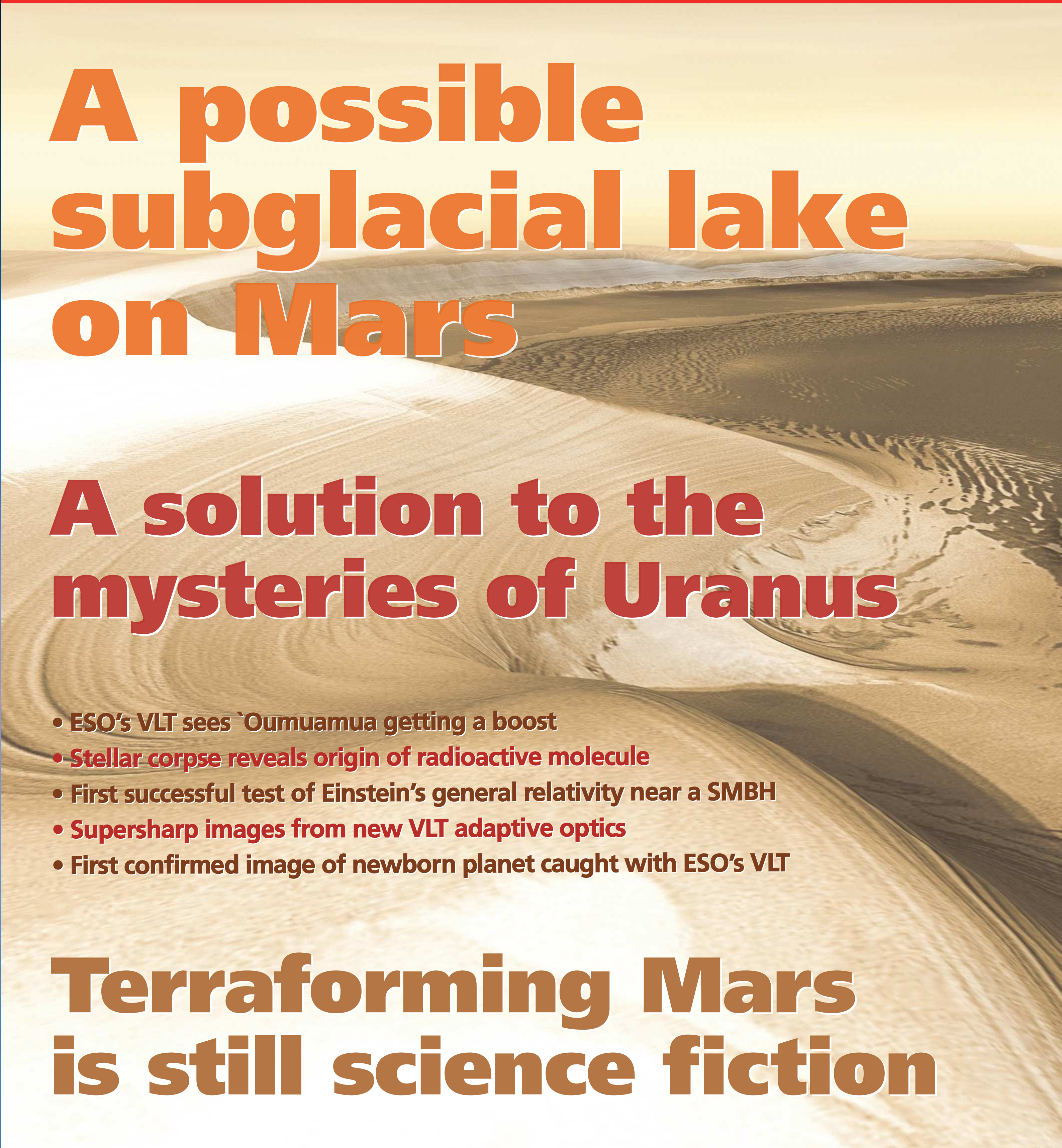
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS HAPPENING IN SPACE

FREE ASTRONOMY magazine

Bi-monthly magazine of scientific and technical information ✶ September-October 2018



# A possible subglacial lake on Mars

# A solution to the mysteries of Uranus

- ESO's VLT sees `Oumuamua getting a boost
- Stellar corpse reveals origin of radioactive molecule
- First successful test of Einstein's general relativity near a SMBH
- Supersharp images from new VLT adaptive optics
- First confirmed image of newborn planet caught with ESO's VLT

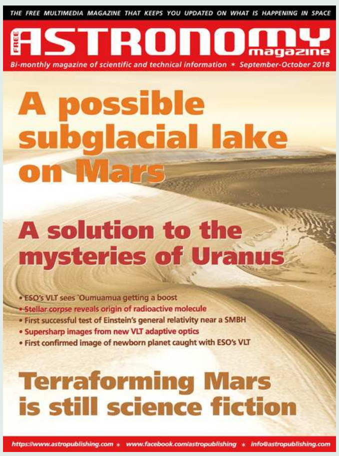
# Terraforming Mars is still science fiction


NortheK
Instruments - Composites - Optics
DALL KIRKHAM 350 MM
F/20 23% OBSTRUCTION
SUPREMAX 33 PRECISION OPTICS FROM SCHOTT
CARBON STRUCTURE - 18-POINT FLOATING CELL
MOTORIZED FOCUSER 2.5" FEATHER TOUCH
VENTILATION AND SUCTION SYSTEM
OF THE BOUNDARY LAYER
WEIGHT 34 KG.
ALSO AVAILABLE IN THE VERSIONS
NEWTON F/4.1 WITH 3" CORRECTOR
RITCHEY CHRÉTIEN WITH F/9
CORRECTOR/REDUCER
CASSEGRAIN CLASSIC F/15
QUARTZ
www.northek.it - www.facebook.com/northek.it - info@northek.it - phone +39 01599521

FREE ASTRONOMY magazine

BI-MONTHLY MAGAZINE OF SCIENTIFIC AND TECHNICAL INFORMATION FREELY AVAILABLE THROUGH THE INTERNET

September-October 2018




English edition of the magazine

l'ASTROFILO

**Editor in chief**
Michele Ferrara

**Scientific advisor**
Prof. Enrico Maria Corsini

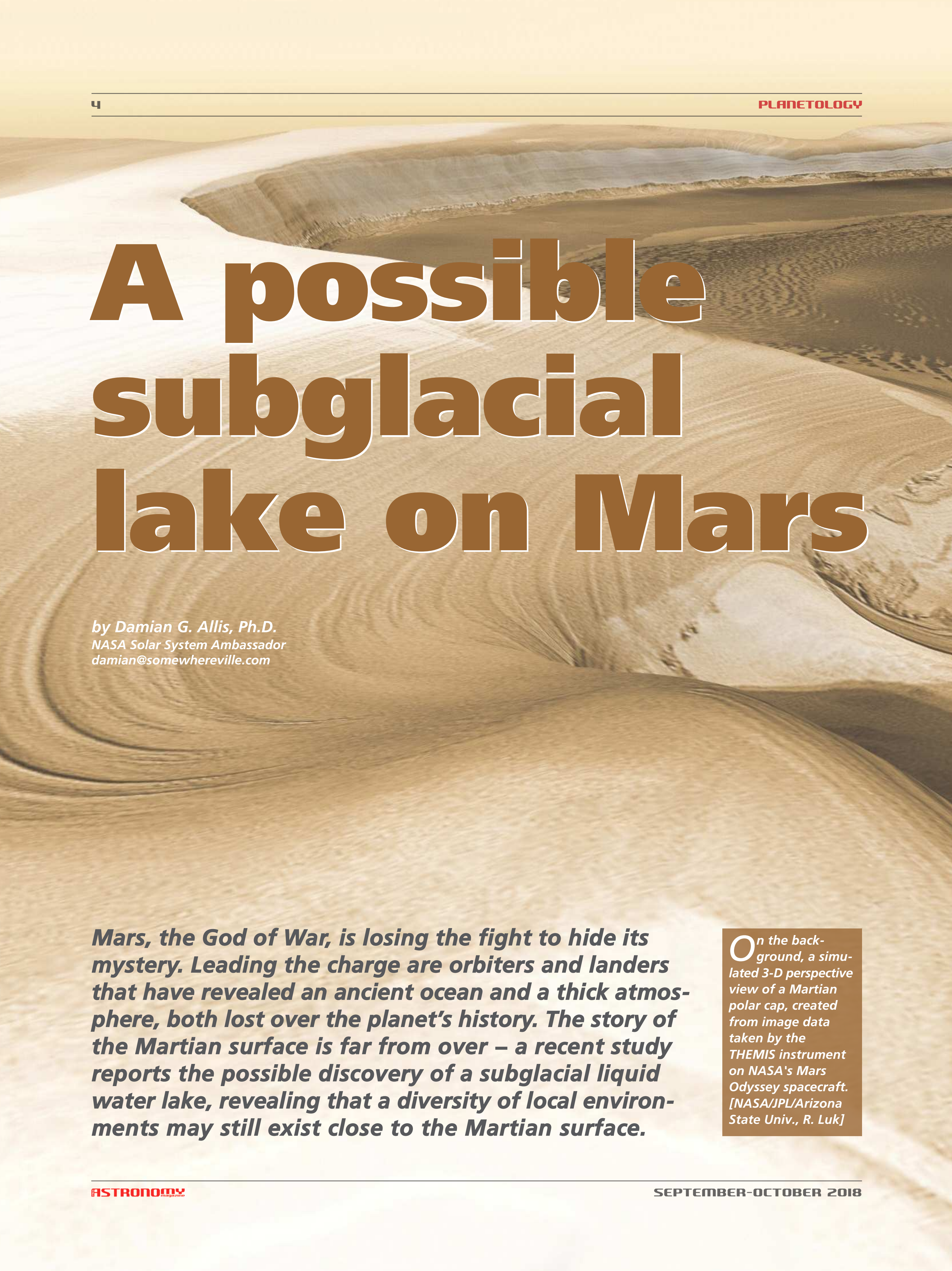
**Publisher**
Astro Publishing di Pirlo L.
Via Bonomelli, 106
25049 Iseo - BS - ITALY
email info@astropublishing.com

**Internet Service Provider**
Aruba S.p.A.
Via San Clemente, 53
24036 Ponte San Pietro - BG - ITALY



**Advertising - Administration**
Astro Publishing di Pirlo L.
Via Bonomelli, 106
25049 Iseo - BS - ITALY
email admin@astropublishing.com

# SUMMARY



# A possible subglacial lake on Mars

*by Damian G. Allis, Ph.D.*
*NASA Solar System Ambassador*
*damian@somewhereville.com*

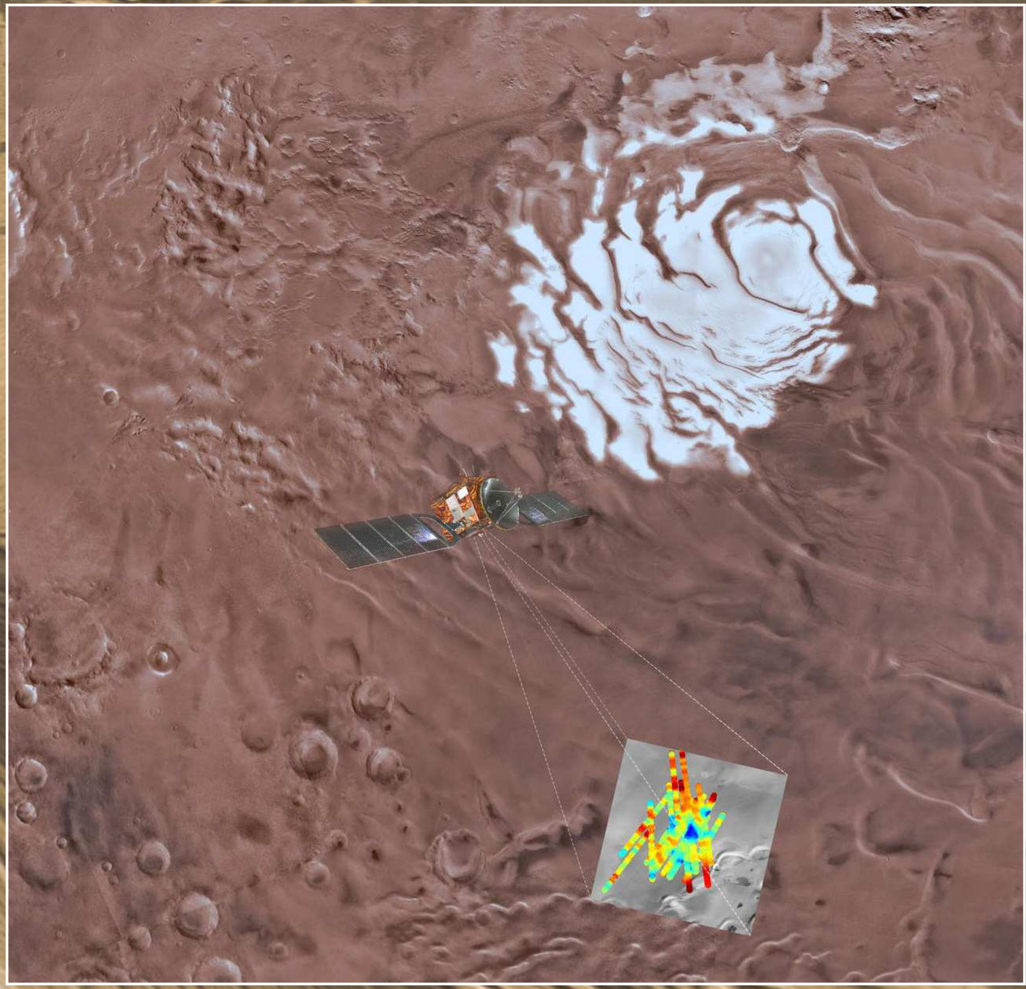
***Mars, the God of War, is losing the fight to hide its mystery. Leading the charge are orbiters and landers that have revealed an ancient ocean and a thick atmosphere, both lost over the planet's history. The story of the Martian surface is far from over – a recent study reports the possible discovery of a subglacial liquid water lake, revealing that a diversity of local environments may still exist close to the Martian surface.***

*On the background, a simulated 3-D perspective view of a Martian polar cap, created from image data taken by the THEMIS instrument on NASA's Mars Odyssey spacecraft. [NASA/JPL/Arizona State Univ., R. Luk]*

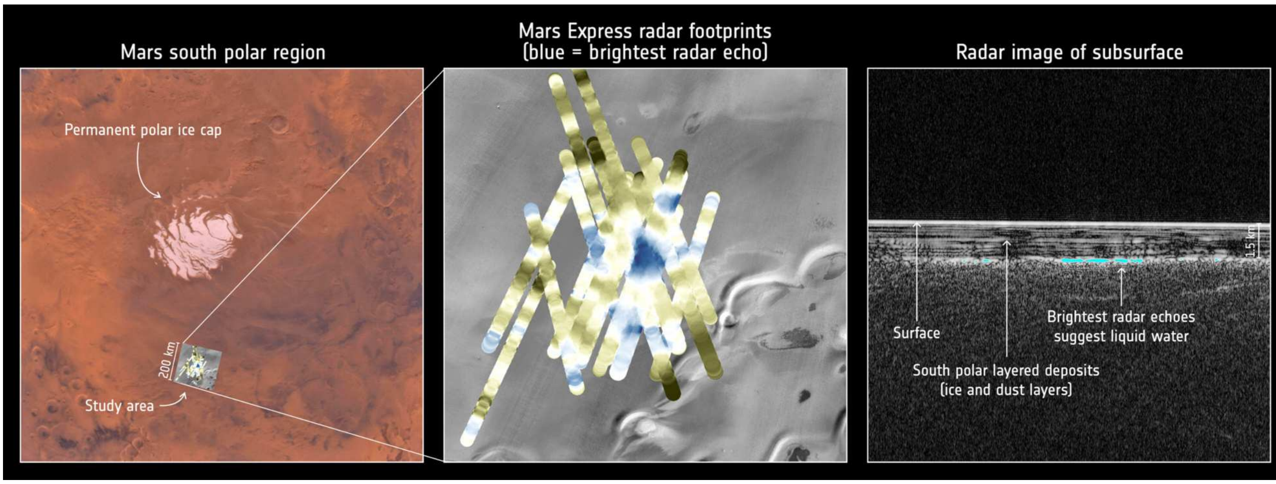
Few topics in planetary science excite researchers and the public more than the discovery of water. To geologists and climatologists, liquid water reveals that conditions must lie within some reasonable temperature regime, providing information about the surface and atmosphere.

For astrobiologists, liquid water is one of the key requirements needed for life as we know it. Space engineers see liquid water less as the stuff of life as they do the stuff of cost reduction – water in liquid form means a readier source for both propellant and consumption.

Among the known water-bearing bodies beyond Earth, only Mars has combined rapid scientific discovery with public engagement and technical capability with economic feasibility. A recent study of Planum Australe in the southern polar ice cap region using the Mars Advanced Radar for Subsurface and Ionospheric Sounding, or MARSIS, instrument on the European Space Agency (ESA) Mars Express Orbiter (MEO) reports the detection of what might be an active location of persistent, still-liquid water – although not a body of liquid easily accessible or, for that matter, in a form usable by future colonists. The Italian research collaboration, led by Roberto Orosei at the Italian National Institute for Astrophysics in Bologna, published the findings of their 12-year study in the July 25th issue of *Science* magazine (DOI:10.1126/science.aar7268).



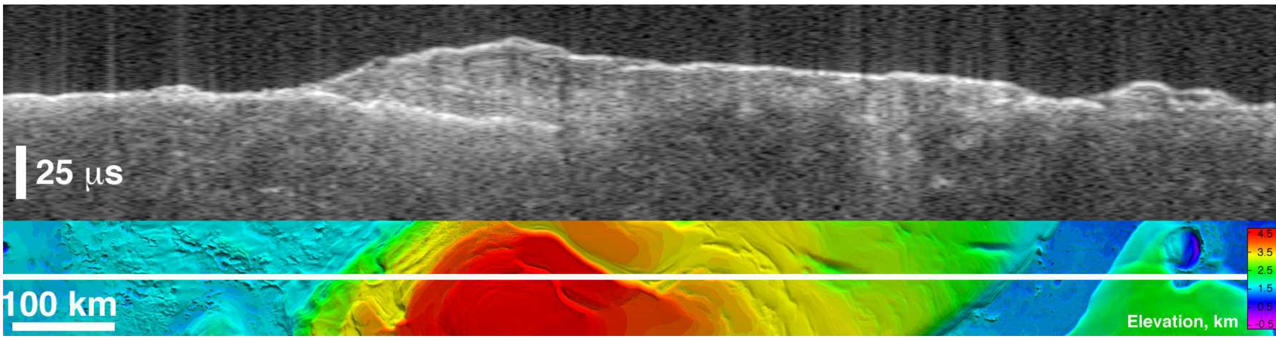
*The Mars Express spacecraft used its MARSIS experiment to send radio waves down to Mars and interpret the echoes it sent back. Based on the data, scientists believe there is water below the surface of Mars. [ESA]*



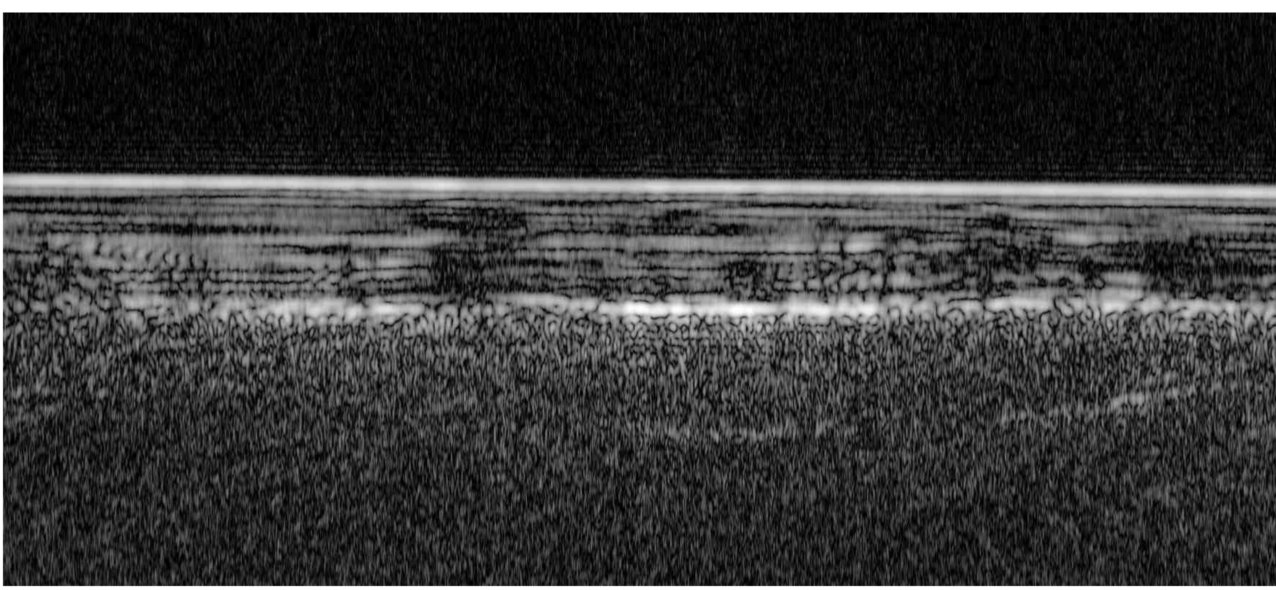

*ESA's Mars Express has used radar signals bounced through underground layers of ice to find evidence of a pond of water buried below the south polar cap. Twenty-nine dedicated observations were made between 2012 and 2015 in the Planum Australe region at the south pole using the Mars Advanced Radar for Subsurface and Ionosphere Sounding instrument, MARSIS. A new mode of operations established in this period enabled a higher quality of data to be retrieved than earlier in the mission. The 200 km square study area is indicated in the left-hand image and the radar footprints on the surface are indicated in the middle image for multiple orbits. The greyscale background image is a Thermal Emission Imaging System image from NASA's Mars Odyssey, and highlights the underlying topography: a mostly featureless plain with icy scarps in the lower right (south is up). The footprints are colour-coded corresponding to the 'power' of the radar signal reflected from features below the surface. The large blue area close to the centre corresponds to the main radar-bright area, detected on many overlapping orbits of the spacecraft. A subsurface radar profile is shown in the right hand panel for one of the Mars orbits. The bright horizontal feature at the top represents the icy surface of Mars in this region. The south polar layered deposits – layers of ice and dust – are seen to a depth of about 1.5 km. Below is a base layer that in some areas is even much brighter than the surface reflections, highlighted in blue, while in other places is rather diffuse. Analysing the details of the reflected signals from the base layer yields properties that correspond to liquid water. The brightest reflections are centred around 193°E/81°S in the intersecting orbits, outlining a well-defined, 20 km-wide zone. [Context map: NASA/Viking; THEMIS background: NASA/JPL-Caltech/Arizona State University; MARSIS data: ESA/NASA/JPL/ASI/Univ. Rome; R. Orosei et al 2018]*

The search that detected what might be liquid water began upon MEO entering orbit in 2003, but the study itself is based on data collected from 2012 and 2015. MARSIS sends radar signals and measures the properties of the reflected beams – including the time it takes for signals to bounce and return and the difference in intensity of the sent signal and returned reflections. The time and intensity of the reflections reveal information about the surface – fast returns may mean solid rock immediately below, while interfaces between rock and ice, or ice and water and rock, produce more complicated and delayed signals. Liquid water is a very different material than either rock or ice in terms of radar reflectivity, making its presence stand out brightly compared to the material around it. These patches were observed during early passes of the MEO, but were not always observed for reasons that have to do with how the data was processed.

