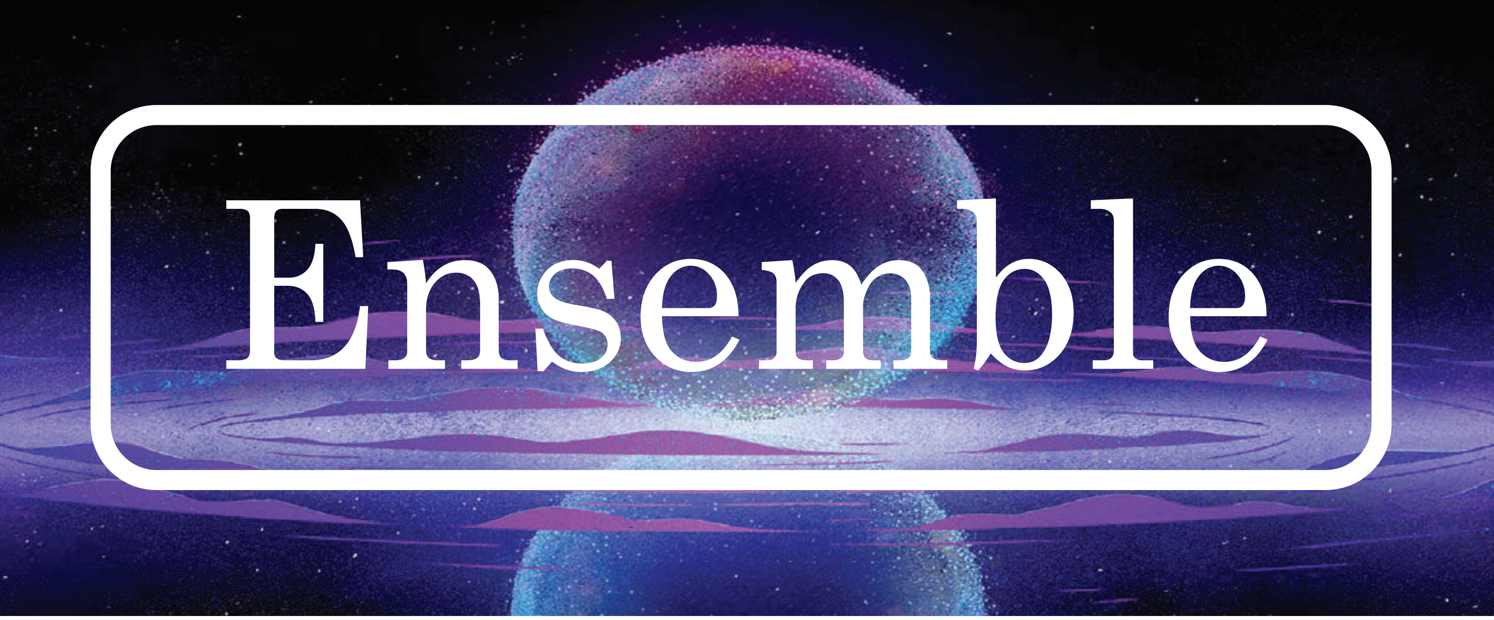
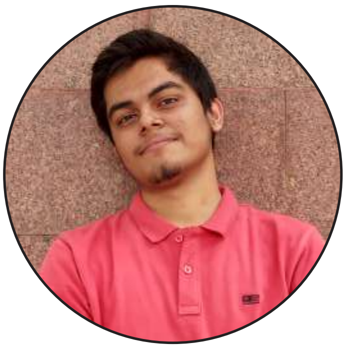


Ensemble

THE CONCEPTION

This Newsletter was conceived as part of our undergraduate physics club at IISc to keep the readers updated about the enthralling new findings in the field of physics. We hope to bring the current happenings in physics to the fingertips of our readers and make their journey of keeping up with the contemporary world of physics easier and a bit more fun!



Debadrito Roy
Co-convenor

Soumyadeep Sarma
Co-convenor

IN THIS ISSUE

Rupsa Dasgupta

A sleep-deprived physics student who never stops talking about the universe and her love for Taylor Swift, books, her guitar and Real Madrid.

