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VOL. XXII NO. 30 ■ PRICE ₹7.00 /WITH HINDUSTAN ₹ 12.50 (₹ 10.50 IN FARIDABAD) ■ 44 PAGES. AREA SPECIFIC PAGES EXTRA.

{Sunday}
Hindustan Times
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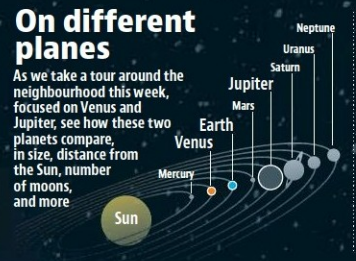

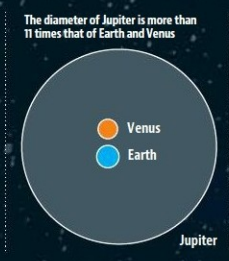

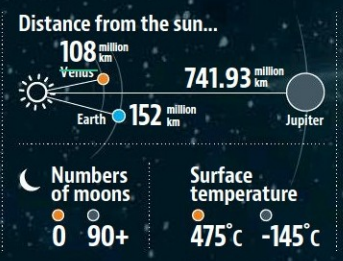

Neighbourhood watch

How well do we know our neighbours? New space missions are headed to planets we haven't focused on in decades – to Venus, next door; and to distant Jupiter. They seek answers to very specific questions. Could Venus have been a lot more like Earth (with water, and even life)? What made it the hellscape it is now? And what can the gas giant Jupiter, the oldest planet, tell us about what's next for the solar system?

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Venus is a bit like the architect who lives quietly next door for years, and turns out to be a serial killer.

Our nearest planetary neighbour is roughly the same size as Earth. It is almost equidistant from the Sun. It is a terrestrial orb (rather than a gas giant like Jupiter). But, as it turns out, the similarities are entirely superficial.

The clouds that cover Venus all year round contain sulphuric acid, and circle the globe at 100 metres per second, like a Category 4 hurricane that never dissipates.

The atmosphere is almost entirely carbon dioxide, trapping all the planet's heat. As a result, its surface temperature stands at over 450 degrees Celsius, making it hotter than even Mercury, which is far closer to the Sun.

It is so hot on Venus that the planet's sulphuric acid rain (that's an acid with a boiling point of 337 degrees Celsius) evaporates before it hits the ground.

How could two planets born around the same time, almost equidistant from their star, be so different? As our planet warms, answers to Venus's past could hold clues to the future of Earth, researchers say.

Getting close enough to seek those answers, however, poses a series of challenges.

Venus is less than 60 million km away from Earth (for perspective, the moon is about 400,000 km away). But it maintains its searing temperatures even at night, owing to the runaway greenhouse effect created by its carbon dioxide. Its atmospheric pressure is at an intense 93 times that of Earth at sea level.

As a result, only four spacecraft have made it to the surface so far (all part of the Soviet Venera missions), and they only survived briefly — from a few minutes to a few hours — before they were cooked and crushed by the planet.

A hot mess

As we've peered at our neighbour through the decades, though, the view has been changing.

Humanity's first interplanetary mission headed to Venus, given its proximity. This was the US National Aeronautics and Space Administration (NASA)'s Mariner 2 fly-by, in 1962. It gathered the first granular data on the planet. The Mariner 10, launched in 1973, relayed the first close-up images.

With each fresh set of data, estimates of surface temperature and atmospheric pressure were revised upwards.

Then the Venera landers were crushed in the 1970s, and humanity moved on to places with more promise: back to the Moon, and on to Mars (which is roughly half the size of Earth and at least five times farther).

In recent years, however, orbiters have returned. The European Space Agency's (ESA) Venus Express, launched in 2005, found evidence of granite-like rocks, which caused some excitement because on Earth they only form in the presence of water.

The Japan Aerospace Exploration Agency's (JAXA) Akatsuki, the only spacecraft currently orbiting this neighbour, has been studying Venus' mysterious atmospheric dynamics since 2015, using cameras set to different wavelengths. Other missions — including Hubble, the Parker Solar Probe and ESA's Solar Probe — have flown past and added to the data.

What we've learnt, from these fly-bys and from ground observations via radio telescopes and climate models, is astounding.

Scientists believe that Venus once held an abundance of water, possibly for as much as two to three billion years, long enough for the planet to have been habitable. (The solar system, incidentally, is about 4.6 billion years old.) They have found traces of phosphine in the planet's atmosphere. This is a compound that is produced as waste by bacteria on earth, and is hence considered a biomarker.