Radar measurements performed by the MEO before 2010 were processed by the onboard computer, involving data averaging before being sent to Earth. This is efficient, but resulted in only some of the data containing evidence for liquid water radar reflections – all due to the detected region being relatively small compared to the surveyed region. Astrophotographers know the consequences of omission attributed to the preprocessing of images by onboard computers – raw image formats are always preferred from DSLR cameras over the compressed jpeg formats that sacrifice image quality and fine detail for portability. In 2010, a change was made to the way the radar image data handled, with select data stored and returned to Earth unmodified. The techniques used to obtain this raw radar data from 2012 to 2015 are not just a feat of engineering,




*The upper image of this composite is a 'radargram' from the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) on board ESA's Mars Express. It shows data from the subsurface of Mars in the water-ice-rich layered deposits that surround the south pole of the planet. The lower image shows the position of the ground track of the spacecraft (indicated by a white line) on a topographic map of the area based on data from the MOLA laser altimeter on board NASA's Mars Global Surveyor. The images are 1250 kilometers wide. The MARSIS radar echo trace splits into two traces on the left side of the image, at the point where the ground track crosses from the surrounding plains onto elevated layered deposits. The upper trace is the echo from the surface of the deposits, while the lower trace is interpreted to be the boundary between the lower surface of the deposits and the underlying material. The strength of the lower echo suggests that the intervening material is nearly pure water ice. Near the image center, the bright lower echo abruptly disappears for unknown reasons. The time delay between the two echoes reaches a maximum of 42 microseconds left of center, corresponding to a thickness of 3.5 kilometres of ice. The total elevation difference shown in the topographic map is about 4 kilometres between the lowest surface (purple) and the highest (red). [NASA/JPL/ASI/ESA/Univ. of Rome/MOLA Science Team]*

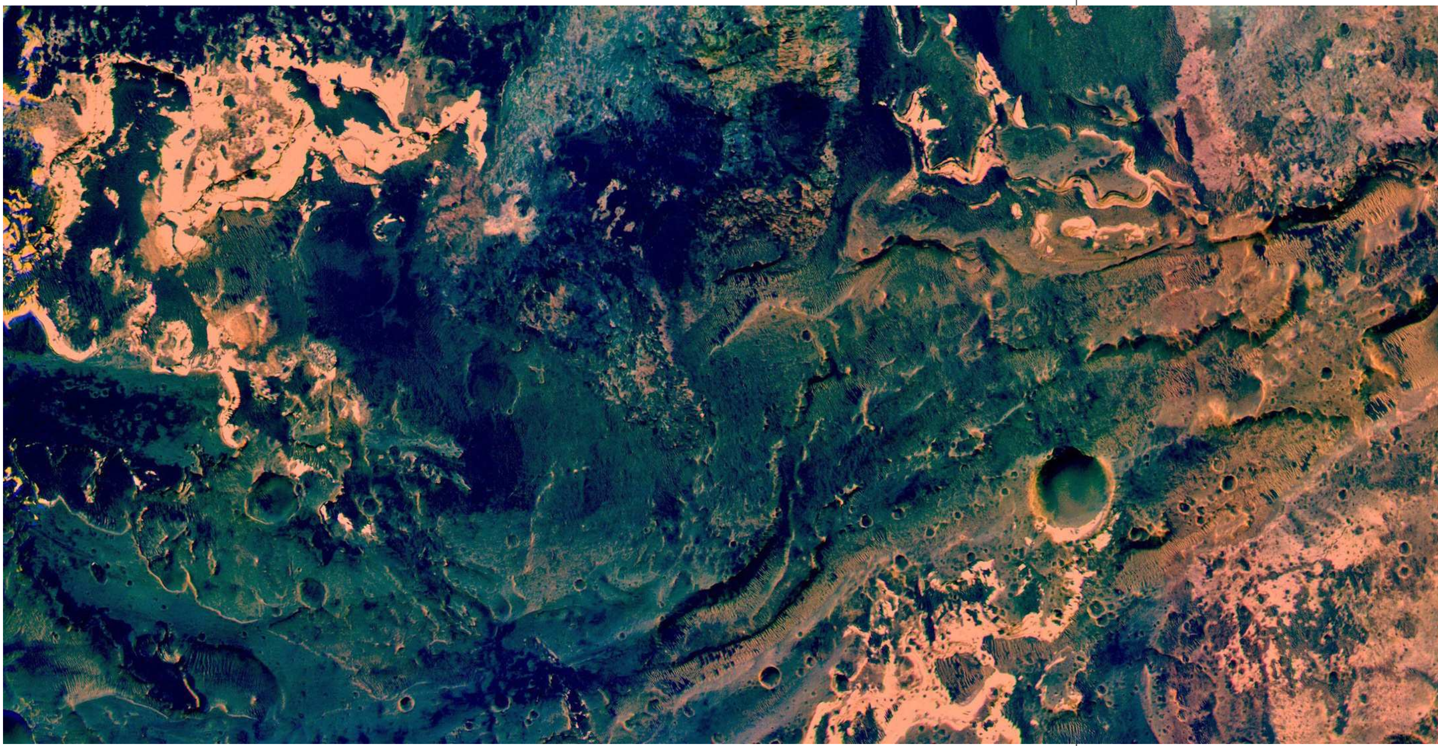


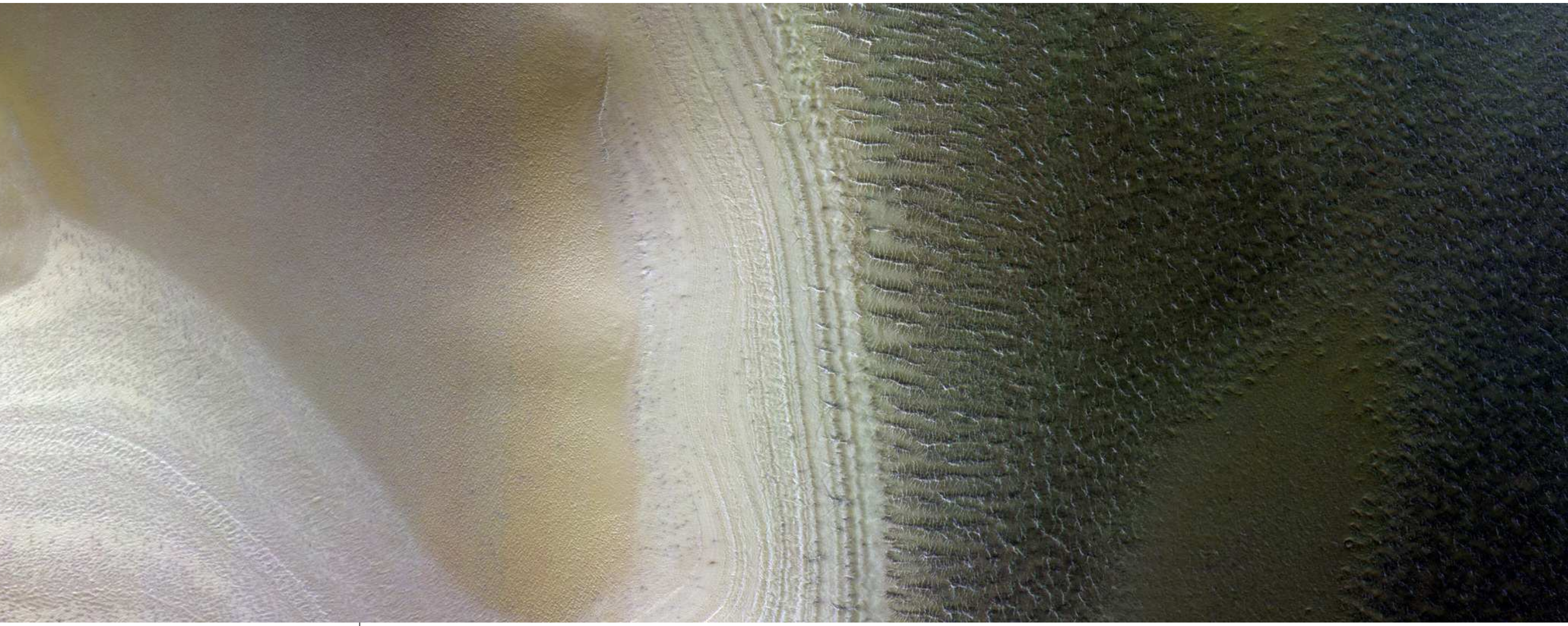
*ESA's Mars Express has used radar signals bounced through underground layers of ice to identify a pond of water buried below the surface. This image shows an example radar profile for one of 29 orbits over the 200 x 200 km study region in the south polar region of Mars. The bright horizontal feature at the top corresponds to the icy surface of Mars. Layers of the south polar layered deposits – layers of ice and dust – are seen to a depth of about 1.5 km. Below is a base layer that in some areas is even much brighter than the surface reflections, while in other places is rather diffuse. The brightest reflections from the base layer – close to the centre of this image – are centred around 193°E/81°S in all intersecting orbits, outlining a well-defined, 20 km wide subsurface anomaly that is interpreted as a pond of liquid water. [ESA/NASA/JPL/ASI/Univ. Rome; R. Orosei et al. 2018]*

ExoMars Trace Gas Orbiter captured this view of part of the south polar ice cap on Mars on 13 May 2018. The poles of Mars have huge ice caps that are similar to Earth's polar caps in Greenland and Antarctica. These caps are composed primarily of water ice and were deposited in layers that contain varying amounts of dust. They are referred to as the martian Polar Layered Deposits (PLD). Thanks to massive canyons that dissect the layered deposits, orbiting spacecraft can view the layered internal structure. The ExoMars orbiter's Colour and Stereo Surface Imaging System, CaSSIS, viewed this 7 x 38 km segment of icy layered deposits near the margin of the South PLD, which extend as far north as 73°S. Here, CaSSIS has imaged remnant deposits within a crater at this margin. The beautiful variations in colour and brightness of the layers are visible through the camera's colour filters. It highlights the bright ice and the redder sandy deposits toward the top of the image. The ExoMars pro- gramme is a joint endeavour between ESA and Roscosmos. [ESA/Roscosmos/CaSSIS, CC BY-SA 3.0 IGO]

but are also a testament to the abilities of researchers and their equipment to be flexible when new approaches are needed – even when technicians must be creative from tens or hundreds of millions of kilometers away.

The temperature of this liquid body cannot be directly measured without knowledge of its actual composition, but the estimated temperature for the ice/rock interface at the polar caps is as low as -68°C. The measure-



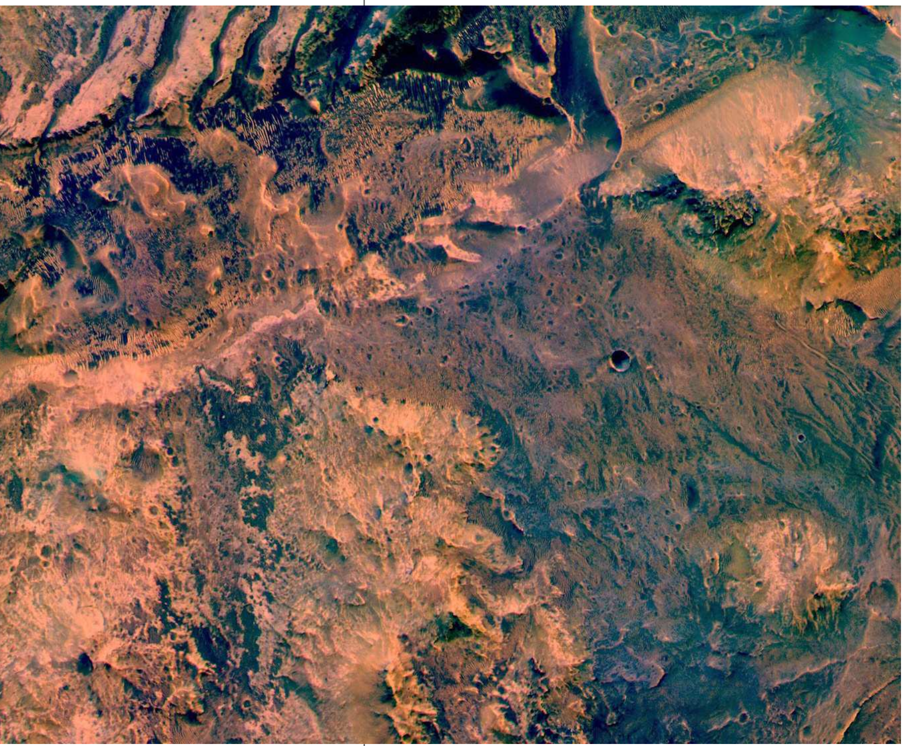


ment of high radar reflectivity aside, astrogeologists and new chemistry students alike might ask the same question – what possible conditions could depress the freezing point of water so low? To begin, the detected liquid water at the south polar cap is below 1.5 km of ice. Water behaves differently under pressure than most other molecules because of the way it forms crystals when it freezes – the average distance between molecules actually increasing slightly compared to the liquid phase, producing a slightly less dense solid. You know this from experience – when a lake freezes over, even the largest pieces of ice float. If water behaved like most other liquids upon freezing, ice would sink to the bottom.

Frozen water under high pressure relieves the strain from above by having its lattice fall back into unstructured, more closely-spaced water molecules. This is how ice skaters are able to move smoothly around an ice rink – the pressure exerted by their body melts the ice directly in contact with their skates, producing a tiny pocket of liquid water over which the skates glide.

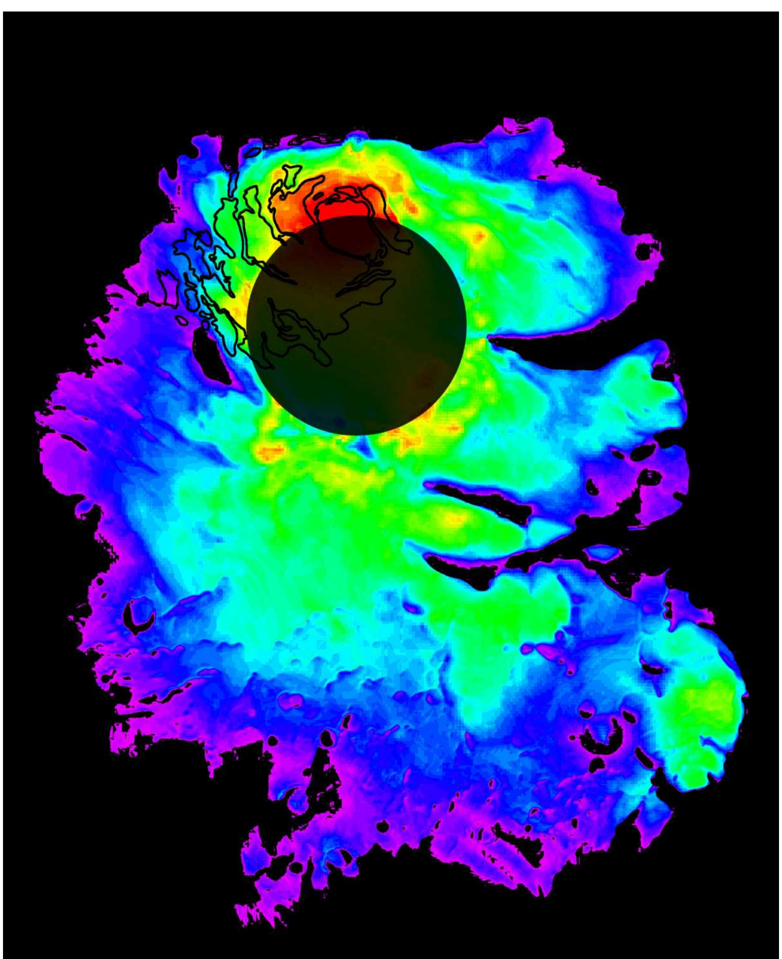
An analogous high-pressure situation exists on Earth. Lake Vostok is the largest of the nearly 400 subglacial lakes discovered in Antarctica. At 250 km long by 50 km wide, averaging almost one-half km in depth, Vostok is a massive fresh-water liquid body buried under more than 4 km of ice. Lake Vostok lies between a massive ice sheet and solid rock – just the situation detected on Mars. The conditions that make Lake Vostok and other subglacial lakes liquid on Earth are easier to explain away using only a pressure argument – the pressure experienced in Lake Vostok is a combination of 4.5 km of ice above and an Earth gravity three-times greater than that of Mars.

The detected liquid water on Mars is under one-third as much ice on a planet with one-third the gravity, which produces only a small fraction of the pressure experi-

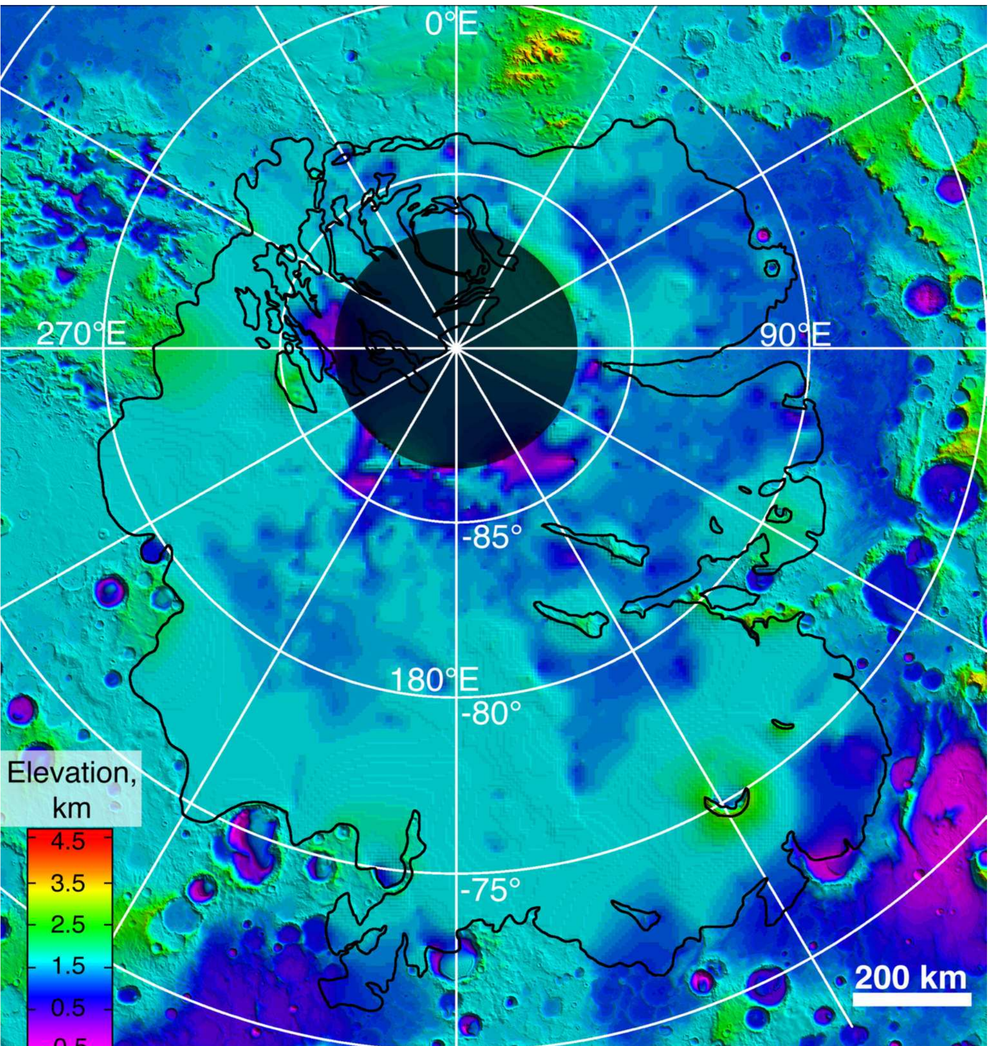


*ExoMars Trace Gas Orbiter showing the region where the ancient Uzboi Vallis enters Holden crater in the southern hemisphere of Mars. The valley begins on the northern rim of the Argyre basin and was formed by running water. The fluvial deposits are clearly visible in the impact cratered terrain. The image was taken by the orbiter's Colour and Stereo Surface Imaging System, CaSSIS on 31 May 2018 and captures an approximately 22.7 x 6.6 km segment centred at 26.8°S/34.8°W. North is to the bottom left in this orientation. [ESA/Roscosmos/CaSSIS, CC BY-SA 3.0 IGO]*

enced by the Vostok fresh water. Additionally, thermal energy may contribute to the estimated -3°C temperature for Lake Vostok – an almost balmy temperature compared to the possible -68°C temperature for the detected Martian liquid water.
Pressure from above is an obvious contributor in the Martian case because we see the ice sheet – but it cannot be the only factor given what we know about the response of ice to pressure from above. A second contributing factor is difficult to measure directly for a liquid water body buried so deeply, but is the basis for our understanding of all forms of liquid water on the Martian surface today. To lower the freezing point of water at home, simply add table salt (NaCl). Fresh water freezes at 0°C, the freezing point of seawater rests at -2°C, and a saturated salt water sample freezes at -21°C – all due to how the $Na^+$ and $Cl^-$ ions disrupt ice formation. The ice-disrupting behavior of salts can be enhanced by mixing several different kinds of salts together. On Mars, the perchlorates of sodium (Na), magnesium (Mg), and calcium (Ca) have all been detected by the many rovers capable of analyzing the chemical make-up of surface samples. In the right concentrations, it is possible to depress the freezing point to as low as -74°C – slightly colder than the predicted temperature of the detected liquid zone. The necessary ingredients for greatly depressing the freezing point of water may all be present in the reflective zones both in terms of chemistry and geology – although it must be noted that this liquid water would be anything but drinkable. All indications for present liquid water on Mars are much better described as very salty brines. On Earth, brines are used as a preservative – a liquid better suited for killing microbial



*This map shows the thickness of the south polar layered deposits of Mars, an ice-rich geologic unit that was probed by the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) on board ESA's Mars Express. The map was generated by comparing the elevation of the bed as determined by MARSIS with the high-resolution map of surface topography obtained by the Mars Orbiter Laser Altimeter (MOLA) aboard NASA's Mars Global Surveyor. The thickness of the layered deposits is shown by colors, with purple representing the thinnest areas, and red the thickest. The total volume of ice in the layered deposits is equivalent to a water layer 11 metres deep, if spread evenly across the planet. [NASA/JPL/ASI/ESA/Univ. of Rome/MOLA Science Team/USGS]*




*This map shows the topography of the south polar region of Mars, including topography buried by thick deposits of icy material. The map is a combination of subsurface elevation data acquired by the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) aboard the ESA's Mars Express orbiter and surface elevation data acquired by the Mars Orbiter Laser Altimeter aboard NASA's Mars Global Surveyor orbiter. The black line shows the boundary of the south polar layered deposits, an ice-rich geologic unit that was probed by MARSIS. Elevation values within the black outline, as measured by MARSIS, show the topography at the boundary between the layered deposits and the underlying material, an interface known as the 'bed' of the deposits. The elevation of the terrain is shown by colors, with purple and blue representing the lowest areas, and orange and red the highest. The total range of elevation shown is about 5 kilometres. The radar data reveal previously undetected features of topography of the bed, including depressions as deep as 1 kilometre shown in purple in the near-polar region. The boundary of the layered deposits was mapped by scientists from the U.S.G.S. The dark circle in the upper center is the area pole-ward of 87° south latitude, where MARSIS data cannot be collected. The map covers an area 1670 by 1800 kilometres. [NASA/JPL/ASI/ ESA/Univ. of Rome/ MOLA Science Team/USGS]*

life than a medium in which such organisms might exist.

That final – and most interesting – question remains. Could this possible briny, subglacial lake support life? The general consensus is that the chances are very small. When scientists state that liquid water is a necessity for life, implicit in that statement is the fact that liquid water has enough energy to allow organic molecules to move and chemistry to happen. A possibly -68°C salty brine is far removed from tropical sea water, allowing, at best, slow movement of dissolved molecules and only slow and infrequent chemistry. That said, Earth is full with extremophiles that grow and thrive in environments that would quickly kill off other organisms – and 4 billion years is a long time to adapt to inhospitable conditions.

Upcoming Mars missions will be directly probing the likelihood of existing or ancient life on the planet, and astrobiologists anxiously await the findings. To have life develop independently on two or more bodies in our own Solar System would fundamentally change our perceptions of life beyond our very small neighborhood in ways far more profound than how the discovery of exoplanets has changed our understanding of planetary formation.

