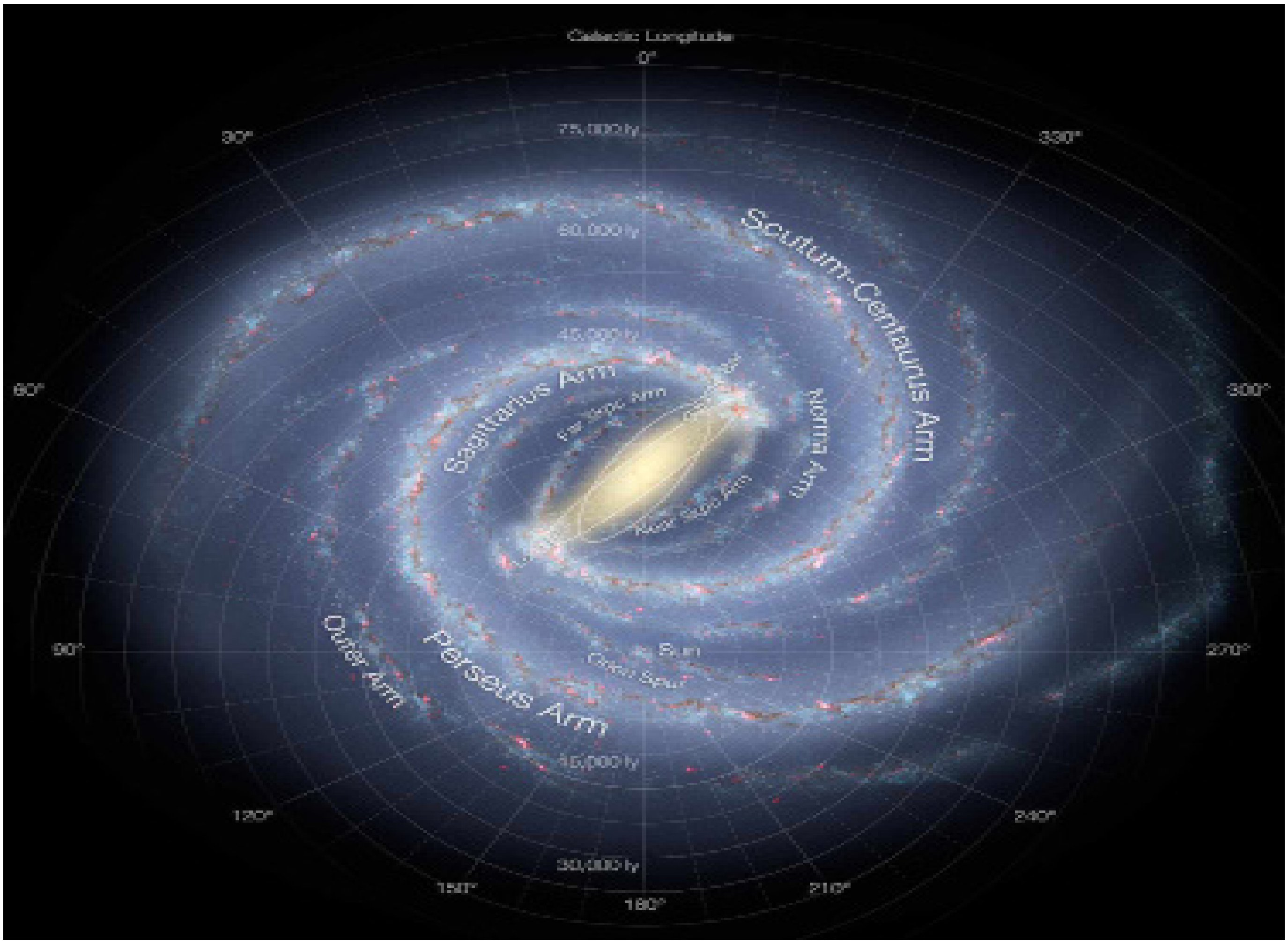
Webb's image of NGC 1512 shows a face-on barred spiral galaxy anchored by its central region (Credits: NASA, ESA, CSA, STScI, J. Lee (STScI), T.Williams (Oxford), PHANGS Team).

