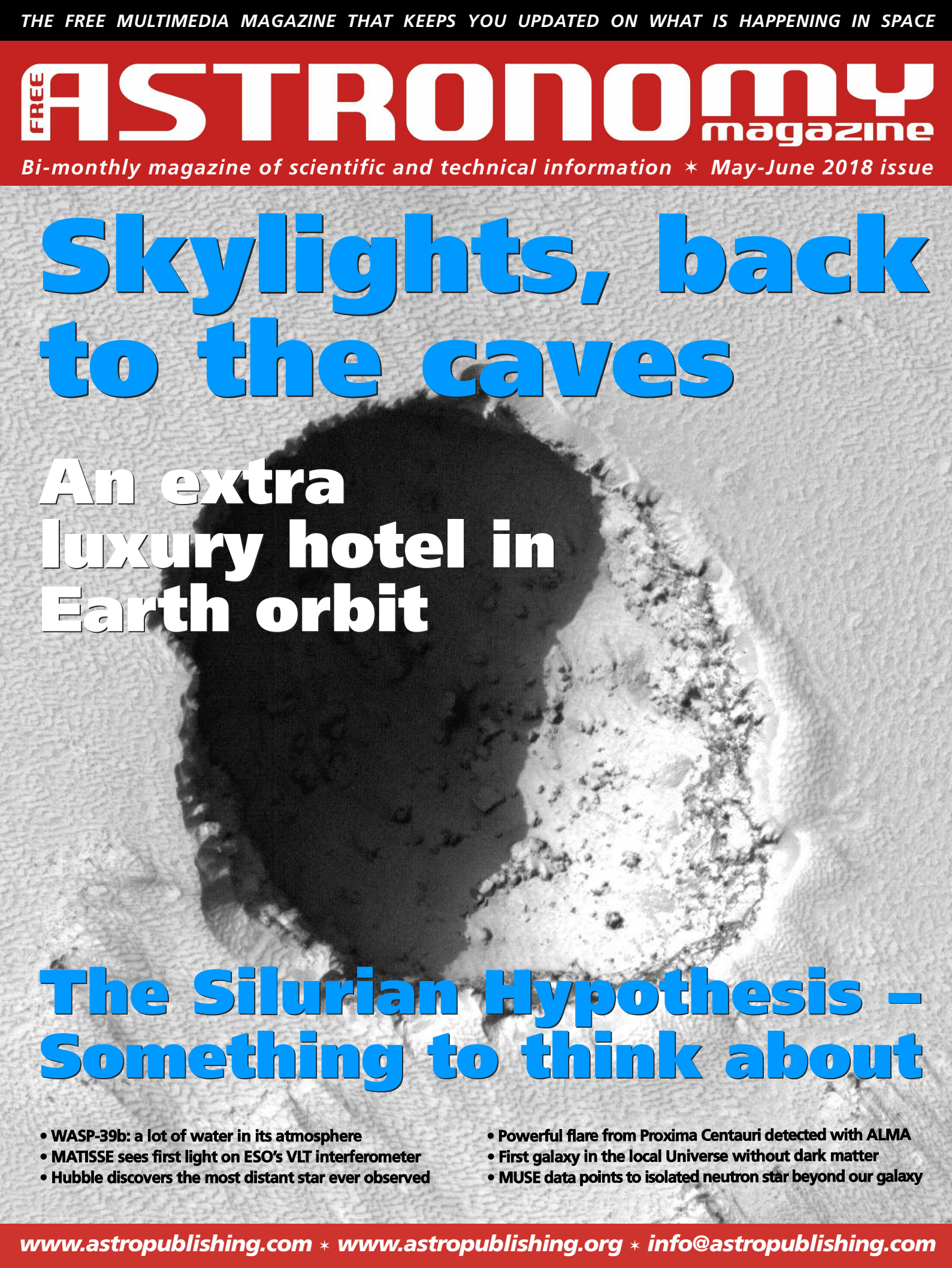
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS HAPPENING IN SPACE

FREE ASTRONOMY magazine

Bi-monthly magazine of scientific and technical information ✶ May-June 2018 issue

Skylights, back to the caves

An extra luxury hotel in Earth orbit



The Silurian Hypothesis – Something to think about

- WASP-39b: a lot of water in its atmosphere
- MATISSE sees first light on ESO's VLT interferometer
- Hubble discovers the most distant star ever observed
- Powerful flare from Proxima Centauri detected with ALMA
- First galaxy in the local Universe without dark matter
- MUSE data points to isolated neutron star beyond our galaxy

www.astropublishing.com ✶ www.astropublishing.org ✶ info@astropublishing.com

NortheK

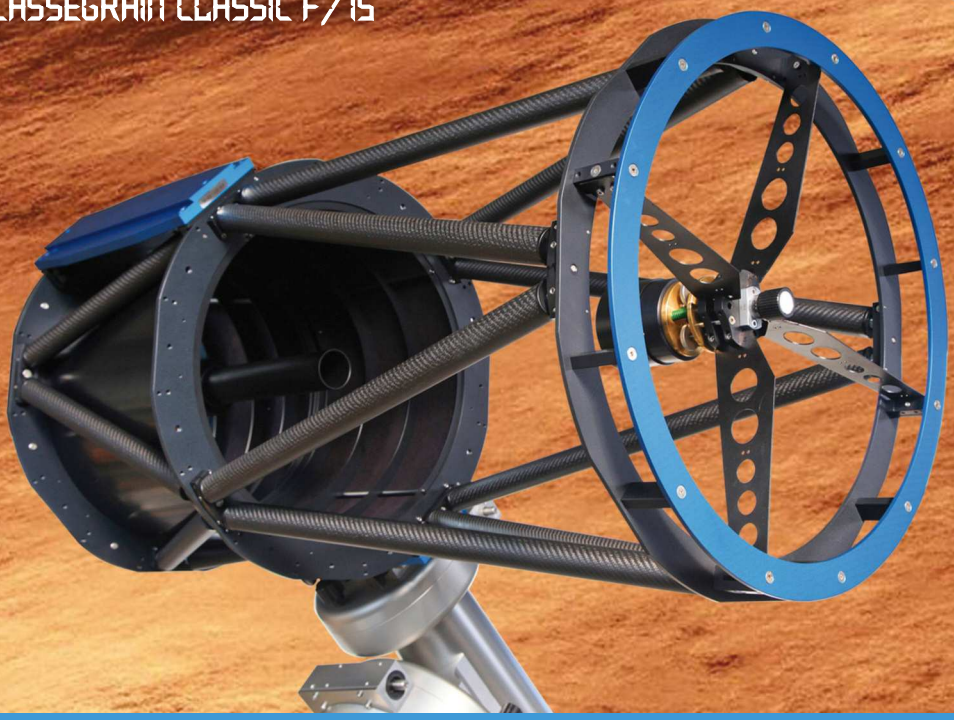
Instruments - Composites - Optics

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

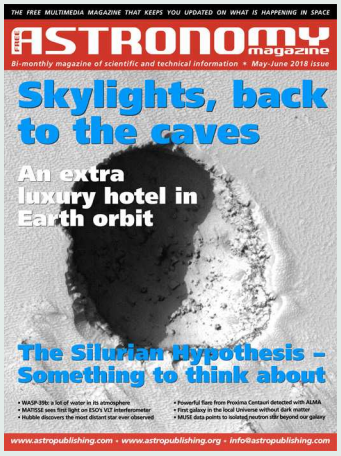


www.northek.it - www.facebook.com/northek.it - info@northek.it - phone +39 01599521

FREE ASTRONOMY magazine

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

May-June 2018



English edition of the magazine

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

Lunar and mar back to the ca

by Michele Ferrara

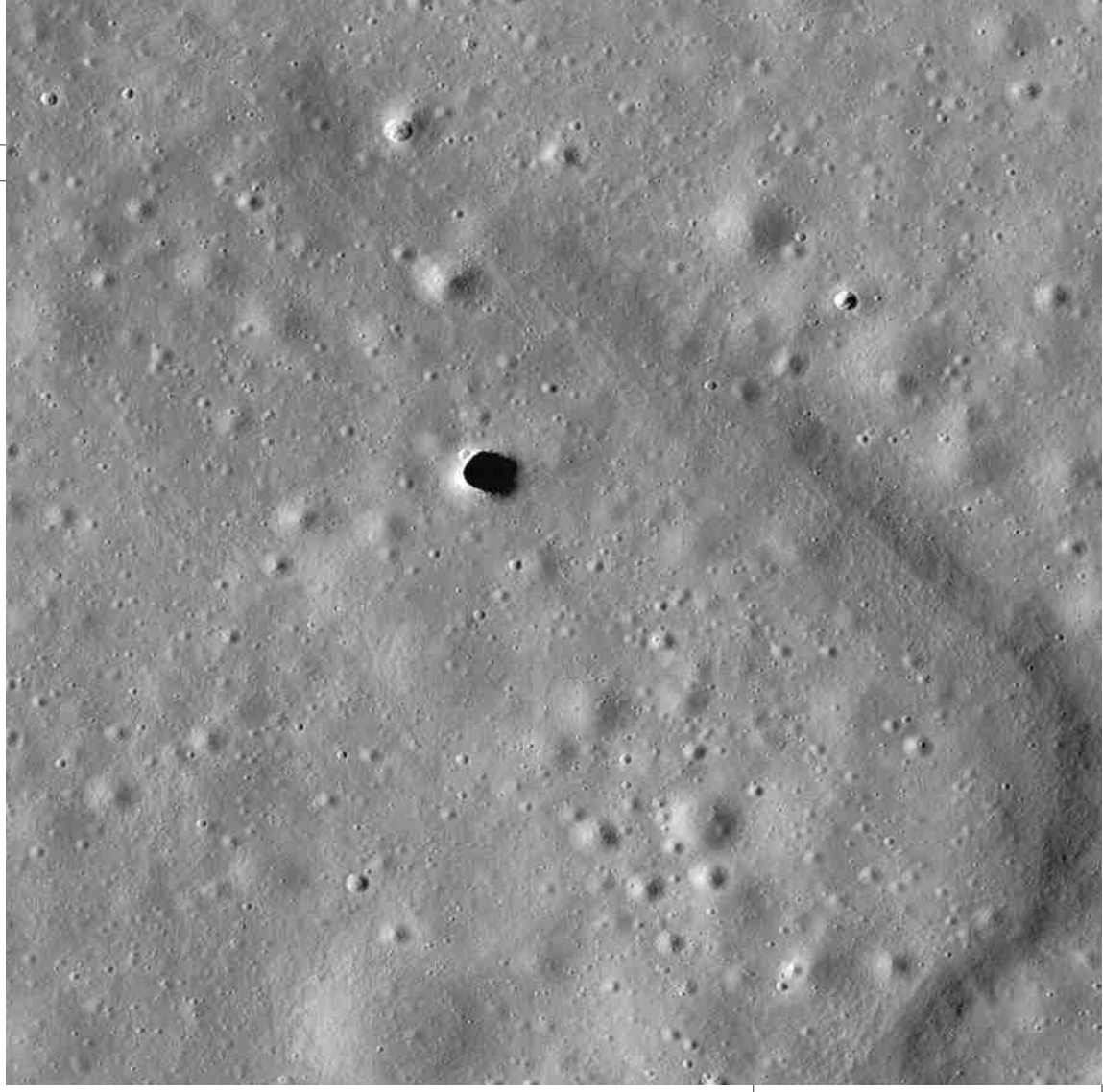
revised by Damian G. Allis
NASA Solar System Ambassador

Illustrators and designers have almost always represented future human settlements on the Moon and Mars in the form of modular structures easily visible from above. It is instead very likely that the first extraterrestrial bases will be hidden underground, within geological formations capable of defending the settlers from the dangers of outer space.

tian skylights, ves

ESA astronauts training in lava tubes in Lanzarote. The first extraterrestrial bases will perhaps be installed in environments similar to this one. [ESA/S. Sechi]

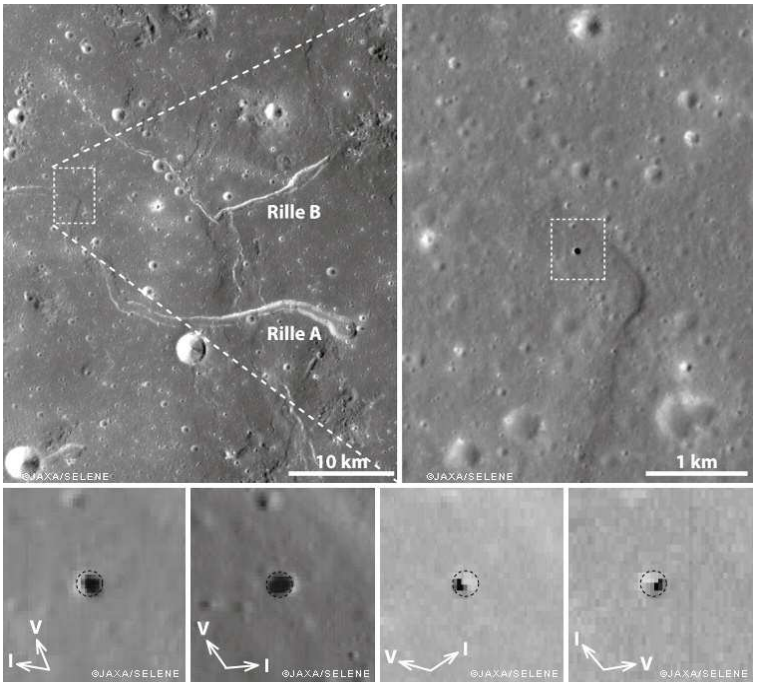
Human beings will eventually colonize the Moon and Mars. Before this happens, effective solutions must be found to the two main threats putting at risk the safety of those who, even for relatively short periods of time, will live within lunar and martian bases. These two threats are harmful solar radiation and meteorite bombardment. As we all know, the Moon is practically devoid of atmosphere, while the atmosphere of Mars is extremely rarefied to the point that the pressure at the surface is just 0.6% that at Earth's surface. Without an adequate atmosphere, the Sun's ultraviolet and X-ray radiation are alone more than enough, both on the Moon and Mars,



to severely affect any form of life not adequately sheltered. The same is true for meteorites that, like bullets, impact the lunar surface without braking.

The rarefied martian atmosphere provides little protection, capable of only disintegrating meteorites within certain limits of mass and composition.

It is conceivable that a permanent human settlement either on the Moon or Mars could efficiently shield its inhabitants from both harmful radiation and sudden changes in temperature between day and night, but very little could be done against the impact of meteorites with even modest masses. Many readers have certainly seen the photographs of those shimmering metallic meteorites that the martian rovers have encountered along their journeys. They are tens of centimeters wide and several kilograms in weight: what would happen if an object of that type fell on an inhabited settlement?



The priority of the future colonization of the solar system's planetary bodies will, therefore, be to protect the bases from unceasing solar radiation and the occasional (but probable in the long term) impact of smaller meteorites.

One of the solutions in colonization proposals that has become increasingly familiar in recent years is to cover the bases, at least

The Marius Hills pit is a possible skylight in a lava tube in an ancient volcanic region of the Moon called the Marius Hills. This LROC image is the highest resolution image of the pit to date. Image width is 1200 meters. [NASA/GSFC/ Arizona State University]
Left, images of the Marius Hills pit as observed under different solar illumination conditions by the SELENE/ Kaguya Terrain Camera and Multiband Imager. [JAXA/SELENE]

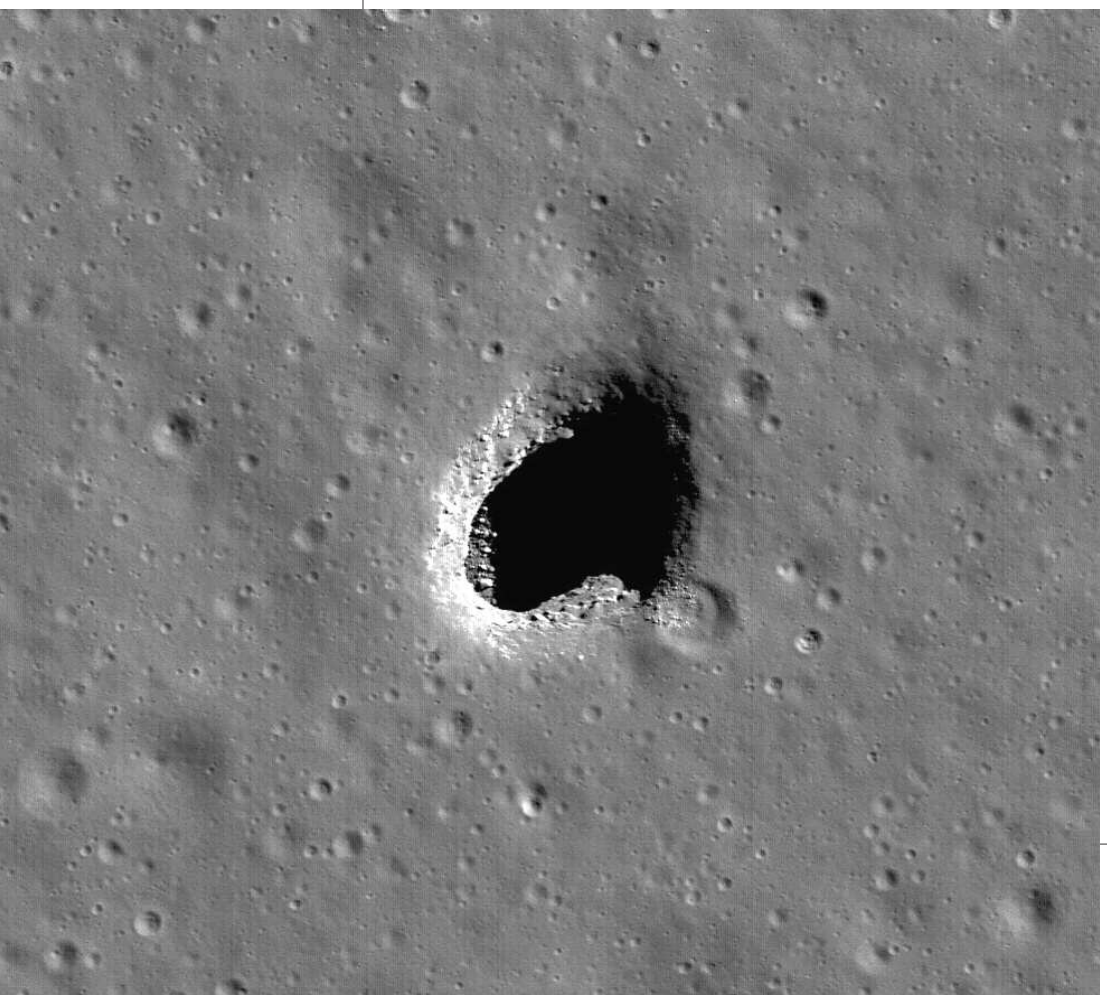
An example of a lava tube: the floor was the crust on a former lava river that fell inward as it drained from beneath. [Dave Bunnell] Below, this cavern in Mare Ingenii is almost twice the size of the one in the Marius Hills. [NASA/Goddard/ASU]

those on the Moon, with a few meters of regolith, the typical dusty material that surrounds the surface of our satellite. This solution is certainly suitable for defense against harmful radiation and micrometeorites, but it may be an unsuitable choice to counteract the effects of impactors several tens of centimeters in diameter or larger.

