#1 | Nov' 24

inScight

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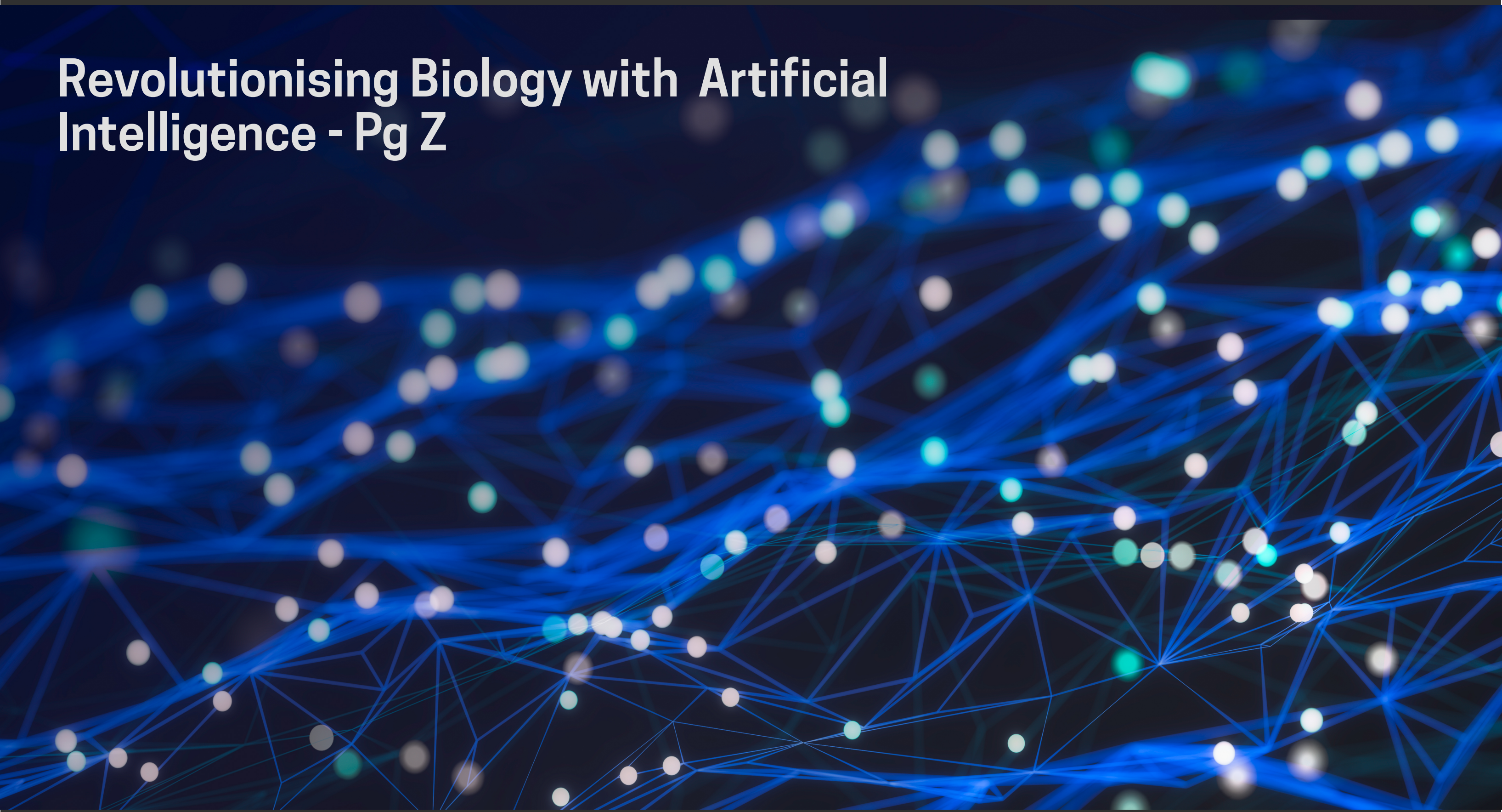

Revolutionising Biology with Artificial Intelligence - Pg Z

InScight is an e-magazine run by volunteers and hosted by IISER Kolkata, aiming to bring science to the masses. scicomm.iiserkol.ac.in

Editorial

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Swarnendu Saha,
Chief Editor, InScight

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Kolkata Connection with 2020 Physics Nobel Prize: The Role of A K Raychaudhuri

Alekhya Kundu (IISER Kolkata)

The 2020 Nobel Prize in Physics honored groundbreaking work on black holes, but a lesser-known contributor to this discovery was Kolkata-born physicist A K Raychaudhuri. His 1955 paper laid the foundation for the famous Penrose-Hawking Singularity Theorems, reshaping our understanding of spacetime singularities. Raychaudhuri's equation demonstrated that singularities were a natural outcome of Einstein's gravity, a pivotal insight that influenced the Nobel-winning research. Despite his profound contributions, Raychaudhuri remains relatively unknown in India. His story connects Kolkata to one of the most significant scientific achievements of our time.