featureless disk, these features arise from disk instabilities that result in deviations from perfect circular motion due to the redistribution of angular momentum among stars and gas. Bars are remarkably common in large cosmic structures, present in approximately two-thirds of nearby disk galaxies, including our neighboring sister galaxy Andromeda. However, a historical puzzle has concerned the fraction of barred galaxies at high redshift. Recent high-resolution imaging from JWST reveals bars in galaxies at redshifts greater than $z > 2$, marking the first time we have observed bars in the early universe. This discovery forces us to re-examine the origins of these instabilities, as bars appear to form much earlier in cosmic history than previously believed, fundamentally challenging our understanding of galactic evolution.

In an idealized axisymmetric disk, stars rotate in circular orbits under the influence of a symmetric gravitational potential. However, the introduction of non-axisymmetric modes—perturbations that break the symmetry—disrupts this orderly equilibrium. When such perturbations grow, they result in a transfer of angular momentum: inner stars generally lose angular momentum to outer disk as well surrounding dark matter halo and move outwards (or into elongated orbits), reinforcing the bar structure. This process is highly non-linear and complex, making analytical predictions difficult. The pioneering work by Ostriker and Peebles in 1973 established a critical stability criterion, suggesting that a massive Dark Matter Halo is essential to stabilize a cold stellar disk against the rapid formation of bar instabilities. Their central thesis was that a strong central potential increases stellar velocity dispersion—the random, non-circular motion of stars—which inhibits non-axisymmetric modes from growing unbounded. This theoretical framework helps explain why approximately one-third of local disk galaxies remain unbarred, suggesting that halo properties play a decisive role in determining galactic morphology. The Ostriker-Peebles study utilized both analytical calculations and N-body simulations with only hundreds of particles, representing cutting-edge computational capability at that time. Today, state-of-the-art simulations incorporate billions of particles, capturing high-fidelity dynamics far beyond what was previously possible.

A critical limitation of the Ostriker and Peebles framework was the assumption of a static or rigid dark matter halo. The halo itself possesses angular momentum, or spin, and the exchange of momentum between the disk and the rotating halo can be significant and consequential. With the growth of High-Performance Computing and the development of efficient algorithms, we can now simulate "live" halos that rotate in realistic ways. Our high-resolution N-body simulations of Milky Way-like systems reveal crucial insights into this interaction. First, increasing the internal angular momentum (spin) of the dark matter halo significantly accelerates the timescale of bar formation within the disk. This demonstrates that halo properties are not passive but actively drive galactic evolution. Second, as bars reach peak strength during their temporal evolution, they often undergo a vertical instability known as the buckling mode. This instability causes the bar to bend out of the galactic plane, ultimately resulting in the formation of Box, Peanut, or X-shaped structures in the galactic center—features that are more pronounced in galaxies residing in high-spin halos. Third, our linear perturbation theory, test particle simulations, and high-resolution N-body simulations reveal that galactic bars experience reduced dynamical friction in these rotating halo scenarios, contrary to earlier predictions made by Martin D. Weinberg in 1985. Weinberg's calculations were founded on the classical Chandrasekhar dynamical friction formula, which assumes a uniform, static background. Our work demonstrates that Weinberg's approach missed the critical role of the specific distribution function of dark matter halo particles in modulating the friction experienced by the bar. In acknowledgment of these findings, Weinberg himself has recognized the precision and validity of these new high-resolution results, illustrating the collaborative and self-correcting nature of modern astrophysics.