Could there have once been life on Venus? Could Venus have once been a lot more like Earth?

Venus fly trap

New missions are seeking answers. Four, a mix of orbiters and atmospheric probes, are headed there in the coming decade, including one by the Indian Space Research Organisation (ISRO).

NASA's DaVinci and Veritas missions are slated for launch between 2028 and 2030. ESA's EnVision mission is due for launch in 2031.

ISRO's Shukrayaan 1 is set to head out as early as December 2024 or, failing that launch window, in 2031. This four-year orbiter mission is designed "to probe the surface, sub-surface, atmosphere and upper atmosphere, and understand its seasons as well as the Venus-Sun interactions," says Anil Bhardwaj, director of the Physical Research Laboratory in Ahmedabad, a unit of the Government of India's Department of Space.

Shukrayaan 1 will be the closest ISRO has ever come to the Sun. It will travel 40% of the distance between us and our star, Bhardwaj points out. A key challenge will be keeping the craft from being sucked into Sun's orbit.

JAXA's Akatasuki, for instance, was launched in May 2010; failed to enter orbit around Venus owing to a technical mishap; then got dragged into the Sun's immense gravitational pull and went spinning around it for five years before it could be manoeuvred back towards its original destination in orbit around Venus.

If all goes well, radar, infrared cameras and other instruments on board Shukrayaan 1 will collect data on Venus's composition and atmospheric characteristics, in the hopes that these will provide new clues into the theory of an Earth-like early life.

"There are fundamental reasons to look into our neighbour's backyard," Bhardwaj says.

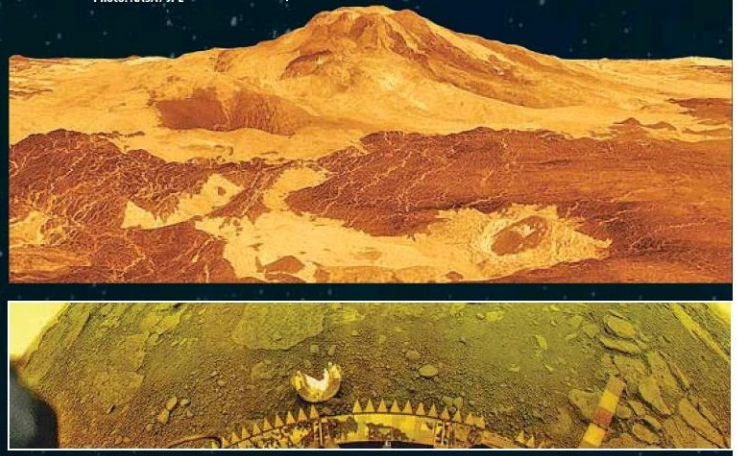
"There is a curiosity to understand what happed to a planet that is terrestrial like Earth, is almost the same size, and is a similar distance from the Sun... What happened for it to end up so different? Understanding that could help us understand what could happen here on Earth, millions of years from now."

ISRO'S SHUKRAYAAN 1 IS SET TO HEAD OUT TO VENUS AS EARLY AS DECEMBER 2024. IT WILL TRAVEL 40% OF THE DISTANCE BETWEEN US AND OUR STAR, THE CLOSEST ISRO HAS EVER COME TO THE SUN

This year, scientists studying data from NASA's Magellan mission (launched in 1989) found geological evidence of recent volcanic activity. A volcanic vent changed shape and grew in size over eight months, in 1991, the data shows. The computer-generated 3D model below represents Maat Mons, one of the planet's largest volcanoes. Understanding volcanic activity on Venus could help unlock some of the mysteries of its past.

How much like Earth was it really? A new NASA mission, the Veritas orbiter, due for launch in 2030, will probe the surface and study its core from a low orbit. Its high-resolution maps could offer more clues.
Photo: NASA / JPL

Beneath the clouds, Venus is a hellscape. This computer-simulated view of the planet's surface was created in 2020, using data from NASA's Magellan mission launched in 1989. It helps to remember that the planet's thick white clouds are made up largely of sulfuric acid, and travel around the globe at 100 metres per second, like a Category 4 hurricane that never dissipates. An atmosphere made up largely of carbon dioxide has trapped all the planet's heat. Surface temperatures are so high — over 450 degrees Celsius — that even the sulfuric-acid rain evaporates before it hits the ground.
Photo: NASA / JPL-CalTech