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In Conversation with ISRO Scientist Shyama Narendranath

Swarnendu Saha, Suman Halder (IISER Kolkata)

"Often, our work is viewed as something exotic, while in reality, science is fundamental to our daily lives", Shyamna Narendranath remarks on the research scene in India. Swarnendu and Suman sat down with her to discuss her life, her work, the reality of space research in India and the state of academia within the country.

SS. Good afternoon, ma'am. So, to start off, can you tell us about your background? Starting from when you were a student, how did you eventually reach the place you're in now after all these years?

SN. I can't say that I started out thinking I wanted to be a scientist. I come from Palakkad, a small town in Kerala. Back then, things were very different. The mobile phone, for instance, came into my life during my MSc. So, your generation can't even imagine a time without the internet or such technology. Exposure to the outside world was quite low.

Academically, I was a good student, but I was really interested in dance. I trained in classical dance, and most of my school days were focused on dancing. In Kerala, school youth festivals are taken very seriously, and every school participates. So, I was always involved in that.

SS. Oh, have you been trained in Kathakali, or was it another form of classical dance?

SN. Actually, I started with Bharatanatyam, and have been training in Odissi for the past 15 years. I'm still passionate about dance, and I continue to perform. So, initially, I wanted to be a dancer. I even had a short story published when I was in the 6th grade. At that time, I thought maybe I'd become a writer. But becoming a scientist was never something I considered when I was young. Probably, my interest in science began during my post-graduation. I had excellent teachers who really made the subject interesting. For young children, it's so important to have good teachers. If you love the subject, it's often because you had an amazing teacher.

I always had good English teachers, so I loved English, even though I was pursuing a degree in Physics. In fact, during my undergraduate years, I looked forward to my English classes more than my Physics ones. But things changed during my MSc when I had some excellent professors in Physics. They made me understand what I was doing. That's when I had a turning point.

SH. So, did you realize that you wanted to pursue research during your MSc?

SN. Yes, it was during a small summer project that I first thought research might be an option. I had the opportunity to visit Bangalore and stay there alone for the first time. I met many PhD scholars, and that's when I realized research could be something I'd like to pursue. Before that, I never considered it seriously.

SH. And did you think about teaching as a career?

SN. Yes, like many girls of my time, the plan was to finish MSc, do a B.Ed., and then teach. That's the path I was following. Teaching was seen as a suitable career for women. In my MSc Physics class, there were actually more girls than boys. But when I did my short summer project, I realized there was more I could do, and I became really interested in research.

SS. But at that time, societal expectations must have been a challenge, especially for women pursuing PhDs.

SN. Absolutely. There was definitely pressure. I got married soon after my MSc and moved to Bangalore. Fortunately, I continued my studies. I taught as a guest lecturer at a college for six months, even though I didn't have a B.Ed. at the time. Then, I joined as a Junior Research Fellow (JRF). But within a few months, I was pregnant, so I had to take a break. After my daughter was born, I resumed when she was three and half months old.

SS. Wow, that must have been quite a challenge - balancing motherhood and studies.

SN. Yes, it was. I did my coursework for the PhD while working as a JRF in the Astronomy Program at the Indian Institute of Science (IISc), and I was able to complete it with the support of my family, especially my mother. I also had an excellent PhD supervisor, which is very important for a successful PhD journey.

SH. You mentioned working with international space agencies. Can you tell us about that?

SN. Yes, I was fortunate to be part of India's first lunar mission, Chandrayaan-1. I worked on an instrument that was developed in collaboration with the European Space Agency. It was built at the Rutherford Appleton Laboratory in the UK, so I got the opportunity to go and work. It was a difficult period because I had to leave my daughter behind, but with the support of my family, I managed. It was a new experience, and it gave me significant exposure. Working on Chandrayaan-1 was a turning point in my career. That project really helped shape my future work in space missions.