# ESO's VLT sees `Oumuamua getting a boost

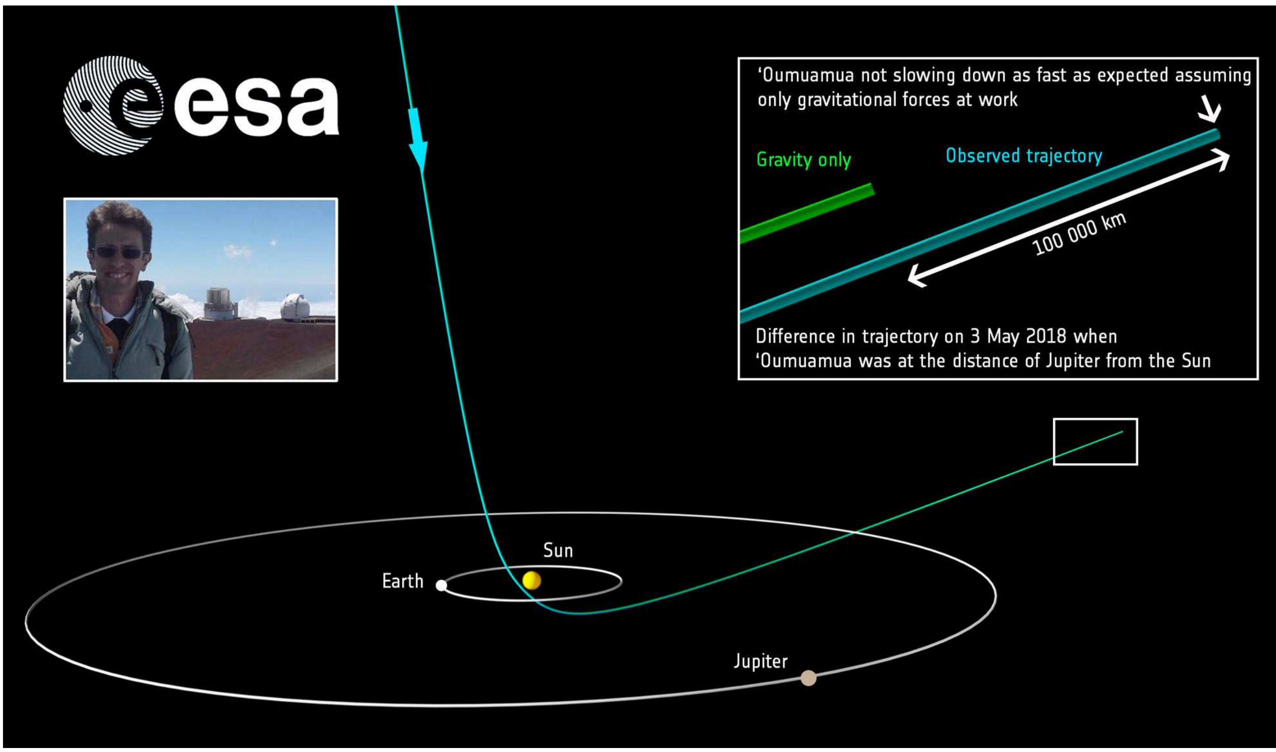
*by ESO*

`Oumuamua — the first interstellar object discovered within our Solar System — has been the subject of intense scrutiny since its discovery in October 2017. `Oumuamua, pronounced "oh-MOO-ah-MOO-ah", was first discovered using the Pan-STARRS telescope at the Haleakala Observatory, Hawaii. Its name means "scout" in Hawaiian, and reflects its nature as the first known object of interstellar origin to have entered the Solar System. The original observations indicated it was an elongated, tiny object whose colour were similar to that of a comet.

Now, by combining data from the ESO's Very Large Telescope and other observatories, an international team of astronomers has found that the object is moving faster than predicted. The measured gain in speed is tiny and `Oumuamua is still slowing down because of the pull of the Sun — just not as fast as predicted by celestial mechanics. The team, led by Marco Micheli (European Space Agency) explored several scenarios to explain the faster-than-predicted speed of this peculiar interstellar visitor. The most likely explanation is that `Oumuamua is venting material from its surface due to solar heating — a behaviour known as outgassing. The thrust from this ejected material is thought to pro-

*This artist's impression shows the first interstellar object discovered in the Solar System, `Oumuamua. Observations made with ESO's Very Large Telescope, the NASA/ESA Hubble Space Telescope, and others show that the object is moving faster than predicted while leaving the Solar System. Researchers assume that venting material from its surface due to solar heating is responsible for this behaviour. This outgassing can be seen in this artist's impression as a subtle cloud being ejected from the side of the object facing the Sun. As outgassing is a behaviour typical for comets, the team thinks that `Oumuamua's previous classification as an interstellar asteroid has to be corrected. [ESA/Hubble, NASA, ESO, M. Kornmesser]*

Animation based on an artistic representation showing the first interstellar object, `Oumuamua. [ESA/Hubble, NASA, ESO, M. Kornmesser]




*This diagram shows the orbit of the interstellar object `Oumuamua as it passes through the Solar System. It shows the predicted path of `Oumuamua and the new course, taking the new measured velocity of the object into account. `Oumuamua passed the distance of Jupiter's orbit in early May 2018 and will pass Saturn's orbit January 2019. It will reach a distance corresponding to Uranus' orbit in August 2020 and of Neptune in late June 2024. In late 2025 `Oumuamua will reach the outer edge of the Kuiper Belt, and then the heliopause — the edge of the Solar System — in November 2038. In the inset, Marco Micheli. [ESA]*

vide the small but steady push that is sending `Oumuamua hurtling out of the Solar System faster than expected — as of 1 June 2018 it is traveling at roughly 114,000 kilometres per hour. Such outgassing is a behaviour typical for comets and contradicts the previous classification of `Oumuamua as an interstellar asteroid. *"We think this is a tiny, weird comet,"* commented Marco Micheli. *"We can see in the data that its boost is getting smaller the farther away it travels from the Sun, which is typical for comets."* Usually, when comets are warmed by the Sun they eject dust and gas, which form a cloud of material — called a coma — around them, as well as the characteristic tail. However, the research team could not detect any visual evidence of outgassing. *"We did not see any dust, coma, or tail, which is unusual,"* explained co-author Karen Meech of the University of Hawaii, USA. Meech led the discovery team's characterisation of `Oumuamua in 2017. *"We think that `Oumuamua may vent unusually large, coarse dust grains."*

The team speculated that perhaps the small dust grains adorning the surface of most comets eroded during `Oumuamua's journey through interstellar space, with only larger dust grains remaining.

Though a cloud of these larger particles would not be bright enough to be detected, it would explain the unexpected change to `Oumuamua's speed. Not only is `Oumuamua's hypothesised outgassing an unsolved mystery, but also its interstellar origin. The team originally performed the new observations on `Oumuamua to exactly determine its path which would have probably allowed it to trace the object back to its parent star system. The new results means it will be more challenging to obtain this information.

*"The true nature of this enigmatic interstellar nomad may remain a mystery,"* concluded team member Olivier Hainaut, an astronomer at ESO. *"`Oumuamua's recently-detected gain in speed makes it more difficult to be able to trace the path it took from its extrasolar home star."*

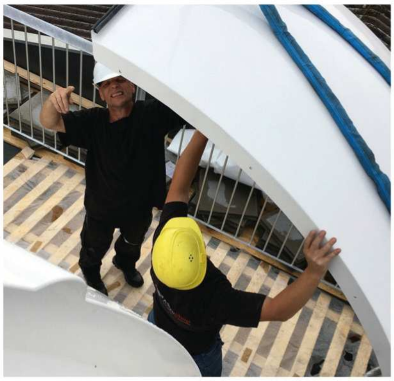

# Make the dream of having your own observatory reality

*Many amateur astronomers would love to have their own observatory. Your telescope then no longer has to be moved and remains ready for immediate use at any time. The dome protects the telescope from stray light, wind and weather.*

**Consulting – Planning – Assembly**

Astroshop has a team of over 50 employees who have been working to make astronomical observing easier and more exciting for over 15 years. Our specialists in large stationary telescopes and observatories will be more than happy to advise you on the best way to go about achieving the dream of having your own observatory.

We offer everything from a single source: telescope, dome and complete set-ups – we are looking forward to hand your own private observatory over to you – complete and ready to use!



Our customers include not only experienced amateur astronomers, but also clubs, schools, universities and other institutions - in many countries in Europe and worldwide.

> You can see some of our reference projects at www.astroshop.eu/observatories

Contact

**Address**
Astroshop.eu • c/o nimax GmbH
Otto-Lilienthal-Straße 9 • 86899 Landsberg • Germany

**Phone**
+49 8191 94049-61

**Mail**
service@astroshop.eu

Astroshop.eu

# Hubble and Gaia team up to fuel cosmic conundrum

***by NASA/ESA***

Combining observations from NASA's Hubble Space Telescope and the European Space Agency's (ESA) Gaia space observatory, astronomers further refined the previous value for the Hubble constant, the rate at which the universe is expanding from the big bang 13.8 billion years ago. But as the measurements have become more precise, the team's determination of the Hubble constant has become more and more at odds with the measurements from another space observatory, ESA's Planck mission, which is coming up with a different predicted value for the Hubble constant.

Planck mapped the primeval universe as it appeared only 360,000 years after the big bang. The entire sky is imprinted with the signature of the big bang encoded in microwaves. Planck measured the sizes of the ripples in this Cosmic Microwave Background (CMB) that were produced by slight irregularities in the big bang fireball. The fine details of these ripples encode how much dark matter and normal matter there is, the trajectory of the universe at that time, and other cosmological parameters.

These measurements, still being assessed, allow scientists to predict how the early universe would likely have evolved into the expansion rate we can measure today. However, those predictions don't seem to match the new measurements of our nearby contemporary universe.

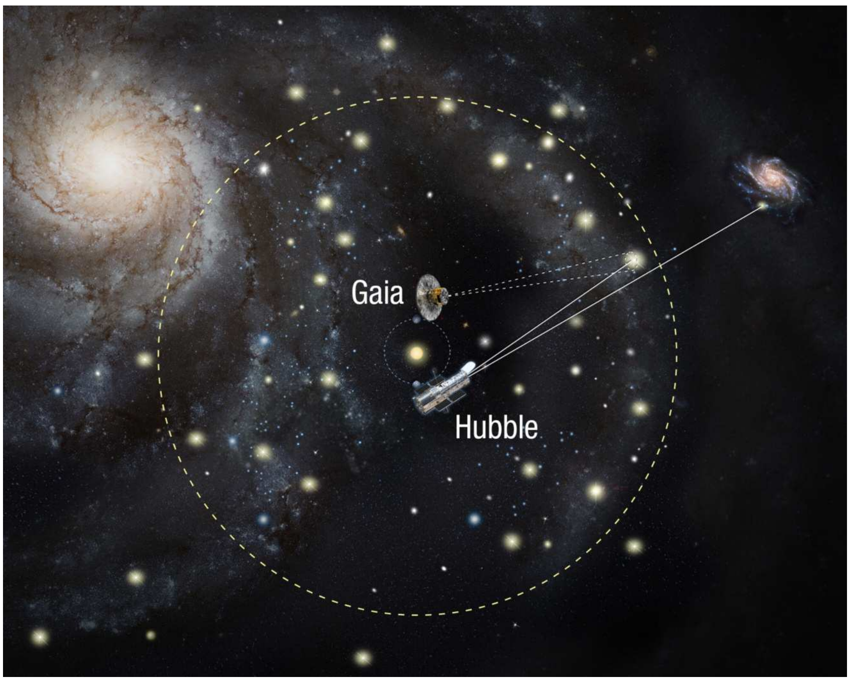
*"With the addition of this new Gaia and Hubble Space Telescope data, we now have a serious tension with the Cosmic Microwave Background data,"* said Planck team member and lead analyst George Efstathiou of the Kavli Institute for Cosmology in Cambridge, England, who was not involved with the new work.

*"The tension seems to have grown into a full-blown incompatibility between our views of the early and late time universe,"* said team leader and Nobel Laureate Adam Riess of the Space Telescope Science Institute and the Johns Hopkins University in Baltimore, Maryland. *"At this point, clearly it's not simply some gross error in any one measurement. It's as though you predicted how tall a child would become from a growth chart and then found the adult he or she became greatly exceeded the prediction. We are very perplexed."*

In 2005, Riess and members of the SHOES (Supernova H0 for the Equation of State) Team set out to measure the universe's expansion rate with unprecedented accuracy. In the following years, by refining their techniques, this team shaved down the rate measurement's uncertainty to unprecedented levels. Now, with the power of Hubble and Gaia combined, they have reduced that uncertainty to just 2.2 percent. Because the Hubble constant is needed to estimate the age of the universe, the long-sought answer is one of the most important numbers in cosmology. It is named after astronomer Edwin Hubble, who nearly a century ago discovered that the universe was uniformly expanding in all directions — a finding that gave birth to modern cosmology.

Galaxies appear to recede from Earth proportional to their distances, meaning that the farther away they are, the faster they appear to be moving away. This is a consequence of expanding space, and not a value of true space velocity. By measuring the value of the Hubble constant over time, astronomers can construct a picture of our cosmic evolution, infer the make-up of the universe, and uncover clues concerning its ultimate fate.

The two major methods of measuring this number give incompatible results. One method is direct, building a cosmic "distance ladder" from measurements of stars in our local universe. The other method uses the CMB to measure the trajectory of the universe shortly after the Big Bang and then uses physics to describe the universe and extrapolate to the present expansion rate. Together, the measurements should provide an end-to-end test of our basic understanding of the so-called "Standard Model" of the universe. However, the pieces don't fit.




*Using two of the world's most powerful space telescopes — NASA's Hubble and ESA's Gaia — astronomers have made the most precise measurements to date of the universe's expansion rate. This is calculated by gauging the distances between nearby galaxies using special types of stars called Cepheid variables as cosmic yardsticks. By comparing their intrinsic brightness as measured by Hubble, with their apparent brightness as seen from Earth, scientists can calculate their distances. Gaia further refines this yardstick by geometrically measuring the distances to Cepheid variables within our Milky Way galaxy. This allowed astronomers to more precisely calibrate the distances to Cepheids that are seen in outside galaxies. [NASA, ESA, and A. Feild (STScI)]*

Using Hubble and newly released data from Gaia, Riess' team measured the present rate of expansion to be 73.5 kilometers (45.6 miles) per second per megaparsec. This means that for every 3.3 million light-years farther away a galaxy is from us, it appears to be moving 73.5 kilometers per second faster. However, the Planck results predict the universe should be expanding today at only 67.0 kilometers (41.6 miles) per second per megaparsec. As the teams' measurements have become more and more precise, the chasm between them has continued to widen, and is now about 4 times the size of their combined uncertainty.

Over the years, Riess' team has refined the Hubble constant value by streamlining and strengthening the "cosmic distance ladder," used to measure precise distances to nearby and far-off galaxies. They compared those distances with the expansion of space, measured by the stretching of light from nearby galaxies. Using the apparent outward velocity at each distance, they then calculated the Hubble constant.

To gauge the distances between nearby galaxies, his team used a special type of star as cosmic yardsticks or milepost markers. These pulsating stars, called Cepheid variables, brighten and dim at rates that correspond to their intrinsic brightness. By comparing their intrinsic brightness with their apparent brightness as seen from Earth, scientists can calculate their distances.

Gaia further refined this yardstick by geometrically measuring the distance to 50 Cepheid variables in the Milky Way. These measurements were combined with precise measurements of their brightnesses from Hubble. This allowed the astronomers to more accurately calibrate the Cepheids and then use those seen outside the Milky Way as milepost markers.

*"When you use Cepheids, you need both distance and brightness,"* explained Riess. Hubble provided the information on brightness, and Gaia provided the parallax information needed to accurately determine the distances. Parallax is the apparent change in an object's position due to a shift in the observer's point of view. Ancient Greeks first used this technique to measure the distance from Earth to the Moon.

*"Hubble is really amazing as a general-purpose observatory, but Gaia is the new gold standard for calibrating distance. It is purpose-built for measuring parallax—this is what it was designed to do,"* Stefano Casertano of Space Telescope Science Institute and a member of the SHOES Team added.

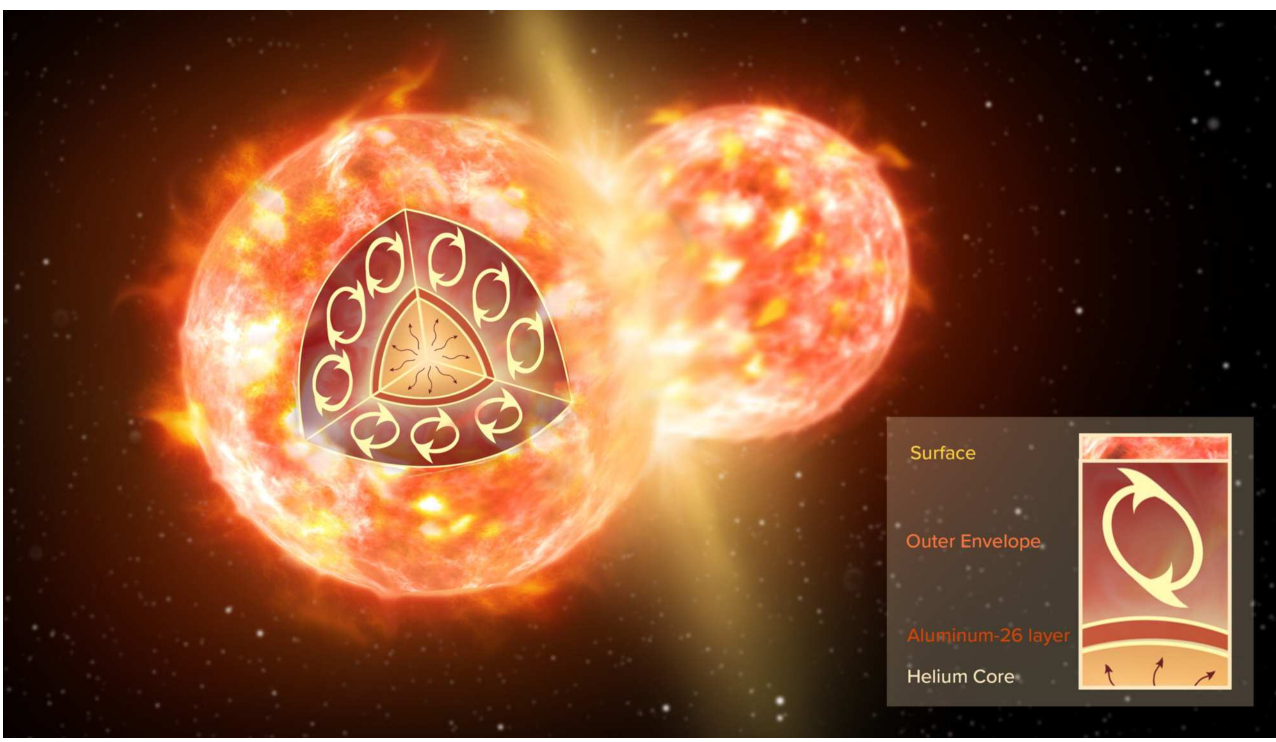
*"Gaia brings a new ability to recalibrate all past distance measures, and it seems to confirm our previous work. We get the same answer for the Hubble constant if we replace all previous calibrations of the distance ladder with just the Gaia parallaxes. It's a crosscheck between two very powerful and precise observatories."*

The goal of Riess' team is to work with Gaia to cross the threshold of refining the Hubble constant to a value of only one percent by the early 2020s. Meanwhile, astrophysicists will likely continue to grapple with revisiting their ideas about the physics of the early universe.

# Stellar corpse reveals origin of radioactive molecules

*by ESO*

A team of astronomers led by Tomasz Kamiński (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA), used the Atacama Large Millimeter/submillimeter Array (ALMA) and the NOrthern Extended Millimeter Array (NOEMA) to detect a source of the radioactive isotope aluminium-26. The source, known as CK Vulpeculae, was first seen in 1670 and at the time it appeared to observers as a bright, red "new star". Though initially visible with the naked eye, it quickly faded and now requires




*Artist impression of the collision of two stars, like the ones that formed CK Vulpeculae The inset illustrates the inner structure of one red giant before the merger. A thin layer of 26-aluminium (brown) surrounds a helium core. An extended convective envelope (not to scale), which forms the outermost layer of the star, can mix material from inside the star to the surface, but it never reaches deep enough to dredge 26-aluminium up to the surface. Only a collision with another star can disperse 26-aluminium. [NRAO/AUI/NSF; S. Dagnello]* powerful telescopes to see the remains of this merger, a dim central star surrounded by a halo of glowing material flowing away from it. 348 years after the initial event was observed, the remains of this explosive stellar merger have led to the clear and convincing signature of a radioactive version of aluminum, known as aluminium-26. This is the first unstable radioactive molecule definitively detected outside of the Solar System. Unstable isotopes have an excess of nuclear energy and eventually decay into a stable form.

*"This first observation of this isotope in a star-like object is also important in the broader context of galactic chemical evolution,"* notes Kamiński. *"This is the first time an active producer of the radioactive nuclide aluminum-26 has been directly identified."* Kamiński and his team detected the unique spectral signature of molecules made up of aluminum-26 and fluorine ($^{26}AlF$) in the debris surrounding CK Vulpeculae, which is about 2000 light-years from Earth. As these molecules spin and tumble through space, they emit a distinctive fingerprint of millimetre-wavelength light, a process known as rotational transition. Astronomers consider this the "gold standard" for detections of molecules. The observation of this particular isotope provides fresh insights into the merger process that created CK Vulpeculae. It also demonstrates that the deep, dense, inner layers of a star, where heavy elements and radioactive isotopes are forged, can be churned up and cast into space by stellar collisions.

*"We are observing the guts of a star torn apart three centuries ago by a collision,"* remarked Kamiński.

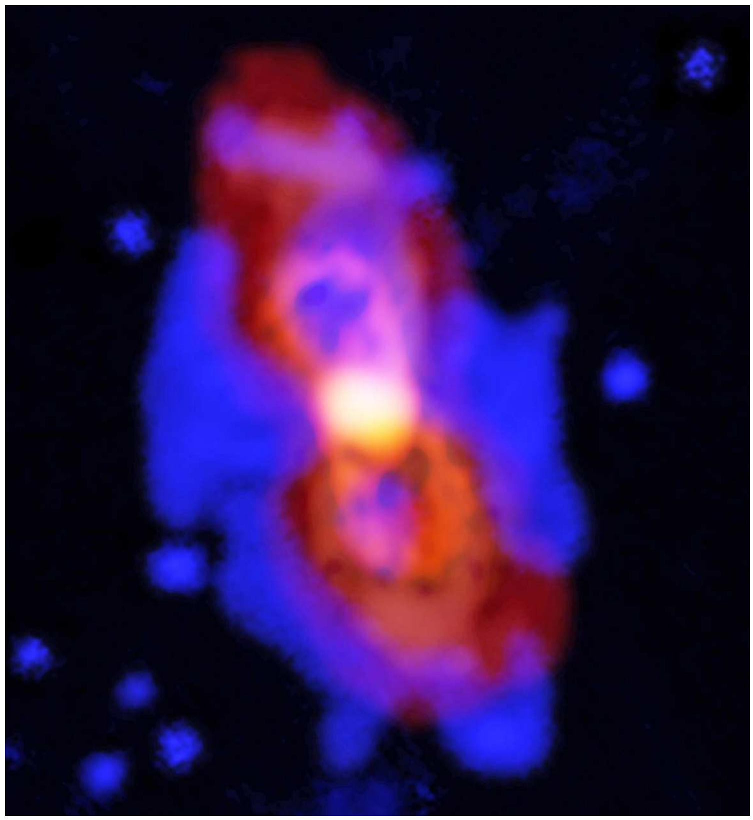
The astronomers also determined that the two stars that merged were of relatively low mass, one being a red giant star with a mass somewhere between 0.8 and 2.5 times that of our Sun.

Being radioactive, aluminium-26 will decay to become more stable and in this process one of the protons in the nucleus decays into a neutron. During this process, the excited nucleus emits a photon with very high energy, which we observe as a gamma ray.

Previously, detections of gamma ray emission have shown that around two solar masses of aluminium-26 are present across the Milky Way, but the process that created the radioactive atoms was unknown.

Furthermore, owing to the way that gamma rays are detected, their precise origin was also largely unknown.