Only four spacecraft have touched down on Venus's surface so far, and they only survived for a few minutes to a few hours. Between the extremely high temperature and the air-pressure levels (93 times that of Earth at sea level), the Soviet-era Venera vessels that landed in the 1970s and '80s managed to relay only a few images to Earth before they were crushed and cooked. The images show a desolate, mustard-coloured landscape strewn with rocks.
Photo: Russian Academy of Sciences / Ted Stryk

{ SPIN CYCLE } OBSERVATIONS IN ORBIT

Taking the telescopic view

VENUS IN RETROGRADE

- Our nearest planetary neighbour is almost the same size as Earth, and almost an equal distance from the Sun (about 108 million km, against Earth's 152 million km).
- It rotates on its axis in the opposite direction to all the other planets. Venus is the only planet on which the sun rises in the west and sets in the east.
- It has the slowest rotational period of any planet in the solar system. At less than two metres per second, it takes 243 earth days to complete one rotation on its axis.
- Data obtained from the European Space Agency's Venus Express orbiter shows that the planet's rotation is slowing further.
- Windspeeds, on the other hand, are accelerating, owing to a phenomenon called super-rotation. The planet's thick cloud layer takes just over four earth days to circle its globe.

DROPS OF JUPITER

- Jupiter is thought to be the first planet to have formed in our solar system. It is more than twice the size of all the other planets combined.
- It has more than 90 moons, 12 of which were officially recognised as recently as this year. The four biggest — Ganymede, Europa, Callisto and Io — were the first non-Earth moons to be discovered, in 1610, by the astronomer Galileo.
- Jupiter doesn't have a land mass, but is thought to be covered in a sea of liquid metallic hydrogen, beneath which is a dense, molten core.
- Its magnetic field is stronger than Earth's by a factor of 10, but it is what scientists call "lumpy" — stronger in some spots, weaker in others. This makes manoeuvring a spacecraft even a few million kilometres from its surface fairly tricky.
- Jupiter has the shortest day in the solar system, taking just 10 earth hours to spin on its axis. It takes 12 earth years (or 4,383 days) to complete one revolution around the Sun.

A rather whimsical view of the gas giant Jupiter, taken by NASA's James Webb Space Telescope. This composite image represents the planet as seen through two filters. In a rare bonus, its faint rings are visible too.
Photo: NASA, ESA, CSA, Jupiter ERS Team; image processing by Ricardo Hueso (UPV/EHU), Judy Schmidt

(Above left) This close-up of Jupiter's south pole was taken by NASA's Juno Probe in 2016. It is a composite of multiple images taken by the JunoCam on three separate orbits, combined to show the entire area in daylight. Each swirl is an Earth-sized cyclone; they are so densely clustered that some are colliding at the edges.
Juno, which will continue to orbit Jupiter until 2025, has been instrumental in understanding this planet better. "We knew, going in, that Jupiter would throw us some curves," Scott Bolton, Juno principal investigator from the Southwest Research Institute in the US, said in a statement soon after this image was taken. "But now that we are here we are finding that Jupiter can throw the heat, as well as knuckleballs and sliders. There is so much going on here that we didn't expect, that we have had to take a step back and begin to rethink of this as a whole new Jupiter."
(Above right) This close-up of a swirling vortex on Jupiter was captured by Juno in 2018, from just 7,000 km from the gas giant's cloud tops, on its 16th close fly-by.
Photos: NASA / JPL-Caltech / SwRI / MSSS / Betsy Asher Hall / Gervasio Robles and NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt / Sean Doran

{ NEW FAQS } THE GAS GIANT

Is Jupiter still shaping the solar system?

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Jupiter is the oldest, most influential (being by far the biggest), and arguably the most intriguing planet in the neighbourhood.

It was the first to form, three million years after the birth of the solar system. (Saturn came next, within the first 10 million years; as did the ice giants Uranus and Neptune). Jupiter is a gas giant, with no known solid land. Beneath its giant storms is a sea of liquid metallic hydrogen, and a dense metal core.

It is so large that it maintains a massive orbital system of its own, with over 90 known moons, including the four planet-sized ones: Io, Europa, Ganymede and Callisto.

It draws in comets and asteroids, giving it the nickname "vacuum cleaner of the solar system". But this can make it a tricky neighbour. While it draws space objects away from Earth, it can also fling things our way.

In 2021, two scientists at Harvard University presented a new theory about how the Chicxulub impactor ended up here. The paper (by astronomer Avi Loeb and astrophysics student Amir Siraj, published in the journal Nature) states that the massive asteroid / comet got caught in Jupiter's gravitational field, and hurled towards Earth.