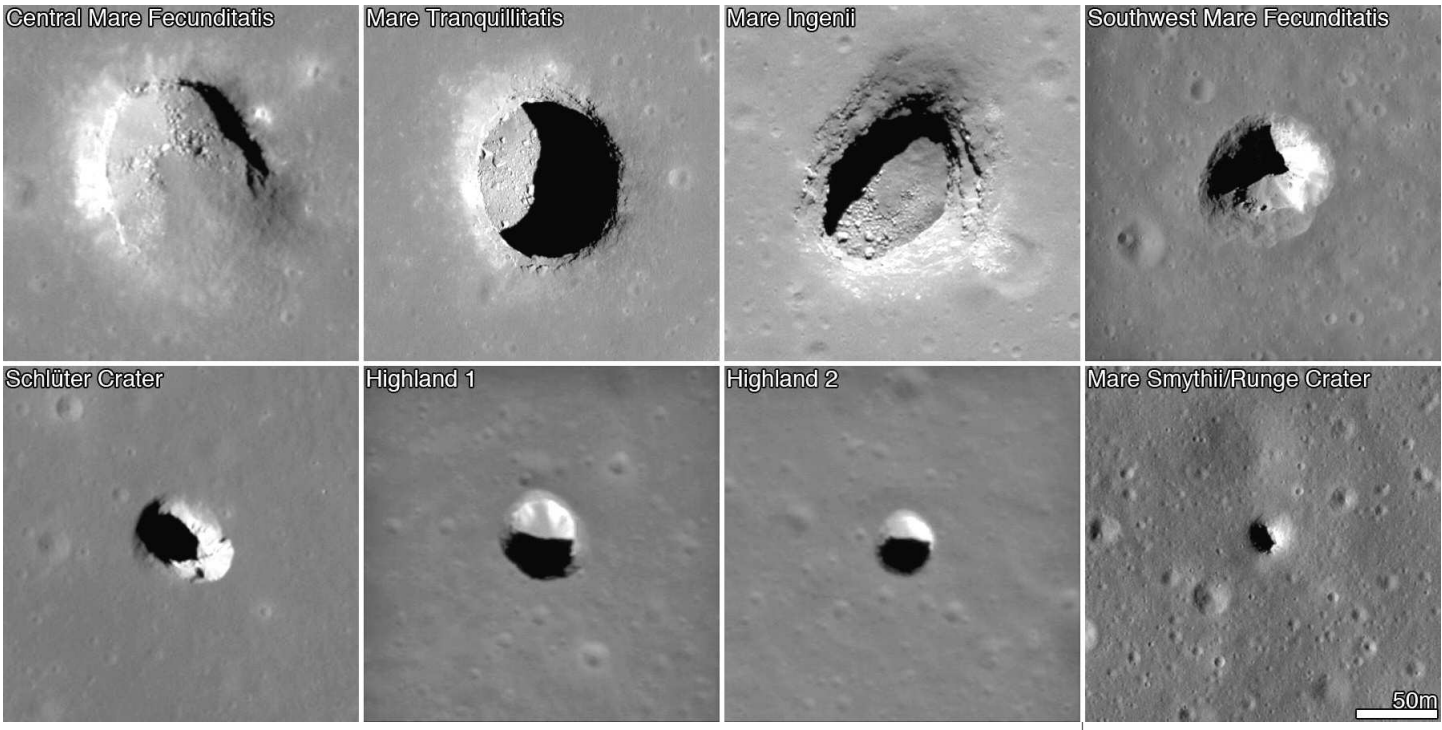
Moreover, an engineering problem arises, that of having to send to the lunar surface (worse on the martian one) all the machines necessary to dig, carry and lay hundreds or thousands of tons of regolith.

The placement of that much regolith over bases is a significant obstacle to the realization of projects of this type, a problem that grows proportionally with the size of the base to be installed and protected.

Habitation would be much simpler if there were geological structures on the Moon and Mars that would naturally shield future human settlements. Incredibly, such features seem to exist on both bodies, and in recent times researchers have gathered more and more convincing evidence for them.



The geological structures in question are long underground tunnels that may be large enough to accommodate the population of a small city. The evidence that those types of formations are present on the Moon dates back to the 60s, when the surface of our satellite was photographed and examined with particular attention as part of the planned Apollo landings. Researchers noticed in the images many narrow and long channels, meandering in vast areas affected in the very distant past by massive effusions of lava (essentially short-lived lava seas and the floors of major impact craters).

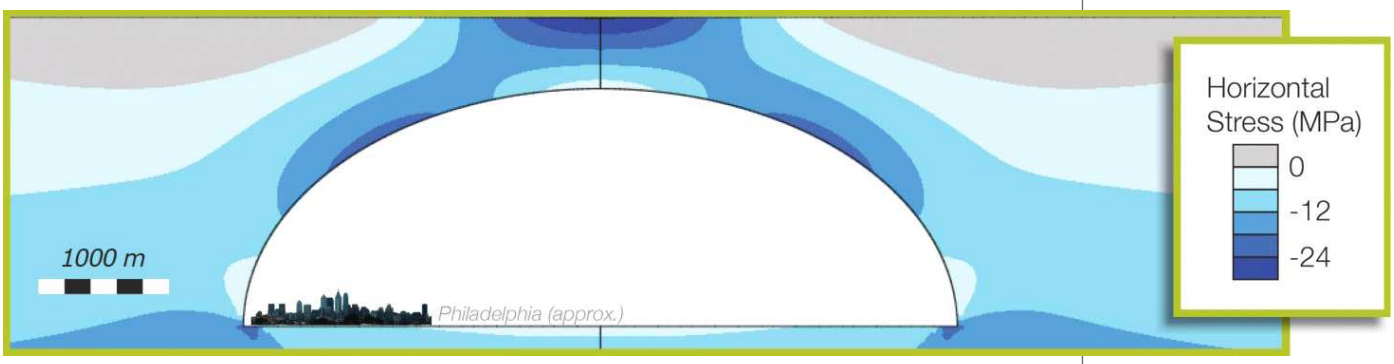


Skylights found on the Moon, some of which may be the entrances to lunar caves. Detailed exploration is required to verify cave presence. [LROC images, ASU]

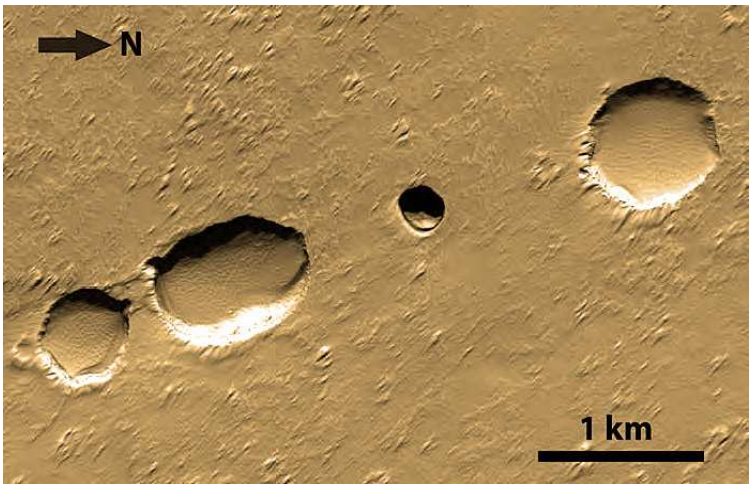
Among the various hypotheses advanced to explain the origin of those channels, called "rilles," one proposed that these channels were originally petrified lava tubes that had their roofs collapse.

Examples of rilles are also present in Earth's volcanic areas (Hawaii, Iceland, Australian North Queensland, Galapagos Islands, Lanzarote and Sicily) and the mechanism through which they formed is rather simple: a stream of lava emerged onto the surface and, following the surface features of the territory on which it flowed, this lava channeled along a slight slope. Due to the lower temperature of the external environment, the outer surface of the flow cooled and solidified, creating a real lava rock pipe. When the eruption ceased, the remaining lava in the tube exited, leaving the hollow, cooler shell behind.

At this point, many external factors can act on the structure. If the tube roof is not thick



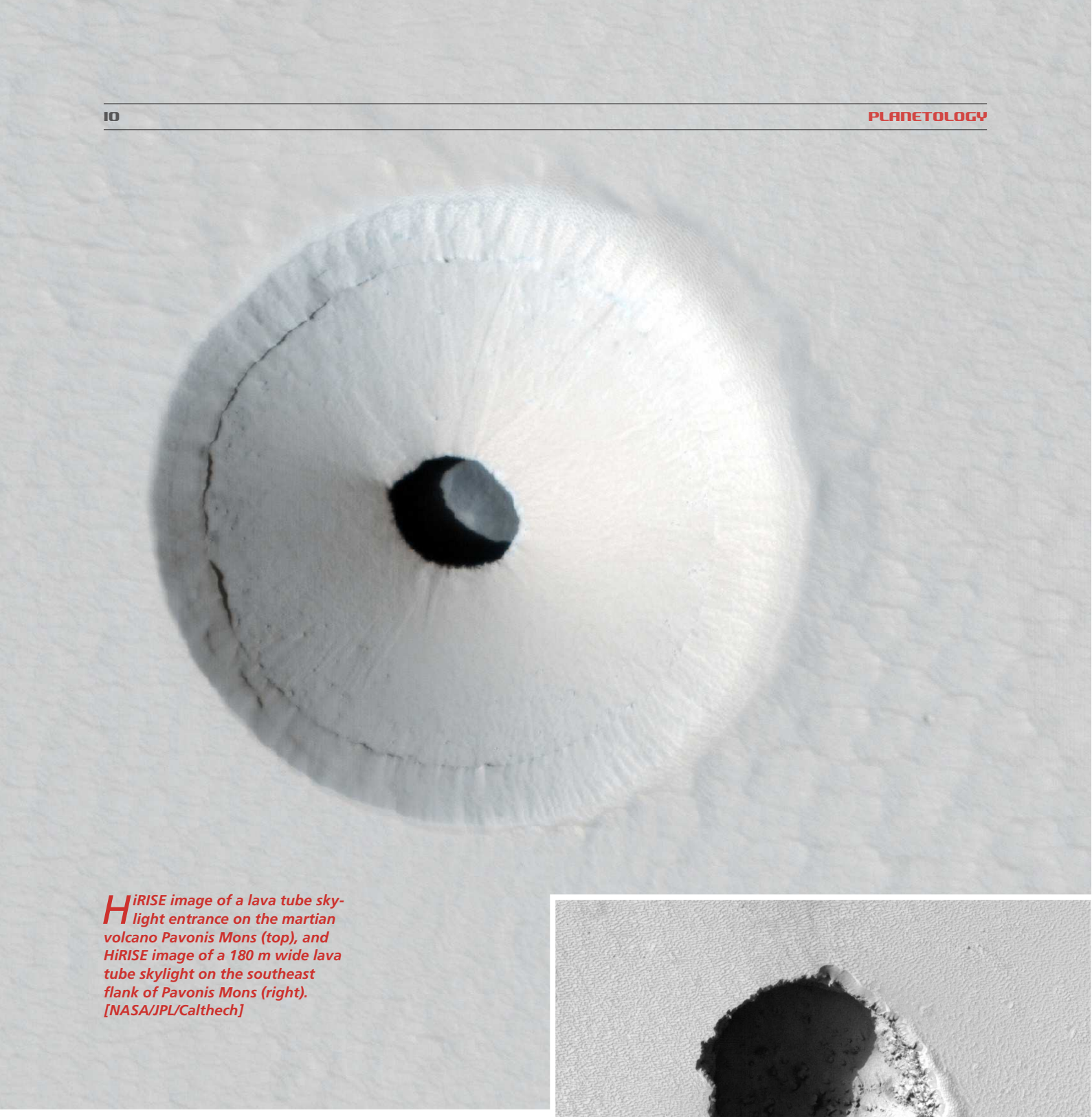
The city of Philadelphia is shown inside a theoretical lunar lava tube. A Purdue University team of researchers explored whether lava tubes more than 1 kilometer wide could remain structurally stable on the Moon. [Purdue University/courtesy of David Blair]



A typical over-crusted lava tube on the northern side of Arsia Mons in the Tharsis volcanic province of Mars. These structures are skylight openings to an underground conduit. [NASA/JPL/University of Arizona] Below, a hypothetical underground view of the same lava tube.

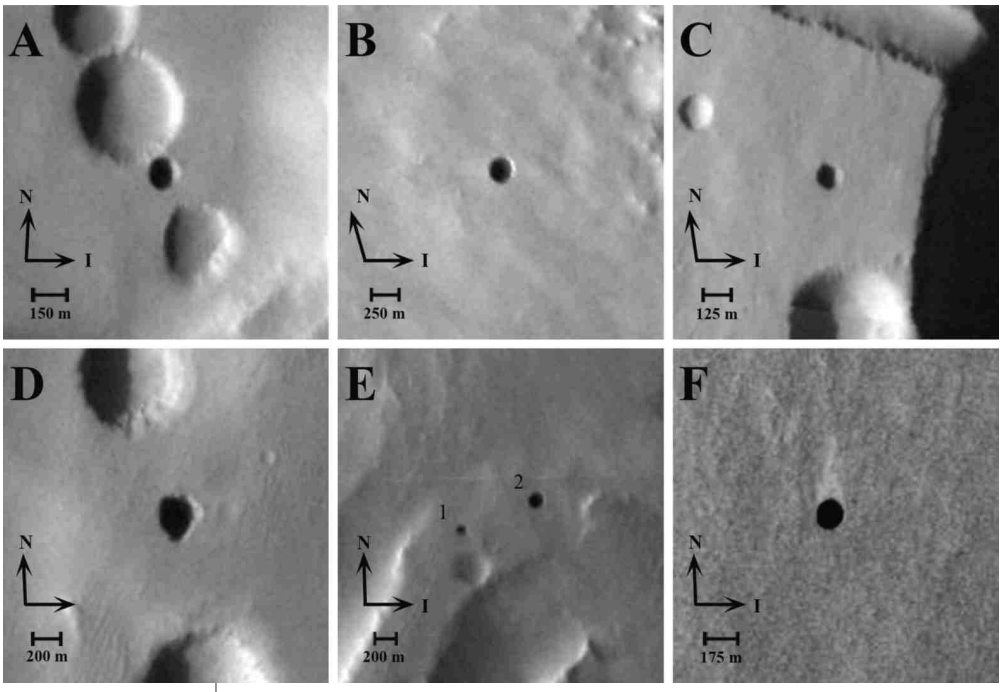
and sturdy enough to support the solidified rock, it can collapse to the floor of the tube itself, revealing the existence of the tunnel when viewed from above. A rille is born. However, the roof of the lava tube does not always collapse. In this case, a long tunnel remains that is almost indistinguishable from the surrounding surface when viewed from above. The width of this tunnel depends on the mass and, therefore, the gravity of the planetary body at the surface of which the tunnel formed. Mathematical models indicate that on Earth, a lava tube can be up to about 30 meters wide; on Mars, the limit is close to 250 meters; on the Moon, there could exist lava tubes up to 5 km wide and hundreds of km long.