The Beautiful Physics of the Beautiful Game

Even if one is not passionate about sports, one will most likely be familiar with the ecstatic shouts of "gooooaaaalll!" emanating from various households during competitions like the FIFA World Cup or the UEFA Champions League. That is the sound of none other than dedicated football fans who, despite being from diverse origins, are all united by their love for following 22 players kicking around a ball for 90 minutes. That is the beauty of football, a sport played and followed by most nations of the world. International competitions like the FIFA World Cup and club tournaments like the Champions League and European domestic leagues are avidly watched throughout the world. Most watch "the beautiful game" for its fluidity of play, with the players flaunting neat tricks and flicks with the ball at their feet, and displaying their technical skill with long-range strikes in free kicks and corner kicks. A corner kick is one which is taken from one corner of the pitch, when the opposition sends the ball over the goal line (the boundary of the pitch), out of play. A free kick, on the other hand, is one which is taken by a player when their team is fouled by the opposition anywhere on the field besides the penalty box. These strikes are often attempted from tight angles and especially in free kicks, occasionally resulting in goals which are truly beautiful to watch. But how exactly do these strikes work? How does physics permit the ball to curl around the defenders and hit the back of the net? Football fans may remember an astounding goal from a free kick, scored by Brazilian defender Roberto Carlos against France, in 1997. The shot was taken 35 meters from goal, and the ball followed a curved trajectory so magnificent that it looked almost impossible. In fact, the goal was so astonishing that it compelled physicists to study it extensively and figure out the mechanism behind it. A French team from Ecole Polytechnique, Palaiseau, published their findings in the New Journal of Physics (co-owned by the Institute of Physics and German Physical Society). They discovered that a phenomenon called the Magnus effect was at work here, which guided the ball (a projectile) to curve through the air (a fluid). According to Newton's 1st Law of Motion, an object will move in the same direction and velocity until an external force is applied to it. But in the case of this goal, the ball's spin was what did the trick of curving it mid-path. Carlos struck the ball up high and to the right, but it was also rotating on its own axis as it moved. The ball started on a straight trajectory, with air resistance on both sides slowing its movement. On one side, the airflow opposed the spin of the ball, reducing the air velocity and creating a high-pressure zone (following Bernoulli's Principle, which states that fluid pressure is inversely proportional to the speed of the fluid). On the other side, the airflow was in the same direction as the spin, increasing the air velocity and leading to a region of low pressure. This difference in air pressure caused the ball to swerve towards the low-pressure zone towards the end of its path.

The French researchers also discovered that the large distance from which Carlos had taken the free kick was also a necessary condition for creating a spiral trajectory, where the ball bent at the last moment.

This entire phenomenon is known as the Magnus effect. It was experimentally demonstrated by German physicist HG Magnus in 1852, but initially, it was described by Sir Isaac Newton after a game of tennis back in 1672. It is applied to an object spinning through a fluid, where its trajectory gets modified. This is the same effect which is at work when a player takes a corner kick and curls the ball towards the penalty box or takes a shot at goal from a difficult angle. It also serves as the explanation for the motion of frisbees and baseballs.

This reasoning can thus be applied to some wonder-goals seen in recent times, like Real Madrid midfielder Toni Kroos' direct goal from a corner kick in a Spanish Super Cup match in 2020, or Juventus forward Paulo Dybala's free-kick from a parallel angle to the goalpost, in a Champions League fixture in 2019.

After Carlos' legendary free kick, many commented that it "defied the laws of physics", but in reality, we can see how this subject governs everything around us and can even explain seemingly bizarre events. Thus, the next time we exult after our favourite team scores a goal, we will be able to understand the real mechanics behind it.

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Shalini Bhattacharya

"Content writer but can't write a line about myself"

EIGENVALUES AND WHY IS IT EVERYWHERE

Imagine your life; simple science life with pretty little equations, neat diagrams when suddenly you get hit with eigenvalues. And just like that you see them everywhere, in algebra, magnetism, quantum, programming, google search engine, facial recognition, in the star plus serials, someone knocks at your door- its eigenvalue wielding a knife. But why? WHY? Why is it more frequent than Elon Musk on Twitter? How is it important? Can it solve world hunger? Stop climate crisis??