It landed, of course, in what is now Mexico; leaving a crater 93 miles across and 12 miles deep; sparking a wave of devastation that rolled across the planet, altered the climate, and began the mass extinction that wiped out the dinosaurs 66 million years ago.

But there are other reasons Jupiter matters. Astrophysicists believe it played a key role in shaping the solar system as we know it. Over and over, in other solar systems, gas giants such as this one occupy central positions. They are often found to have migrated to these positions by pushing smaller terrestrial planets aside, or engulfing them. Is this where the solar system is headed? Or how it was formed?

"We can't understand the origin of the solar system – and how Earth came about – without understanding how Jupiter formed," says the why-we're-exploring-Jupiter statement on the website of the US National Aeronautics and Space Administration (NASA).

> There is so much we don't know about what lies beneath Jupiter's thick gases, or why its satellites are dominated by elements that are quite different from its own. Every mission tells us a little bit more.
>
> ANIL BHARDWAJ, director, Physical Research Laboratory

And, as our search for sentient life continues, the focus is on the moons Ganymede (which is larger than Mercury and Pluto), Callisto and Europa, which are suspected to hold subsurface oceans of water.

Three new missions aim to study these moons in the coming decade. The European Space Agency (ESA's) Jupiter Icy Moons Explorer or JUICE was launched in 2023 and will take about five years to get there. NASA's Europa Clipper, due for launch in 2024, aims to focus on Europa. China National Space Administration's Tianwen-4 mission will launch a Jupiter orbiter in 2029.

The key challenge will be analysing the composition of the water, which is hidden beneath several hundred kilometres of ice. Infrared and microwave cameras, among other instruments, will hopefully offer a clearer view of the moons and their planet too.

"There is still so much we don't know about what lies beneath Jupiter's thick gases," says Anil Bhardwaj, director of the Physical Research Laboratory in Ahmedabad, a unit of the Government of India's Department of Space. "We don't know why its satellites are dominated by elements that are quite different from its own. These are some of the intriguing questions, and every mission tells us a little bit more."

VIEW: What accounts for our current obsession with the moon?

VIEW: Reaching for the star: A close look at our history of staring at the sun

culture

Four-wing drive

Flying cars are finally taking off. Permits are being issued; price tags discussed. But already, new hurdles have emerged. Most are EVs, but where is the power to come from? And who exactly will pilot them?

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Science-fiction suggested we'd have flying cars decades ago.

They were in Robert Zemeckis's Back to the Future (1985), set in the 1980s. In Ridley Scott's Blade Runner (1982), set in 2019 and based on Philip K Dick's 1968 sci-fi classic, Do Androids Dream of Electric Sheep? In the 1960s animated series The Jetsons, set in 2062.

That last timeline might just check out. Test flights, in the real world, are currently being conducted in China, Brazil, Slovakia, Japan and the US, among other countries.

This month, the US Federal Aviation Administration (FAA) granted approvals to California-based Alef Aeronautics to test its Model A, which can ply on roads and in the air. It has a sticker price of $299,999 (about Rs 2.5 crore) and is due for release in 2025.

In May, Eve Air Mobility, the flying-car division of Brazil-based aerospace company Embraer, successfully completed wind-tunnel tests for its flying vehicle, Eve. The company hopes to launch commercial operations for the flying taxi by 2026.

In late 2022, Xpeng Aeroht, the flying-car division of the Chinese Xpeng Motors, was granted a "special flight permit" to begin testing its two-seater, X2, in the skies and on the roads of Guangzhou. The vehicle has a maximum flight time of 35 minutes and can reach speeds of up to 135 km/h.

In 2021, Slovakian company Klein Vision's AirCar completed a 35-minute flight between two airports, a distance of about 80 km. This hybrid land-air car has wings that open out from the body in about 2.25 minutes. It will likely cost about $550,000 (about Rs 4.5 crore), with two-, three- and four-seater options available.

Japanese company SkyDrive is working on the SD-05, which it plans to release as an air taxi during the World Exposition in Osaka in 2025. With a relatively low range of 15 km, the three-seater will have a top speed of 100km/h.

All these are electric vertical take-off and landing vehicles or eVTOLs, electricity being the only fuel that would be affordable on this scale. But merely arriving at this stage has raised fresh challenges.

First, how is a national grid to support a population with flying EVs, particularly given the growing popularity of non-flying EVs and the added strain that is already placing on power infrastructure? How is a carbon footprint of flying cars to be rationalised, without a more effective switch to renewable sources?