SH. You've spent a lot of time as a student and as a scientist at major space agencies like NASA, the European Space Agency, and JAXA. How do their approaches compare to ours? Especially with the perception that ISRO achieves a lot with significantly less funding.

SN. There's no debate—NASA is far ahead in terms of technology. They landed the first humans on the moon in 1969, and we haven't sent humans to space yet. Their technological advancement is evident. However, in India, we are conditioned to work with limited resources. It's not just in space research—across sectors, there's always a resource crunch. Our approach is more about optimizing what we have. In many cases, we spend more time on things and make up for the lack of resources with extra effort. In NASA, industries take on parts of the technology development. Here, we still rely heavily on academic institutions and agencies like ISRO to develop technology in-house. But India is in a phase of transition. Over the next 10-20 years, I believe we'll see more involvement of private industries in space missions.

SS. There's a lot of pride in India about the Mars mission, Mangalyaan. It was achieved on a limited budget, but how does it compare to missions from NASA?

SN. Yes, Mangalyaan was a great achievement in terms of engineering. However, from a scientific perspective, it's not on the same scale as NASA's Maven mission to Mars. The amount of science that came out of Maven is much greater. The Indian mission was more about demonstrating that we could navigate a spacecraft to Mars and make it work within our constraints.

SH. Could you talk a bit about Chandrayaan-3 and how that mission was planned?

SN. I think Chandrayaan-3 was very critical for ISRO and India's planetary program. After Chandrayaan-2's near-success, we needed Chandrayaan-3 to work to ensure the continuation of our planetary missions. The success of Chandrayaan-3 proved that we could achieve a soft landing on the moon, and now we are well-positioned to plan future lunar missions.

SH. When it comes to research funding in India, especially in space research, how do you feel about the current budget allocations?

SN. Without adequate funding, research progress is slow. In order to innovate, we need new funding. There is a push from the government to involve academic institutions more, which is a positive development. We need to focus on core research, while industries can undertake more of the technology development. This transition will take time, but it's necessary for the future.

SS. What about the Chandrayaan-3 mission's scientific studies? What have we learned from it?

SN. The mission included several instruments, bothon the lander and the rover. The rover analyzed the composition of the surface, and it seemed to be a fairly (cont.) homogeneous area. The lander carried a Langmuir probe to measure the electron density in the moon's exosphere, and a seismometer to measure moonquakes, though the data we collected over 10.5 days did not record any significant seismic activity. The mission was a great success overall, contributing valuable data for future lunar exploration.

SS. And the Aditya L1 mission? How is that going?

SN. Aditya L1 launched in September, and it's doing well so far. The spacecraft is in a halo orbit around the Lagrange point L1. The payloads are still being calibrated, but the mission is on track, and we expect some significant scientific findings from it soon.

SS. When you look back at your journey, from a student to a scientist, and the progress of ISRO, how do you feel about the way society views scientists in India?

SN. I think there is still a gap, but missions like the Chandrayaan and Mangalyaan are making people more aware of ISRO and the work we do. That being said, I believe there's still a need for better science communication. People should know the time and effort it takes to make scientific progress. Often, our work is viewed as something exotic, while in reality, science—especially physics—is fundamental to our daily lives.

SH. Do you think the current system supports students interested in pursuing research careers?

SN. There are challenges. Many bright students are discouraged from pursuing research because of financial insecurity. The stipends are often not enough, and delays in funding can make life difficult for students. I've seen students struggle just to pay rent while pursuing their passion for research. This situation can dissuade many from continuing in science, and it's something that needs attention.

SH. Do you think the research ecosystem in India needs improvement, especially in terms of job opportunities?

SN. Yes, definitely. Many of our postdocs don't return to India because there aren't enough job opportunities here. We need to create more positions and ensure that talented researchers have a place to contribute. Other countries, like China, have programs where they send postdocs abroad with the requirement that they return and work for their space agencies. We could benefit from similarinitiatives in India.

SS. As we conclude, do you have any final thoughts or advice for the next generation of scientists?

SN. I would encourage students to be patient and

(cont.) persistent. Success in science doesn't come quickly. Itrequires time, effort, and the willingness to face failures along the way. But the satisfaction of contributing to knowledge and discovery is worth it. Focus on the long-term impact of your work, not just the number of papers you publish. At the end of the day, it's about making a meaningful contribution to the field.