Motivated by these discoveries regarding the impact of dark matter halo spin on non-axisymmetric structure formation in the Milky Way, we systematically explored how halo spin influences disk dynamics across a broad range of parameters. We



This detailed annotated artist's impression shows the structure of the Milky Way, including the location of the spiral arms and other components such as the bulge. This version of the image has been updated to include the most recent mapping of the shape of the central bulge deduced from survey data from ESO's VISTA telescope at the Paranal Observatory. Credit: NASA / JPL-Caltech / ESO / R. Hurt examined disks spanning from dwarf galaxies to massive systems and varied the kinematic nature of the disk—that is, the velocity dispersion—from cold systems with minimal random motion to hot systems with substantial velocity randomness. These extensive N-body experiments yielded a surprising and counterintuitive result: across all disk masses, hotter disks form bars significantly earlier than colder disks when both interact with a spinning halo. The physical mechanism behind this observation relates to a more efficient exchange of angular momentum from the disk to the surrounding dark matter halo in hot and thick disk configurations in the early universe. This finding reshapes our understanding of galactic bar formation and suggests that the thermal state of a disk is as important as its halo environment in determining its morphological evolution.

The detection of bars at high redshifts by JWST and ALMA observations challenges the standard assembly history of galaxies in the ΛCDM paradigm. If bars form readily and early, it suggests that gravitational instabilities and non-linear dynamical processes operate more efficiently than current models predict. To resolve this tension between observations and theory, future research must pivot toward sophisticated Cosmological Zoom-in Simulations. These simulations embed Milky Way-type galaxies within their full cosmological context, allowing us to track their assembly from the early universe to the present day. A key advantage of this approach is the ability to test the role of baryonic physics—sub-grid processes including star formation rates, stellar feedback mechanisms, and Supermassive Black Hole (AGN) feedback—on disk stability and bar formation. These sub-grid physics models are essential because they govern how energy is distributed throughout the galaxy and can fundamentally alter the disk's susceptibility to instabilities. Cosmological zoom-in simulations of one highly resolved Milky Way galaxy offer an economical and computationally efficient pathway to bridge the gap between large-scale cosmic structure and the intricate internal dynamics of individual galaxies, providing a unified framework for understanding galactic evolution from first principles.

References:

1. Kataria, S. K. & Shen, J. Effects of Inner Halo Angular Momentum on the Peanut/X Shapes of Bars. Astrophys. J. 940, 175 (2022).
2. Chiba, R. & Kataria, S. K. Origin of reduced dynamical friction by dark matter haloes with net prograde rotation. Mon. Not. R. Astron. Soc. 528, 4115–4124 (2024).
3. Kataria, S. K. & Shen, J. Importance of Initial Condition on Bar Secular Evolution: Role of Halo Angular Momentum Distribution Discontinuity. Astrophys. J. 970, 45 (2024).
4. Chen, B.-H., Kataria, S. K., Shen, J. & Guo, M. Dependency of the Bar Formation Timescale on the Halo Spin. Astrophys. J. 994, 124 (2025).

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ARTICLE

LUNAR WATER-ICE DETECTION USING SPECTRAL ANALYSIS

The Moon has an axial tilt of 1.54°. It is an angle between the equatorial plane and the ecliptic plane, or simply the ecliptic (the orbital plane around the Earth) of the Moon. Due to this slight tilt, the topographic deformations in the Lunar Polar Regions are permanently shadowed by the Sun's rays. These regions are commonly referred to as Permanently Shadowed Regions (PSRs).

The absence of sunlight causes an extreme temperature drop (lower than 110 K) and thus, these regions act as 'cold traps' (Li et al., 2018). These cold traps accumulate volatile molecules and preserve them over a geologic time scale. This accumulation mainly occurs at the PSRs on airless planetary bodies. However, on surfaces that attain temperatures higher than 100 K, water ice cannot be preserved due to the process of sublimation (Fisher et al., 2017).