I had the same question (that is, if you had this question as well. If not you can be on your merry little way); so I did some digging and what I found impressed me. But before we begin on this splendid adventure let's see what eigenvectors are, just to be on the same page.
As the name suggests, eigenvectors are well… vectors, albeit a special kind which is always along the same line even after it goes through a transformation and eigenvalues are scaling coefficients which stretch or squeeze the vectors.

Forget eigenvectors, why vectors in the first place? Well, the consensus seems to be… why not, we needed something which could express the magnitude and direction of a concept and bam we have vectors. And so we peppered in some math and defined space around it. But then we all know how to solve a system of linear equations (throwback to 6th grade) which worked perfectly fine till our high school education. What seemed to go wrong after that? College? Probably.

The history of eigenvectors begins with penguins. Just kidding, it began when Euler had a deep fascination for rotating rigid bodies and their principal axes. And Lagrange realized that the principal axes are the eigenvectors of the inertia matrix. You could try naming all the famous mathematicians and chances are that they have contributed to eigenvalues, it took years of liquified golden brains to conjure up the world of eigenvalues that we study in one semester; so naturally, I was flabbergasted when I researched for this article. There's oceans' worth of information about them and counting. I could write about the applications of eigenvalues for every issue of this newsletter for years and still have some left for my midday meals.

Let's say… population, of the multitude of examples I read about, a very relevant topic for all of us. suppose we have two cities. Each year, some fraction of city A's population moves to B. And some fraction of city B's population moves back to A. If this keeps up year after year, what happens in the long run? Will the populations reach a steady state, or will one city empty out into the other? The answer is difficult but, it can be made easy.
We define a transformation matrix which represents the inflow and outflow of people from both the cities and raise it to power (x). The power denotes the number of years after which you're accessing the cities.

So the total no. of people at any given time is the matrix raised to x, times the initial no. of people. Which… is tedious, to say the least, if you know how matrix multiplication works. Instead, we redefine the matrix in terms of eigenvalues and eigenvectors such that all the mathematical jargon gets bypassed into a simple linear combination of eigenvectors. What we arrive at is the eigenvalue raised to power x, times the eigenvector. In this special case (Markov matrix if you wanna read further about it) the eigenvalues are always 1, and the other is always less than one. Now we are in a position where, as the no. of years passed increases, our population matrix increases and finally acquires a steady state.

Now this example was just about two cities, the same can be extrapolated into n number of cities with thousands of different rates, and beautifully enough we'll arrive at a similar answer. Many models and concepts can be narrowed down to numbers in a matrix and eigenvectors is a brilliant tool which can be applied to the matrix to help solve them, which begs us to wonder, is there a unifying factor connecting all these seemingly different things? Why do these systems behave in a linear algebraic way? What does this mean about the systems that do not behave in this way? Could something explain the working of our universe down to each brain- each atom? Maybe the answer to this is lurking in the shadows somewhere, maybe we are asking the wrong questions or maybe we already know the answer and I need to do a better job at researching. Who knows? Not me for sure (only for now).

Quantum Algorithms and The Genetic Code

Delve deep into the world of Quantum Algorithms and how it models genomic processes.

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4 Feb 2023

5:30 pm

Physics Dept.
IISc Bengaluru

Prof. Apoorva D. Patel

Santhra Jojan

Heyy there ! I'm just a friendly Slytherin.

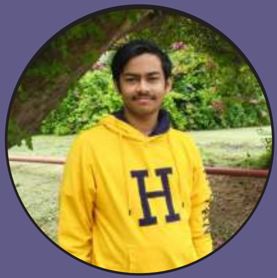
JWST FINDS “GREEN PEAS“

IAs non-surprising as it might be, James Webb Space Telescope found “Green pea” galaxies instead of the ones in the kitchen. Duhh, dad joke alert!

JWST recently found “Green pea” galaxies. These are incredibly compact galaxies found in parts of the early universe, are around 5% the size of the Milky Way or 5000 light-years across, and have an incredible amount of ultraviolet emission leaking out. These emissions heat up the gas cloud in the surroundings to extreme temperatures resulting in a glow. Such an exorbitant amount of energy is released making oxygen glow and give its characteristic green color.