Shyama Narendranath is a scientist at U R Rao Satellite Centre, ISRO. She is a part of Chandrayaan-2 and other Indian planetary programs. She has been awarded the Zubin Kembhavi award by the Astronomical Society of India.

Latest in Research

In this issue's *Latest in Research*, we showcase simplified overviews of recent research articles from the domain of physics., helped by both internal and external contributions. The next issue will focus on the earth sciences.

Earth has its own electric field weaker than a pencil battery

Reference: Collinson, G.A., Glocer, A., Pfaff, R. et al., Nature 632, 1021–1025 (2024)

Contributed by: Chitradeep Saha (CESSI, IISER Kolkata)

Our planet Earth also has a global electric field – as fundamental as its gravity and magnetic fields. Researchers have successfully measured this electric field for the first time. The quest started over half a century ago when a steady stream of outgoing plasma particles was detected near the Earth's poles. Theories have been proposed and refined over time to understand this peculiar phenomenon. Peculiar. Because the temperature of the outflowing plasma is too cold to evaporate due to solar radiation. Therefore, existing knowledge of global energy fields failed to explain it. Alternatively, the existence of an independent, electric field was hypothesized. However, more mature technology was required to make precise measurements and test the hypothesis. The research team flew a suborbital rocket through the arctic skies that touched the exosphere while sampling various ionospheric properties. The photoelectron spectrometer onboard detected a minute change in electric potential of 0.55 volts – less than that of a standard AA battery – across an altitude range of ~500 km, confirming the existence of such a global electric field. Due to an asymmetric gravitational pull on the lighter electrons and heavier ion cores, charge separation occurs in the atmosphere. The Coulombic force partially counteracts this charge separation; the associated electric field is ambipolar, as it works in both directions. The net effect of this global ambipolar field is to puff up the atmosphere, lifting some ions high enough to escape through the polar caps and giving rise to polar winds.

Exploring Fractional Chern Insulator States in Multilayer Graphene Moiré Superlattices

Reference: Zhongqing Guo, Xin Lu, Bo Xie, and Jianpeng Liu, Phys. Rev. B 110, 075109 (2024)

Contributed by: Abhirup Mukherjee (IISER Kolkata)

Fractional Chern insulators are analogs to fractional quantum Hall states but arise in lattice systems without external magnetic fields. They require the presence of isolated flat bands with nonzero Chern numbers and appropriate quantum geometrical properties, which are possible in graphene-based moiré superlattices. Recent experimental observations of fractional quantum anomalous Hall effects in transition metal dichalcogenides (TMDs) and graphene superlattices have motivated interest in the exploration of FCI states in moiré superlattices. The authors aim to provide a theoretical understanding of these states through a systematic analysis of their properties. By using the RG approach, the authors develop a low-energy model that captures the interactions between electrons and their environment. Using the Hartree-Fock approximation, the authors identify two competing ground states at integer filling factors: one with a Chern number of 1, indicating topological order, and another with a trivial Chern number of 0. They then explore fractional filling factors through exact diagonalisation and observe the emergence of FCI states in various configurations. These FCI states appear at different fractional filling factors, depending on the specific setup and displacement field applied. The study highlights that FCI states are more robust in pentalayer and hexalayer systems, where topologically nontrivial flat bands are more isolated, thus favoring the emergence of FCIs at fractional fillings. This work advances the understanding of FCIs in multilayer graphene moiré superlattices, demonstrating that these states can arise under experimentally relevant conditions.

Earth has its own electric field weaker than a pencil battery

Reference: Collinson, G.A., Glocer, A., Pfaff, R. et al., Nature 632, 1021–1025 (2024)

Contributed by: Chitradeep Saha (CESSI, IISER Kolkata)

Our planet Earth also has a global electric field – as fundamental as its gravity and magnetic fields. Researchers have successfully measured this electric field for the first time. The quest started over half a century ago when a steady stream of outgoing plasma particles was detected near the Earth's poles. Theories have been proposed and refined over time to understand this peculiar phenomenon. Peculiar. Because the temperature of the outflowing plasma is too cold to evaporate due to solar radiation. Therefore, existing knowledge of global energy fields failed to explain it. Alternatively, the existence of an independent, electric field was hypothesized. However, more mature technology was required to make precise measurements and test the hypothesis. The research team flew a suborbital rocket through the arctic skies that touched the exosphere while sampling various ionospheric properties. The photoelectron spectrometer onboard detected a minute change in electric potential of 0.55 volts – less than that of a standard AA battery – across an altitude range of ~500 km, confirming the existence of such a global electric field. Due to an asymmetric gravitational pull on the lighter electrons and heavier ion cores, charge separation occurs in the atmosphere. The Coulombic force partially counteracts this charge separation; the associated electric field is ambipolar, as it works in both directions. The net effect of this global ambipolar field is to puff up the atmosphere, lifting some ions high enough to escape through the polar caps and giving rise to polar winds.