Poorva Singh, Research Scholar, Dept. of SPASE, IITK

However, it is found that when the Moon is hypothesized to be on its paleo-axis (previous maximum principal axis of inertia/spin axis before true polar wander), the ice stability depth at some cold trap regions is greater than zero. It was hypothesized by researchers that the Moon rotated to its current axis from the paleo-axis about 2 – 3 Ga (Gya / billion) years ago (Siegler et al., 2016). The low rate of water supply on the surface of the Moon and a fast rate of Impact Gardening for many years is responsible for the low abundance and patchy distribution of Surface Exposed Water Ice in newly formed cold traps (Schorghofer et al., 2017).

The long-term process of impact events on the surface of the Moon that stir the outer crust, called Impact Gardening, and the phenomenon of shifting poles known as True Polar Wander, might have some association with surface-exposed water ice. The surface-exposed ice has a strong 'spatial coherence' with temperatures less than 110 K in PSRs (cold traps) (Li et al., 2018). Water and ice from different celestial bodies, such as comets and meteorites, and solar wind-induced iron reduction are deposited in cold traps. Thermophysical Properties on the lunar surface (scattered sunlight, thermal re-radiation, and internal heat, light reflected from Earth's surface) control the thermal behavior of the lunar surface, which in turn preserves the ice in the cold traps (Wei et al., 2016).

It has been found that only ~3.5% of lunar cold traps exhibit ice. This makes Moon differ-

Image Credit: NASA-a setting earth

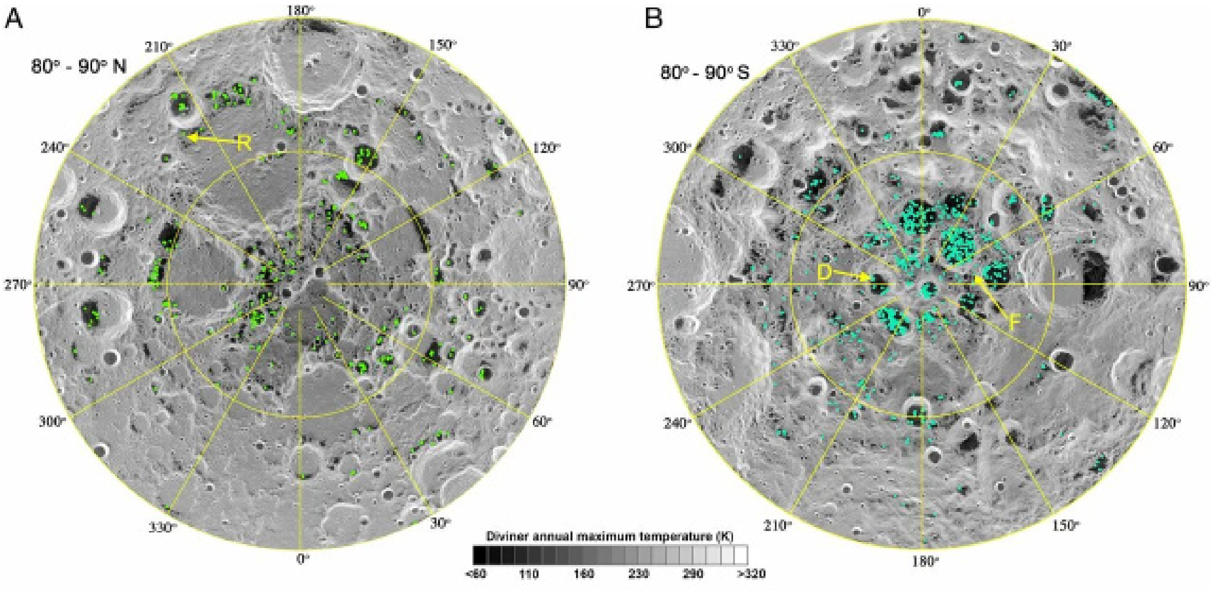


Fig. 1: Water-ice deposits on (a) the North Pole and (b) the South Pole of the Moon