Among hundreds of galaxies that are discovered every day, why is this one taking the astrophysics community by storm? Because the” green pea” galaxies have an intense rate of star formation, about 100 times more than usual, by mass. This should be a rarer phenomenon in the older early universe (lower redshift) and far more common in the younger denser parts of the universe (higher redshift). Still, not the best part. What is remarkable is that as reported in a paper published by James Rhoads these galaxies have a redshift ranging from 6.9 to 8.4, which simply means that the light from these galaxies shot when the universe was just around 700 million years old. Now, since the glow is green which is due to the excitation of oxygen as said before it implies that oxygen had formed within just 700 million years of the Big Bang.

Why is oxygen forming that early a surprise or even relevant? It’s because there was the time after the Big Bang dubbed as Cosmic Blackout when the energy was so magnificent in the universe that electrons and protons would not combine together, so naturally for the elements to form there should have been a cooling factor, implying a technically dubbed “re-ionization “stage. By discovering more such galaxies, scientists hope to map out the time scale at which the elements like oxygen started forming. Thus, giving us an insight into how early planets and other forms of life started to take shape.



Avneet Sharma

A CS undergrad with a knack for sci-fi, I'm fascinated by strange phenomena in physics.

WORMHOLE CREATED INSIDE GOOGLE'S QUANTUM COMPUTER… OR WAS IT?

WHAT ARE WORMHOLES?

If you are a sci-fi enthusiast, then you might already be familiar with the concept of a wormhole, also called an Einstein-Rosen bridge (named after Albert Einstein and Nathan Rosen who predicted it). It has been featured time and again in popular media, most notably Star Trek, Doctor Who and the Marvel Cinematic Universe (Remember Bifrost from the Thor movies?). For a beginner, black holes will seem identical to wormholes. However, there is a big distinction between the two. A black hole isn't necessarily a hole in space but a dense mass and the visible vortex effect often associated with black holes is merely the accretion disk of visible matter being drawn toward it. However, a wormhole – never discovered, but consistent with the general theory of relativity – is a tunnel that connects two black holes at different locations in space-time. These locations are not limited to short distances such as a few meters or even extremely long distances such as a billion light years, but also different points in time, or even different universes.

ALL THE BUZZ

In November 2022, a team led by Maria Spiropulu at Caltech, implemented the novel 'wormhole teleportation protocol' using Sycamore, Google's quantum computer, at Google Quantum AI, Santa Barbara, California. The experiment, which grabbed headlines throughout the world, was a first-of-a-kind "quantum gravity experiment on a chip", as described by Spiropulu. They beat competing researchers who aim to do quantum teleportation using IBM and Quantinuum's quantum computer. Reportedly, the experiment can be seen as evidence for the holographic principle, an axiom in string theory and a supposed property of quantum gravity that states that the description of a volume of space can be thought of as encoded on a lower-dimensional boundary to the region.

WHAT DO WE KNOW ABOUT WORMHOLES TODAY?

To understand the significance of the breakthrough, we need to go a little back in time. The idea of the holographic wormhole originated from two papers published in 1935: one by Einstein and Rosen, known as ER, the other by the two of them and Boris Podolsky, known as EPR. The first paper, ER, aimed to address the limitations of Einstein's theory of relativity, as pointed out by Schwarzschild who showed that mass can gravitationally attract itself to the point where it is infinitely concentrated, causing space-time to be so sharply curled that variables

become infinite and Einsteins's equations fail. We now know that these 'singularities' occur throughout the universe – at the centers of black holes where all nearby light gets trapped. They removed singularities from Schwarzschild's equations and replaced them with extra-dimensional tubes (or wormholes) connecting different parts of space-time. However, the paper failed to include another key phenomenon which would become significant later in the description of wormholes – quantum entanglement, which they identified two months back in their second paper, EPR.

Decades later, the idea that space-time and everything in it is a projection of a hologram gained popularity, with John Wheeler and Gerard t'Hooft playing a major role in establishing the holographic principle. In 1994, Leonard Susskind, quantum gravity theorist, proposed that a space-time described by general relativity is equivalent to a system of quantum particles on its lower-dimensional boundary. Juan Maldacena, another quantum gravity theorist, showed in 1997 that a kind of space called anti-de Sitter (AdS) space is a hologram.