Until a decade ago, the existence of tunnels outside of the Earth was still a matter of debate, but between 2009 and 2010 there was a turning point. Indeed, Kaguya (JAXA) and Lunar Reconnaissance Orbiter (NASA) probes succeeded in photographing cavities that give access to vast spaces in the lunar subsoil. More than 200 such cavities, called "skylights", are known today and are thought to be the result of the collapse of short sections of the roofs of numerous lava tubes. In some, if not all cases, the collapse could have been triggered by the impact of a slightly massive meteorite, a dynamic that would explain the typically circular or moderately elongated appearance of many skylights. Simultaneous with the discovery of skylights on the Moon, some have also been observed on Mars, above all thanks to the Mars



HiRISE image of a lava tube skylight entrance on the martian volcano Pavonis Mons (top), and HiRISE image of a 180 m wide lava tube skylight on the southeast flank of Pavonis Mons (right). [NASA/JPL/Calthech]

Reconnaissance Orbiter. Curiously, one of the most famous lunar skylights, the circular one visible in Marius Hills, has dimensions comparable to those of a famous elongated martian skylight visible in the region of Pavonis Mons: the former is 65 meters wide and 80 meters deep; the latter is 190×160 meters wide and at least 115 meters deep. We do not know how long the lava tubes connected to these and other skylights are, and we also do not know if they are empty for long distances or if,



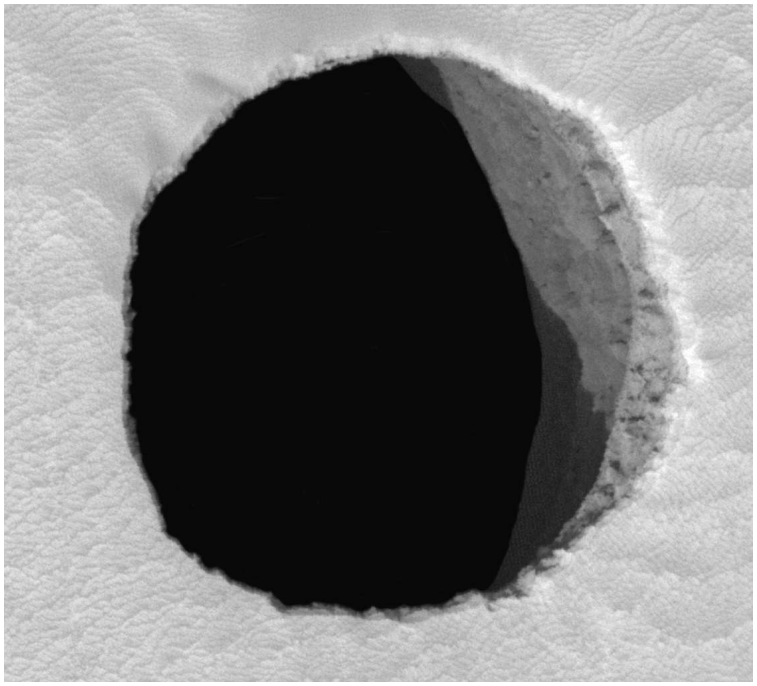
THEMIS image of probable cave entrances on Arsia Mons. The pits have been informally named (A) Dena, (B) Chloe, (C) Wendy, (D) Annie, (E) Abby (left) and Nikki, and (F) Jeanne. [NASA]

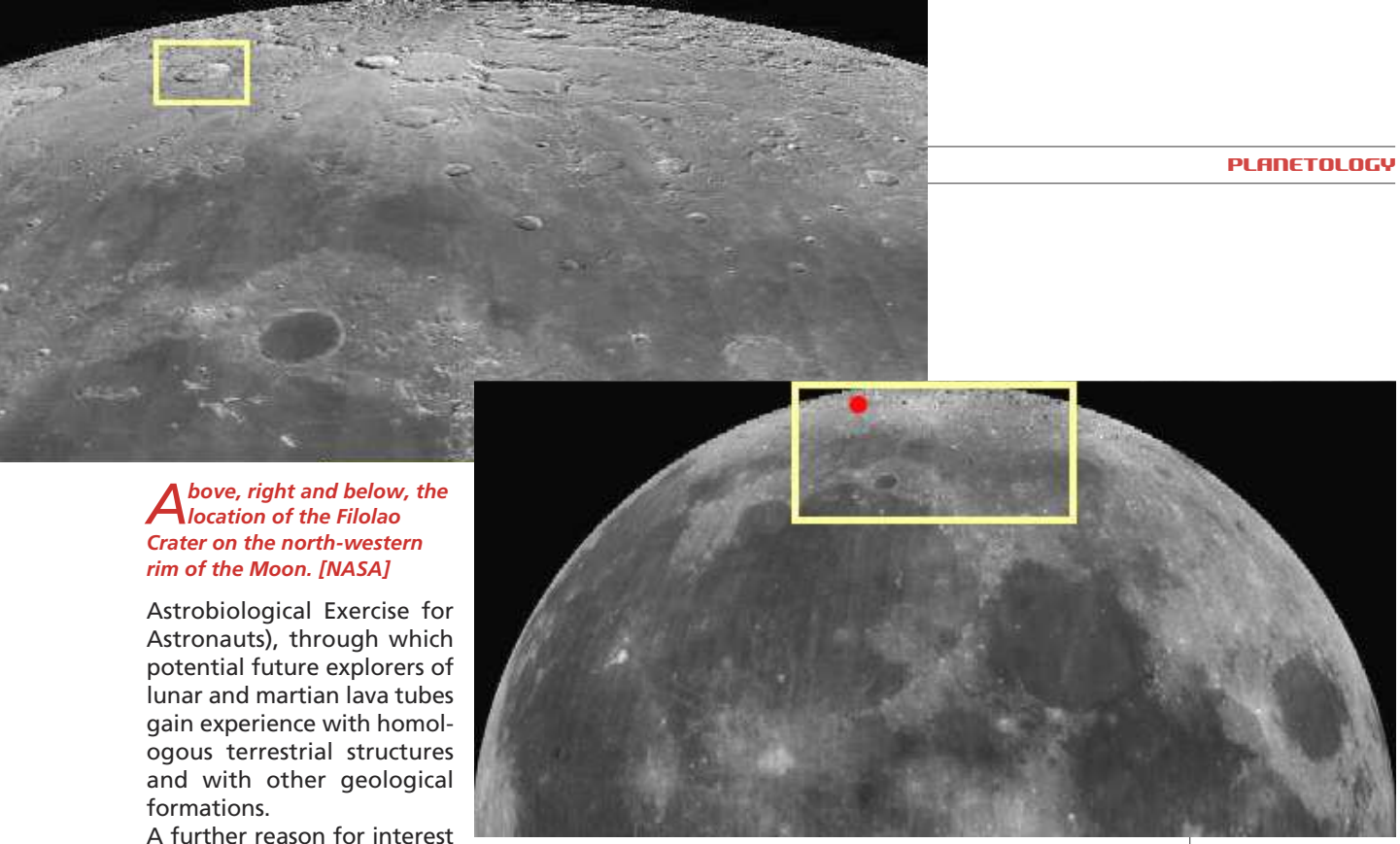
on the contrary, they are mostly filled with solidified lava residue. Considering just the sizes of the skylights mentioned above, it is already clear that lunar and martian lava tubes are undoubtedly suitable for accommodating permanent human bases of considerable size while also providing easy access to the surface through the skylights.

Since these structures have remained unaltered for likely millions of years, it's equally likely they are solid and stable enough to remain unchanged for a very long time.

Therefore, they do not only represent an excellent solution to external threats (within certain limits), but they may also offer the opportunity to create large airtight environments filled with breathable air. It is important to notice that any underground bases installed in those subterranean cavities would also be naturally protected from thermal variations between day and night, which are very severe on the Moon and less extreme on Mars. The interest of researchers in the lava tubes has increased significantly in recent years. They are already planning an orbiter that is specialized for the discovery and measurement of those structures through sophisticated radar techniques – the LAROSS mission (Lunar Advanced Radar Orbiter for Subsurface Sounding).

Specific training programs for astronauts are already being implemented, such as PANGAEA (Planetary Analogical Geological and

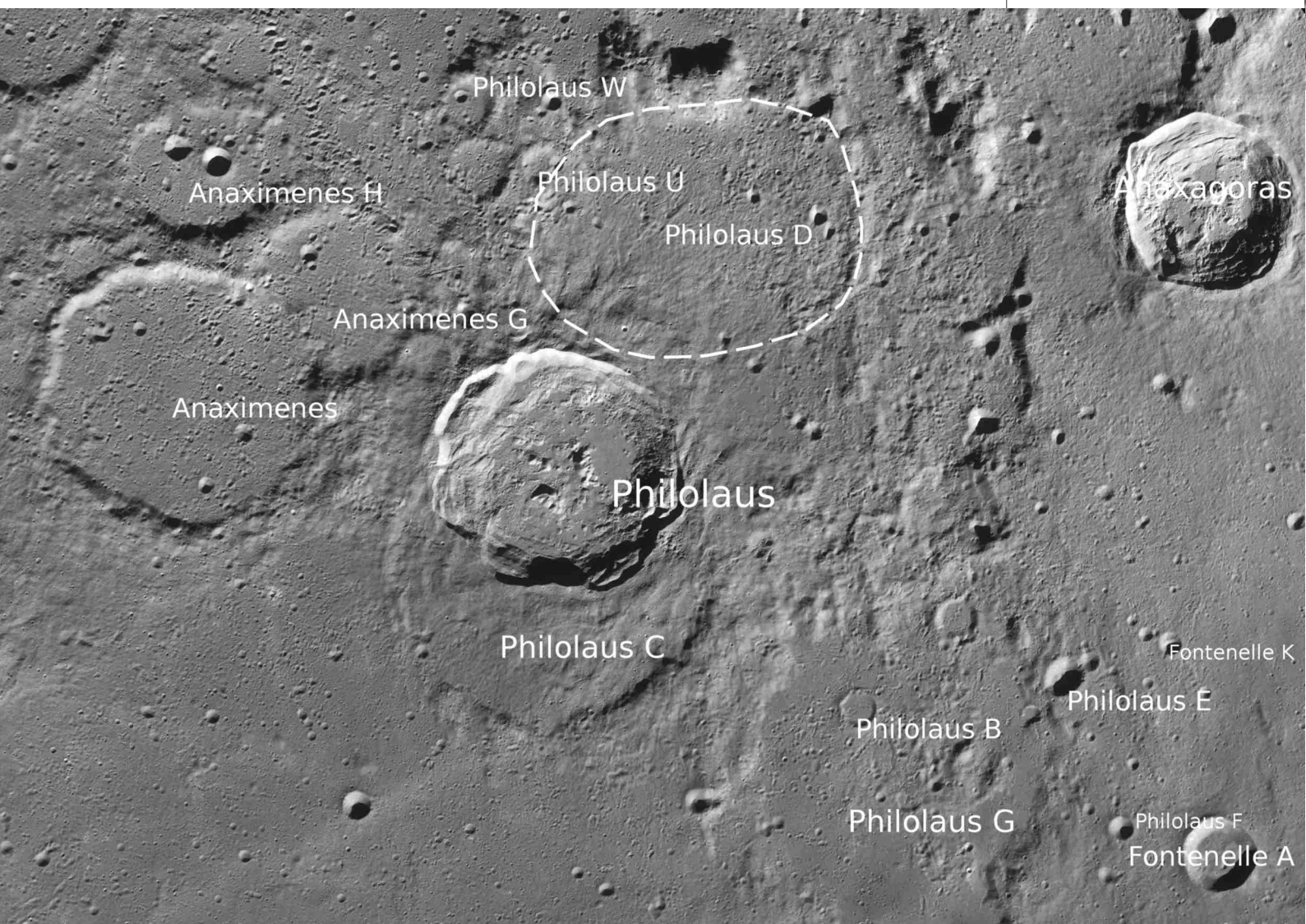




Above, right and below, the location of the Filolao Crater on the north-western rim of the Moon. [NASA]

Astrobiological Exercise for Astronauts), through which potential future explorers of lunar and martian lava tubes gain experience with homologous terrestrial structures and with other geological formations.

A further reason for interest in lava tubes is the discovery, announced last January by the SETI Institute and the Mars Institute at NASA's Lunar Science for Landed Missions Workshop, of three small cavities in the Philolaus Crater (70 km in diameter), only 550 km away from the lunar north pole. Identified in images recorded by the Lunar Reconnaissance Orbiter, the new skylights



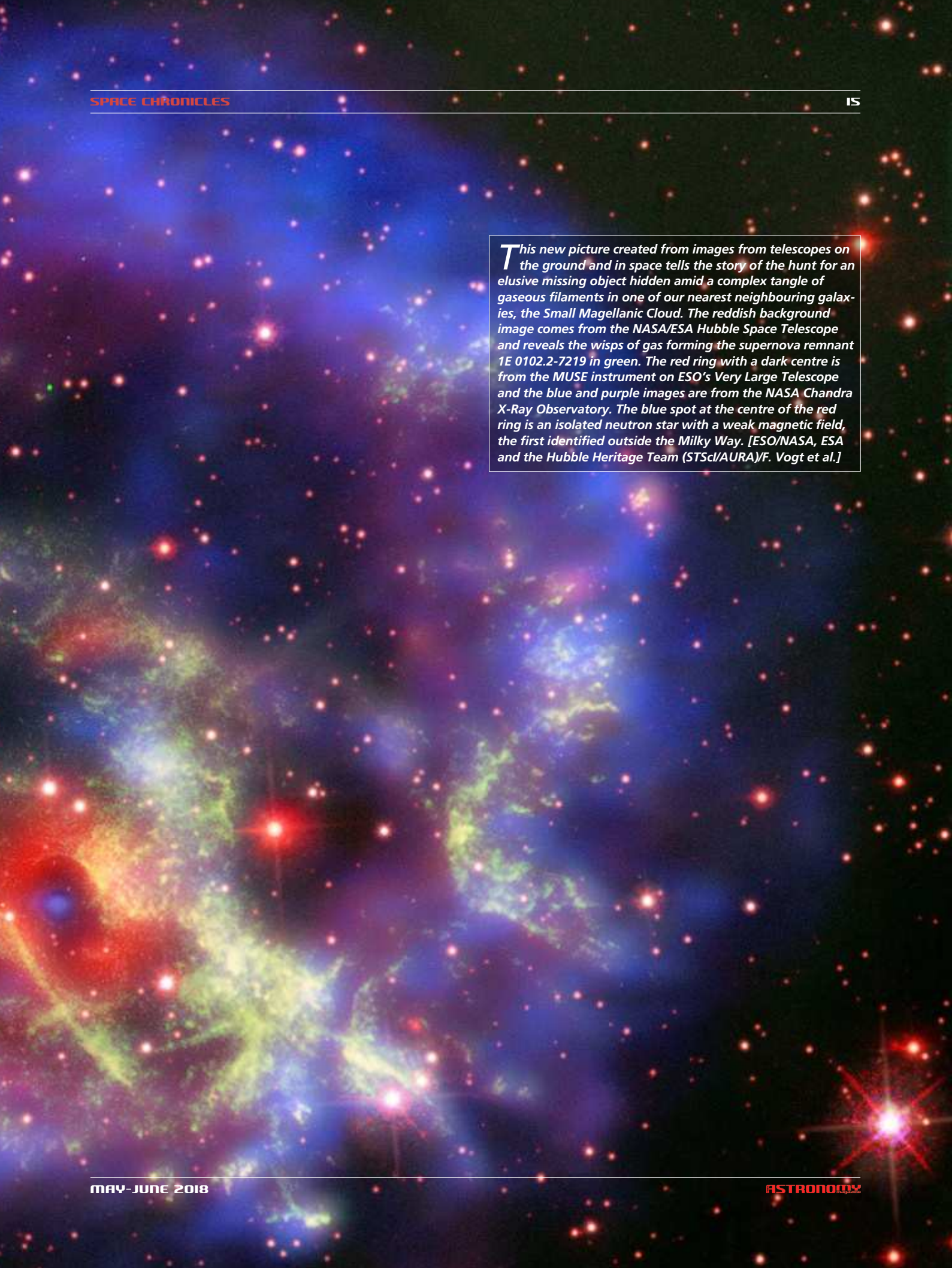
Artist's impression of a surface exploration crew investigating a typical, small lava tunnel, to determine if it could serve as a natural shelter for the habitation modules of a lunar base. [NASA's Johnson Space Center, John R. Lowery]
Right, a virtual tour in the Filolao Crater. [SETI Institute, NASA]

are between 15 and 30 meters wide and appear completely dark due to the low elevation of the Sun above the horizon. It is not possible to state with certainty whether these cavities allow access to one or more underground tunnels. Nevertheless, their position close to the lunar north pole makes them a primary target for future explorations, since the presence of ice water in the subsoil of high latitude lunar territories has already been demonstrated. The newly discovered cavities could give access to deposits of this precious resource and therefore be ideal places to establish the first lunar bases. Here is what planetologist Pascal Lee, discoverer of the three skylights, declared in this regard: "*Our next step should be further exploration, to verify whether these pits are truly lava tube skylights, and if they are, whether the lava tubes actually contain ice. This is an exciting possibility that a new generation of caving astronauts or robotic spelunkers could help address. Exploring lava tubes on the Moon will also prepare us for the exploration of lava tubes on Mars. There, we will face the prospect of expanding our search for life into the deeper underground of Mars where we might find environments that are warmer, wetter, and more sheltered than at the surface.*" ■

MUSE data points to isolated neutron star beyond our galaxy

by ESO

Spectacular new pictures, created from images from both ground- and space-based telescopes, tell the story of the hunt for an elusive missing object hidden amid a complex tangle of gaseous filaments in the Small Magellanic Cloud, about 200,000 light-years from Earth. New data from the MUSE instrument on ESO's Very Large Telescope in Chile has revealed a remarkable ring of gas in a system called 1E 0102.2-7219, expanding slowly within the depths of numerous other fast-moving filaments of gas and dust left behind after a supernova explosion. This discovery allowed a team led by Frédéric Vogt, an ESO Fellow in Chile, to track down the first ever isolated neutron star with low magnetic field located beyond our own Milky Way galaxy. The team noticed that the ring was centred on an X-ray source that had been noted years before and designated p1. The nature of this source had remained a mystery. In particular, it was not clear whether p1 actually lies inside the remnant or behind it. It was only when the ring of gas — which includes both neon and oxygen — was observed with MUSE that the science team noticed it perfectly circled p1. The coincidence was too great, and they realised that p1 must lie within the supernova remnant itself. Once p1's loca-



This new picture created from images from telescopes on the ground and in space tells the story of the hunt for an elusive missing object hidden amid a complex tangle of gaseous filaments in one of our nearest neighbouring galaxies, the Small Magellanic Cloud. The reddish background image comes from the NASA/ESA Hubble Space Telescope and reveals the wisps of gas forming the supernova remnant 1E 0102.2-7219 in green. The red ring with a dark centre is from the MUSE instrument on ESO's Very Large Telescope and the blue and purple images are from the NASA Chandra X-Ray Observatory. The blue spot at the centre of the red ring is an isolated neutron star with a weak magnetic field, the first identified outside the Milky Way. [ESO/NASA, ESA and the Hubble Heritage Team (STScI/AURA)/F. Vogt et al.]