Exploring Fractional Chern Insulator States in Multilayer Graphene Moiré Superlattices

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General Science Quiz

This week's questions are brought to you by Alekhya (IISER Kolkata) and Archita (HHU, Düsseldorf).

Q1. This Nobel Prize-winning physicist has an element named after him. His wife, upon being shown the results of his experiment for the first time, said, 'I have seen my death!'. Who is the scientist?

(a) Wilhelm Roentgen
(b) Pierre Curie
(c) Henri Becquerel
(d) Enrico Fermi

Q2. Dr Dilip Mahalanabis, an Indian paediatrician, is famous for pioneering one of the most important medical advances of the 20th century that dramatically saved lives during the cholera outbreak in Bangladesh in 1971. What is this medical advancement?

(a) Vaxchora vaccine
(b) Oral rehydration solution (ORS)
(c) Zinc supplementation
(d) Ringer's lactate

Q3. This physician was one of the pioneers of plastic and dental surgery, and was one of the first to attribute malaria to mosquitoes. The Royal Australasian College of Surgeons at Melbourne has a statue in his honour. Who is he?

(a) Sushruta
(b) Hippocrates
(c) Herophilus
(d) Dioscorides

Q4. As part of the National Quantum Mission, this Indian research institute is leading the efforts to create a 100-qubit quantum computer, and recently completed end-to-end testing of a 6-qubit processor, in collaboration with DRDO and TCS. Name the research institute.

(a) Indian Institute of Science Education and Research Pune
(b) Indian Institute of Science (IISc), Bengaluru
(c) Tata Institute of Fundamental Research (TIFR), Mumbai
(d) Raman Research Institute (RRI), Bengaluru

Q5. Diamond is traditionally known to reside at the top of Mohs' scale of mineral hardness since it can scratch all other minerals on the scale. However, scientists in modern years have discovered other materials that are in fact harder than diamond, and would go above diamond in a modern Mohs' scale. Name such a naturally-occuring mineral.

(a) Lonsdaleite
(b) Boron carbide
(c) Moissanite
(d) Cubic boron nitride

Q6. In Nomine Terra Calens is a music piece composed by Dr Lucy Jones by converting scientific data from the past 138 years regarding a major global issue into various musical notes. The musical piece was performed by Jones and the Los Angeles Baroque at the Los Angeles Natural History Museum in 2019. What global issue was being studied?

(a) Global warming
(b) Shortage of drinking water
(c) Depleting energy sources
(d) Increasing air pollution levels

Q7. Kamala Sohonie was the first Indian woman to be conferred the degree of PhD, for her ground-breaking work on the electron transport chain. However, she was initially refused admission to one of India's premier research institutes by the institute's director, simply because she was a woman! Who was the director?

(a) C V Raman
(b) Homi J Bhabha
(c) Shanti Swarup Bhatnagar
(d) Vikram Sarabhai

Q8. String theorists at IISc recently stumbled upon a series representation of a certain irrational number, while studying quantum scattering of high-energy particles. Srinivasa Ramanujan has also worked on representations of this number. Which number are we talking about?

(a) ‘Pi’
(b) Euler’s number e
(c) The golden number
(d) Euler–Mascheroni constant

Q9. Hennig Brand was a German alchemist who, while searching for the 'philosopher’s stone,' discovered a new material that gave off a pale-green glow by concentrating boiled-down urine. What was this new element?

(a) Zinc sulphide
(b) Strontium aluminate
(c) Sulphate
(d) Phosphorus

Q10. This 20th century European mathematician, during a US citizenship test, claimed before Judge Phillip Forman that the US constitution had a loophole that could reverse democratic government itself. His theorems in mathematical logic are referred to by his name today. Who is he?

(a) André Weil
(b) David Hilbert
(c) Georg Cantor
(d) Kurt Gödel