However, even though Maldacena's discovery might seem enticing, the actual universe is de Sitter space, an ever-growing sphere driven outward by its own positive energy. By contrast, AdS space is infused with negative energy — resulting from a difference in the sign of one constant in the equations of general relativity — giving the space a "hyperbolic" geometry: Objects shrink as they move outward from the center of the space, becoming infinitesimal at an outer boundary. Maldacena showed that space-time and gravity inside an AdS universe exactly correspond to properties of a quantum system on the boundary (specifically a system called a conformal field theory, or CFT).

Later, Maldacena showed that the state of a pair of entangled particles is mathematically dual to a rather dramatic hologram: a pair of black holes in AdS space whose interiors connect via a wormhole. In an email to Susskind, Maldacena coined the equation "ER = EPR," which suggests that Einstein Rosen bridges between black holes are created by EPR-like correlations between their microstates. Susskind and Maldacena then co-wrote that the duality might be more general and that any EPR correlated system may be connected by an ER bridge.

THE EXPERIMENT

Building upon "ER = EPR," Harvard researchers Daniel Jafferis, Ping Gao, and Aron Wall discovered that by linking two sets of entangled particles, it's possible to perform an operation on the left set which maintains the wormhole leading to the right set and transfers a qubit through it. The SYK model, as it is called, is a system of matter particles that interact in groups rather than pairs, first described in 1993. However, it gained significance in 2015 when physicist Alexei Kitaev found that it could be mapped to a one-dimensional black hole in AdS space.

To use Jafferis and Gao's wormhole teleportation protocol on Spiropulu's quantum computer, the team simplified the process using neural networks and reduced the 53 qubits to 7 qubits with 5 four-way interactions while preserving the wormhole signature. One qubit was added to the left model, causing its information to spread, then a magnetic pulse rotated the qubits' states, causing the information to unspread and focus at a particle on the right, before the qubits were measured to determine if teleportation was successful.

After two years of gradual improvements and noise reduction efforts, a peak was observed indicating the transfer of information through the wormhole. Apart from that, an unexpected pattern in the way information spread and

un-spread among the qubits, known as “size winding”, showed up despite the researchers not training their neural network to preserve it, making it an experimental discovery about holography. Jafferis said this discovery confirmed the robustness of holographic duality and showed that their gravitational picture was correct.

CRITICISM

A clarification is rightfully needed here in response to the enthusiastic (and eventually erroneous) coverage of the experiment by the media. It should be noted that a wormhole has not been ‘created’ in the lab (with much disappointment to sci-fi fans), it has been ‘simulated’ for a hypothetical space we do not inhabit.

Moreover, since Maldacena discovered the AdS/CFT correspondence 25 years ago, physicists have attempted to find a similar holographic duality for de Sitter space, which is the expanding universe with positive energy that we live in. However, this has proven to be much more difficult than finding a correspondence for AdS space, leading some to question whether de Sitter space can be made holographic. Critics believe that the two types of space are fundamentally different, with AdS space having a clear outer boundary that allows for easier holography, while de Sitter space only has unclear boundaries at the farthest point we can see and the infinite future, making it difficult to project a hologram of space-time.

WHAT’S NEXT?

Susskind thinks it's time to focus on the practicality of de Sitter space and move away from the AdS space. He has proposed that de Sitter space could be a hologram of a version of the SYK model, where the number of particles in each interaction grows with the square root of the total number of particles. This idea is not yet proven but has some evidence, though the system is more complex than what has been programmed so far. Susskind believes that with the discovery of one holographic wormhole, more will follow

Amisha Khedwal

Hey everyone, I'm Amisha khedwal from St. Xavier's college, Mumbai pursuing Bsc. I'm currently in my second year. I have a passion for writing. I enjoy writing on a variety of topics specifically physics and I take pleasure in immersing myself in learning about new and exciting areas.