With these new measurements, astronomers have definitively detected for the first time an unstable radioisotope in a molecule outside of our Solar System. At the same time, however, the team have concluded that the production of aluminium-26 by objects similar to CK Vulpeculae is unlikely to be the major source of aluminium-26 in the Milky Way. The mass of aluminium-26 in CK Vulpeculae is roughly a quarter of the mass of Pluto, and given that these events are so rare, it is highly unlikely that they are the sole producers of the isotope in the Milky Way galaxy. This leaves the door open for further studies into these radioactive molecules.



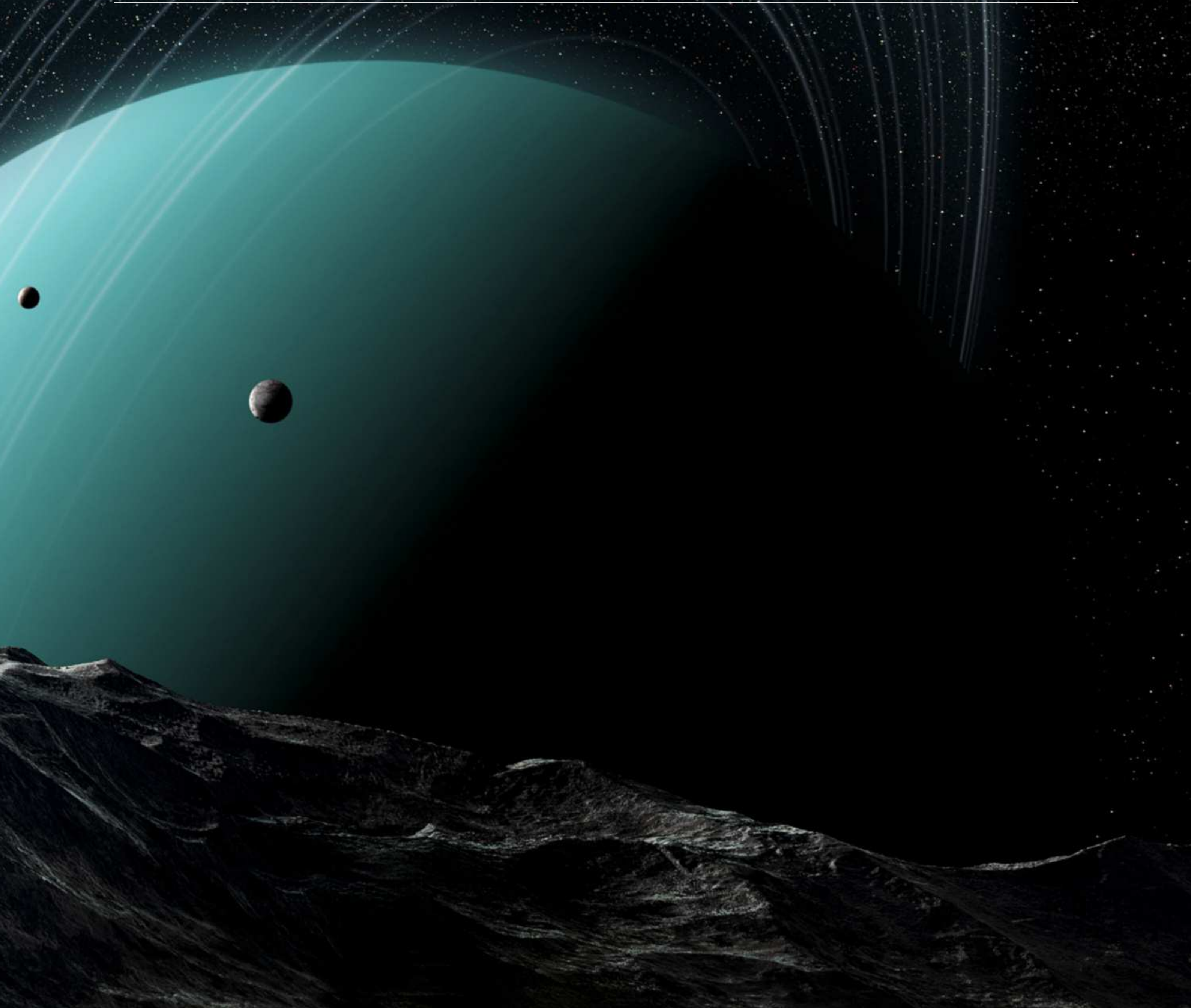
*Composite image of CK Vulpeculae, the remains of a double-star collision. This impact launched radioactive molecules into space, as seen in the orange double-lobe structure at the centre. This is an ALMA image of 27-aluminum monofluoride, but the rare isotropic version of AlF resides in the same region. The red, diffuse image is an ALMA image of the broader dust in the region. The blue is optical data from the Gemini observatory. [ALMA (ESO/NAOJ/NRAO), T. Kamiński; Gemini, NOAO/AURA/NSF; NRAO/AUI/NSF, B. Saxton]*

# A solution to the mysteries of Uranus

by Michele Ferrara

revised by Damian G. Allis
NASA Solar System Ambassador

***Planetology has made great strides in the last few decades. Thousands of exoplanets have been discovered and the atmospheres of distant worlds have been investigated, to the point of our being able to make meteorological forecasts. And yet, in our own solar system, there is the planet Uranus, for which we cannot distinguish the north pole from the south pole, we do not know why its rotation axis is lying horizontal in its orbit, and we do not even know why its atmosphere is much colder than expected. Recent numerical simulations provide answers to some of these questions, but a complete understanding of Uranus still alludes us.***



*Spectacular photomontage made by Jimmy Wallebring (Örebro, Sweden), which shows Uranus, some large moons, and rings as seen from the huge canyon Messina Chasma that characterizes the surface of the satellite Titania.*

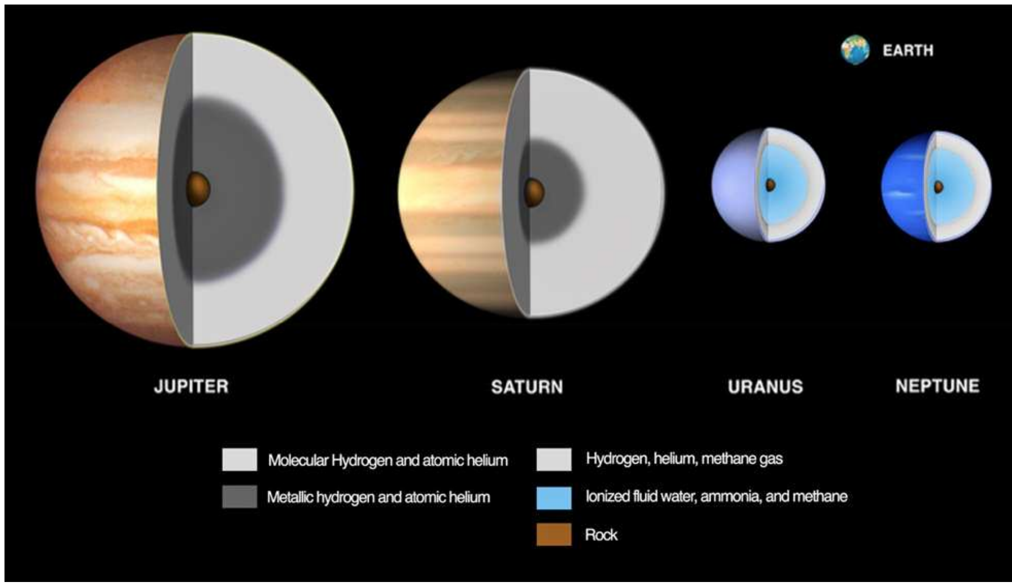
**Let's face it, Uranus is hardly ever a leading topic in the popularization of astronomy, perhaps more famous as the brunt of childish humor than scientific inquiry. There are not comparatively many exciting things to say about the seventh planet of our solar system. After the fast flyby performed by the Voyager 2 probe on January 24, 1986, which produced a leap in our knowledge of Uranus, only a few other pieces of information were added thanks to sporadic observations using large ground-based telescopes and, above all, the Hubble Space Telescope.**

**Even today, the modern profile of Uranus is only approximate: it is a frozen giant 50 thousand km in diameter; it is slightly larger but slightly less massive than Neptune; it probably has a small rocky nucleus topped by a dense and fluid ocean of water, methane and ammonia; it has an atmosphere dominated by hydrogen and helium, with a small percentage of methane that gives the planet its typical blue-green color.**

This brief description, however, neglects the two most mysterious aspects that make Uranus a very interesting subject for planetologists: its rotation axis is practically lying on the orbital plane, and its external atmosphere is colder than those of all the other planets – including Neptune, which is more than 1.5 billion km farther from the Sun. How are these peculiarities explained?
The first hypothesis on the exceptional inclination of the rotation axis of Uranus dates back to the mid-60s, when the Russian astronomer Viktor Safronov (father of the planetesimal theory, related to the formation of the planets) claimed that the large tilt in the rotation axis was the result of a collision between Uranus and a massive planet wandering in the solar system.

*The great British astronomer of German origin Wilhelm (William) Herschel, portrayed in 1785 by Lemuel Francis Abbott. On the side, the historic telescope with which he discovered the planet Uranus.*

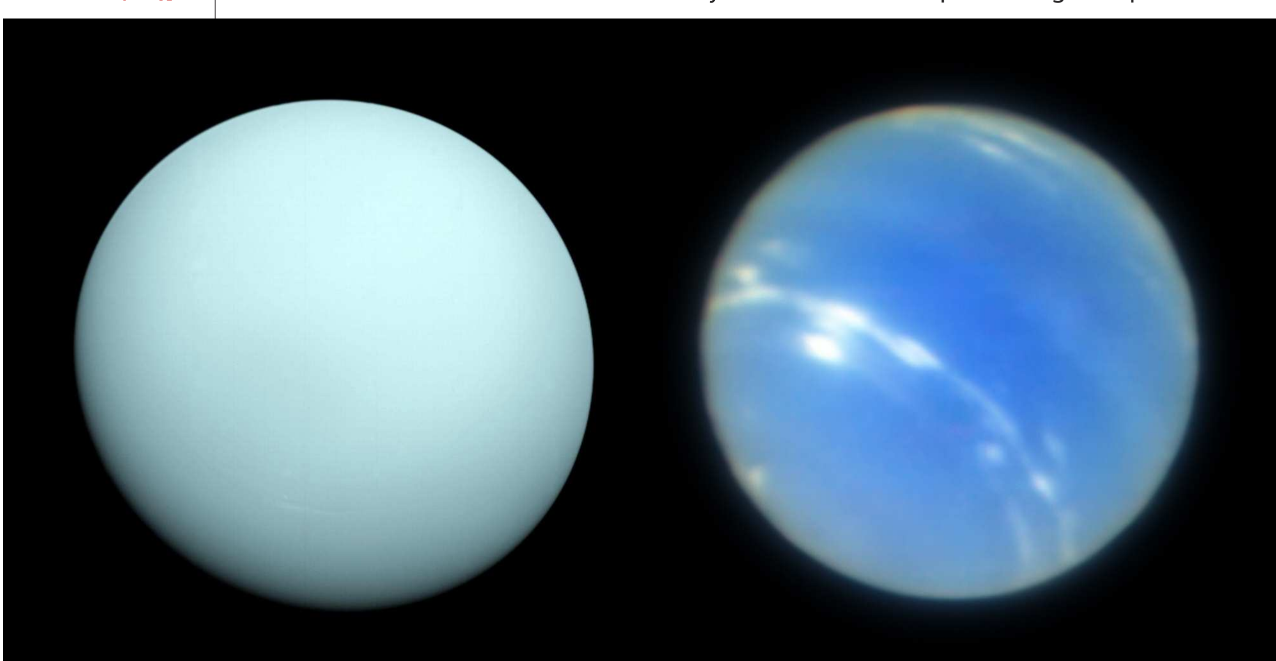
The idea found a discreet consensus in the scientific community, but since it was impossible to prove its validity at the time, it remained just an idea. Twenty years later (then around the mid-1980s), astronomers realized that the upper atmosphere of Uranus was incredibly cold: -224°C (-371°F). This temperature is what one would expect if the upper atmosphere was heated almost exclusively by the Sun and not by internal heating from the planetary core - as happens in the other giant planets. The surface thermal emission of Uranus is approximately in equilibrium with the insola-

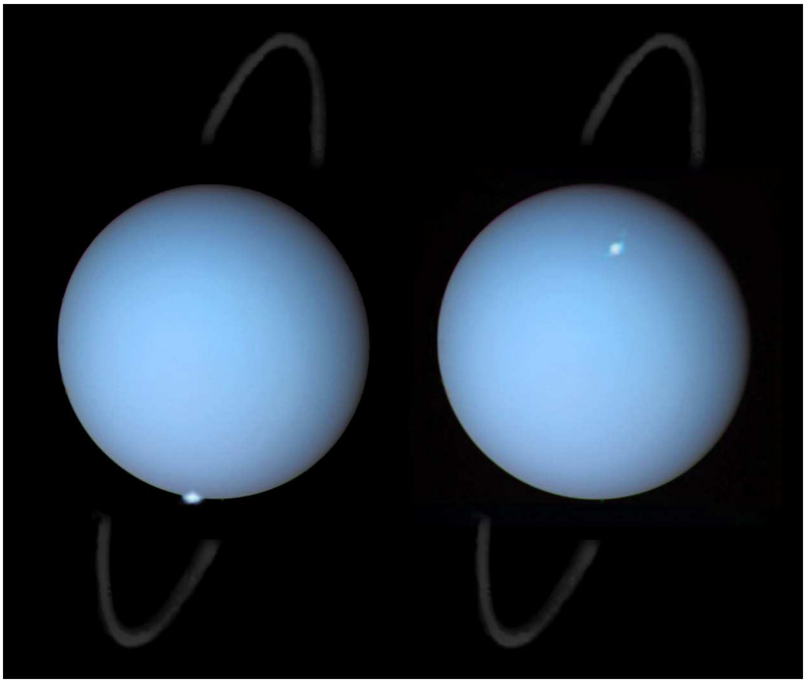



*Compositional differences among the giant planets and their relative sizes. Earth is shown for comparison. Jupiter and Saturn are primarily made of hydrogen and helium, the terrestrial planets are almost pure rock, while Uranus and Neptune are thought to be mainly watery. [JPL/Caltech, based on material from the Lunar and Planetary Institute] Below, on the left, Uranus imaged by the Voyager 2 spacecraft in 1986; on the right, Neptune recently imaged by the VLT in Chile. [NASA/JPL-Caltech, ESO/P. Weilbacher (AIP)]*

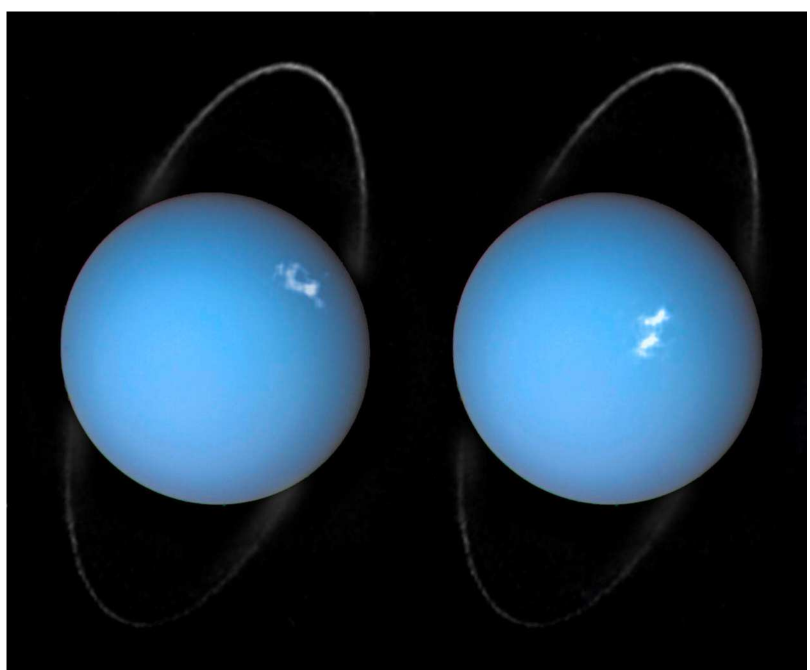
tion, which means that the heat flowing from below is negligible, a strange thing if we consider that the core temperature is estimated to be 5000°C. It is as if there was a layer of insulating material that prevents internal heat from radiating into the upper atmosphere and to outer space.

Almost at the same time as the discovery of this temperature anomaly, another equally enigmatic one was discovered: the magnetic field axis is highly asymmetrical, inclined more than 60° compared to the rotation axis and, moreover, not passing through the center of the planet. The origin of a planetary magnetic field is the rotation of a fluid mass – to have this axis not pass through the planet's center



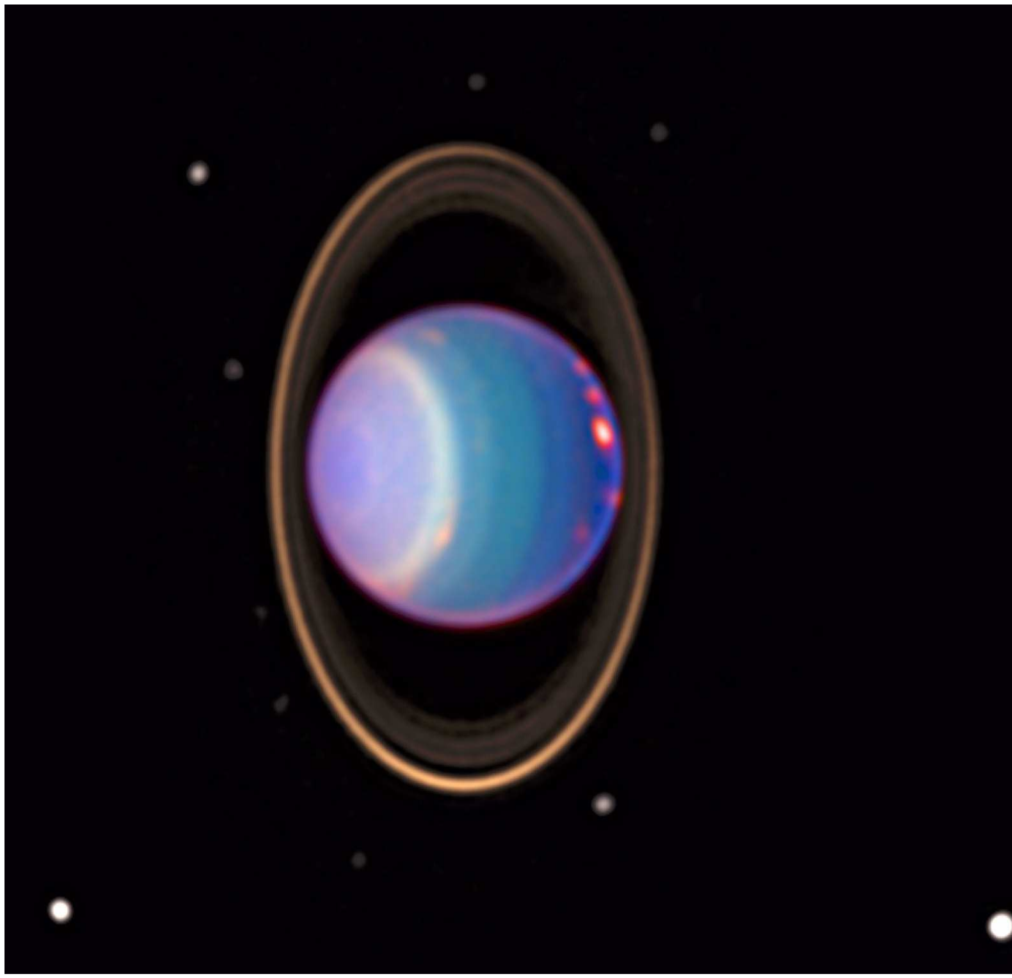


means that the fluid mass inside Uranus must be distributed very inhomogeneously. Can all these oddities of Uranus be brought back to a single cause? Possibly.
Both the thermal and magnetic anomalies are compatible with a planetary collision hypothesis: an event of that type would have conferred enormous quantities of material and energy to an existing planetary body already formed and differentiated, thus deeply altering its rotational structure and properties.
Testing Safronov's hypothesis has been a priority for planetologists for decades, but in spite of this, not much has been accomplished, even when considering the objective difficulty of studying an impenetrable planet placed almost 3 billion km from Earth. However, in some cases, what cannot be deduced by means the direct observation can be understood through computer simulations, which offer the not-negligible advantage of being able to represent a phenomenon with a decidedly long time duration if necessary.
The first convincing attempt to simulate the hypothetical impact suffered by Uranus shortly after the formation of the planetary system dates back to '92 and was run by a team of researchers led by W. L. Slattery. Because of the limited computing power available at the time, less than 10,000 particles virtually endowed with mass were included in the simulations. This meant the original simulation was of low resolution and not able to effectively (or at all) represent the less massive components of the two colliding bodies – and ignored the young Uranian atmosphere. Nonetheless, Slattery and colleagues succeeded in representing the collision event with sufficient detail to establish that the ideal mass of the impacting body had to be between 1 and 3 terrestrial masses. It was, in fact, by attributing these values to the virtual projectile that the dynamics of the impact provided scenarios similar to the real one.



*In the images on this page, we see the disk of Uranus (taken from the Voyager 2 probe in 1986) surrounded by its ring system (photographed by the Gemini Observatory in 2011, above, and by the Hubble Space Telescope, right). The white spots on the planet's disk are polar aurorae, imaged in the ultraviolet by Hubble. The strong phase displacement between the rotation axis and the magnetic axis is apparent. [NASA, ESA, and L. Lamy (Observatory of Paris, CNRS, CNES)]*

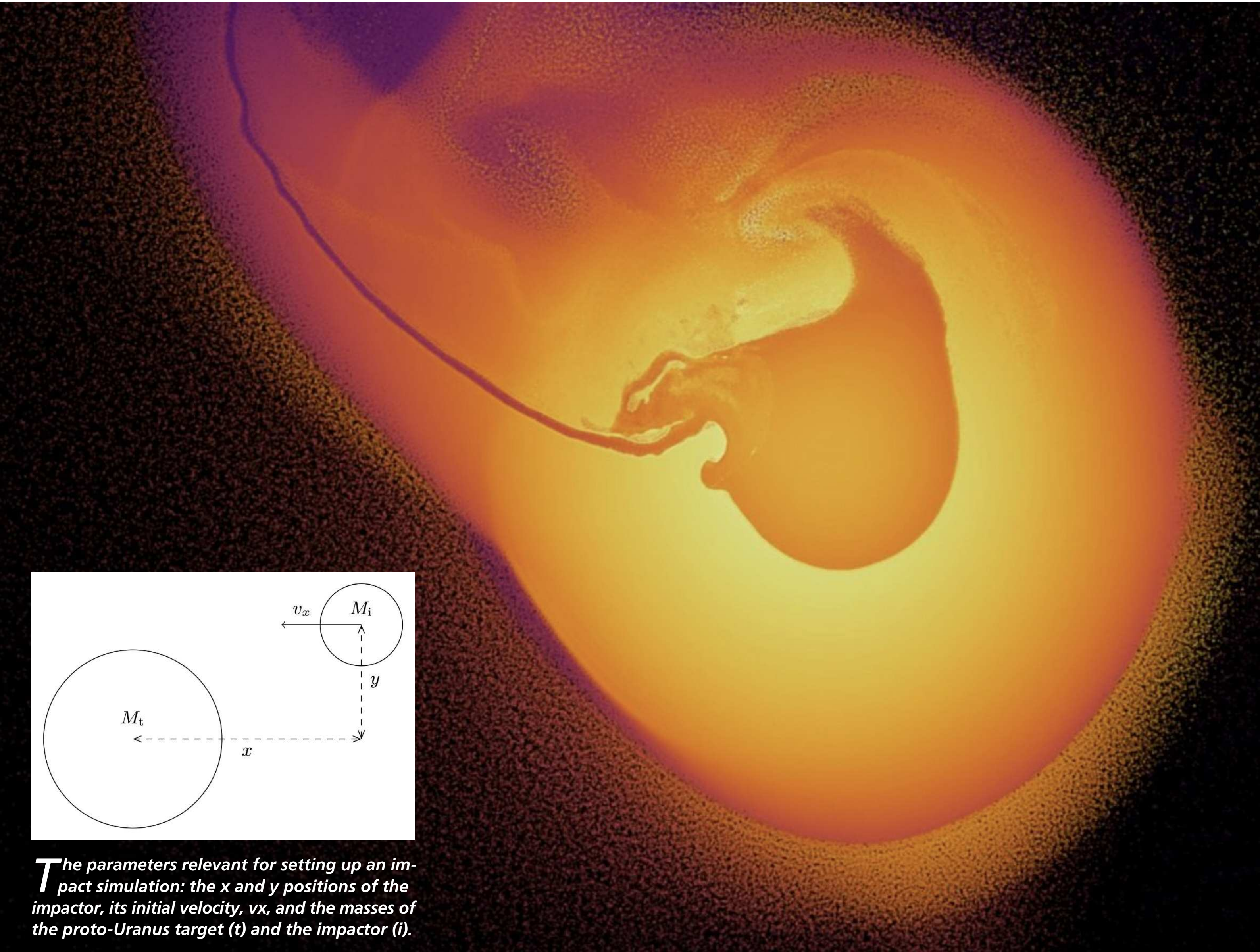
*This false-color image, created by Erich Karkoschka, processing data produced 20 years ago by Hubble's Near Infrared Camera and Multi-Object Spectrometer, shows numerous clouds (some of which are relatively warm), the ring system and 10 of the 27 moons orbiting around the planet. [NASA/JPL/STScI]*



In addition to the inclination of the rotation axis, it was also possible to represent within approximation the inhomogeneities of the internal structure that resulted from the mass carried by the impactor, and thus to give an answer to the question of the anomalous positioning of the magnetic field.