This picture from the NASA/ESA Hubble Space Telescope sets the scene for the story of the hunt for an elusive missing object hidden amid a complex tangle of gaseous filaments in one of our nearest neighbouring galaxies, the Small Magellanic Cloud. The wisps of gas forming the supernova remnant 1E 0102.2-7219 show up in blue near the centre of the picture. Part of the massive star-forming region, N 76, also known as Henize 1956, appears at the lower right in green and pink. [NASA, ESA and the Hubble Heritage Team (STScI/AURA)]

tion was known, the team used existing X-ray observations of this target from the Chandra X-ray Observatory to determine that it must be an isolated neutron star, with a low magnetic field. In the words of Frédéric Vogt: *"If you look for a point source, it doesn't get much better than when the Universe quite literally draws a circle around it to show you where to look."*

When massive stars explode as supernovae, they leave behind a curdled web of hot gas and dust, known as a supernova remnant. These turbulent structures are key to the redistribution of the heavier elements — which are cooked up by massive stars as they live and die — into the interstellar medium, where they eventually form new stars and planets.

Typically barely ten kilometres across, yet weighing more than our Sun, isolated neutron stars with low magnetic fields are thought to be abundant across the Universe, but they are very hard to find because they only shine at X-ray wavelengths. The fact that the confirmation of p1 as an isolated neutron star was enabled by optical observations is thus particularly exciting.

Co-author Liz Bartlett, another ESO Fellow in Chile, sums up this discovery: *"This is the first object of its kind to be confirmed beyond the Milky Way, made possible using MUSE as a guidance tool. We think that this could open up new channels of discovery and study for these elusive stellar remains."* ■

A new generation of observatories at unbeatable prices

The best newcomer - The Canadian manufacturer NexDome has brought a revolutionary new observatory dome design onto the market. The major feature is a **modular design** with two significant advantages - **low transport costs** and **straightforward construction which takes just a few hours**. Never before has a top observatory been so affordable!
Astroshop is the European distributor for NexDome. We can deliver from our warehouse for only € 60 within Germany and for € 150 the rest of Europe. **And, of course, we can naturally also provide advice and service for NexDome observatories.**

THE ADVANTAGES

- *Internal diameter of 2.2 meters provides enough space for a 14 inch Schmidt-Cassegrain or a 1400mm focal length refractor.*
- *Observation window can be opened beyond the zenith.*
- *The dome can be easily rotated by hand thanks to the lightweight ABS plastic construction, but it can also be motorized at no great cost - we can provide the appropriate motors and control units.*
- *The number of compartments for accessories can be freely selected - up to six of these storage accessory bays are possible.*
- *Should any part of the observatory ever be damaged, it can be individually and inexpensively replaced thanks to the modular design.*
- *Solarkote® coating protects against UV radiation and ensures high weather resistance for all parts.*
- *5 years warranty on all ABS parts.*

50355 **€ 4.390**
Complete observatory, including walls
51264 **€ 3.108**
Observatory dome without walls

Enter the product number into the search field!

> More on NexDome.eu!

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

Astronomers discover S0-2 star is single and ready for Einstein test

by Keck Observatory

Astronomers have the "all-clear" for an exciting test of Einstein's Theory of General Relativity, thanks to a new discovery about S0-2's star status. Up until now, it was thought that S0-2 may be a binary, a system where two stars circle around each other. Having such a partner would have complicated the upcoming gravity test. But in a study published recently in *The Astrophysical Journal*, a team of astronomers led by a UCLA scientist from Hawaii has found that S0-2 does not have a significant other after all, or at least one that is massive enough to get in the way of critical measurements that astronomers need to test Einstein's theory.

The researchers made their discovery by obtaining spectroscopic measurements of S0-2 using W. M. Keck Observatory's OH-Suppressing Infrared Imaging Spectrograph (OSIRIS) and Laser Guide Star Adaptive Optics. *"This is the first study to investigate S0-2 as a spectroscopic binary,"* said lead author Devin Chu of Hilo, an astronomy graduate student with UCLA's Galactic Center Group. *"It's incredibly rewarding. This study gives us confidence that a S0-2 binary system will not significantly affect our ability to measure gravitational redshift."* Einstein's Theory of General Relativity predicts that light coming from a strong gravitational field gets stretched out, or "redshifted." Researchers expect to directly measure this phenomenon beginning in the spring as S0-2 makes its closest approach to the supermassive black hole at the center of our Milky Way galaxy. This will allow the Galactic Center Group to witness the star being pulled at maximum gravitational strength – a point where any deviation to Einstein's theory is expected to be the greatest. *"It will be the first measurement of its kind,"* said co-author Tuan Do, deputy director of the Galactic Center Group. *"Gravity is the least well-tested of the forces of nature. Einstein's theory has passed all other tests with flying colors so far, so if there are deviations measured, it would certainly raise lots of questions about the nature of gravity!"* *"We have been waiting 16 years for this,"* said Chu.

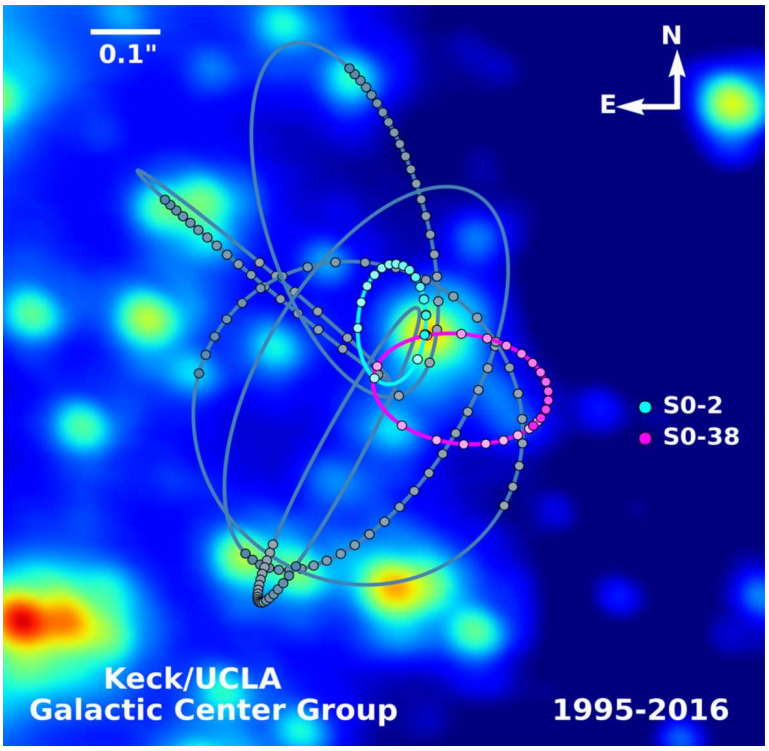
The UCLA Galactic Center Group takes a photo together during a visit to Keck Observatory, located atop Maunakea, Hawaii. Members of the group will return to the Observatory this spring to begin observations of S0-2 as the star travels towards its closest distance to the Galactic Center's supermassive black hole. [UCLA Galactic Center Group]

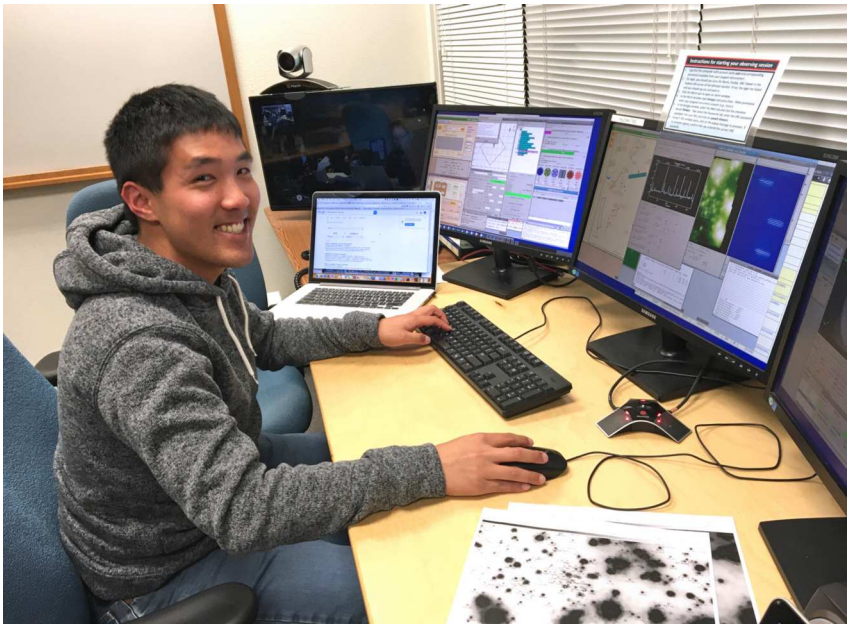
"We are anxious to see how the star will behave under the black hole's violent pull. Will S0-2 follow Einstein's theory or will the star defy our current laws of physics? We will soon find out!"

The study also sheds more light on the strange birth of S0-2 and its stellar neighbors in the S-Star Cluster. The fact that these stars exist so close to the supermassive black hole is unusual because they are so young; how they could've formed in such a hostile environment is a mystery. *"Star formation at the Galactic Center is difficult because the brute strength of tidal forces from the black hole can tear gas clouds apart before they can collapse and form stars,"* said Do. *"S0-2 is a very special and puzzling star,"* said Chu. *"We don't typically see young, hot stars like S0-2 form so close to a supermassive black hole. This means that S0-2 must have formed a different way."* There are several theories that provide a possible explanation, with S0-2 being a binary as one of them. *"We were able to put an upper limit on the mass of a companion star for S0-2,"* said Chu. This new constraint brings astronomers closer to understanding this unusual object. *"Stars as massive as S0-2 almost always have a binary companion. We are lucky that having no companion makes the measurements of general relativistic effects easier, but it also deepens the mystery of this star,"* said Do.

The Galactic Center Group now plans to study other S-Stars orbiting the supermassive black hole, in hopes of differentiating between the varying theories that attempt to explain why S0-2 is single. ■

The orbit of S0-2 (light blue) located near the Milky Way's supermassive black hole will be used to test Einstein's Theory of General Relativity and generate potentially new gravitational models. [S. Sakai/ A.Ghez/ W. M. Keck Observatory/UCLA Galactic Center Group]





Lead author Devin Chu of Hilo, Hawaii is an astronomy graduate student at UCLA. The Hilo High School and 2014 Dartmouth College alumnus conducts his research with the UCLA Galactic Center Group, which uses the W. M. Keck Observatory on Hawaii Island to obtain scientific data. [D. Chu]

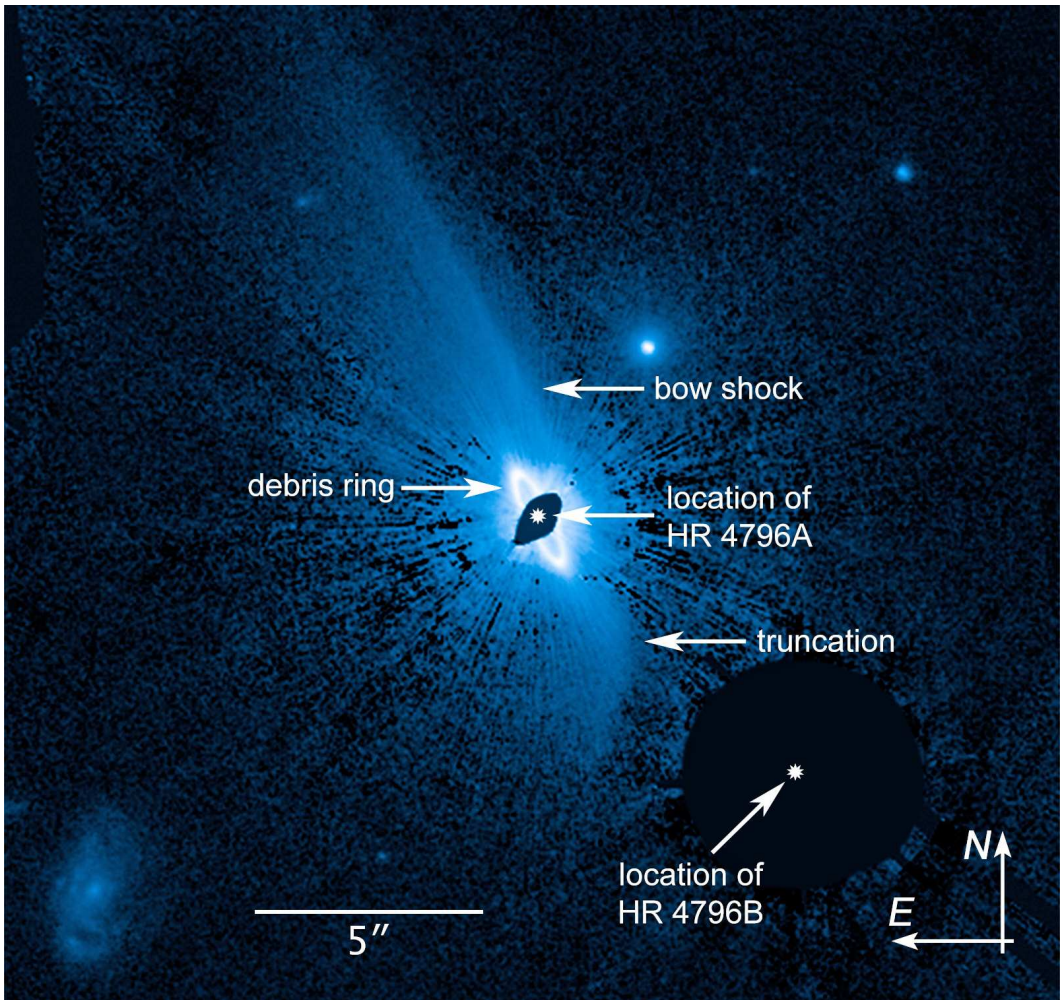
Huge system of dusty material enveloping HR 4796A discovered

by NASA/ESA

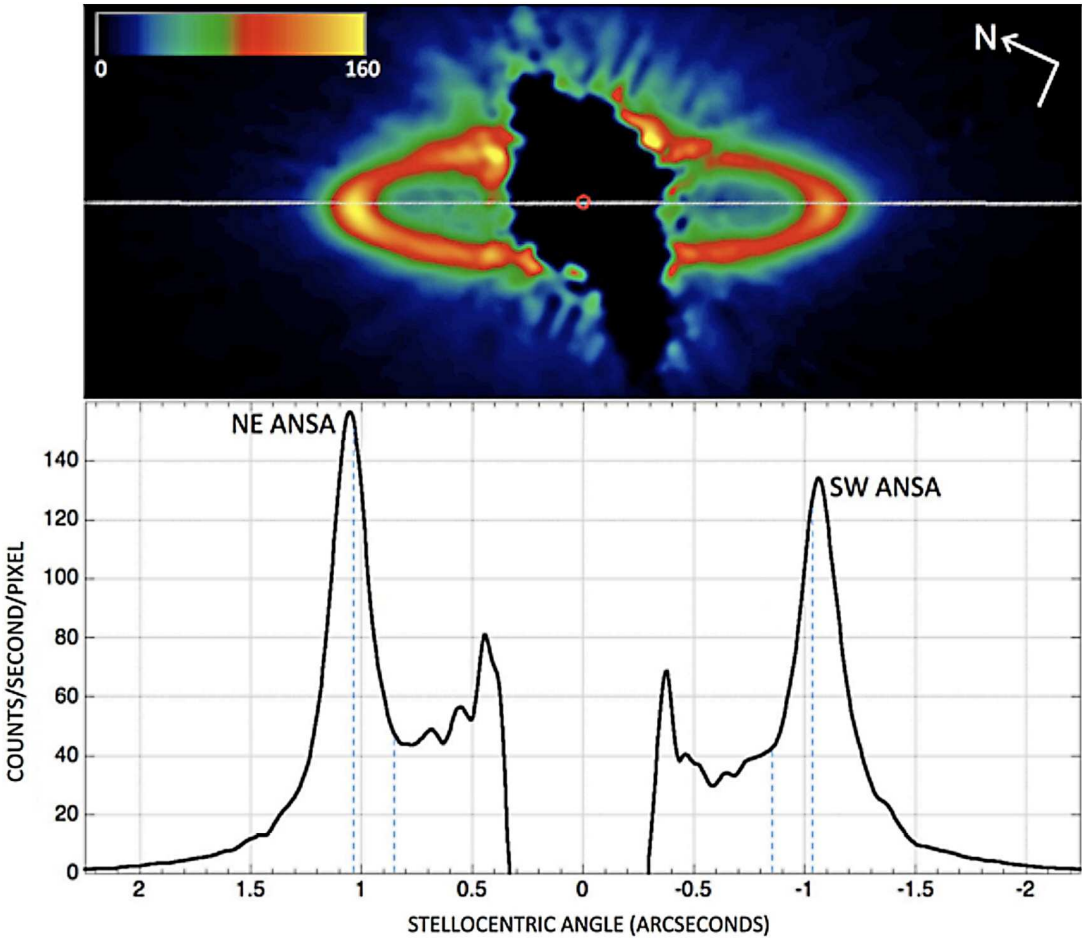
Astronomers have used NASA's Hubble Space Telescope to uncover a vast, complex dust structure, about 150 billion miles across, enveloping the young star HR 4796A.

A bright, narrow, inner ring of dust is already known to encircle the star and may have been corralled by the gravitational pull of an unseen giant planet.