THE FAR FLUNG PERIL OF SPACE DEBRIS

So what would really happen to you, if you were stranded in space with a hail of space debris floating around? The standard space suit carries 8 hours of oxygen plus 30 minutes reserve. If you cannot refill or find a safe atmosphere in that time the CO2 level builds up and you eventually black out. With all that space debris floating around you, you are likely to bring a vicious rip in your space suit. If you depressurize and expose yourself into the vacuum, after a couple of minutes you won't remain conscious, scampering off into the infinite void. Therefore, the threat of space junk is real.

Space junk, or space debris, is any piece of machinery or debris left by humans in space.It can refer to both big and small objects such as dead satellites that have failed or been left in orbit at the end of their mission or smaller objects like bits of debris or paint flecks that have fallen off a rocket.Since 1975, humans have flung nearly ten thousand satellites into the sky most of which are now defunct or destroyed. Some like Sputnik have burned up. Thousands like Vanguard, still orbit around the planets and and other celestial bodies for decades or centuries. They are nothing more than a ballistic scrap creating hazards to astronauts and unmanned space flights.

As of 2021, the United States Space Surveillance Network tracked more than 15,000 debris flying around, some even smaller than 1 cm. Since both the debris and spacecraft are traveling at extremely high speed (approximately 15,700 mph in low Earth orbit), a collision of even a tiny piece of orbital debris with a spacecraft could create a space flotsam which can cost human lives and ruin fortunes.

For instance, A company called Celestis fires capsules launched a symbolic portion of cremated remains into near-space.(The ashes of Gene Roddenberry, the creator of "Star Trek," were sent aloft) In 2007, a shuttle jettisoned a fourteen-thousand-pound tank of ammonia, it later burned up over the South Pacific Ocean. Moreover, astronomers have accidentally let objects fall into orbit during space walks: a camera, a spatula, a glove, a mirror, eventually contributing to this hazard. Small or large objects, retrieving anything from space is immensely difficult and has been only on a handful of occasions.

The first person to believe that space pollution could lead to immense environmental damage was Don Kesseler, a NASA astrophysicist in 1978. The Kessler Syndrome is a scenario in which the density of objects in Low Earth Orbit (LEO) is high enough that collisions between objects could cause a cascade where each collision generates space debris that increases the likelihood of further collisions.

To describe the phenomena briefly, as the number of satellites in earth orbit increases the probability of collision also increases. The collating satellites would produce orbiting fragments, each of which would increase the odds of further collisions, causing a domino effect, therefore creating a belt of debris around the earth.

If the cascade is already underway, it would take years to reach a point where it's happening in real-time. Implying that humans will be forbidden from the cosmos and will be limited to one-planet species for many lifetimes, physically and intellectually. The space debris could ruin ground-based astronomy, too, hemming in our minds as well as our rockets.

The collision probability is closer to 1 in 20, according to the Leolabs company that runs a ground-based radar array that monitors collision risks for objects in low-Earth orbits. Recently, in September 2019,a Starlink satellite and an ESA satellite almost collided when operators at SpaceX failed to check their email and missed some urgent missives from their counterparts at ESA.And over the summer of 2021, McDowell tweeted, the Chinese space station twice dodged Starlink satellites that may have passed within 1 kilometer of the station.

Although scary, it doesn't always lead to large amounts of devastation, like shown in the 2013 movie 'Gravity'. It depicts the space shuttle and ISS being damaged by a cloud of debris, which is formed when a Russian missile destroys a defunct satellite. Which is false, as the Debris takes weeks or months to spread out in space and could not possibly have attacked the ISS quickly. Moreover, it will break into fragments and not form a dense cloud as shown in the film.

Recently a professor of Geological Sciences at Brown University, quoted that "Space is not just a trash can, it's really something we have to take care of'. It is true, isn't it? Space is getting crowded and more so because of the freely floating litter. Therefore creating an urgent need to clean.

The Space industry has taken initiatives for the same, wherein we can bring the debris down on Earth's atmosphere and burn up this waste. By employing colossal magnets, harpoons, or nets, researchers plan to knock the junk out and create a safe space. In a larger prospect there is an urgent need to adopt greener materials, use eco-friendly processes on ground so as to preserve Earth's orbital environment, and make it free of debris

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