A cataclysmic event of that magnitude could not occur without some record among the large array of moons (not less than 27) that surround the planet: the material flung into orbit by the impact may have contributed to generating many of them. It is obvious that understanding the exact dynamics of the event would add relevant information to the general picture of the planetary system evolution as a whole. Nevertheless, after the work of the Slattery team, it took 26 years to see another group of researchers return to the simulation of Uranus and develop a better model. The first author of the new work is Jacob A. Kegerreis, of the Institute for Computational Cosmology of Durham University, UK. The results of the simulations appeared in the July issue of *The Astrophysical Journal*. Being able to count on (obviously) superior modern computing power, Kegerreis and colleagues started a series of simulations that included over fifty different scenarios of an impact between a young Uranus and an unknown planet in our early solar system.

By including around one million virtual particles, the new simulations succeeded in representing with good resolution the distribution of the rocky, icy and gaseous components before, during and after the impact.




*The parameters relevant for setting up an impact simulation: the x and y positions of the impactor, its initial velocity, vx, and the masses of the proto-Uranus target (t) and the impactor (i).*

The results of the new study essentially confirm those obtained by the team of Slattery, especially with regard to the mass of the adapter, undoubtedly close to twice that of the Earth. Additionally, the Kegerreis team has shown how and where the mass and energy conferred by the unknown planet may have settled inside the young Uranus.

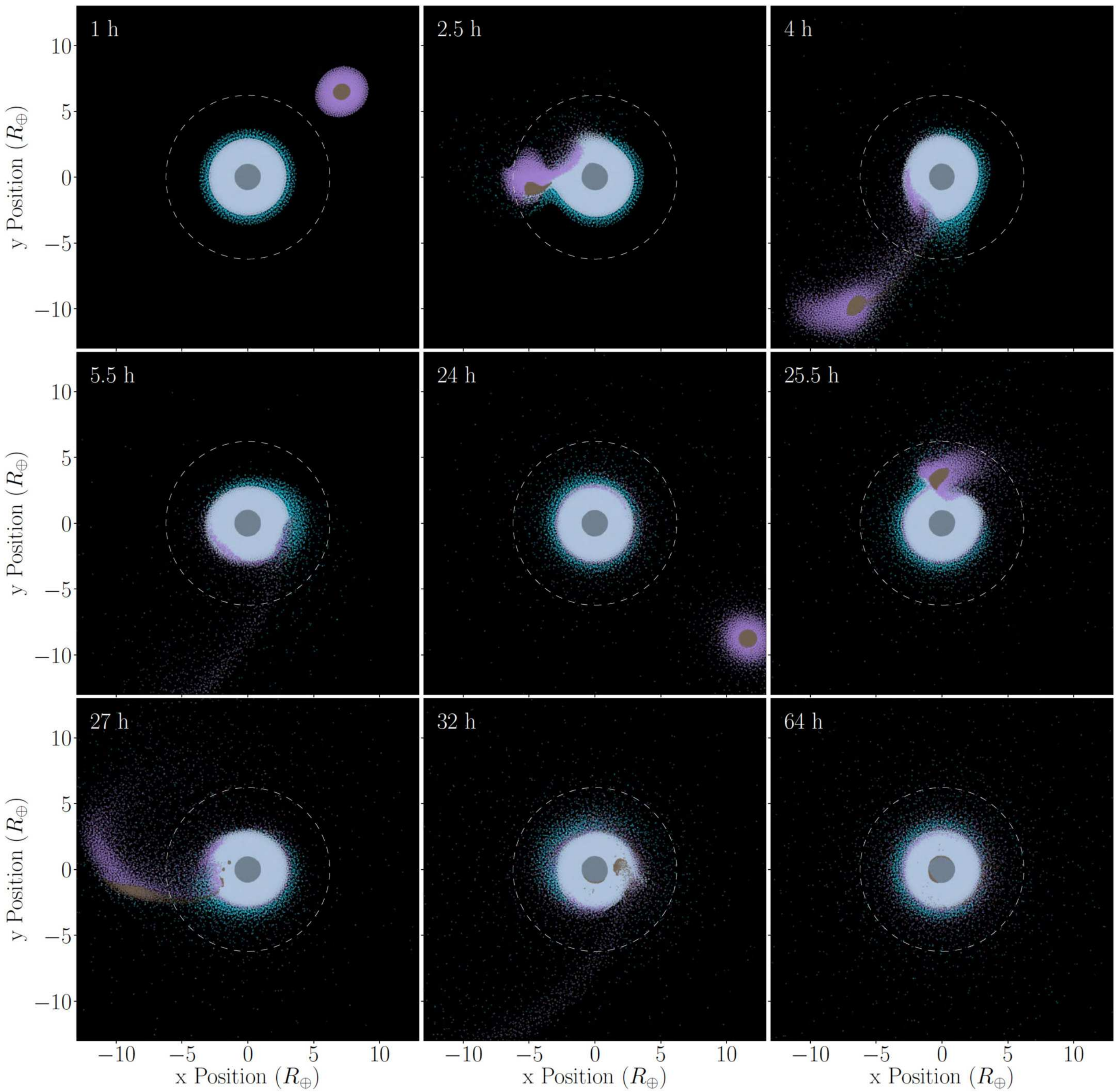
Among all the combinations of the variables considered, some final scenarios effectively represent what we see in reality.

Most likely the collision was grazing, with the impactor having penetrated the frozen mantle of the young Uranus, fragmenting and dissolving the icy masses involved in the event.

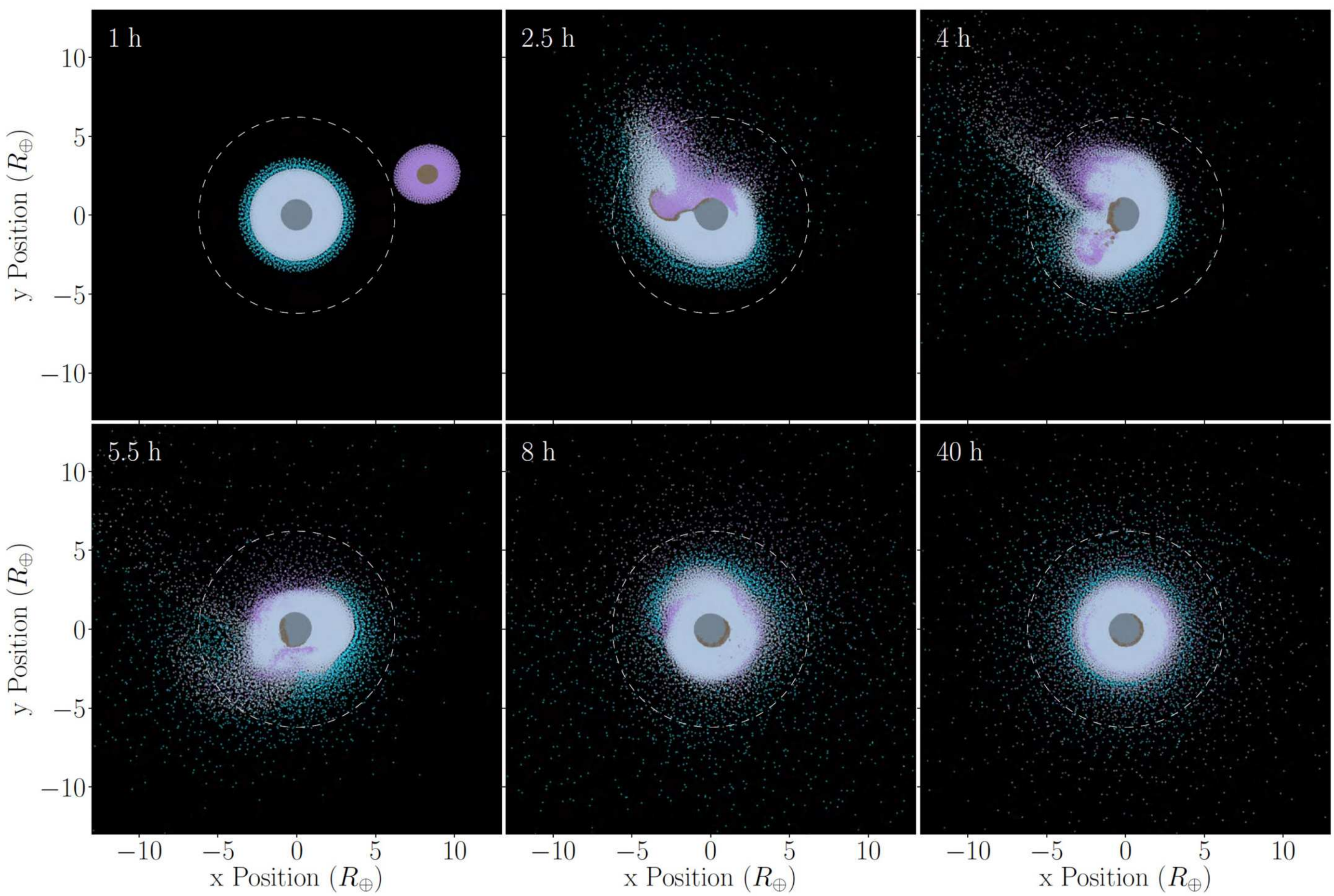
Up to 40% of the rock component of the projectile became unevenly distributed outside the nucleus of Uranus. The icy component spread more evenly in the outer part of the mantle of the giant planet, where it formed an ice shell with properties perhaps different from those of the pre-existing ice. About this, what the authors of the study say in the sci-

***Above, a frame of a simulation by the Kegerreis team. In this stage of the collision between the two planets, Uranus has almost completely engulfed the intruder. The nucleus of the latter, similar to an umbilical cord, is falling towards the Uranus nucleus. The brightness is proportional to the developed energy. [ApJ, J. Kegerreis et al.] The video on the side shows the dynamics of the double grazing collision. [J. Kegerreis/ Durham University]***

entific article appearing in the ApJ is quite interesting: *"This layer of impactor ice could also be a compositional boundary if the icy material is not identical to that in the proto-Uranus."* [...] *"Sub-adiabatic temperature gradients are typically created toward the outer regions of the icy mantle, where most of the impactor ice is deposited."* [...] *"Our simulations are showing a thermal boundary layer that might suppress convection and provide a blanket to contain the heat in the central region of Uranus."*




*A summary of the two phases collision suffered by Uranus, with the indication of the times. [ApJ, J. Kegerreis et al.]*




According to the researchers, it could be just that layer of ice gained by Uranus that inhibits the propagation of internal heat towards the outside. Among the fifty scenarios developed by the Kegerreis team, those that in the final result overlap better with reality require a grazing impact, possibly occurring in two distinct phases: a first crawled contact, lasting a few hours and enough to slow and curb the trajectory of the intruder, then a true impact occurring after about a day, with the total destruction and assimilation of the impactor within the next 24 hours.

This "soft" dynamic would have allowed the young Uranus to keep about half of its original atmosphere in case of an impactor of 2

*A summary of the single-phase collision suffered by Uranus, with the indication of the times. Everything is completed in about two days. As in the previous series, R indicates the radius of Uranus. The video on the side shows six different impact simulations, with a decreasing centrality. [ApJ, J. Kegerreis et al.]*

*This view of Uranus was recorded by Voyager 2 on January 25, 1986, as the spacecraft left the planet behind and set forth on its cruise to Neptune. Voyager was 1 million kilometers (about 600,000 miles) from Uranus when it acquired this wide-angle view. [NASA/JPL]*

Earth masses. If the impactor was 3 Earth masses, only one third of the early atmosphere would have remained within the Roche radius (about 6 Uranus radii), the limit beyond which the expelled material (rocks, ice, and gas) would end up either contributing to form moons and rings or would end up being ejected farther into space.

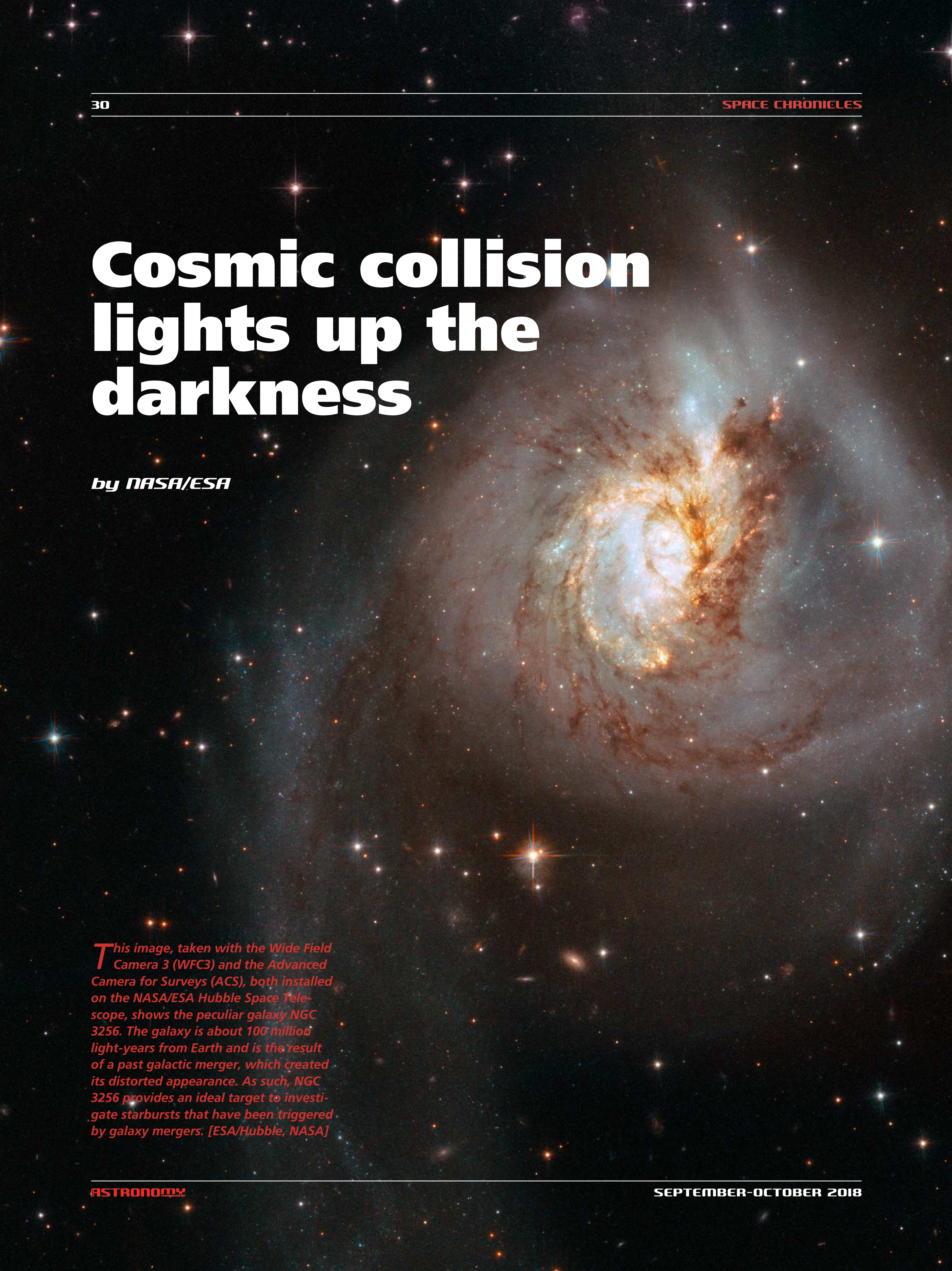
It is interesting to note that the simulations of the Kegerreis team, in addition to providing valid answers to the questions of the magnetic field and the severe temperature of the upper atmosphere, produce a final planet with an inclination of the rotation axis fully compatible with the current one of Uranus.

There is still one aspect that remains unsolved that not even the simulations can account for presently. It concerns the real position of the geographical poles: as strange as it may seem, even today there is no agreed upon answer among the planetologists on which is the north pole of Uranus and which is the south pole. In fact, the rotation axis could be inclined either slightly less than 98° or slightly more than 82°. In the first case, the north pole would be below the orbital plane, and the planet would have a direct rotation, such as that of the Earth. In the second case, the north pole would be above the orbital plane, and the rotation would be retrograde, such as that of Venus (whose retrograde motion can almost certainly be attributed to gravitational braking operated by the Sun on the dense atmosphere of the planet).

It seems near-impossible to understand how the ice giant's geographic poles are arranged. Perhaps the answer could come from future simulations with even higher numerical resolution, reconstructing with great precision the physical properties of the planet by reducing all of the possible variables down to a single set. This highest-quality model would hopefully provide great insights into the mysterious world that hit Uranus 4 billion years ago. ■

# Cosmic collision lights up the darkness

***by NASA/ESA***



*This image, taken with the Wide Field Camera 3 (WFC3) and the Advanced Camera for Surveys (ACS), both installed on the NASA/ESA Hubble Space Telescope, shows the peculiar galaxy NGC 3256. The galaxy is about 100 million light-years from Earth and is the result of a past galactic merger, which created its distorted appearance. As such, NGC 3256 provides an ideal target to investigate starbursts that have been triggered by galaxy mergers. [ESA/Hubble, NASA]*

*This video zooms in on the spiral galaxy NGC 3256, about 100 million light-years away. It starts with a view of the night sky focused on the constellation of Vela (The Sails), as seen from the ground. It then zooms through observations from the Digitized Sky Survey 2, and ends with a view of the galaxy obtained with the NASA/ESA Hubble Space Telescope. [ESA/Hubble, NASA, Digitized Sky Survey 2. Acknowledgement: Davide De Martin]*

Located about 100 million light-years away in the constellation of Vela (The Sails), NGC 3256 is approximately the same size as our Milky Way and belongs to the Hydra-Centaurus Supercluster. It still bears the marks of its tumultuous past in the extended luminous tails that sprawl out around the galaxy, thought to have formed 500 million years ago during the initial encounter between the two galaxies, which today form NGC 3256. These tails are studded with young blue stars, which were born in the frantic but fertile collision of gas and dust.

When two galaxies merge, individual stars rarely collide because they are separated by such enormous distances, but the gas and dust of the galaxies do interact — with spectacular results. The brightness blooming in the centre of NGC 3256 gives away its status as a powerful starburst galaxy, host to vast amounts of infant stars born into groups and clusters. These stars shine most brightly in the far infrared, making NGC 3256 exceedingly luminous in this wavelength domain. Because of this radiation, it is classified as a Luminous Infrared Galaxy. NGC 3256 has been the subject of much study due to its luminosity, its proximity, and its orientation: astronomers observe its face-on orientation, that shows the disc in all its splendour. NGC 3256 provides an ideal target to investigate starbursts that have been triggered by galaxy mergers. It holds particular promise to further our understanding of the properties of young star clusters in tidal tails.

As well as being lit up by over 1000 bright star clusters, the central region of NGC 3256 is also home to crisscrossing threads of dark dust and a large disc of molecular gas spinning around two distinct nuclei — the relics of the two original galaxies. One nucleus is largely obscured, only unveiled in infrared, radio and X-ray wavelengths.

These two initial galaxies were gas-rich and had similar masses, as they seem to be exerting roughly equal influence on each other. Their spiral disks are no longer distinct, and in a few hundred million years time, their nuclei will also merge and the two galaxies will likely become united as a large elliptical galaxy. ■

# First successful test of Einstein's general relativity near a SMBH

*by ESO*

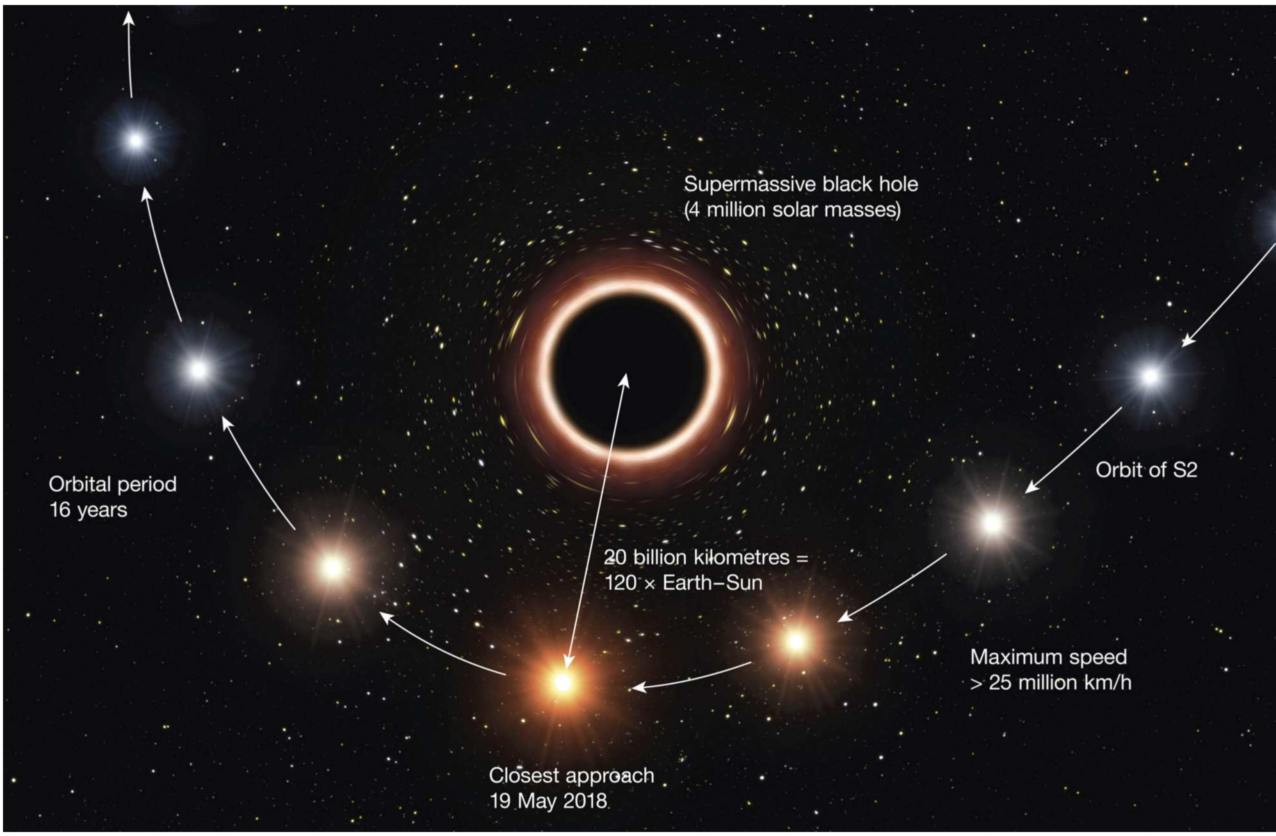
Obscured by thick clouds of absorbing dust, the closest supermassive black hole to the Earth lies 26,000 light-years away at the centre of the Milky Way. This gravitational monster, which has a mass four million times that of the Sun, is surrounded by a small group of stars orbiting around it at high speed. This extreme environment — the strongest gravitational field in our galaxy — makes it the perfect place to explore gravitational physics, and particularly to test Einstein's general theory of relativity.