This newly discovered huge structure around the system may have implications for what this yet-unseen planetary system looks like around the 8-million-year-old star, which is in its formative years of planet construction. The debris field



This is a Hubble Space Telescope photo of a vast, complex dust structure, about 150 billion miles across, enveloping the young star HR 4796A. [NASA, ESA, and G. Schneider (University of Arizona)]



Surface brightness image of the HR 4796A debris ring. [G. Schneider et al.]

of very fine dust was likely created from collisions among developing infant planets near the star, evidenced by a bright ring of dusty debris seen 7 billion miles from the star. The pressure of starlight from the star, which is 23 times more luminous than the Sun, then expelled the dust far into space. But the dynamics don't stop there. The puffy outer dust structure is like a donut-shaped inner tube that got hit by a truck. It is much more extended in one direction than in the other and so looks squashed on one side even after accounting for its inclined projection on the sky. This may be due to the motion of the host star plowing through the interstellar medium, like the bow wave from a boat crossing a lake. Or it may be influenced by a tidal tug from the star's red dwarf binary companion (HR 4796B), located at least 54 billion miles from the primary star. *"The dust distribution is a telltale sign of how dynamically interactive the inner system containing the ring is,"* said Glenn Schneider of the University of Arizona, Tucson, who used Hubble's Space Telescope Imaging Spectrograph (STIS) to probe and map the small dust particles in the outer reaches of the HR 4796A system, a survey that only Hubble's sensitivity can accomplish. *"We cannot treat exoplanetary debris systems as simply being in isolation. Environmental effects, such as interactions with the interstellar medium and forces due to stellar companions, may have long-term implications for the evolution of such systems.*

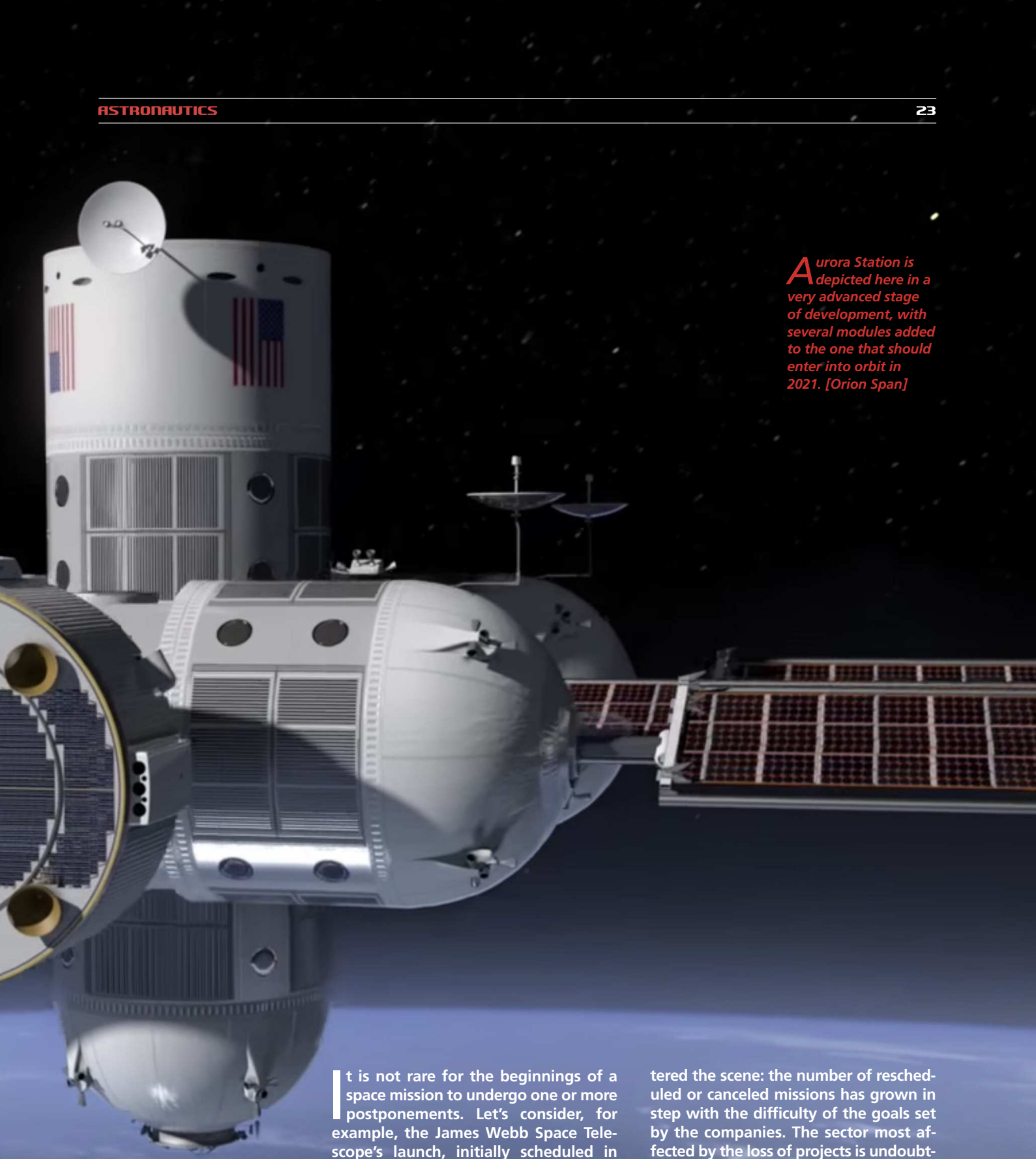
The gross asymmetries of the outer dust field are telling us there are a lot of forces in play (beyond just host-star radiation pressure) that are moving the material around. We have seen effects like this in a few other systems, but here's a case where we see a bunch of things going on at once," Schneider further explained. Though long hypothesized, the first evidence for a debris disk around any star was uncovered in 1983 with NASA's Infrared Astronomical Satellite. Later photographs revealed an edge-on debris disk around the southern star Beta Pictoris. In the late 1990s, Hubble's second-generation instruments, which had the capability of blocking out the glare of a central star, allowed many more disks to be photographed. Now, such debris rings are thought to be common around stars. About 40 such systems have been imaged to date, largely by Hubble. ■

An extra luxury hotel in Earth orbit

by Michele Ferrara

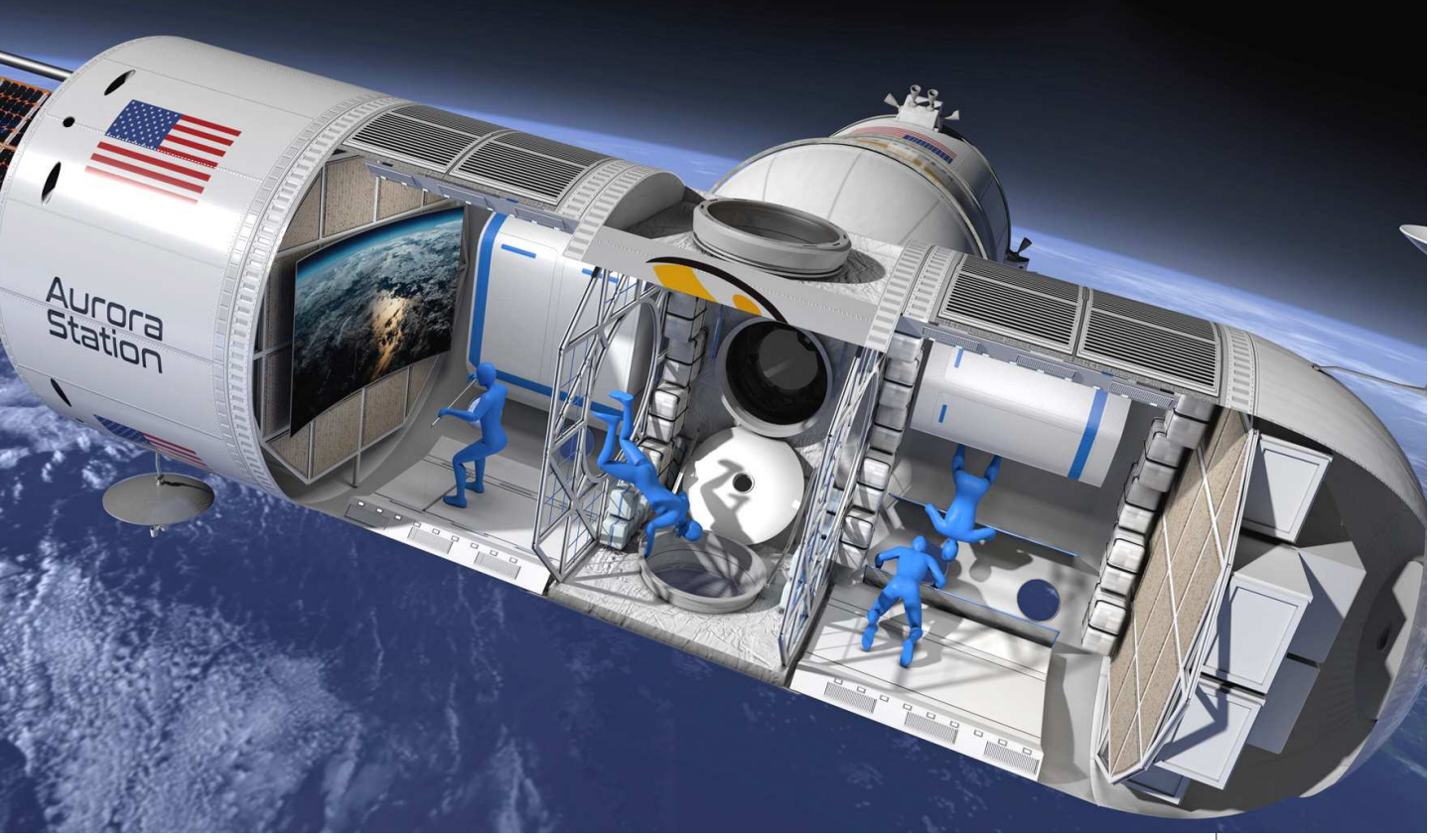
revised by Damian G. Allis
NASA Solar System Ambassador

"Making space accessible to everyone" – this is the most often used slogan by private aerospace companies that, more and more numerous, propose themselves as tour operators able to offer vacations in Earth orbit. While all of the projects proposed so far have yet to succeed, the latest arrival, known as Aurora Station, could have more luck. In any case, space will not be accessible to everyone just yet.



Aurora Station is depicted here in a very advanced stage of development, with several modules added to the one that should enter into orbit in 2021. [Orion Span]

It is not rare for the beginnings of a space mission to undergo one or more postponements. Let's consider, for example, the James Webb Space Telescope's launch, initially scheduled in 2018, then delayed to 2019, and now expected in 2020. This problem has become even more evident as some dozens of private aerospace companies have entered the scene: the number of rescheduled or canceled missions has grown in step with the difficulty of the goals set by the companies. The sector most affected by the loss of projects is undoubtedly that of space tourism. It often happens that this-or-that company does clamorous announcements promising to carry tourists to low Earth orbit within a



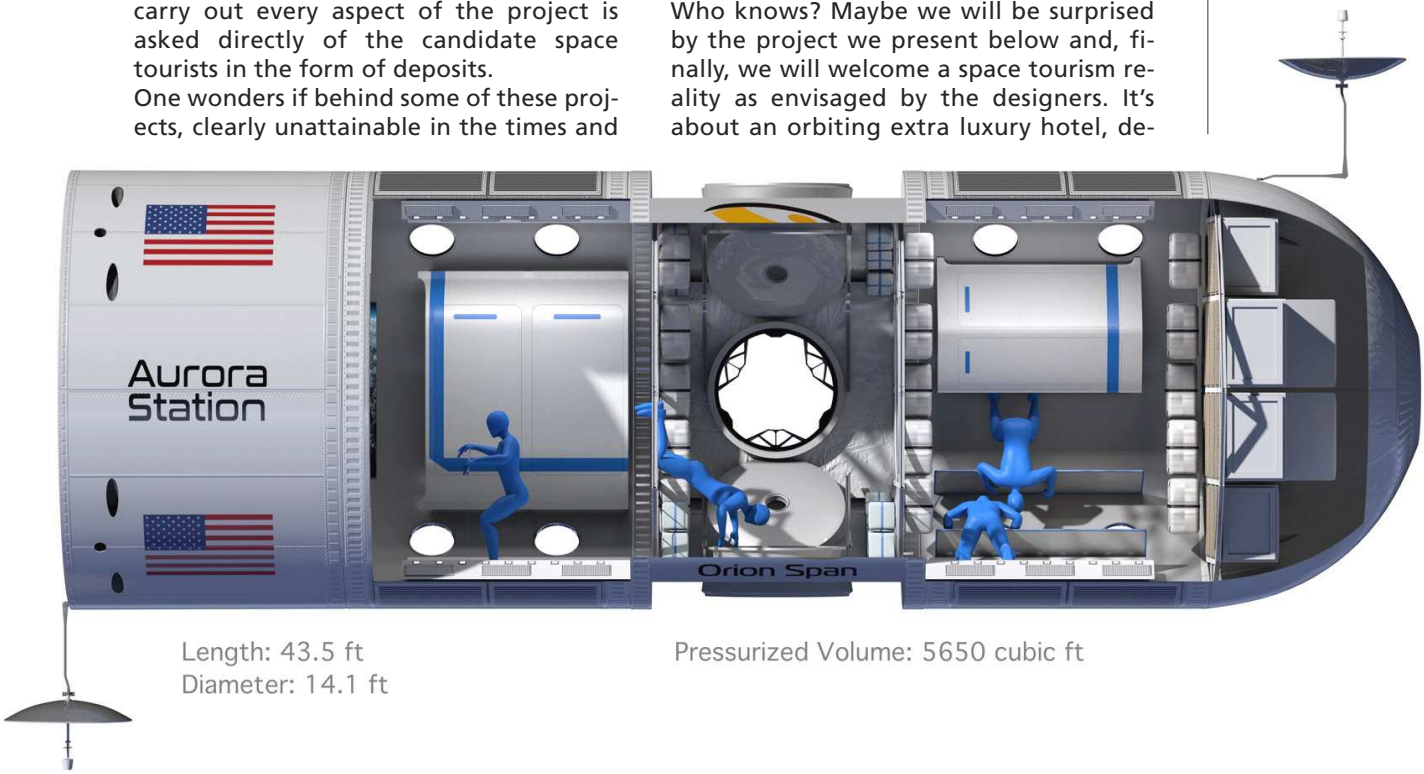
Graphical representation of the internal structure of Aurora Station, seen from different angles. The environments are rather cramped, but the addition of other modules will make the holiday of space tourist accommodations pleasant enough. [Orion Span]

few years or to allow them to circumnavigate the Moon and Mars, or even to deliver passengers down to their surfaces.

The curious thing is that even the most ambitious of these projects are apparently feasible, being able to rely on necessary technologies and skills that exist today. Almost always when these projects are announced, they share some aspects that leave us perplexed, not to say suspicious: they are generally still on paper and far from the development phase; they have mission start dates surprisingly close and improbable, considering the large number of contingencies that may arise; finally, at least some part of the capital necessary to carry out every aspect of the project is asked directly of the candidate space tourists in the form of deposits.

One wonders if behind some of these projects, clearly unattainable in the times and terms that are proposed, there is not the precise intent to scrape together capital and advertise at low cost to simply make money, exploiting interest in a hypothetical mission to the Moon or to Mars. As usual, after a few years the project vanishes into thin air, and maybe the same designers replace it with another one, still unattainable as proposed but equally useful for financing and advertising purposes. Some space tourism operators are certainly animated by noble intentions, but so far the announced goals for these companies have yet to be accomplished, even as of late for a project announced several years earlier in this magazine.

Who knows? Maybe we will be surprised by the project we present below and, finally, we will welcome a space tourism reality as envisaged by the designers. It's about an orbiting extra luxury hotel, de-



Length: 43.5 ft
Diameter: 14.1 ft

Pressurized Volume: 5650 cubic ft

Above there is a video released by Galactic Suite Ltd. to promote the Galactic Suite Space Resort. The project did not go much beyond this suggestive graphic presentation, commentated by a persuasive voice. [Galactic Suite Ltd.] Alongside, an animated graphic of Aurora Station, the project that perhaps will open the way to space tourism. [Orion Span]

signed to accommodate a few, very wealthy tourists. Called Aurora Station, the new project was presented by the California company Orion Span on April 5th at the Space 2.0 Summit in San Jose. This exclusive orbiting residence is currently planned to be built and taken into orbit by 2021 and receive tourists in 2022.

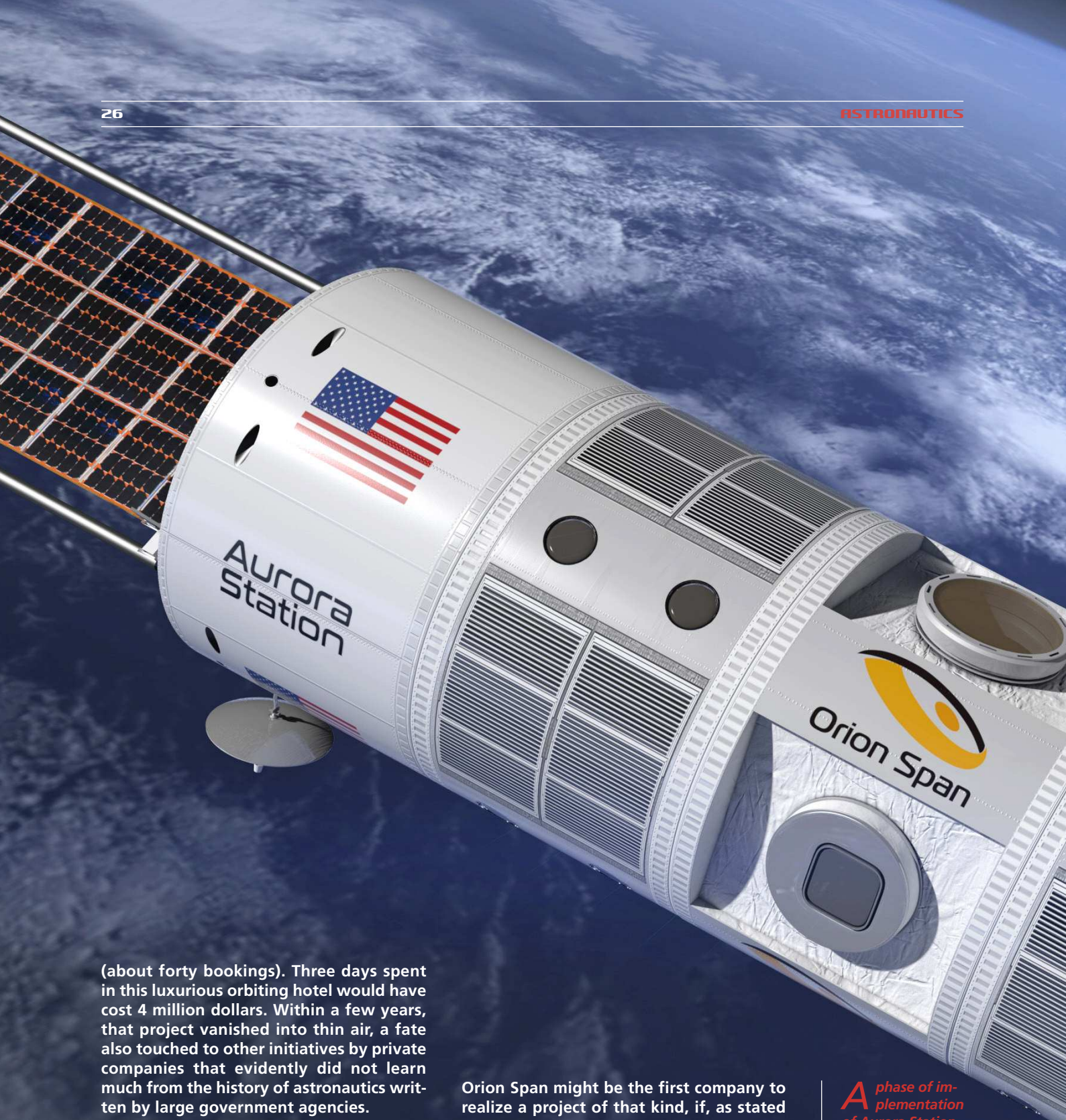
According to the project presented by Orion Span, the basic structure of Aurora Station will be very similar to the fuselage of a private jet – a cylinder no more than 15 meters long and almost 5 meters wide, for a volume that is about five times smaller than that offered by the International Space Station. In that small space, accommodations will be provided for four passengers and two crew members, in addition to a living area, avionics and more. Several auxiliary modules, attached later to the main body, will transform the small hotel into a sort of orbital hub.