Credit: S. Li, P.G. Lucey, R.E. Milliken, P.O. Hayne, E. Fisher, J. Williams, D.M. Hurley, & R.C. Elphic, Direct evidence of surface exposed water ice in the lunar polar regions, Proc. Natl. Acad. Sci. U.S.A. 115 (36) 8907-8912, https://doi.org/10.1073/pnas.1802345115 (2018).

ent from other bodies – Mercury and Ceres, where Surface ice is more common in cold traps. Also, the deposits in cold traps on the surface of Mercury and Ceres are almost pure water, that is, 100% water ice, whereas the lunar equivalent is about ~30 wt% (Neumann et al., 2012; Paige et al., 2013; Platz et al., 2017). This shows that the Moon is different from the bodies in the inner parts of the solar system that have similar polar cold traps. Studies of lunar poles have shown that the South Polar Region having more PSRs, has more Surface Exposed Ice than the North Polar Region. Figure 1 (Li et al., 2018) shows the ice deposits in the cold traps of the lunar North and South Polar Regions.

It is also found that surface-exposed ice is not affected by Earthshine; thus, ice at both lunar poles has no bias between the near-side and far-side. The detection of three absorption bands – 1300 nm, 1500 nm, and 2000 nm- shows the presence of water ice (H2O ice) (Li et al., 2018).

By analyzing Radiative Transfer Model results, it can be seen that ice-regolith mixtures with >30 wt% ice have four water-ice absorptions – 1100 nm, 1300 nm, 1500 nm, and 2000 nm, whereas ice-regolith mixtures with >5 wt% ice have three strong absorptions – 1300 nm, 1500 nm and 2000 nm (Hapke, 1981). Figure 2 shows a USGS laboratory-based spectrum of ice frost, which was generated at a 77 K temperature, where prominent dips in the spectral curve at the water absorption regions can be seen..

Scientists identify water ice by looking for specific "absorption bands" in light spectra. Water ice is typically confirmed by dips at 1100 nm, 1300 nm, 1500 nm, and 2000 nm. The intensity of an absorption dip in a spectrum is determined by calculating the band depth of the water absorption bands. The strength of an absorption feature is determined using the following calculation:

$$\text{Band Depth} = 1 - \frac{R}{R_c}$$

where:

- R: The reflectance value of the actual band spectra.
- Rc: The reflectance value of the continuum-removed spectra

Once the Band Depth is calculated, a filtering process is applied to isolate water ice from the surrounding lunar soil:

- Masking: Any pixels that do not show a positive Band Depth (values > 1) across all four primary absorption bands are excluded.
- Classification: Pixels that maintain these criteria are flagged as

potential ice-bearing pixels. • Verification: To confirm the presence of water, the reflectance spectra of these potential pixels are directly compared against the known laboratory spectra of

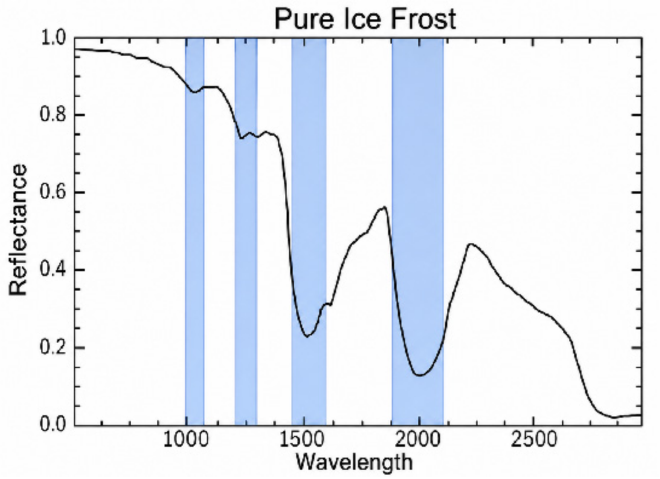


Fig.2: Pure Ice Frost Reflectance Spectra with Water Absorption Band.

Pure Ice Frost (typically generated at 77 K). This comparison helps distinguish true ice signatures from noise or other mineral variations.