New infrared observations from the exquisitely sensitive GRAVITY, SINFONI and NACO instruments on ESO's Very Large Telescope (VLT) have now allowed astronomers to follow one of these stars, called S2, as it passed very close to the black hole during May 2018. At the closest point this star was at a distance of less than 20 billion kilometres from the black hole and moving at a speed in excess of 25 million kilometres per hour — almost three per cent of the speed of light.

The team compared the position and velocity measurements from GRAVITY and SINFONI respectively, along with previous observations of S2 using other instruments, with the predictions of Newtonian gravity, general relativity and other theories of gravity. The new results are inconsistent with Newtonian predictions and in excellent agreement with the predictions of general relativity.

These extremely precise measurements were made by an international team led by Reinhard Genzel of the Max Planck Institute for Extraterrestrial Physics (MPE) in Garching, Germany, in conjunction with collaborators around the world, at the Paris Observatory–PSL, the Université Grenoble Alpes, CNRS, the Max Planck Institute for Astronomy, the University of Cologne, the Portuguese CENTRA – Centro de Astrofisica e Gravitação and ESO. The observations are the culmination of a 26-year series of ever-more-precise observations of the centre of the Milky Way using ESO instruments. *"This is the second time that we*

*This animation shows the path of the star S2 as it passes very close to the supermassive black hole at the centre of the Milky Way. As it gets close to the black hole the very strong gravitational field causes the colour of the star to shift slightly to the red, an effect of Einstein's general thery of relativity. In this graphic the colour effect, speed and size of the objects have been exaggerated for clarity. [ESO/M. Kornmesser]*



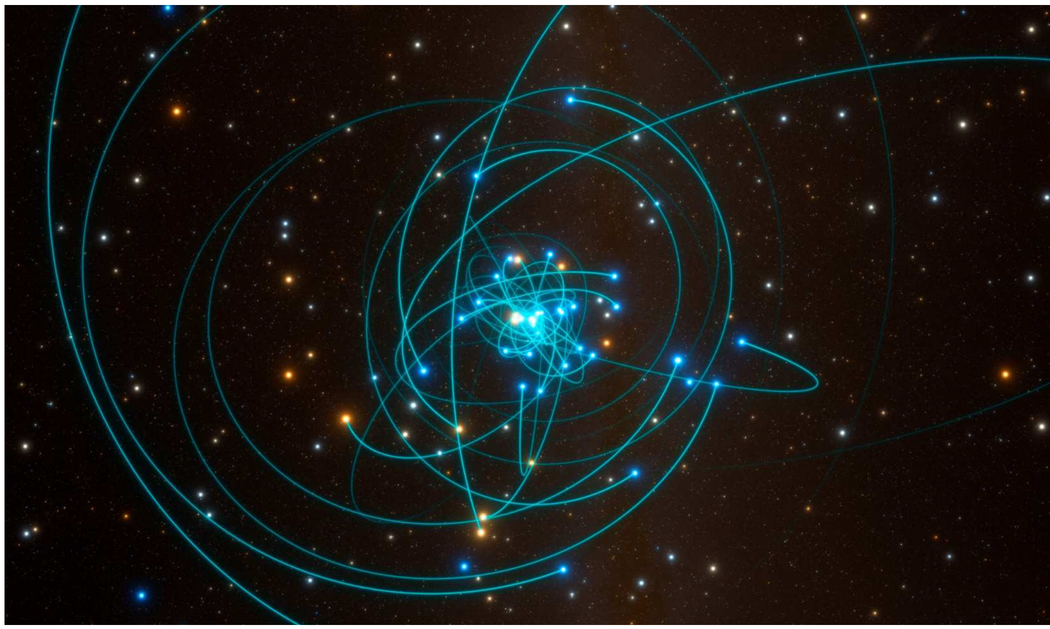

*This artist's impression shows the path of the star S2 as it passes very close to the supermassive black hole at the centre of the Milky Way. As it gets close to the black hole the very strong gravitational field causes the colour of the star to shift slightly to the red, an effect of Einstein's general theory of relativity. In this graphic the colour effect and size of the objects have been exaggerated for clarity. [ESO/M. Kornmesser]*

*have observed the close passage of S2 around the black hole in our galactic centre. But this time, because of much improved instrumentation, we were able to observe the star with unprecedented resolution,"* explains Genzel. *"We have been preparing intensely for this event over several years, as we wanted to make the most of this unique opportunity to observe general relativistic effects."*

The new measurements clearly reveal an effect called gravitational redshift. Light from the star is stretched to longer wavelengths by the very strong gravitational field of the black hole. And the change in the wavelength of light from S2 agrees precisely with that predicted by Einstein's theory of general relativity. This is the first time that this deviation from the predictions of the simpler Newtonian theory of gravity has been observed in the motion of a star around a supermassive black hole. The team used SINFONI to measure the velocity of S2 towards and away from Earth and the GRAVITY instrument in the VLT Interferometer (VLTI) to make extraordinarily precise measurements of the changing position of S2 in order to define the shape of its orbit. GRAVITY creates such sharp images that it can reveal the motion of the star from night to night as it passes close to the black hole — 26,000 light-years from Earth.

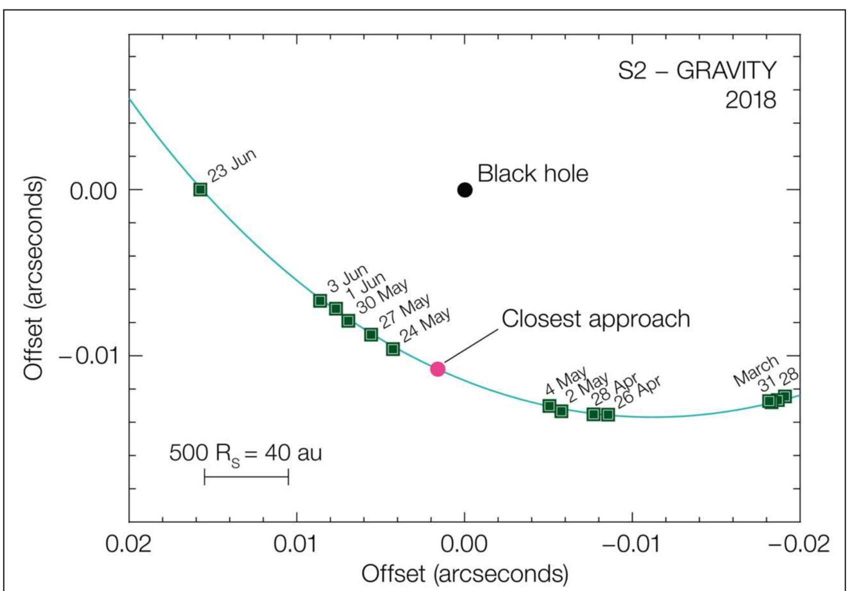
*"Our first observations of S2 with GRAVITY, about two years ago, already showed that we would have the ideal black hole laboratory,"* adds Frank Eisenhauer (MPE), Principal Investigator of GRAVITY and the SINFONI spectrograph. *"During the close passage, we could even detect the faint glow around the black hole on most of the images, which allowed us to precisely follow the star on its orbit, ultimately leading to the detection of the gravitational redshift in the spectrum of S2."*

More than one hundred years after he published his paper setting out the equations of general relativity,



*This simulation shows the orbits of stars very close to the supermassive black hole at the heart of the Milky Way. One of these stars, named S2, orbits every 16 years and is passing very close to the black hole in May 2018. This is a perfect laboratory to test gravitational physics and specifically Einstein's general theory of relativity. [ESO/L. Calçada/ spaceengine.org]*

Einstein has been proved right once more — in a much more extreme laboratory than he could have possibly imagined!




*This diagram shows the motion of the star S2 as it passes close to the supermassive black hole at the centre of the Milky Way. It was compiled from observations with the GRAVITY instrument in the VLT interferometer. At this point the star was travelling at nearly 3% of the speed of light and its shift in position can be seen from night to night. The sizes of the star and the black hole are not to scale. [ESO/MPE/GRAVITY Collaboration]*

Françoise Delplancke, head of the System Engineering Department at ESO, explains the significance of the observations: *"Here in the Solar System we can only test the laws of physics now and under certain circumstances. So it's very important in astronomy to also check that those laws are still valid where the gravitational fields are very much stronger."*

Continuing observations are expected to reveal another relativistic effect very soon — a small rotation of the star's orbit, known as Schwarzschild precession — as S2 moves away from the black hole.

Xavier Barcons, ESO's Director General, concludes: *"ESO has worked with Reinhard Genzel and his team and collaborators in the ESO Member States for over a quarter of a century.*

*It was a huge challenge to develop the uniquely powerful instruments needed to make these very delicate measurements and to deploy them at the VLT in Paranal. The discovery is the very exciting result of a remarkable partnership."*

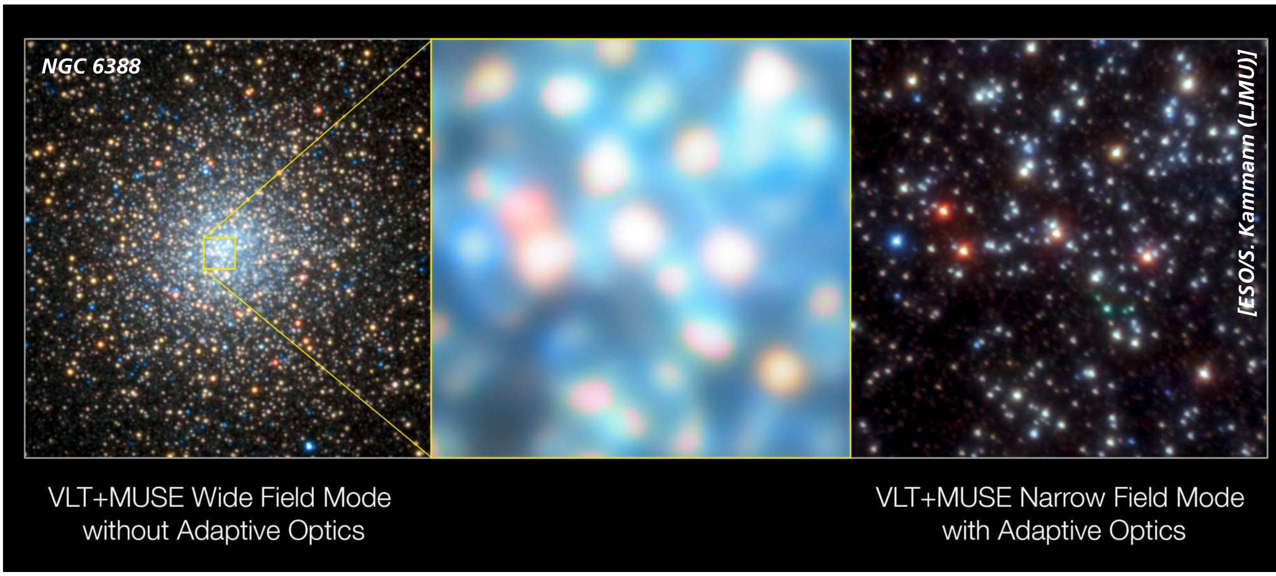
# Supersharp images from new VLT adaptive optics

**by ESO**

The MUSE (Multi Unit Spectroscopic Explorer) instrument on ESO's Very Large Telescope (VLT) works with an adaptive optics unit called GALACSI. This makes use of the Laser Guide Star Facility, 4LGSF, a subsystem of the Adaptive Optics Facility (AOF). The AOF provides adaptive optics for instruments on the VLTs Unit Telescope 4 (UT4). MUSE was the first instrument to benefit from this new facility and it now has two adaptive optics modes — the Wide Field Mode and the Narrow Field Mode. The MUSE Wide Field Mode coupled to GALACSI in ground-layer mode corrects for the effects of atmospheric turbulence up to one kilometre above the telescope over a comparatively wide field of view.


*These images of the planet Neptune were obtained during the testing of the Narrow-Field adaptive optics mode of the MUSE/GALACSI instrument on ESO's Very Large Telescope. The image on the right is without the adaptive optics system in operation and the one on the left after the adaptive optics are switched on. [ESO/P. Weilbacher (AIP)]*

But the new Narrow Field Mode using laser tomography corrects for almost all of the atmospheric turbulence above the telescope to create much sharper images, but over a smaller region of the sky. With this new capability, the 8-metre UT4 reaches the theoretical limit of image sharpness and is no longer limited by atmospheric blur. This is extremely difficult to attain in the visible and gives images comparable in sharpness to those from the NASA/ESA Hubble Space Telescope. It will enable astronomers to study in unprecedented detail fascinating objects such as supermassive black holes at the centres of distant galaxies, jets from young stars, globular clusters, supernovae, planets and their satellites in the Solar System and much more. Adaptive optics is a technique to compensate for the blurring effect of the Earth's atmosphere, also known as astronomical seeing, which is a big problem faced by all ground-based telescopes. The same turbulence in the atmosphere that causes stars to twinkle to the naked eye results in blurred images of the Universe for large telescopes. Light from stars and galaxies becomes distorted as it




passes through our atmosphere, and astronomers must use clever technology to improve image quality artificially. To achieve this four brilliant lasers are fixed to UT4 that project columns of intense orange light 30 centimetres in diameter into the sky, stimulating sodium atoms high in the atmosphere and creating artificial Laser Guide Stars. Adaptive optics systems use the light from these "stars" to determine the turbulence in the atmosphere and calculate corrections one thousand times per second, commanding the thin, deformable secondary mirror of UT4 to constantly alter its shape, correcting for the distorted light. MUSE is not the only instrument to benefit from the Adaptive Optics Facility. Another adaptive optics system, GRAAL, is already in use with the infrared camera HAWK-I. This will be followed in a few years by the powerful new instrument ERIS. Together these major developments in adaptive optics are enhancing the already powerful fleet of ESO telescopes, bringing the Universe into focus. This new mode also constitutes a major step forward for the ESO's Extremely Large Telescope, which will need Laser Tomography to reach its science goals. These results on UT4 with the AOF will help to bring ELT's engineers and scientists closer to implementing similar adaptive optics technology on the 39-metre giant. ■


*The image of the planet Neptune on the left was obtained during the testing of the Narrow-Field adaptive optics mode of the MUSE instrument on ESO's Very Large Telescope. The image on the right is a comparable image from the NASA/ESA Hubble Space Telescope. Note that the two images were not taken at the same time so do not show identical surface features. [ESO/P. Weilbacher (AIP)/NASA, ESA, and M.H. Wong and J. Tollefson (UC Berkeley)]*

# Terraforming Mars is still science fiction

*by Michele Ferrara*

*revised by Damian G. Allis*
*NASA Solar System Ambassador*

***That the destiny of humanity is to colonize other planets is a near-certainty, but this will happen in a future so far off that the ways by which we might do so are highly speculative. Surely, if the population increases to unsustainable levels, we will reach a point at which either a strict global birth control will be implemented or we will need to hasten our transition to a more space-faring species, else risk putting our civilization at risk. Those who think that the population surplus can easily be transferred to space are ignoring considerable difficulties.***

In science fiction novels and movies, the problem of overpopulation of the Earth is raised from time to time, and the solution typically proposed is the transfer of the population surplus to space bases and colonies built in Earth orbit or on other planetary bodies. In reality, solutions of this type would be technologically possible, but they certainly would not solve the problem. Indeed, only an irrelevant fraction of the Earth's population could be transferred: thousands of people if we want to be realistic; millions of people if we want to be visionaries. Unfortunately, there is already a clear population surplus in some regions compared to the distributions of available resources: starvation, mass migrations and wars are witness to this. The UN predicts that in 2050, the human population will number almost 10 billion, 33% more than today. In 2100, the forecasts indicate an optimistic 11-12 billion. If these predicted values turn out to be correct, there will be about 4 billion more people than today, and it is unlikely that, in the absence of sufficient resources on Earth, those people can be transferred elsewhere. For almost fifty years, actual humans have not traveled more than 500 km from the surface of our planet, and every few years we delude ourselves with the notion that someone may soon succeed in setting foot on Mars. How can we seriously think that in the coming decades we will solve the problem of overpopulation by transferring, who knows how and who knows where, a non-negligible part of humankind?For large numbers of settlers, circumscribed extraterrestrial environments are not enough – we will need an entire planet, and we do not know of another immediately habitable one nearby.

*In the background, an artist's image of an early Mars, when the planet was very similar to Earth. [Created for the MAVEN mission by the Lunar and Planetary Institute]*

The scientific literature, once again, suggests a possible solution: transforming Mars from an inhospitable world into a habitable planet through a series of interventions whose aim is to regenerate the Martian atmosphere, creating a greenhouse effect capable of raising the average temperature to the surface and re-establishing the ancient water cycle.
The first explicit reference to this fanciful transformation appeared in 1942 in a story by Jack Williamson, published in Astounding Science-Fiction. It was on that occasion that the author used for the first time the term "terraform" (which became a verb in the 90s), which is the process of transforming an unlivable planet into an Earth, with all of the environmental conditions and affinities of our home world.
What seemed like only a bizarre utopia in 1942 became within a few decades a topic of discussion among scientists. In the 1970s, thanks also to the futuristic vision of Carl Sagan, NASA promoted a feasibility study for terraforming Mars. The scientists and engineers involved in the study came to the surprising conclusion that it was possible to make that planet habitable.
Since the end of the seventies, many scientific articles have been produced on terraforming Mars, which have proposed different ways to achieve substantially the same final scenario.
The terraforming of Mars is an ever-growing topic of discussion, with the real difficulties needed to be to overcome to start the process ever-

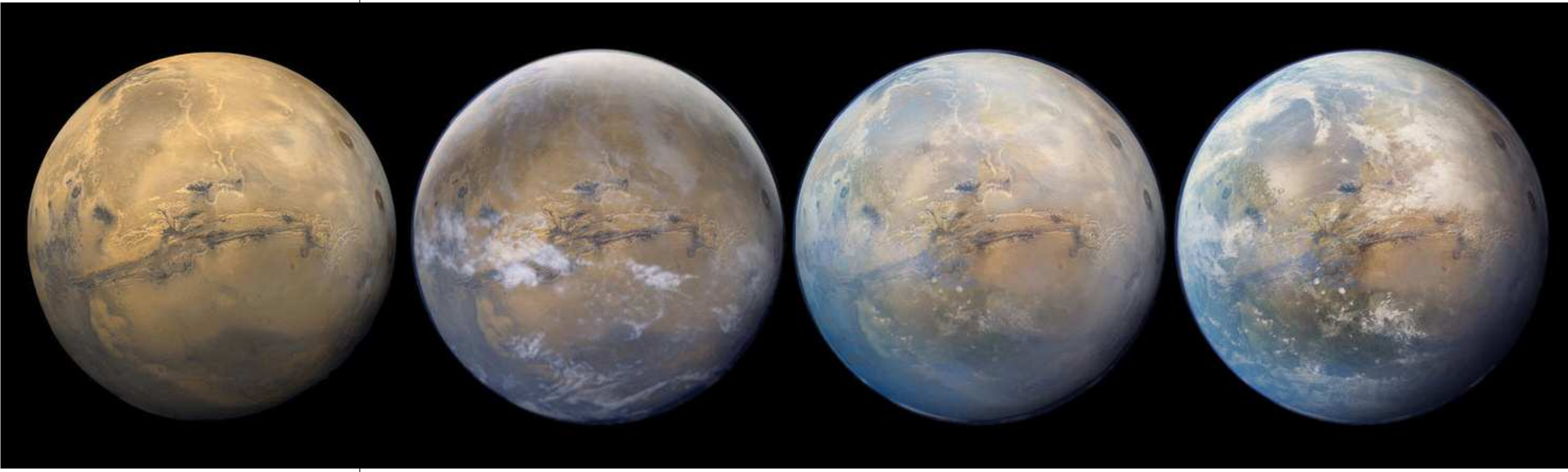
*Photomontage made from images from Nature Communications showing Mars in its current appearance – red and arid – to the left, in contrast to the same landscape covered with water more than three billion years ago. [Nature Publishing Group/ AFP/Archives/Jon Wade, James Moore]*

*Billions of years ago, when the Red Planet was young, it appears to have had a thick atmosphere that kept temperatures warm enough to support surface oceans of liquid water – a critical ingredient for life. The animation shows how the surface of Mars might have appeared during this ancient clement period, beginning with a flyover of a Martian lake. The artist's concept is based on evidence that Mars was once very different. Rapidly moving clouds suggest the passage of time, and the shift from a warm-and-wet to a cold-and-dry climate is shown as the animation progresses. The lakes dry up, while the atmosphere gradually transitions from Earthlike blue skies to the dusty pink and tan hues seen on Mars today. [Michael Lentz, GSFC/NASA]*

*This animation transitions from an early, wet Mars to present-day dry Mars. [Created for the MAVEN mission by the Lunar and Planetary Institute]*

more evident in the minds of scientists and futurists.

As already mentioned, the primary objective is the thickening of the Martian atmosphere. It's like moving the clock back over three billion years to when some form of life on that planet was sustainable.



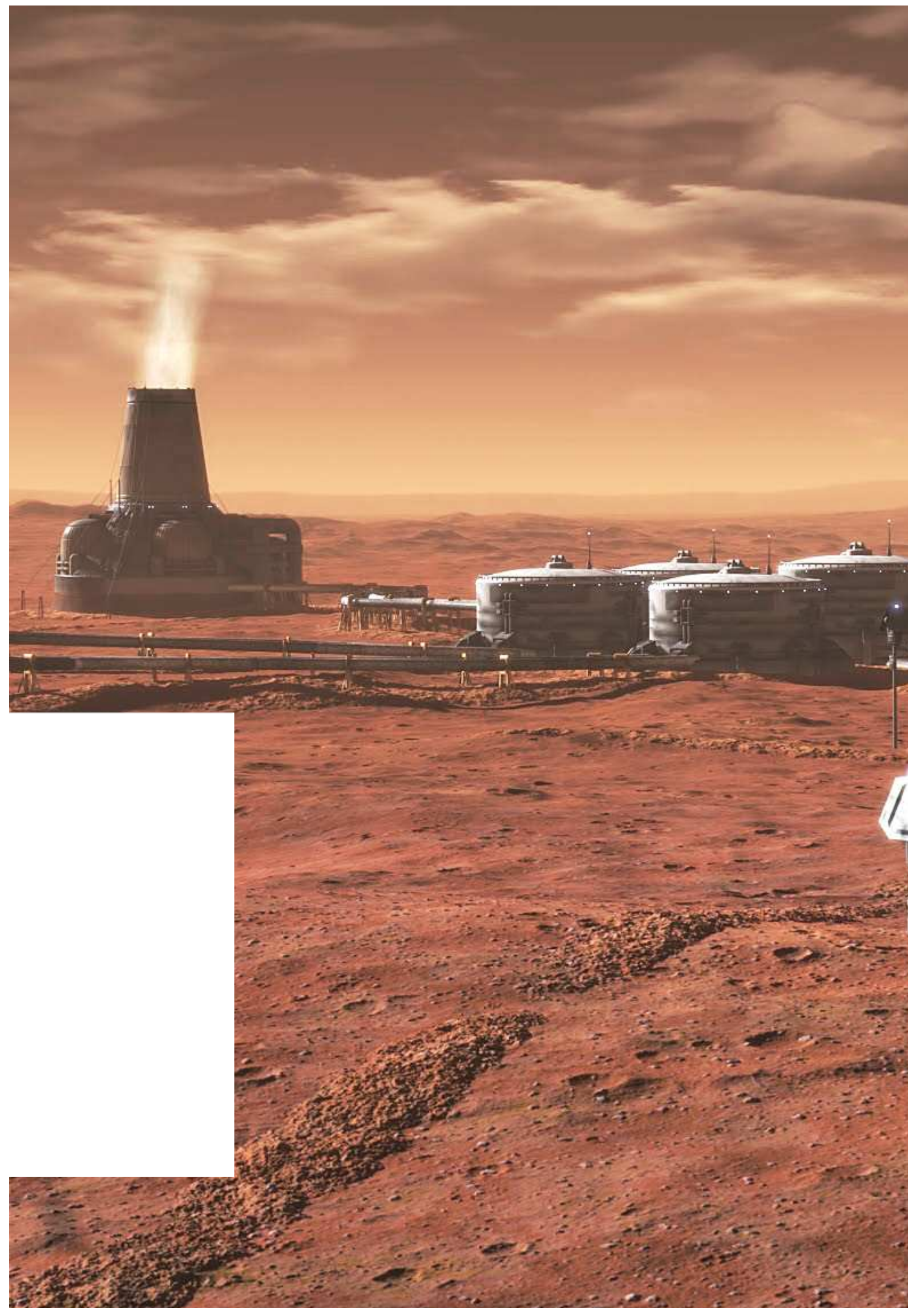
*Artist's impression of the terraforming of Mars, from its current state to a livable world. [William Black]*

The current Martian atmosphere produces a surface pressure of just 6 millibars (0.6% of the Earth's). It is composed of 96% carbon dioxide ($CO_2$), while the remaining 4% includes argon, nitrogen, oxygen and carbon monoxide. $CO_2$ is a greenhouse gas - if it were possible to sublimate the $CO_2$ contained in the form of ice in the polar ice caps, in the ground and in the subsoil, it would be possible to significantly raise the atmospheric pressure and, therefore, the surface temperature. As a consequence, the atmospheric water vapor content would also increase, giving the greenhouse effect a further boost.