As stated by Frank Bunger, founder and CEO of Orion Span, and some of his collaborators, cruises aboard Aurora Station will last 12 days and will cost each participant $9.5 million. To book this peerless holiday, however, a deposit of "just" $80,000 is enough, and the company is already gathering online subscriptions.

Unlike the claustrophobic space stations hitherto put into orbit, Aurora Station will be equipped with large windows that will allow its inhabitants to fully enjoy the vision of the night sky and the Earth.

Of course, space tourists will have to attend special training for astronauts, which usually lasts a couple of years. Orion Span declares that it wants to concentrate that training into just 3 months, a choice made to reduce part of the costs with respect to the first tourist flights in history. On balance, the ticket to Aurora Station is planned to cost less than half (or even less than a quarter) of those paid by Dennis Tito and six other space tourists, who between 2001 and 2009 spent 20 to 40 million dollars to spend one to two weeks on board the International Space Station using Russian Soyuz spacecraft as carriers.

The idea of exploiting space for permanent tourism is anything but new: the first orbital hotel projects date back over a decade ago. Some may remember the Galactic Suite Space Resort, a project presented in 2007 by a company from Barcelona, which arose considerable interest both among international investors and candidate tourists



(about forty bookings). Three days spent in this luxurious orbiting hotel would have cost 4 million dollars. Within a few years, that project vanished into thin air, a fate also touched to other initiatives by private companies that evidently did not learn much from the history of astronautics written by large government agencies.

While it is undeniable that private aerospace industry is achieving excellent results in the field of carriers and is close to offering suborbital flights at reasonable prices, it is also true that orbital tourism still appears far on the horizon (not to mention interplanetary tourism, now just a mere fantasy).

Orion Span might be the first company to realize a project of that kind, if, as stated by its spokespersons, it is true that Aurora Station is currently under construction in Houston, Texas.

Here's how Bunger presented the project at the San Jose meeting: *"We developed Aurora Station to provide a turnkey destination in space. Upon launch, Aurora Station goes into service immediately, bring-*

A phase of implementation of Aurora Station, starting from the first segment (in the foreground), which will be brought into orbit in 2021 and will welcome tourists in 2022. [Orion Span]

In this scene, a spacecraft approaches Aurora Station with new tourists on board, replacing those who have completed their space holidays. [Orion Span]

ing travelers into space quicker and at a lower price than ever seen before, while still providing an unforgettable experience". And here's what he added about the future development in orbit of the luxury hotel: *"Aurora Station is incredibly versatile and has multiple uses beyond serving as a hotel. We will offer full charters to space agencies who are looking to achieve human spaceflight in orbit for a fraction of the cost – and only pay for what they use. We will support zero-gravity research, as well as in-space manufacturing. Our architecture is such that we can easily add capacity, enabling us to grow with market demand like a city growing skyward on Earth. We will later sell dedicated modules as the world's first condominiums in space. Future Aurora owners can live in, visit, or sublease their space condo. This is an exciting frontier, and Orion Span is proud to pave the way"*. Bunger's optimism is enviable, but some aspects of the initiative remain nebulous. For example, Orion Span did not provide information on the choice of the carrier that will be used to send Aurora Station into orbit, and this is not a negligible detail, because such a bulky payload requires a tailor-made hold, and both must be developed hand-in-hand. The capacities of the holds currently available on the carrier market are not sufficient to accommodate the main body of Aurora Station.

For our next holidays, let's book a standard hotel, then, in 2022, we will decide whether to update our wish list... ■

NEW MOON TELESCOPES

nmt

The Hybrid

The Classic

Hand Crafted Dobsonians- Made to Order

From 8” to 36”

Featuring The All New SOLID Wood / Aluminum HYBRID!

YouTube

www.newmoontelescopes.com ryan@newmoontelescopes.com

WASP-39b: a lot of water in its atmosphere

by NASA/ESA

Scientists used NASA's Hubble and Spitzer space telescopes to find a large amount of water in the atmosphere of WASP-39b, a hot, bloated, Saturn-mass exoplanet that resides about 700 light-years from Earth. This "hot Saturn" actually has three times as much water as Saturn does. WASP-39b whips around a quiet, Sun-like star, called WASP-39, once every four days. The exoplanet is currently positioned more than 20 times closer to its star than Earth is to the Sun. It is tidally locked, meaning it always shows the same face to its star. [NASA, ESA, and G. Bacon (STScI)]

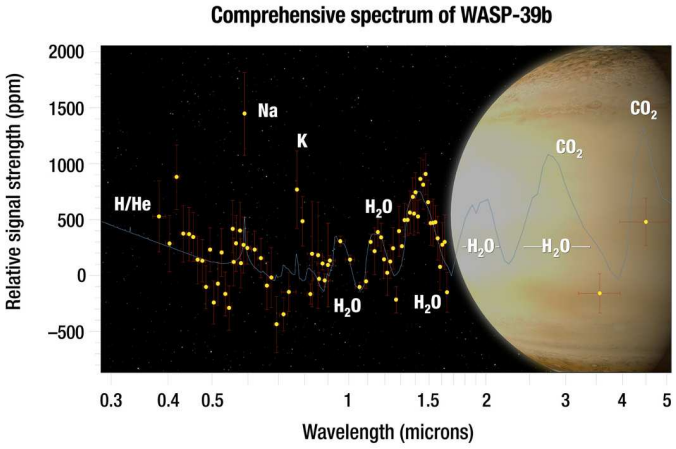
Much like detectives study fingerprints to identify the culprit, scientists used NASA's Hubble and Spitzer space telescopes to identify the "fingerprints" of water in the atmosphere of a hot, bloated, Saturn-mass exoplanet some 700 light-years away. And, they found a lot of water. In fact, the planet, known as WASP-39b, has three times as much water as Saturn does.

Though no planet like this resides in our solar system, WASP-39b can provide new insights into how and where planets form around a star, say researchers. This exoplanet is so unique, it underscores the fact that the more astronomers learn about the complexity of other worlds, the more there is to learn about their origins. This latest observation is a significant step toward characterizing these worlds.

Although the researchers predicted they'd see water, they were surprised by how much water they found in this "hot Saturn." Because WASP-39b has so much more water than our famously ringed neighbor, it must have formed differently.

The amount of water suggests that the planet actually developed far away from the star, where it was bombarded by a lot of icy material. WASP-39b likely had an interesting evolutionary history as it migrated in, taking an epic journey across its planetary system and perhaps obliterating planetary objects in its path.

"We need to look outward so we can understand our own solar sys-



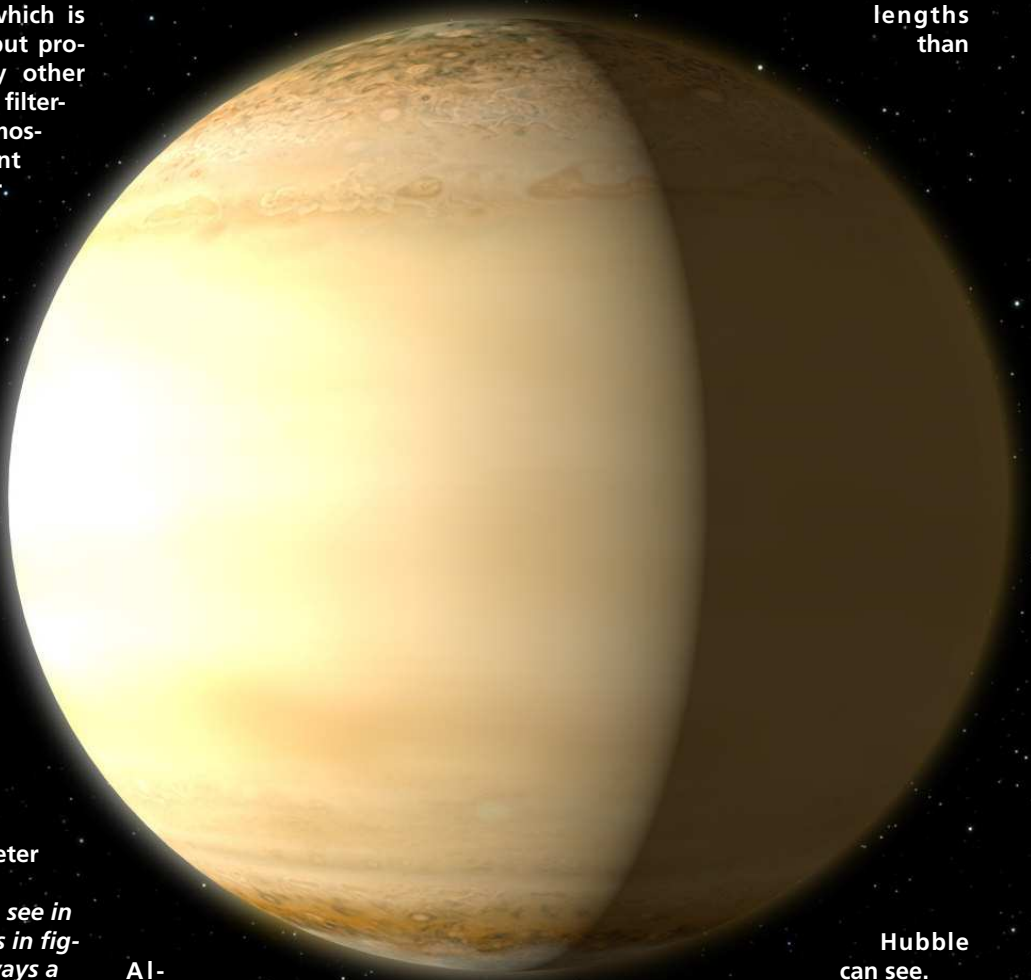
Using Hubble and Spitzer, astronomers analyzed the atmosphere of the "hot Saturn" exoplanet WASP-39b, and they captured the most complete spectrum of an exoplanet's atmosphere possible with present-day technology. By dissecting starlight filtering through the planet's atmosphere into its component colors, the team found clear evidence for water vapor. Although the researchers predicted they would see water, they were surprised by how much water they found — three times as much water as Saturn has. This suggests that the planet formed farther out from the star, where it was bombarded by icy material. [NASA, ESA, G. Bacon and A. Feild (STScI), and H. Wakeford (STScI/Univ. of Exeter)]

tem," explained lead investigator Hannah Wakeford of the Space Telescope Science Institute in Baltimore, Maryland, and the University of Exeter in Devon, United Kingdom. *"But exoplanets are showing us that planet formation is more complicated and more confusing than we thought it was. And that's fantastic!"*

Wakeford and her team were able to analyze the atmospheric components of this exoplanet, which is similar in mass to Saturn but profoundly different in many other ways. By dissecting starlight filtering through the planet's atmosphere into its component colors, the team found clear evidence for water. This water is detected as vapor in the atmosphere. Using Hubble and Spitzer, the team has captured the most complete spectrum of an exoplanet's atmosphere possible with present-day technology. *"This spectrum is thus far the most beautiful example we have of what a clear exoplanet atmosphere looks like,"* said Wakeford. *"WASP-39b shows exoplanets can have much different compositions than those of our solar system,"* said co-author David Sing of the University of Exeter in Devon, United Kingdom. *"Hopefully this diversity we see in exoplanets will give us clues in figuring out all the different ways a planet can form and evolve."*

Located in the constellation Virgo, WASP-39b whips around a quiet, Sun-like star, called WASP-39, once every four days. The exoplanet is currently positioned more than 20 times closer to its star than Earth is to the Sun. It is tidally locked, meaning it always shows the same face to its star.

Its day-side temperature is a scorching 1,430 degrees Fahrenheit (776.7 degrees Celsius). Powerful winds transport heat from the day-side around the planet, keeping the permanent night-side almost as hot.



Although it is called a "hot Saturn," WASP-39b is not known to have rings. Instead, it has a puffy atmosphere that is free of high-altitude clouds, allowing Wakeford and her team to peer down into its depths.

Looking ahead, Wakeford hopes to use the James Webb Space Telescope — scheduled to launch in 2019 — to get an even more complete spectrum of the exoplanet. Webb will be able to give information about the planet's atmospheric carbon, which absorbs light at longer, infrared wavelengths than Hubble can see. By understanding the amount of carbon and oxygen in the atmosphere, scientists can learn even more about where and how this planet formed.

MATISSE sees first light on ESO's VLT interferometer

by ESO

MATISSE (Multi AperTure mid-Infrared SpectroScopic Experiment) observes infrared light — light between the visible and microwave wavelengths of the electromagnetic spectrum, covering wavelengths from 3–13 micrometres (μm). It is a second-generation spectro-interferometer instrument for ESO's Very Large Telescope that can take advantage of multiple telescopes and the wave nature of the light. In this way, it produces more detailed images of celestial objects than can be obtained with any existing or planned single telescope at these wavelengths. After 12 years of development by a large number of engineers and astronomers in France, Germany, Austria, the Netherlands and at ESO, and following an extensive period of demanding work installing and testing this very complex instrument, initial observations have now confirmed that MATISSE is working as expected.

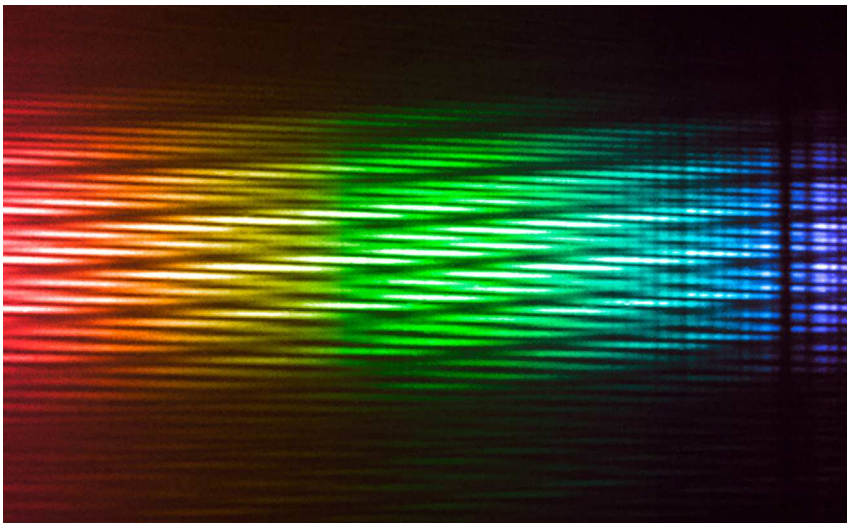
The initial MATISSE observations of the red supergiant star Betelgeuse, which is expected to explode as a supernova in a few hundred thousand years, showed that it still has secrets to reveal. The new observations show evidence that the star appears to have a different size when seen at different wavelengths. Such data will allow astronomers to further study the huge star's surroundings and how it is shedding material into space. The principal investigator of MATISSE, Bruno Lopez (Observatoire de la Côte d'Azur (OCA), Nice, France), explains its unique power: *"Single telescopes can achieve image sharpness that is limited by the size of their mirrors. To obtain even higher resolution, we combine — or interfere — the light from four different VLT telescopes. Doing this enables MATISSE to deliver the sharpest images of any telescope ever in the 3–13 μm wavelength range, where it will complement the James Webb Space Telescope's future observations from space."* MATISSE will contribute to several fundamental research areas in astronomy, focusing in particular on the inner regions of discs around young stars where planets are forming, the study of stars at different stages of their lives, and the surroundings of supermassive black holes at the centres of galaxies.

This picture shows the very complex MATISSE instrument during installation. [ESO]

Thomas Henning, director at the Max Planck Institute for Astronomy (MPIA) in Heidelberg, Germany, and MATISSE co-principal investigator, comments: *"By looking at the inner regions of protoplanetary discs with MATISSE, we hope to learn the origin of the various minerals contained in these discs — minerals that will later go on to form the solid cores of planets like the Earth."*

Walter Jaffe, the project scientist and co-principal investigator from University of Leiden in the Netherlands, and Gerd Weigelt, co-principal investigator from the Max Planck Institute for Radio Astronomy (MPIfR), Bonn, Germany, add: *"MATISSE will give us dramatic images of planet-forming regions, multiple stars, and, when working with the VLT Unit Telescopes, also the dusty discs feeding supermassive black holes. We hope also to observe details of exotic objects in our Solar System, such as volcanoes on Io, and the atmospheres of giant exoplanets."*

MATISSE is a four-way beam combiner, meaning it combines the light collected from up to four of the 8.2-metre VLT Unit Telescopes or up to four of the Auxiliary Telescopes (ATs) that make up the VLTI, performing both spectroscopic and imaging observations. In doing so, MATISSE and the VLTI together possess the imaging power of a telescope up to 200 metres in diameter, capable of producing the most detailed images ever at mid-infrared wavelengths.