Along with these water absorption bands, other SAR data parameters such as Circular Polarisation Ratio (CPR), Lunar Polar-Ice Detection Index (LDPI), and Dielectric constant, can also be incorporated for more accurate results.

References:

1. Fisher, E. A. et al. Evidence for surface water ice in the lunar polar regions using reflectance measurements from the Lunar Orbiter Laser Altimeter and temperature measurements from the Diviner Lunar Radiometer Experiment. Icarus 292, 74–85 (2017).
2. Hapke, B. Bidirectional reflectance spectroscopy: 1. Theory. J. Geophys. Res. Solid Earth 86, 3039–3054 (1981).
3. Li, S. et al. Direct evidence of surface exposed water ice in the lunar polar regions. Proceedings of the National Academy of Sciences 115, 8907–8912 (2018).
4. Neumann, G. A. et al. Bright and dark polar deposits on Mercury: evidence for surface volatiles. Science 339, 296–300 (2013).
5. Paige, D. A. et al. Thermal stability of volatiles in the north polar region of mercury. Science (1979). 339, 300–303 (2013).
6. Platz, T. et al. Surface water-ice deposits in the northern shadowed regions of Ceres. Nature Astronomy 2016 1:1 1, 0007- (2016).
7. Schorghofer, N. et al. The Putative Cerean Exosphere. Astrophys. J. 850, 85 (2017).
8. Siegler, M. A. et al. Lunar true polar wander inferred from polar hydrogen. Nature 531, 480–484 (2016).
9. Wei, G., Li, X. & Wang, S. Thermal behavior of regolith at cold traps on the moon's south pole: Revealed by Chang'E-2 microwave radiometer data. Planet. Space Sci. 122, 101–109 (2016).

6

POEM

ECHOES OF THE VOID

Crab Nebula, Credit: NASA, ESA and Allison Loll/Jeff Hester (Arizona State University). Acknowledgement: Davide De Martin (ESA/Hubble)