Second, how is such traffic to be safely regulated? Who will monitor the many, scattered lift-offs and landing? How will such traffic be regulated?

"There is still the 'final mile' challenge. Brazil's power grids, for instance, aren't prepared for the charging needs of electric flying cars," Luiz Maiuad, a vice-president with Eve Air, said at a press meet in June.

Finally, who will fly the cars? Currently, manual and autonomous or "driverless" flying systems are being tested. Most companies expect to initially launch as flying taxis to be piloted by a well-trained few. This is why most are built to seat not one, but two, three and four at a time. (The taxi model would go some way towards mitigating the high cost of the vehicles too.)

Eventually, other formats will likely emerge (rent, lease, charter?), as companies and regulatory bodies navigate the space. Consultancy McKinsey & Company estimates that over 250 companies are working to develop flying-car prototypes.

Some look like super-sized drones. Others seem inspired by single-engine aircraft. Still others do seem inspired by the Jetsons.

Keeping them light, fast and cheap means that most cannot fly very far; at least, not yet. But expanding power-generation capabilities and new traffic control systems — including altitude and direction norms, in a sort of invisible road network in the skies — could, over time, lead to the adoption of personal aerial vehicles.

How will companies and users keep the carbon footprint low enough to rationalise such a development, amid the climate crisis? Can we switch to renewable sources of power fast enough?

For now, all excitement hinges on the mere possibility of stepping into a small vehicle and flying to work. Financial services company Morgan Stanley estimates that the global flying-car market will be worth $1.5 trillion by 2040.

(From above) TheXPeng X2, SkyDrive SD-05 and Embraer's Eve are at various stages of development. An estimated 250 companies worldwide are currently working to develop flying-car prototypes.

{ THE SPORTING LIFE }

Rudraneil Sengupta

New weapons, new hope for Arsenal

Fans may finally be able to swap blind optimism for the sweet taste of victory... unless the curse of the big buy strikes

After almost winning the Premier League last season, before they were eventually (if inevitably) pipped by Manchester City, Mikel Arteta's patient rebuilding of Arsenal has entered a new, more urgent phase.

The club's massive spending on the transfer market — upwards of £200 million at this point — is a screaming-from-the-rooftop announcement of its ambitions.

In the last couple of weeks, they have got Kai Havertz from Chelsea, to bolster their attacking capabilities; Jurrien Timber from Ajax to give Arteta yet another option in an already robust defence; and, potentially, a player who can win them everything, in Declan Rice.

Full disclosure: I am an Arsenal fan, one of those eternal optimists who believes that every season will be theirs, until that point in the season when it becomes impossible to ignore the evidence to the contrary.

The signing of Rice, therefore, makes me want to break into song. The next Patrick Vieira! Arsenal's answer to City's Rodri!

Last season, there was no player in the Premier League who dispossessed the opposition in attack more than Rice did.

The 24-year-old Englishman doesn't stop at winning the ball; he has the confidence, pace and skill to then turn and drive into the opposition's final third. It's one of football's rarest and most important skills: the ability to turn defence into attack.

The reason this is such a rare and coveted ability in football is because a deep-lying playmaker needs to be a master of pretty much every skill needed on the pitch (except goalkeeping). They must have solid defensive skills — positioning, tackling, intercepting. If they are to carry the ball once they have taken it, they need exceptional pace and acceleration, and excellent dribbling skills.

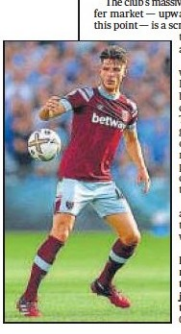
They must also be brilliant readers of the game; know where the spaces are; have a sense of which teammate in the best position to carry a break forward. And they must possess that beating heart of football: the ability to pass. Rice's 88% pass accuracy last season makes him a metronome.

The Arsenal midfielder Thomas Partey is a player very much in the mould of Rice, and together they could form a twin-cylinder engine to power the team to silverware (though there is talk of Partey leaving the club in this transfer window).

There is one catch: the curse of the big-money transfer.

Of the footballers in history whose transfer fees have hit or crossed £100 million, nearly all have failed spectacularly just after. Think of Romelu Lukaku's fractious time at Chelsea, Phillipe Coutinho or Ousmane Dembele at Barcelona, the Paul Pogba trainwreck at Manchester United.

Rice has been signed for £105 million. Perhaps, just this once, the curse will not hold.



Declan Rice, who has moved from West Ham to Arsenal, could be just the magic wand that the club needs.
GETTY IMAGES