This image is a colourised version of the first MATISSE interferometric observations of the star Sirius, combining data from four Auxiliary Telescopes of the VLT. The colours represent the changing wavelengths of the data, with blue showing the shorter wavelengths and red the longer. The observations were made in the infrared, so these are not the colours that would be seen with the human eye. [ESO/MATISSE consortium]

This picture shows the team celebrating the successful first light observations. [ESO/MATISSE consortium]

Initial tests were made with the Auxiliary Telescopes, and further observations with the four VLT Unit Telescopes are planned during the next few months.

MATISSE superimposes the light of an astronomical object from the combined light of multiple telescopes, resulting in an interference pattern that contains information about the appearance of the object, from which an image can then be reconstructed.

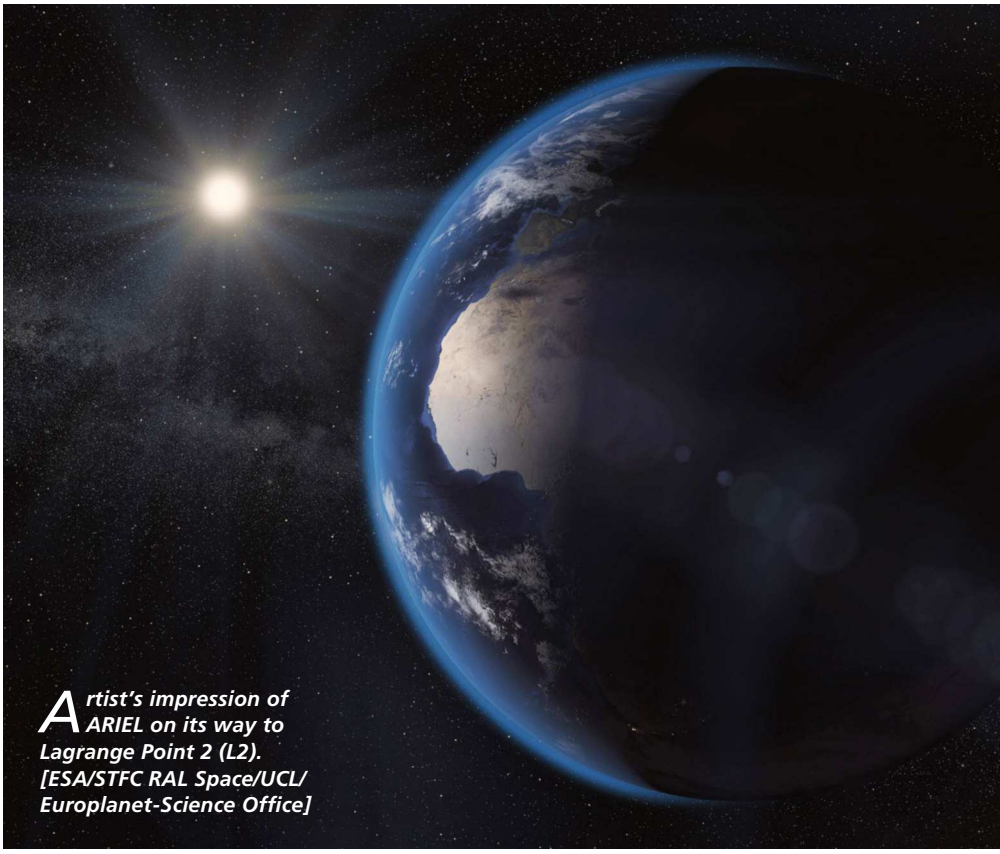
MATISSE's first light marks a big step forward in the scope of current optical/infrared interferometers and will allow astronomers to obtain interferometric images with finer detail over a wider wavelength range than currently possible.

MATISSE will also complement the instruments planned for ESO's upcoming Extremely Large Telescope (ELT), in particular METIS (the Mid-infrared ELT Imager and Spectrograph). MATISSE will observe brighter objects than METIS, but with higher spatial resolution.

Andreas Glindemann, MATISSE project manager at ESO, concludes: *"Making MATISSE a reality has involved the work of many people over many years and it is wonderful to see the instrument working so well. We are looking forward to the exciting science to come!"* ■

ESA chooses ARIEL as its future medium-size space mission

by IAC



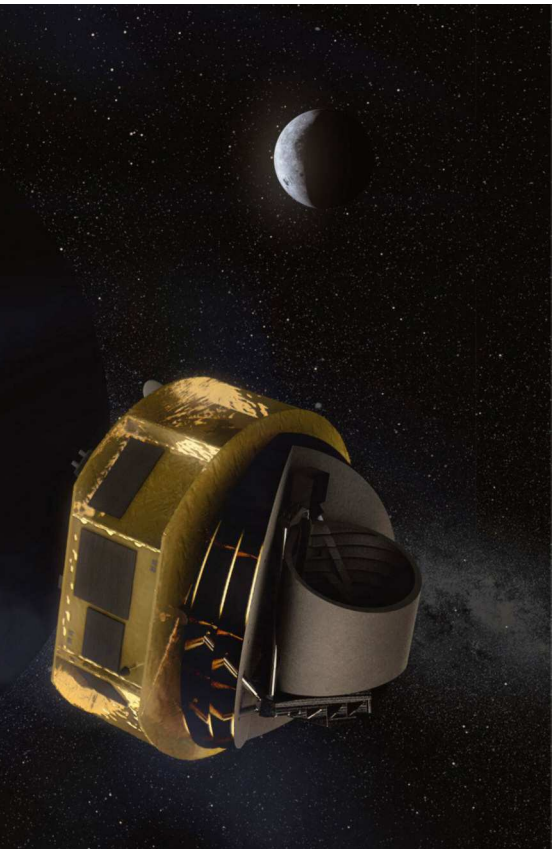
Artist's impression of ARIEL on its way to Lagrange Point 2 (L2). [ESA/STFC RAL Space/UCL/ Europlanet-Science Office]

The European Space Agency (ESA) has just announced that its next medium-size scientific mission will be ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large survey). The project will have a useful lifetime of four years in space and its launch is scheduled for 2028. While it remains in orbit, it will observe around 1,000 planets and carry out the first large scale study of the chemistry of the atmospheres of these exoplanets. *"This mission will enable the systematic study of the formation and evolution of exoplanets, particularly their atmospheres"*, explains Enric Pallé, an IAC researcher and one of the participants in this project. He continues, *"ARIEL will study earthlike planets, but hot ones"*, in other words, those that orbit close to their star.

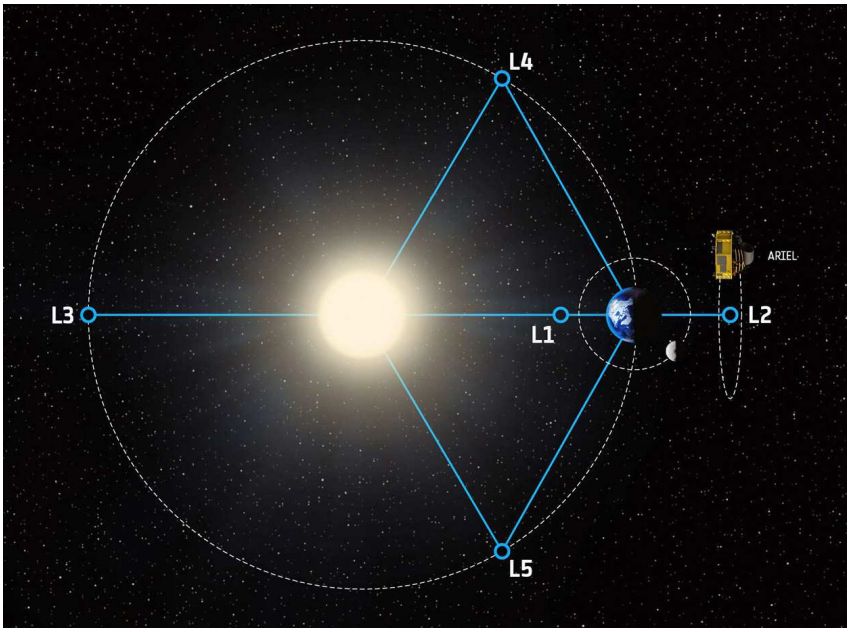
ARIEL was developed by a consortium of more than 60 institutes from 15 ESA countries, including the United Kingdom, France, Italy, Poland, Spain, The Netherlands, Belgium, Austria, Denmark, Ireland, Hungary, Sweden, Germany, and Portugal, with the further collaboration of NASA. The IEEC (Institut d'Estudis Espacials de Catalunya) heads the Spanish participation.

Apart from its scientific contribution, it is participating in the building of the mission, including the satellite's electronic system, which controls the telescope and movements of the secondary mirror, as well as the computer programs that schedule the observations of planets and are used in ESA ground control. The other Spanish institutions involved in the project are the Astrobiology Centre of the Polytechnic University of Madrid and the Instituto de Astrofísica de Canarias (IAC). *"Although, so far, we've discovered around 3800 planets orbiting other stars, the nature of these exoplanets remains very mysterious"*, comments Ignasi Ribas, an astrophysicist at IEEC-CSIC and Principal Investigator of ARIEL in Spain. He adds: *"ARIEL will study a sample that is statisti-*

cally large enough to give us a truly representative picture of what these planets are made of. This will enable us to answer questions on how the chemistry of a planet is linked with the environment in which it was formed, and how its birth and evolution depend on the star it orbits". This mission will study a diverse population of exoplanets, ranging from those of the size of Jupiter and Neptune to the so-called super-earths, in



a large variety of environments. The main emphasis of the mission will be on planets in close orbits around their stars. Hot exoplanets, with temperatures of up to 2000°C, are a natural laboratory in which to study the chemistry and formation of planets, given that their high temperatures maintain the different molecular species in circulation through the atmosphere, thus making them remotely observable.



ARIEL will be placed in orbit around the Lagrange Point 2 (L2), a gravitational balance point 1.5 million kilometres beyond the Earth's orbit around the Sun. [ESA/STFC RAL Space/UCL/Europlanet-Science Office]

ARIEL will have a telescope with a one-metre diameter primary mirror to collect visible and infrared light from these planetary systems orbiting distant stars. A spectrometer will split the light into its constituent 'rainbow' in order to trace the chemical fingerprints of the atmospheric molecules when the planet passes in front of, or behind, the star. A photometer and scanning system will gather information on the presence of clouds in the exoplanet atmospheres and allow the telescope to be pointed towards the star with great stability and precision.

The ARIEL satellite will be launched from Kourou in French Guiana and will be placed in orbit at the L2 Lagrange point, which is a point of gravitational equilibrium 1.5 million kilometres from the Earth (the Sun, Earth, and L2 point form a straight line).

At this point the satellite will be protected from the Sun and will have an unimpeded view of the whole sky in order to observe a large number of exoplanets. The James Webb Space Telescope (JWST), scheduled for launch in 2019, will also be located in this region. In theory, there will be no overlap in time, since ARIEL is planned as a successor mission to the JWST in the study of exoplanets and their atmospheres.

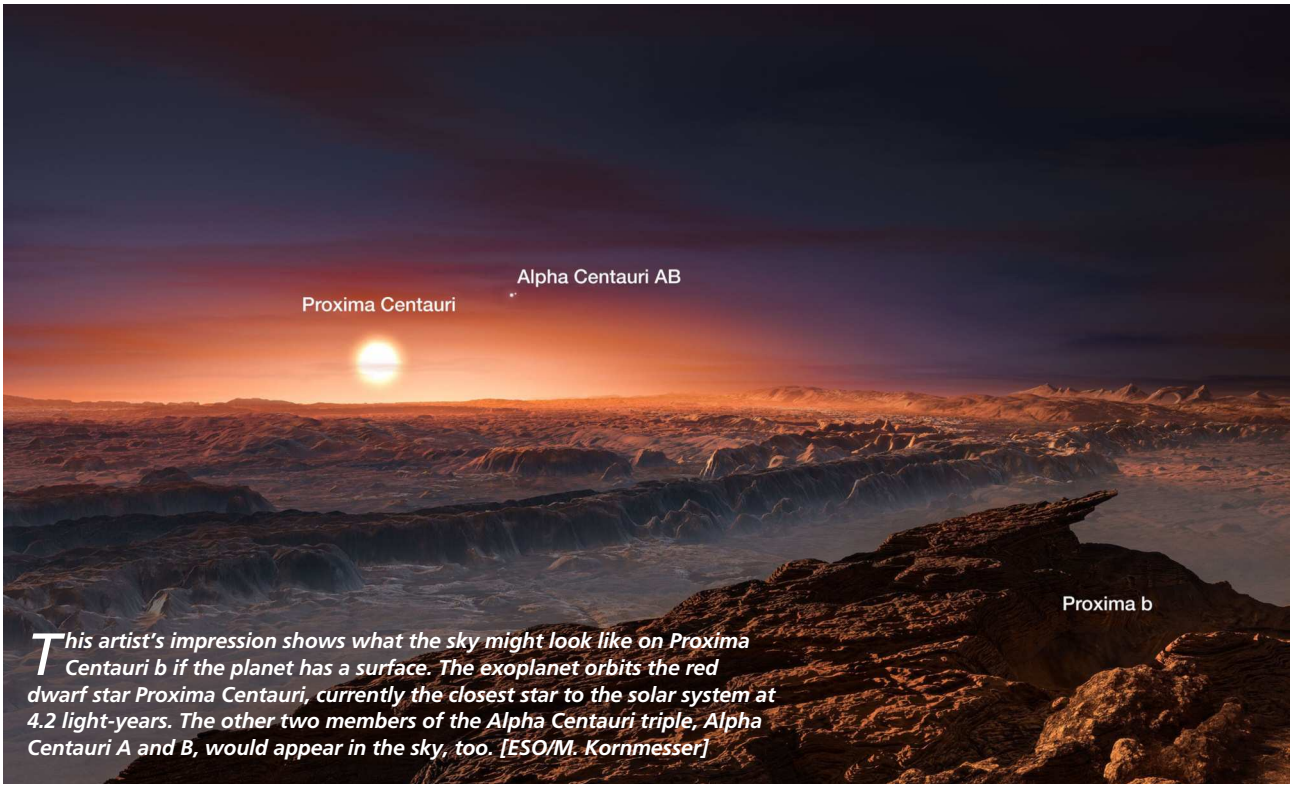
The project manager of Spain's participation in the project, Josep Colomé of the IEEC-CSIC, emphasizes: *"ESA's selection of ARIEL is great news. It gives recognition of the engineering work carried out over the last two years and will boost the space technology we're developing for this and other missions in close collaboration with Industry in the sector. ARIEL enables us to work with world-leading research centres and puts us in the first division of space technology"*. ■

Powerful flare from Proxima Centauri detected with ALMA

by ALMA Observatory

Using data from the Atacama Large Millimeter/submillimeter Array (ALMA), a team of astronomers discovered that a powerful stellar flare erupted from Proxima Centauri last March. This finding, published in *The Astrophysical Journal Letters,* raises questions about the habitability of our solar system's nearest exoplanetary neighbor, Proxima b, which orbits Proxima Centauri.

At its peak, the newly recognized flare was 10 times brighter than our Sun's largest flares, when observed at similar wavelengths. Stellar flares have not been well studied at the millimeter and submillimeter wavelengths detected by ALMA, especially around stars of Proxima Centauri's type, called M dwarfs, which



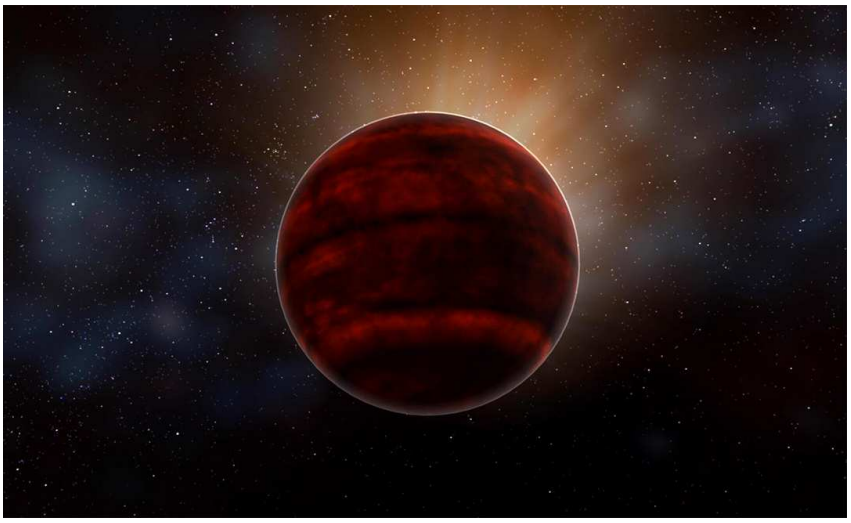
This artist's impression shows what the sky might look like on Proxima Centauri b if the planet has a surface. The exoplanet orbits the red dwarf star Proxima Centauri, currently the closest star to the solar system at 4.2 light-years. The other two members of the Alpha Centauri triple, Alpha Centauri A and B, would appear in the sky, too. [ESO/M. Kornmesser]

are the most common in our galaxy. *"March 24, 2017, was no ordinary day for Proxima Cen,"* said Meredith MacGregor, an astronomer at the Carnegie Institution for Science, Department of Terrestrial Magnetism in Washington, D.C., who led the research with fellow Carnegie astronomer Alycia Weinberger. Along with colleagues from the Harvard-Smithsonian Center for Astrophysics' David Wilner and Adam Kowalski and Steven Cranmer of the University of Colorado Boulder—they discovered the enormous flare when they reanalyzed ALMA observations taken last year.

The flare increased Proxima Centauri's brightness by 1,000 times over 10 seconds. This was preceded by a smaller flare; taken together, the whole event lasted fewer than two minutes of the 10 hours that ALMA observed the star between January and March of last year.

Stellar flares happen when a shift in the star's magnetic field accelerates electrons to speeds approaching that of light.