THE LAST DANCE BEFORE FOREVER

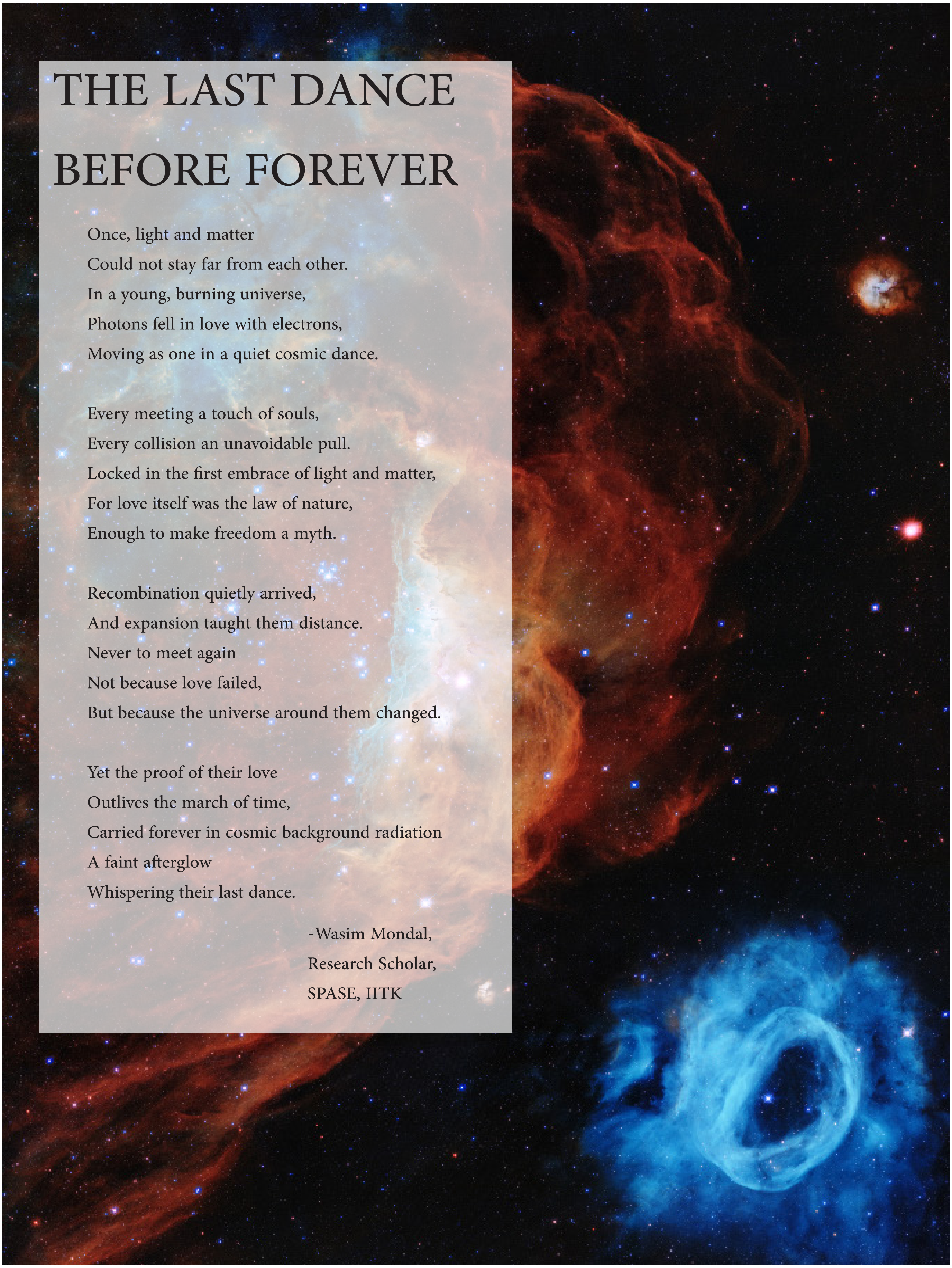
Once, light and matter
Could not stay far from each other.
In a young, burning universe,
Photons fell in love with electrons,
Moving as one in a quiet cosmic dance.

Every meeting a touch of souls,
Every collision an unavoidable pull.
Locked in the first embrace of light and matter,
For love itself was the law of nature,
Enough to make freedom a myth.

Recombination quietly arrived,
And expansion taught them distance.
Never to meet again
Not because love failed,
But because the universe around them changed.

Yet the proof of their love
Outlives the march of time,
Carried forever in cosmic background radiation
A faint afterglow
Whispering their last dance.

-Wasim Mondal,
Research Scholar,
SPASE, IITK



The giant nebula NGC 2014 and its neighbour NGC 2020, Credit: NASA, ESA, and STScI


Photo: Sujoy & Shahebaj

CELESTIAL DOTS

Look up at the sky at night,
You would see stars,
Glimmering bright.

Questions flood my mind,
If what I see,
Really is near or far in time,
Though in my mind,
It's hard to connect the line.

That these dots in the sky,
Shining bright ; with beauty and delight,
Are which celestial entity,
Floating in the empty,
Bound by gravity.

They stare at me,
I stare back for hours,
I say to myself softly,
"Isn't it so pretty!"
And I didn't even realise,
How time passes by so quickly.

Don't think I will ever,
Neither would you,
Find the words to capture,
The essence of space's eternal hue,
Nor would anyone,
Ever perceive it true.

-Naina Aditi
Class: IX,
Kendriya Vidyalaya,
IIT Kanpur

TRIBULATIONS OF THE SANE

A woodcut from 1598 shows an exorcism performed on a woman by a priest and his assistant, with a demon emerging from her mouth, Source: Pierre Boaistuau, et al., Histoires prodigieuses et memorables, extraictes de plusieurs fameux autheurs, Grecs, & Latins, sacrez & prophanes (Paris, 1598), vol. 1.