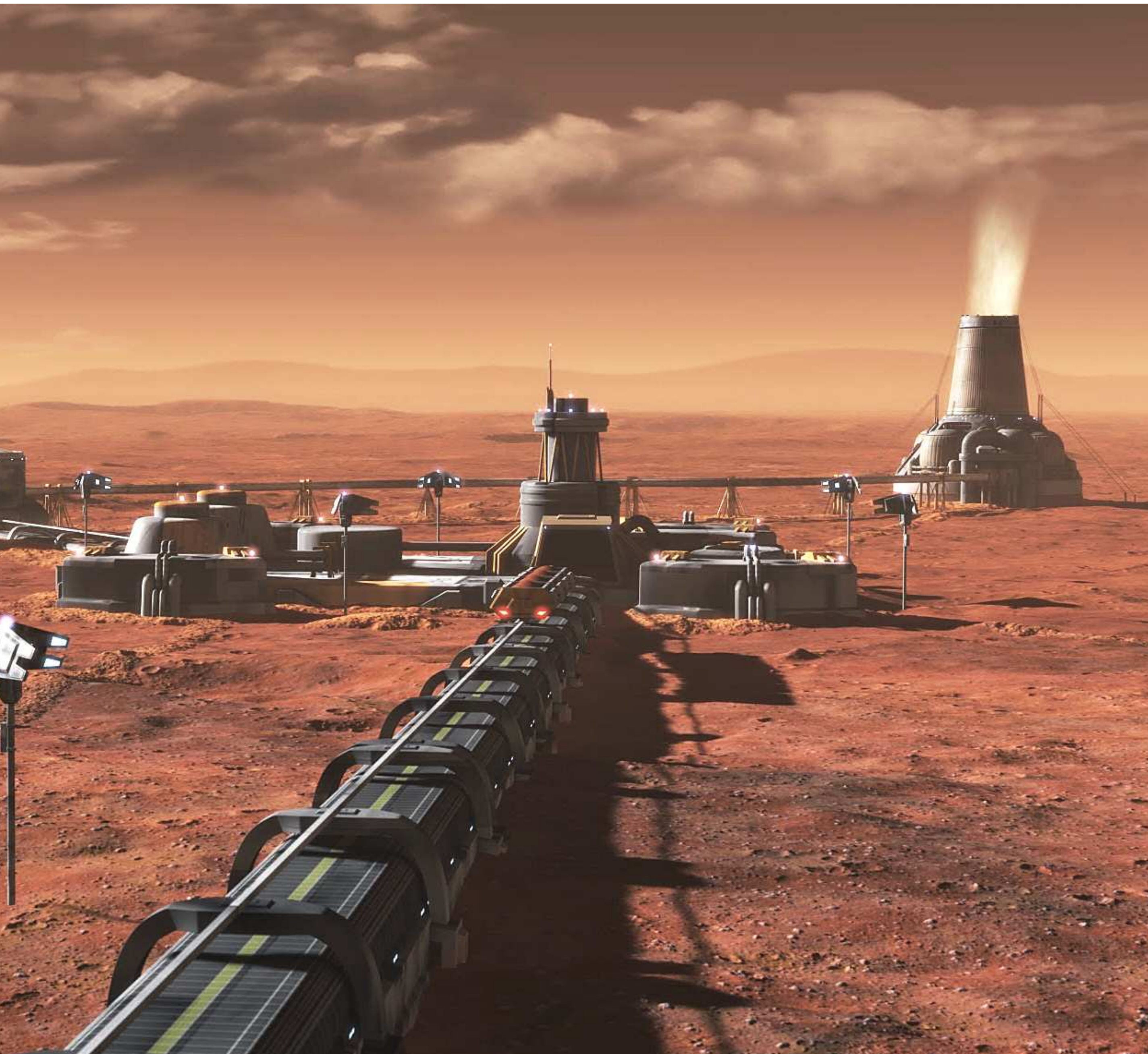
The surface gravity of Mars is equal to 38% that of Earth's. To achieve an atmospheric pressure similar to that on Earth's surface (1013.25 millibars at sea level), the vertical air mass must be significantly greater per unit area to compensate for the lower Martian gravity. That said, to live on the red planet, we might be content with a lower pressure than what we are used to on Earth. Scientists estimate that, at only 190 millibars, a pressurized suit would no longer be necessary and a pure oxygen mask with positive pressure would be sufficient. At 240 millibars (almost ¼ of the average pressure at sea level), a standard high-altitude respirator would suffice. It would obviously be necessary to wear protective clothing against the most energetic photons and the most harmful charged particles, which do not stop being a threat by merely increasing the amount of $CO_2$ in the

atmosphere. To stop the former, an ozone layer is needed, for the latter, a well-structured ionosphere produced by a global magnetic field. Mars is devoid of ozone and shows only a hint of ionosphere, created by relics of an ancient global magnetic field. As a result, the most energetic UV rays, small amounts of X-rays and gamma rays, and many charged particles contained in the solar wind can easily reach the ground. These problems, solvable with appropriate clothing and outdoor excursions limited in duration, are certainly not the most worrisome. In fact, the absence of a magnetosphere similar to that of Earth's allows the solar wind to freely hit the Martian atmosphere and gradually disperse it into space, a process that has been going on for billions of years. We can, therefore, easily understand that it would be entirely in vain to attempt to restore the atmosphere without first restoring a magnetic field able to preserve it.
Although it seems an extreme challenge, in the past few years various solutions have been proposed to address the missing magnetic field. We only mention the last one, suggested in February 2017 by Jim Green, Planetary Science Division Director of NASA, at the Planetary Science Vision 2050 Workshop. Green proposes to create a magnetic

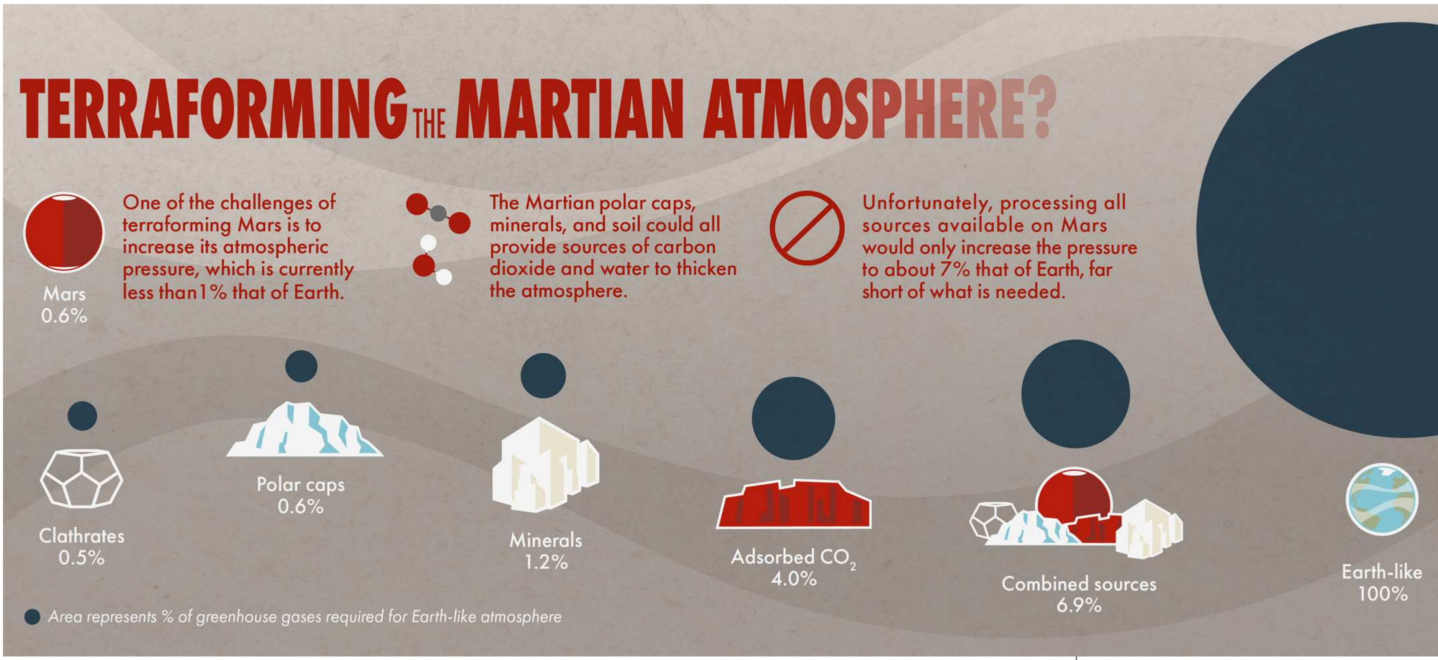
*This artist's model shows where the landing sites are on Mars for Viking 1 & 2, Spirit, Opportunity, Phoenix, and Curiosity, in comparison to possible locations of an early ocean which may have existed billions of years ago. In this depiction, the atmosphere is thicker than the present-day Mars atmosphere, which is only about 1% of Earth's. The locations for the ancient ocean are based on current altitudes and do not reflect the actual ancient topography. [Created for the MAVEN mission by the Lunar and Planetary Institute]*



*Artist's concept of a possible Mars terraforming plant. [National Geographic Channel]*



dipole shield between Mars and the Sun at the Lagrange point L1, about one million km away from the planet. Extended enough to shelter the entire hemisphere facing the Sun, the shield would have the task of diverting the charged particles of the solar wind. Optimistic simulations indicate that the shield, by curbing the atmosphere dispersion, would allow the regeneration of the latter by natural means. In relatively "short" times, atmospheric pressure could rise to about half that of Earth, and all the




chain effects resulting from this would promote the accumulation of liquid water on the surface in an amount estimated at 1/7th of the flow of primordial oceans.

If the shield proposed by Green does not prove to be as efficient as expected, some already known strategies could be implemented at the same time, designed to increase the temperature and accelerate the greenhouse effect. One of these strategies is to reduce the albedo of the regions in which the ice reserves of $CO_2$ and $H_2O$ are most concentrated, so that a higher absorption of the heat coming from the Sun may favor its sublimation. The albedo reduction could be achieved by depositing dark powders taken from the surfaces of Phobos and Deimos, or fostering the localized proliferation of extremophile forms of life carried from the Earth.

Another solution involves the use of huge orbiting mirrors, formed by thin films of aluminated plastic materials, able to reflect the solar heat towards specific areas of the Martian surface.

There are also those who suggest carrying to Mars large amounts of ammonia, methane and other molecules particularly suitable for triggering a greenhouse effect, such as CFCs and PFCs. These molecules are much more efficient than $CO_2$ at promoting greenhouse behavior, but are also decidedly detrimental to the desirable formation of an ozone layer (similar to our terrestrial one), itself essential for reducing the flow of ultraviolet rays that sterilize the Martian surface.

Whatever strategy was to be adopted to reconstitute the magnetic field and the atmosphere, it would be effectively useless if there was not enough $CO_2$ on Mars to consolidate the desired greenhouse effect. So far, scientists have been quite optimistic about the $CO_2$ content, but a very recent study, promoted by NASA and published at the end of July in Nature Astronomy, states exactly the opposite.

The authors are Bruce M. Jakosky (University of Colorado, Boulder) and Christopher S. Edwards (Northern Arizona University). In their article, entitled *"Inventory of $CO_2$ available for terraforming Mars"*, the two researchers examine data collected over the last two decades from various probes that have measured the abundances of $CO_2$ in the atmosphere, on the surface and in the subsoil of Mars, as well as the dispersion of atmospheric gases in space.

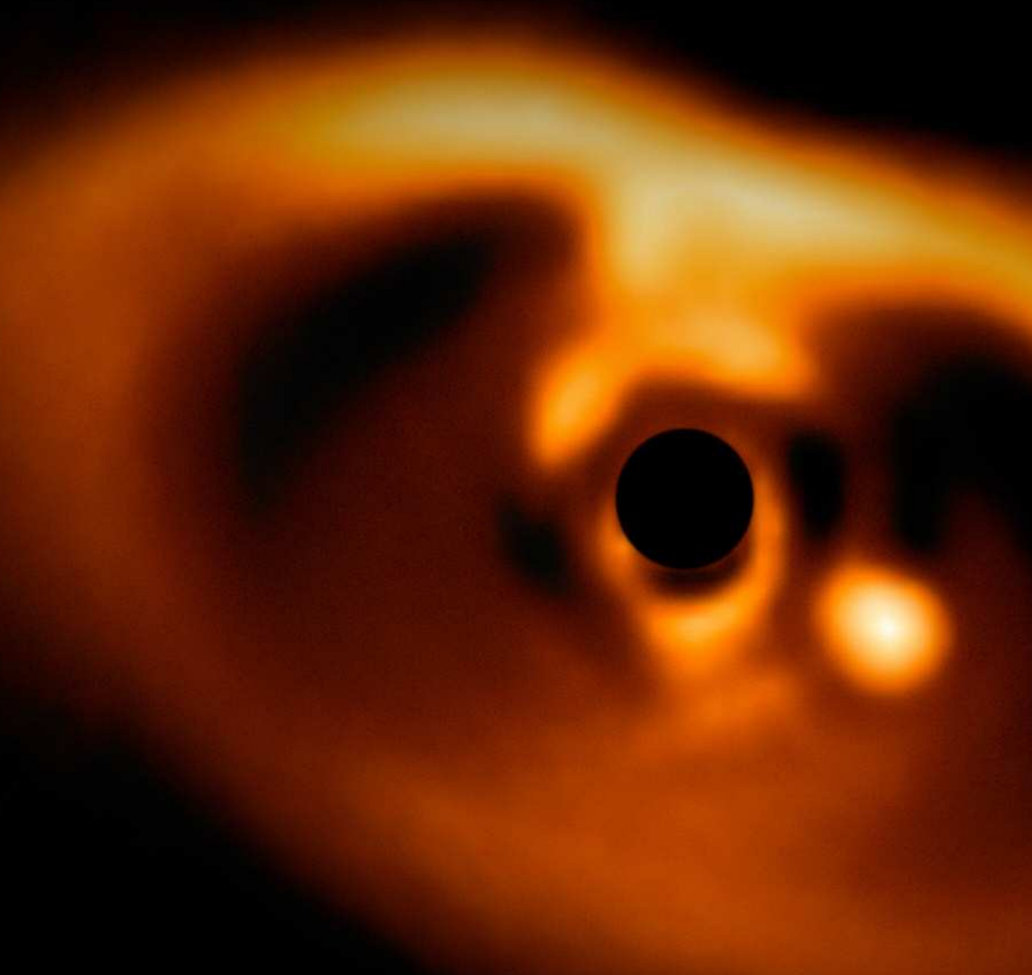
*This infographic highlights the main sources that may contribute to the budget of martian CO2. Unfortunately, the mass of gas that can be released with the current technology is considerably lower than that needed to start the terraforming of Mars. [NASA]*

*Terraforming Mars is for now just a game for kids. This fun pastime, released in 2016 by FryxGames, and integrated with some more recent expansions, is an ideal tool to bring young people closer to important issues. [Enoch Fryxelius, FryxGames, Vellinge, Sweden]*


The results say that even if we were able to vaporize all the $CO_2$ contained in the two polar ice caps, we could only double the atmospheric pressure (from 0.6 mbar to 1.2 mbar). If we succeeded in freeing the $CO_2$ embedded in the dust of the Martian soil, we would get no more than 4% of the optimal pressure. Other small percentages would be added by releasing $CO_2$ contained in subsurface mineral deposits, underground water ice reserves and clathrates.
Taken together, all these possible sources of $CO_2$ (and other less relevant gases) are not sufficient to guarantee the terraforming of Mars. Here is how Jakosky summarizes the situation: *"Our results suggest that there is not enough $CO_2$ on Mars to provide significant greenhouse warming were the gas to be put into the atmosphere; besides, most of the $CO_2$ gas is not accessible and could not be readily mobilized. As a result, terraforming Mars is not possible using present-day technology"*.
In conclusion, the only thing we can realistically do (perhaps) is to try to consolidate the current Martian atmosphere, preventing the dispersion with an artificial magnetosphere and leaving the natural geological degassing, produced by the residual geological activity, the task of raising the pressure on the surface. But this process is so slow that we will have to wait tens or hundreds of millions of years to transfer the population surplus to Mars. How many might we be in that distant future? ■

# First confirmed image of newborn planet caught with ESO's VLT

*by ESO*



*This spectacular image from the SPHERE instrument on ESO's Very Large Telescope is the first clear image of a planet caught in the very act of formation around the dwarf star PDS 70. The planet stands clearly out, visible as a bright point to the right of the centre of the image, which is blacked out by the coronagraph mask used to block the blinding light of the central star. [ESO/A. Müller et al.]*

**Astronomers led by a group at the Max Planck Institute for Astronomy in Heidelberg, Germany have captured a spectacular snapshot of planetary formation around the young dwarf star PDS 70. By using the SPHERE instrument on ESO's Very Large Telescope (VLT) — one of the most powerful planet-hunting instruments in existence — the international team has made the first robust detection of a young planet, named PDS 70b, cleaving a path through the planet-forming material surrounding the young star. The SPHERE instrument also enabled the team to measure the brightness**

*Astronomers using the SPHERE instrument on ESO's Very Large Telescope captured the first clear image of a planet caught in the act of forming in the dusty disc surrounding a young star. The young planet is carving a path through the primordial disc of gas and dust around the very young star PDS 70. The data suggest that the planet's atmosphere is cloudy. [ESO]*

of the planet at different wavelengths, which allowed properties of its atmosphere to be deduced.

The planet stands out very clearly in the new observations, visible as a bright point to the right of the blackened centre of the image. It is located roughly three billion kilometres from the central star, roughly equivalent to the distance between Uranus and the Sun. The analysis shows that PDS 70b is a giant gas planet with a mass a few times that of Jupiter. The planet's surface has a temperature of around 1000°C, making it much hotter than any planet in our own Solar System.

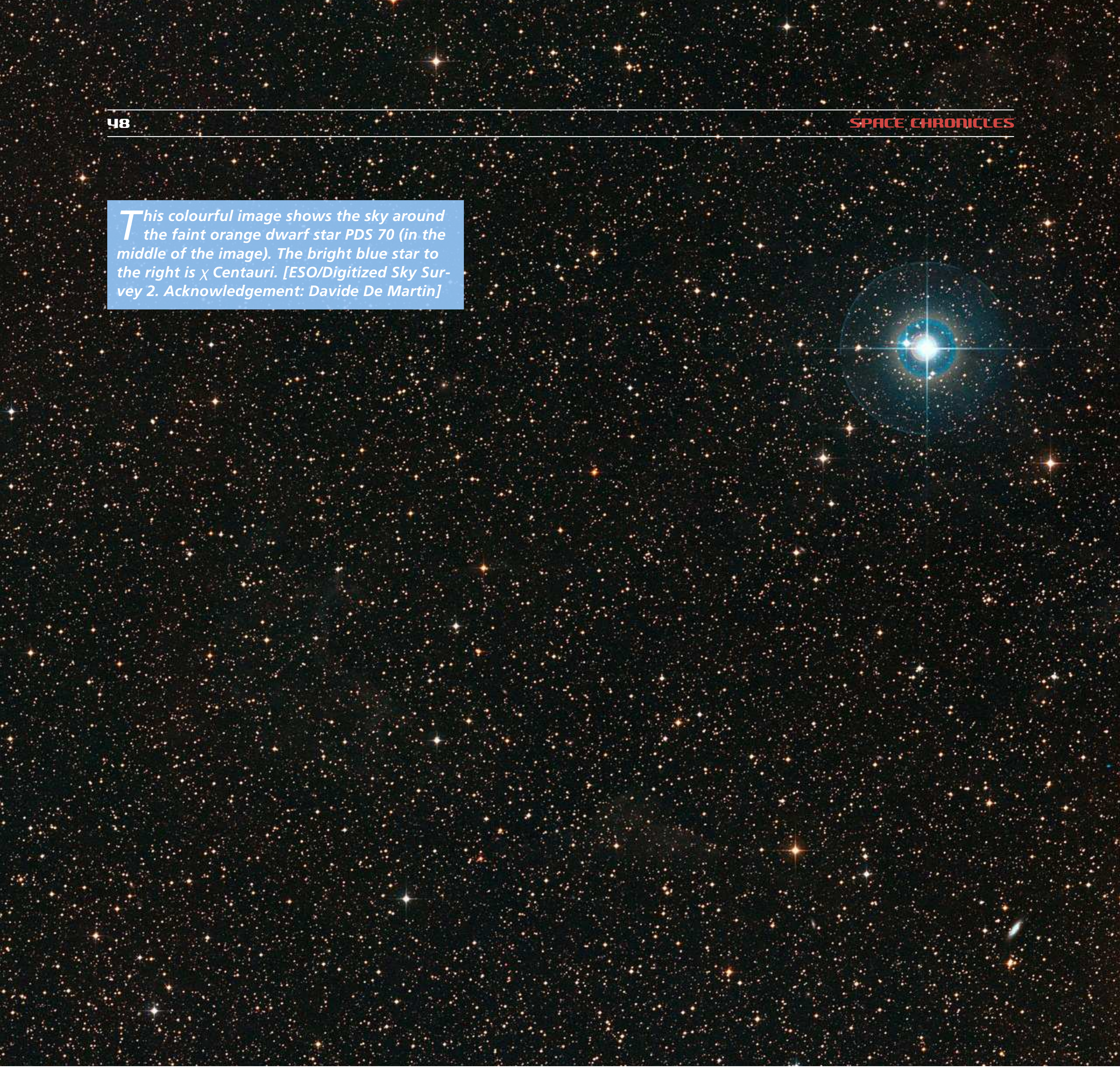
The dark region at the centre of the image is due to a coronagraph, a mask which blocks the blinding light of the central star and allows astronomers to detect its much fainter disc and planetary companion. Without this mask, the faint light from the planet would be utterly overwhelmed by the intense brightness of PDS 70.

*"These discs around young stars are the birthplaces of planets, but so far only a handful of observations have detected hints of baby planets in them,"* explains Miriam Keppler, who lead the team behind the discovery of PDS 70's still-forming planet. *"The problem is that until now, most of these planet candidates could just have been features in the disc."*

The discovery of PDS 70's young companion is an exciting scientific result that has already merited further investigation. A second team, involving many of the same astronomers as the discovery team, including Keppler, has in the past months followed up the initial observations to investigate PDS 70's fledgling planetary companion in more detail.

They not only made the spectacularly clear image of the planet shown here, but were even able to obtain a spectrum of the planet. Analysis of this spectrum indicated that its atmosphere is cloudy.

PDS 70's planetary companion has sculpted a transition disc — a protoplanetary disc with a giant "hole" in the centre. These inner gaps have been known about for decades and it has been speculated that they were produced by disc-planet interaction. Now we can see the planet for the first time.



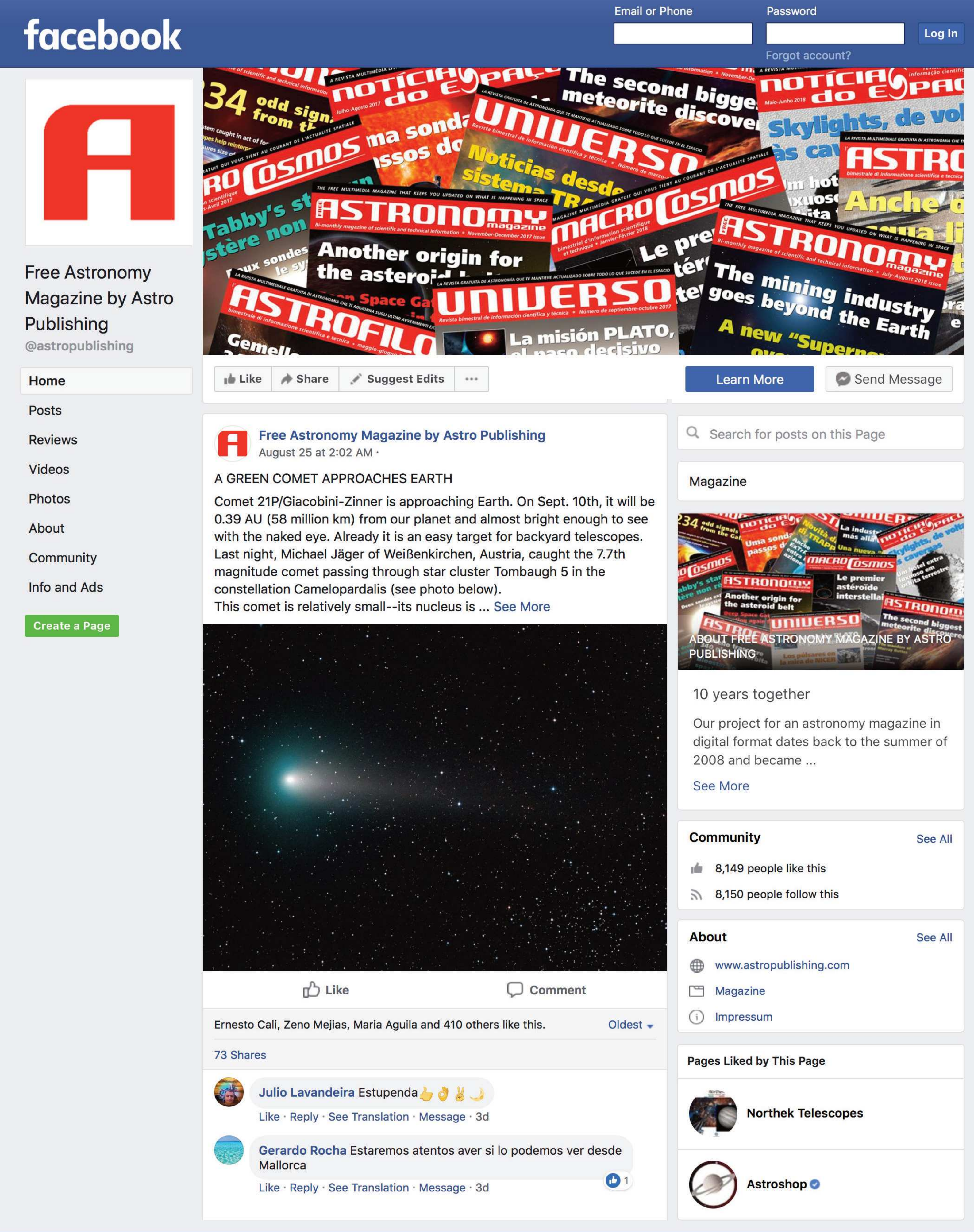
*This colourful image shows the sky around the faint orange dwarf star PDS 70 (in the middle of the image). The bright blue star to the right is χ Centauri. [ESO/Digitized Sky Survey 2. Acknowledgement: Davide De Martin]*

*"Keppler's results give us a new window onto the complex and poorly-understood early stages of planetary evolution,"* comments André Müller, leader of the second team to investigate the young planet. *"We needed to observe a planet in a young star's disc to really understand the processes behind planet formation."*

By determining the planet's atmospheric and physical properties, the astronomers are able to test theoretical models of planet formation. This glimpse of the dust-shrouded birth of a planet was only possible thanks to the impressive technological capabilities of ESO's SPHERE instrument, which studies exoplanets and discs around nearby stars using a technique known as high-contrast imaging — a challenging feat.

Even when blocking the light from a star with a coronagraph, SPHERE still has to use cleverly devised observing strategies and data processing techniques to filter out the signal of the faint planetary companions around bright young stars at multiple wavelengths and epochs.

Thomas Henning, director at the Max Planck Institute for Astronomy and leader of the teams, summarises the scientific adventure: *"After more than a decade of enormous efforts to build this high-tech machine, now SPHERE enables us to reap the harvest with the discovery of baby planets!"*




We are on Facebook since last July. On this page, Astro Publishing provides the latest news on astronomy and astronautics. This page completes the multilingual magazine offered for free on the website. Come and join us!

# Astronomers uncover new clues to the star that wouldn't die

*by NASA/ESA*

What happens when a star behaves like it exploded, but it's still there?

About 170 years ago, astronomers witnessed a major outburst by Eta Carinae, one of the brightest known stars in the Milky Way galaxy. The blast unleashed almost as much energy as a standard supernova explosion. Yet Eta Carinae survived.

An explanation for the eruption has eluded astrophysicists. They can't take a time machine back to the mid-1800s to observe the outburst with modern technology.

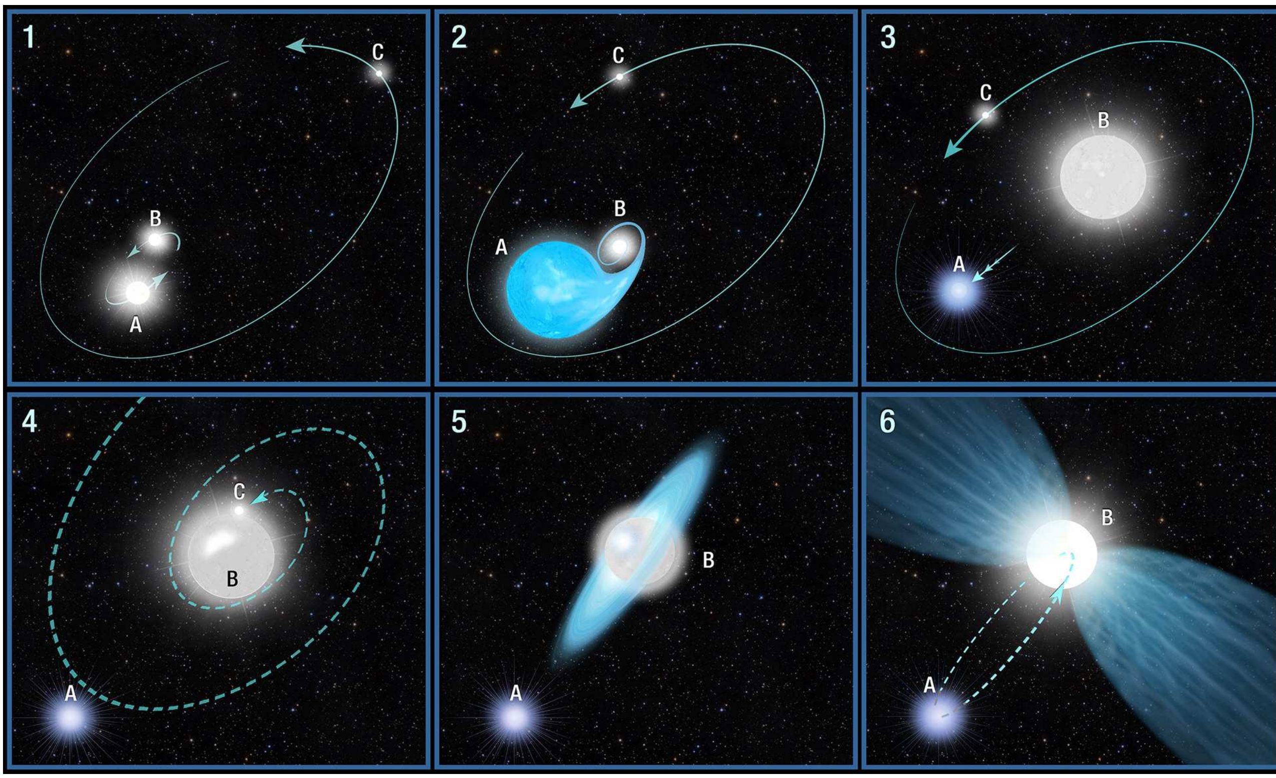
However, astronomers can use nature's own "time machine," courtesy of the fact that light travels at a finite speed through space. Rather than heading straight toward Earth, some of the light from the outburst rebounded or "echoed" off of interstellar dust, and is just now arriving at Earth. This effect is called a light echo. The light is behaving like a postcard that got lost in the mail and is only arriving 170 years later.

By performing modern astronomical forensics of the delayed light with ground-based telescopes, astronomers uncovered a surprise.

The new measurements of the 1840s eruption reveal material expanding with record-breaking speeds up to 20 times faster than astronomers expected. The observed velocities are more like the fastest material ejected by the blast wave in a supernova explosion, rather than the relatively slow and gentle winds expected from massive stars before they die.

*This animation shows how the massive star Eta Carinae survived a major eruption in the 1840s. In this scenario, Eta Carinae initially began as a triple-star system. Two hefty stars in the system are orbiting closely and a third companion is orbiting much farther away. When the most massive of the close binary stars nears the end of its life, it begins to expand and dumps most of its material onto its sibling. The sibling bulks up and becomes extremely bright. The donor star, having lost most of its mass, moves farther away from its monster sibling and interacts with the outermost star. The two stars trade places, with the outermost star getting kicked inward. The inward-moving star falls into the monster sibling, and the two stars merge. The merger produces an explosive event that forms bipolar lobes of material ejected from the giant star. The surviving companion star settles into an elongated orbit around the merged pair, passing through the monster star's outer gaseous envelope every 5.5 years. [NASA, ESA, and G. Bacon (STScI)]*

Based on this data, researchers suggest that the eruption may have been triggered by a prolonged stellar brawl among three rowdy sibling stars, which destroyed one star and left the other two in a binary system. This tussle may have culminated with




*This six-panel graphic illustrates a possible scenario for the powerful blast seen 170 years ago from the star system Eta Carinae. 1 - Eta Carinae initially was a triple-star system. Two hefty stars (A and B) in the system are orbiting closely and a third companion C is orbiting much farther away. 2 - When the most massive of the close binary stars (A) nears the end of its life, it begins to expand and dumps most of its material onto its slightly smaller sibling (B). 3 - The sibling (B) bulks up to about 100 solar masses and becomes extremely bright. The donor star (A) has been stripped of its hydrogen layers, exposing its hot helium core. The mass transfer alters the gravitational balance of the system, and the helium-core star moves farther away from its monster sibling. 4 - The helium-core star then interacts gravitationally with the outermost star (C), pulling it into the fray. The two stars trade places, and the outermost star gets kicked inward. 5 - Star C, moving inward, interacts with the extremely massive sibling, creating a disk of material around the giant star. 6 - Eventually, star C merges with the hefty star, producing an explosive event that forms bipolar lobes of material ejected from the monster sibling. Meanwhile, the surviving companion, A, settles into an elongated orbit around the merged pair. Every 5.5 years it passes through the giant star's outer gaseous envelope, producing shock waves that are detected in X-rays. [NASA, ESA, and A. Feild (STScI)]*

a violent explosion when Eta Carinae devoured one of its two companions, rocketing more than 10 times the mass of our Sun into space. The ejected mass created gigantic bipolar lobes resembling the dumbbell shape seen in present-day images. The results are reported in a pair of papers by a team led by Nathan Smith of the University of Arizona in Tucson, Arizona, and Armin Rest of the Space Telescope Science Institute in Baltimore, Maryland.

The light echoes were detected in visible-light images obtained since 2003 with moderate-sized telescopes at the Cerro Tololo Inter-American Observatory in Chile.

Using larger Magellan telescopes at the Carnegie Institution for Science's Las Campanas Observatory and the Gemini South Observatory, both also located in Chile, the team then used spectroscopy to dissect the light, allowing them to measure the ejecta's expansion speeds. They clocked material zipping along at more than 20 million miles per hour (fast enough to travel from Earth to Pluto in a few days).

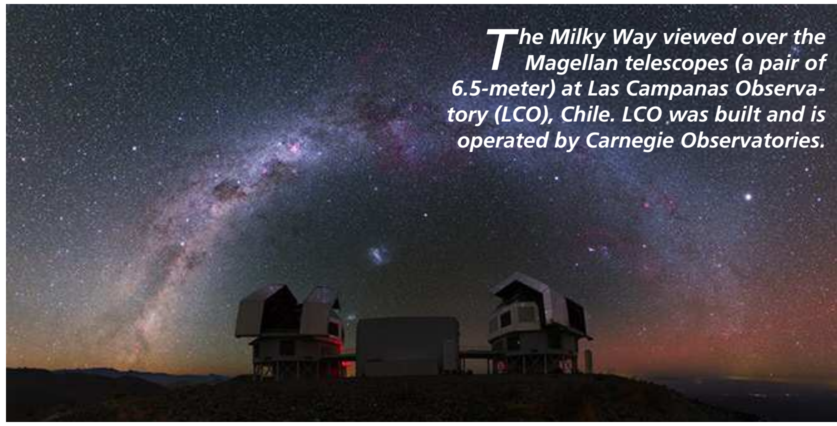
The observations offer new clues to the mystery surrounding the titanic convulsion that, at the time, made Eta Carinae the second-brightest nighttime star seen in the sky from Earth between 1837 and 1858. The data hint at how it may have come to be the most luminous and massive star in the Milky Way galaxy.

*"We see these really high velocities in a star that seems to have had a powerful explosion, but somehow the star survived,"* Smith explained. *"The easiest way to do this is with a shock wave that exits the star and accelerates material to very high speeds."* Massive stars normally meet their final demise in shock-driven events when their cores collapse to make a neutron star or black hole.

Astronomers see this phenomenon in supernova explosions where the star is obliterated. So how do you have a star explode with a shock-driven event, but it isn't enough to completely blow itself apart? Some violent event must have dumped just the right amount of energy onto the star, causing it to eject its outer layers. But the energy wasn't enough to completely annihilate the star.

One possibility for just such an event is a merger between two stars, but it has been hard to find a scenario that could work and match all the data on Eta Carinae. The researchers suggest that the most straightforward way to explain a wide range of observed facts surrounding the eruption is with an interaction of three stars, where the objects exchange mass.

If that's the case, then the present-day remnant binary system must have started out as a triple system. *"The reason why we suggest that members of a crazy triple system interact with each other is because this is the best explanation for how the present-day companion quickly lost its outer layers before its more massive sibling,"* Smith said.

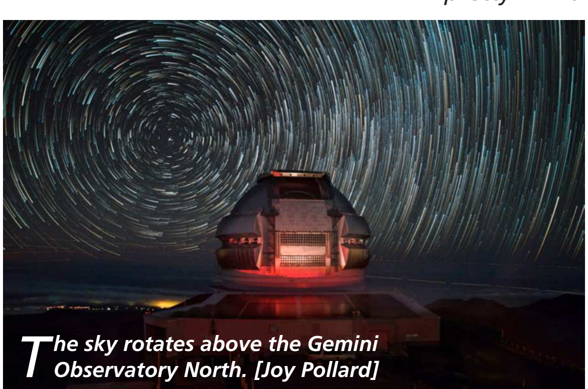


***The Milky Way viewed over the Magellan telescopes (a pair of 6.5-meter) at Las Campanas Observatory (LCO), Chile. LCO was built and is operated by Carnegie Observatories.***

In the team's proposed scenario, two hefty stars are orbiting closely and a third companion is orbiting farther away. When the most massive of the close binary stars nears the end of its life, it begins to expand and dumps most of its material onto its slightly smaller sibling.

The sibling has now bulked up to about 100 times the mass of our Sun and is extremely bright. The donor star, now only about 30 solar masses, has been stripped of its hydrogen layers, exposing its hot helium core.

Hot helium core stars are known to represent an advanced stage of evolution in the lives of massive stars. *"From stellar evolution, there's a pretty firm understanding that more massive stars live their lives more quickly and less massive stars have longer lifetimes,"* Rest explained. *"So the hot companion star seems to be further along in its evolution, even though it is now a much less massive star than the one it is orbiting. That doesn't make sense without a transfer of mass."*



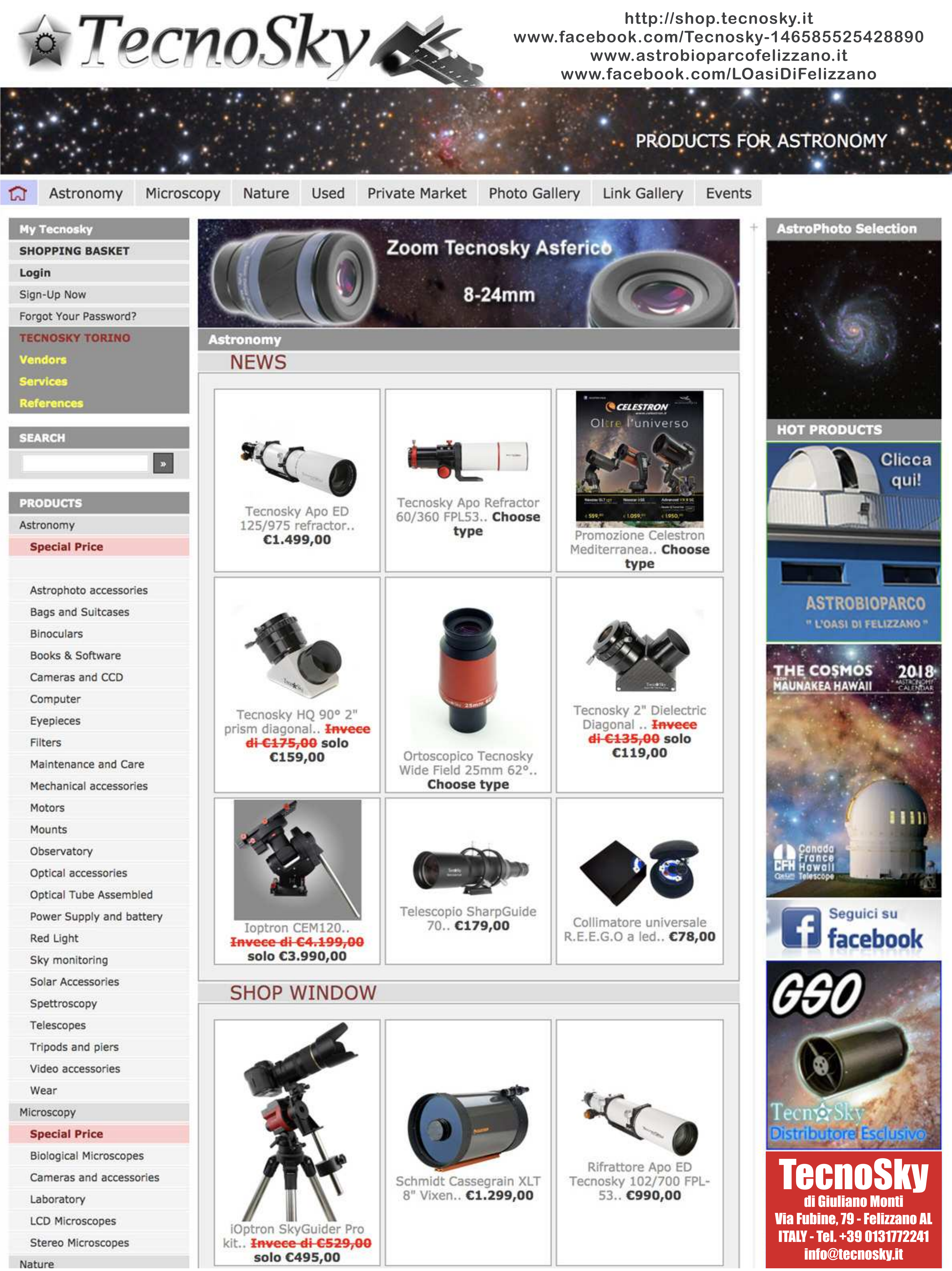
***The sky rotates above the Gemini Observatory North. [Joy Pollard]***

The mass transfer alters the gravitational balance of the system, and the helium-core star moves farther away from its monster sibling. The star travels so far away that it gravitationally interacts with the outermost third star, kicking it inward. After making a few close passes, the star merges with its heavyweight partner, producing an outflow of material.

In the merger's initial stages, the ejecta is dense and expanding relatively slowly as the two stars spiral closer and closer. Later, an explosive event occurs when the two inner stars finally join together, blasting off material moving 100 times faster. This material eventually catches up with the slow ejecta and rams into it like a snowplow, heating the material and making it glow.

This glowing material is the light source of the main historical eruption seen by astronomers a century and a half ago. Meanwhile, the smaller helium-core star settles into an elliptical orbit, passing through the giant star's outer layers every 5.5 years. This interaction generates X-ray emitting shock waves.

A better understanding of the physics of Eta Carinae's eruption may help to shed light on the complicated interactions of binary and multiple stars, which are critical for understanding the evolution and death of massive stars.


TecnoSky
http://shop.tecnosky.it
www.facebook.com/Tecnosky-146585525428890
www.astrobioparcofelizzano.it
www.facebook.com/LOasiDiFelizzano
PRODUCTS FOR ASTRONOMY
Astronomy
Microscopy
Nature
Used
Private Market
Photo Gallery
Link Gallery
Events
My Tecnosky
SHOPPING BASKET
Login
Sign-Up Now
Forgot Your Password?
TECNOSKY TORINO
Vendors
Services
References
SEARCH
PRODUCTS
Astronomy
Special Price
Astrophoto accessories
Bags and Suitcases
Binoculars
Books & Software
Cameras and CCD
Computer
Eyepieces
Filters
Maintenance and Care
Mechanical accessories
Motors
Mounts
Observatory
Optical accessories
Optical Tube Assembled
Power Supply and battery
Red Light
Sky monitoring
Solar Accessories
Spettroscopy
Telescopes
Tripods and piers
Video accessories
Wear
Microscopy
Special Price
Biological Microscopes
Cameras and accessories
Laboratory
LCD Microscopes
Stereo Microscopes
Nature
Zoom Tecnosky Asferico
8-24mm
Astronomy
NEWS
Tecnosky Apo ED 125/975 refractor.. €1.499,00
Tecnosky Apo Refractor 60/360 FPL53.. Choose type
CELESTRON
Oltre l'universo
Promozione Celestron Mediterranea.. Choose type
Tecnosky HQ 90° 2" prism diagonal.. Invece di €175,00 solo €159,00
Ortoscopico Tecnosky Wide Field 25mm 62°.. Choose type
Tecnosky 2" Dielectric Diagonal .. Invece di €135,00 solo €119,00
Ioptron CEM120.. Invece di €4.199,00 solo €3.990,00
Telescopio SharpGuide 70.. €179,00
Collimatore universale R.E.E.G.O a led.. €78,00
SHOP WINDOW
iOptron SkyGuider Pro kit.. Invece di €529,00 solo €495,00
Schmidt Cassegrain XLT 8" Vixen.. €1.299,00
Rifrattore Apo ED Tecnosky 102/700 FPL-53.. €990,00
AstroPhoto Selection
HOT PRODUCTS
Clicca qui!
ASTROBIOPARCO
" L'OASI DI FELIZZANO "
THE COSMOS FROM MAUNAKEA HAWAII
2018 ASTRONOMY CALENDAR
Canada France Hawaii Telescope
Seguici su facebook
GSO
TecnoSky
Distributore Esclusivo
TecnoSky
di Giuliano Monti
Via Fubine, 79 - Felizzano AL
ITALY - Tel. +39 0131772241
info@tecnosky.it