In 1615, a few days before Christmas, a letter arrived.
Mother is on trial! says Margaretha. For witchcraft!
The words of his sister shook Kepler deeply,
as he blamed himself.

Katharina Kepler, a widowed mother,
had always been outspoken,
abrasive, and quarrelsome,
enough reasoning, for those times, to call her a witch.

Defying the laws of planetary motion,
Kepler was in an impossible position.
The trials were peaking in German territories.
If convicted, torture and execution were inevitable.

Despite having no formal training,
Kepler defended his mother, studying the rules governing torture.
He knew when the torture began,
execution was the only path.

His fear put him in isolation;
the furious self toward superstition
led him to write detailed defenses
and fight for five years.

He lost his income,
had multiple children die in infancy,
navigated the self in chaos,
Yet his drive was never lost in his conscious being.

Fighting with his mathematical brain,
Katharina Kepler was released,
becoming one of the few women
to survive a formal witch trial.

The cost of winning is never an easy ordeal.
This case consumed years of Kepler's scientific work.
It deepened his anger toward authority,
but strengthened his belief in reason.

Parallel to the trial years,
Kepler published Harmonices Mundi
(the Third Law of Planetary Motion).
He refined orbital theory,
but his tone was different.

Earlier, he was mythical and optimistic,
immersed in divine geometry.
Post-trial, the shift fell into defensiveness,
hostile to ignorance.

Nurturing human nature, the eccentric kind,
In a mad world, he chose truth and stood behind it:
the truth buried beneath the light,
the light that only a few could find.

-Anirudh Singh,
M. Tech,
SPASE, IITK

अनंत का आह्वान

तारों भरी इस गहरी रात में,
लिखे हैं राज़ ब्रह्मांड के हर बात में।
हर चमक कहती — "तुम हो नन्हे",
फिर भी तुम्हीं में सपने गढ़े।

सूरज जलता अपनी ज्वाला में,
जीवन सँजोता हर उजाला में।
ग्रहों की चाल सिखाती यही,
समय बहता है, ठहरता नहीं।

चाँद की चाँदनी दिल को सहलाए,
अंधियारे में भी आशा जगाए।
ध्रुव तारा बोले — मत हो निराश,
हर अँधेरे में छुपा है प्रकाश।

आकाशगंगा के अनंत बहाव में,
इंसान खोजे खुद को प्रभाव में।
धूल का कण है तन, ये मानो,
पर सोच में ब्रह्मांड समा लो।

ब्लैक होल की चुप्पी, भयावह पुकार,सिखाती है जीवन
का गूढ़ सत्कार।पल्सर की धड़कन, क्वासर का गान,
बुनते हैं रहस्यों का अद्भुत विधान।

हे ब्रह्मांड! तू विशाल, असीम,
तेरे आगे सब कुछ है क्षीण।
फिर भी तेरी ही गोद में मानव,
ढूँढ रहा अपना अस्तित्व अमर।
ज्ञान तेरा दीपक, विज्ञान तेरा नाम,तेरी ही भाषा में लिखी
सृष्टि का ग्रंथ महान।हम सब हैं यात्री, क्षणभंगुर, अपार,-
पर तू ही है अंतिम सत्य, अंतिम सार।

-Nikhil Maheswari
Student Research Associate
SPASE, IIT Kanpur

Hubble views N44 Superbubble, Image Credit: NASA, ESA

SPAGER

The name “SPAGER“ is inspired by the idea of welcoming everyone with the phrase “Welcome aboard, SPASE passengers”. It combines SPA from our department’s name SPASE (Space, Planetary & Astronomical Sciences & Engineering) with GER from “passenGERs“ symbolizing the community embarking together on this journey of discovery. The name also resonates with “pager”, a classic communication device, reflecting the magazine’s role in connecting people and sharing knowledge. It captures both the spirit of exploration and essence of communication.

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Magazine name & background image credit: Ankan Majumdar