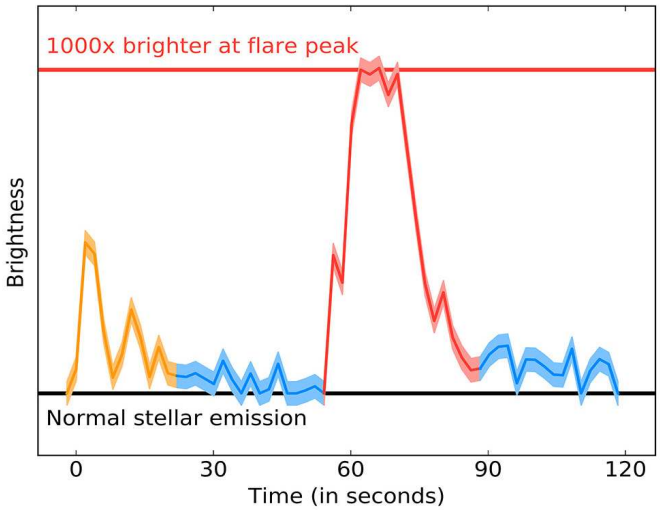
The accelerated electrons interact with the highly charged plasma that makes up most of the star, causing an eruption that produces emission across the entire electromagnetic spectrum. *"It's likely that Proxima b was blasted by high energy radiation during this flare,"* MacGregor explained, adding that it was already known that Proxima Centauri experienced regular, although smaller, X-ray flares. *"Over the billions of years since Proxima b formed, flares like this one could have evaporated any atmosphere or ocean and sterilized the surface, suggesting that habitability may involve more than just being the right distance from the host star to have liquid water."*



Artist impression of a red dwarf star like Proxima Centauri, the nearest star to our sun. New analysis of ALMA observations reveal that Proxima Centauri emitted a powerful flare that would have created inhospitable conditions for planets in that system. [NRAO/AUI/NSF; D. Berry]

An earlier paper that also used the same ALMA data interpreted its average brightness, which included the light output of both the star and the flare together, as being caused by multiple disks of dust encircling Proxima Centauri, not unlike our own solar system's asteroid and Kuiper belts.

But when MacGregor, Weinberger, and their team looked at the ALMA data as a function of observing time, instead of averaging it all together, they were able to see the transient explosion of radiation emitted from Proxima Centauri for what it truly was. *"There is now no reason to think that there is a substantial amount of dust around Proxima Cen,"* Weinberger said. *"Nor is there any information yet that indicates the star has a rich planetary system like ours."* ■

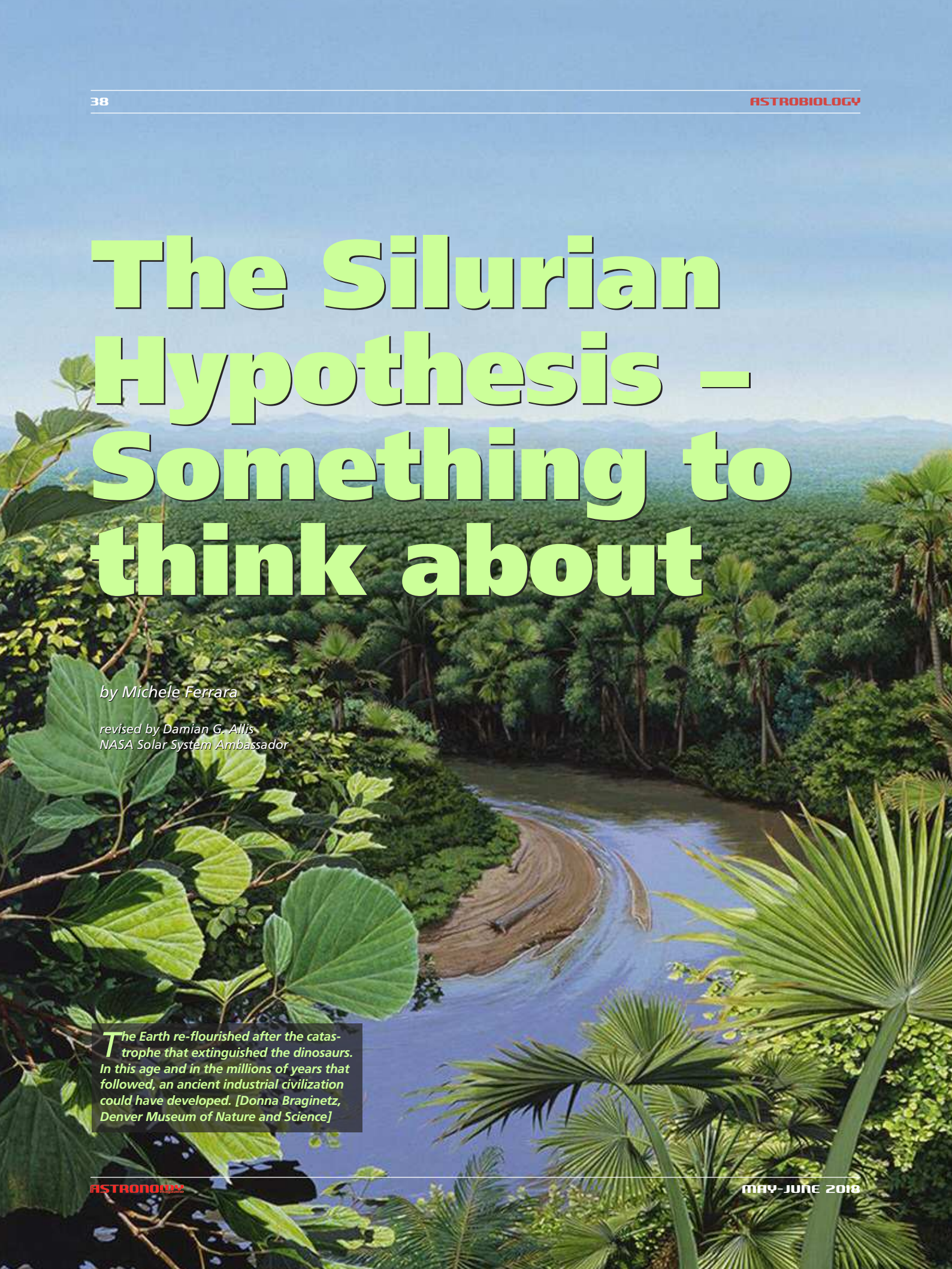


The brightness of Proxima Centauri as observed by ALMA over the two minutes of the event on March 24, 2017. The massive stellar flare is shown in red, with the smaller earlier flare in orange, and the enhanced emission surrounding the flare that could mimic a disk in blue. At its peak, the flare increased Proxima Centauri's brightness by 1,000 times. The shaded area represents uncertainty. [Meredith MacGregor, Carnegie]

The Silurian Hypothesis – Something to think about

by Michele Ferrara

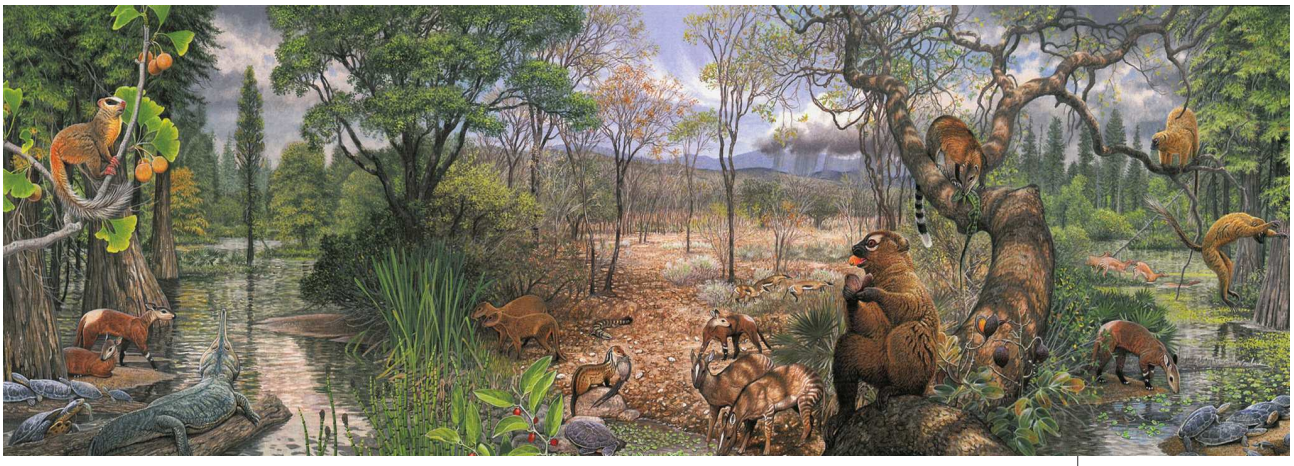
revised by Damian G. Allis
NASA Solar System Ambassador



The Earth re-flourished after the catastrophe that extinguished the dinosaurs. In this age and in the millions of years that followed, an ancient industrial civilization could have developed. [Donna Braginetz, Denver Museum of Nature and Science]

We know so little about life on Earth before the appearance of hominids that there may have even existed industrial civilizations prior to ours without us being aware of them. Now, two scientists propose how to look for the traces of those hypothetical civilizations. If those ancient Terrans respected the ecosystem more than we do, we might never find those traces.

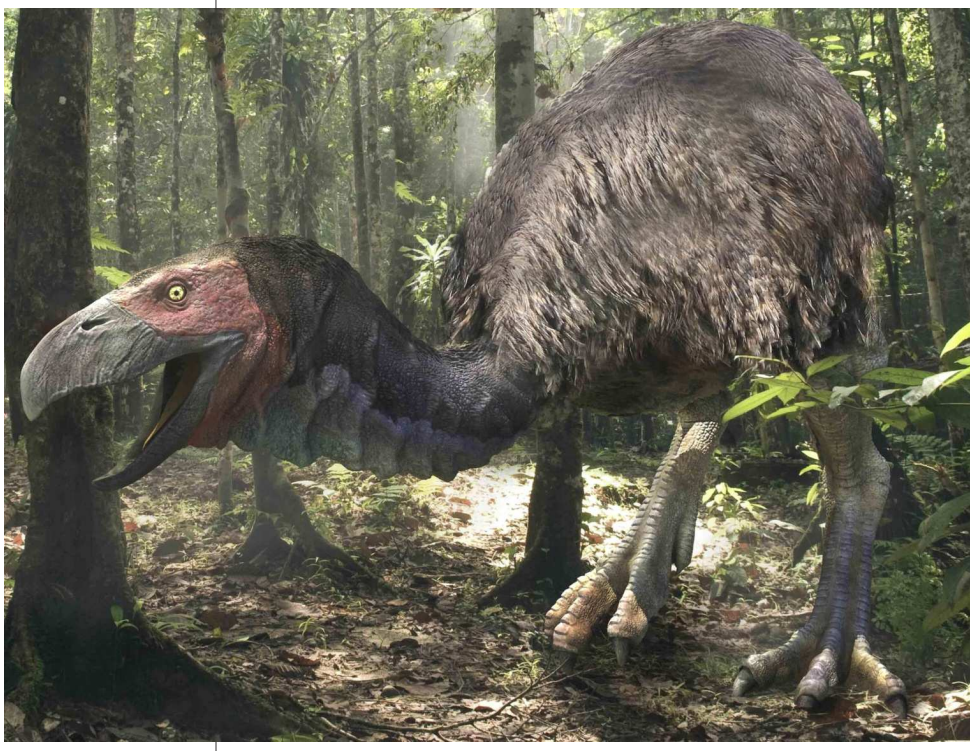
We humans assume that we are the first animal species on our planet to have reached a high degree of technological development, up through becoming an industrial civilization. This belief is based on a series of circumstances which at first sight seem to be incontrovertible. One of them relies on our never having found artifacts and structures incompatible with the history and prehistory of humanity. Moreover, through the study of fossils, we know, at least roughly, the development of life on Earth, and there remains no trace of any species that may have reached a degree of development comparable to ours. But are we really sure that our vision of the past is so comprehensive as to rule out the appearance of previous industrial civilizations? Perhaps yes, but the farther we go back in time, the less defined the picture of the evolution of life on



Earth becomes. Going back tens or hundreds of millions of years, we have more and more fragmented information about the many species that populated the planet. For example, we know very little about our most distant hominid ancestors, whose evolution up to us only covers the last million years, roughly 1% of the period during which complex life developed on land. Much of the remaining 99% escapes us, a period of about 400 million years in which unimaginable scenarios may have occurred. The limitations in our knowledge of life's history are due to the fact that the fraction of living beings that turn into fossils is extremely small and varies widely depending on the weather, the consistency of the organisms, and the habitats in which they lived. The fossil records that have come down to us are a tiny sample, representative of only a small part of the living species that have appeared and disappeared on our planet. We are far from having a complete picture, and you have to consider that over 99% of all species are extinct. On the other hand, it is true that the biological ties between ascending and descending species allow us to fill many gaps – but we cannot rule out that entire evolutionary lines, tens of millions of years long, if not more, may have been irretrievably lost.

If a very advanced civilization existed on Earth before ours, it may have left no fossil evidence of a biological type, but it may

An Earth life scene of 56 million years ago, corresponding to the so-called Paleocene-Eocene Thermal Maximum – a period of thousands of years in which there was an unusually rapid global warming. [National Geographic, Aldo Chiappe] Below, a marshy landscape of the Eocene. [Science History Images/ Alamy Stock Photo]



If a civilization really existed between the Paleocene and the Eocene, it had to compete with rather worrying fauna. One example is the Diatryma Gigantea, a huge carnivorous bird 2 meters tall and a hundred kilograms heavy, which hunted in Europe and North America.

have left behind traces of other kinds, such as artifacts and different types of structures. However resistant these traces might be, the researchers who deal with these topics agree that even the most enduring evidence vanishes within 100-200 million years due to the actions of the geologic, hydrologic and atmospheric activity of our planet. Moreover, even if an industrial civilization prior to ours had appeared in times closer to ours (for example, between 10 and 100 million years ago) and had urbanized the planet for an extension comparable to what we have put in place, any traces would be dispersed over less than 1% of the Earth's surface, and probably buried at great depths.

Discovering direct evidence of an industrial civilization that existed tens or hundreds of millions of years ago would, therefore, require a great deal of luck due to the limited spatial (and perhaps even temporal) distribution of those very ancient remains. If, however, that civilization had reached a level of industrial development comparable to ours, it would have altered and polluted enough the environment to leave a perhaps recognizable mark in the sedimentary rocks.

This possibility has been addressed for the first time by Gavin Schmidt (NASA Goddard Institute for Space Studies) and Adam Frank (Department of Physics and Astronomy, University of Rochester) in a work recently published in the *International Journal of Astrobiology* with the title *"The Silurian Hypothesis: Would it be possible to detect an industrial civilization in the geological record?"*

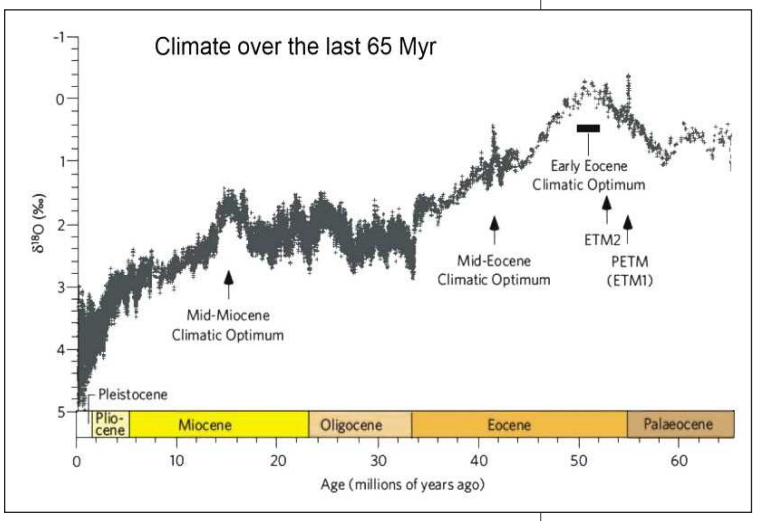
Before briefly examining the interesting arguments of the two authors, we anticipate an easy misunderstanding by noting that the name of the hypothesis does not refer to the Silurian period (about 444-420 million years ago), but derives more trivially from an episode of the TV series Doctor Who, in which an ancient civilization was awakened by human experiments with a nuclear reactor. The study, therefore, does not want to suggest that a civilization may have existed in the Silurian period.

That said, the Silurian Hypothesis of Schmidt and Frank indicates a reasonable way to follow in the search for a hypothetical industrial civilization prior to ours, and does so considering essentially geochemical factors, namely the presence of certain isotopes and their abundances in the geological layers, the presence of synthetic materials and elements, as well as the presence of structural alterations of their ancient territories due to its intensive exploitation.

Today, we are sure to have changed the ecosystem so much as to start a new geological age, which since the 80's has been referred to as the Anthropocene (the last three centuries of the Holocene, characterized by industrialization).

A funny scene of life of a hypothetical civilization of saurians that "existed" no less than 100 million years ago. [University of Rochester illustration/Michael Osadciw]
In the graph below (which shows the curve of the $^{18}O/^{16}O$ isotopic ratio over the last 65 million years), the arrows indicate rapid periods of global warming. The most interesting seems to be the one called PETM. [Zachos et al., Nature]

The impact of human activity on the natural equilibrium of the planet has been so significant that if our civilization died out in a relatively short time, and a similar one were to appear after millions of years, the geologists of the latter could distinguish in the sedimentary rocks the corresponding layer to the Anthropocene, and perhaps understand that at that time the planet was dominated by an irresponsible civilization.
According to Schmidt and Frank, we could do the same thing in the search for ancient civilizations today, and we've only to realize for what and where to look. By excluding possible randomly and inhomogeneously scattered traces, it may be more profitable to look for markers scattered more or less uniformly across the globe. However far from each other two industrial civilizations may be in time (and also in space), they have one thing in common: they consume energy.
On Earth, the most widespread and easy-to-find sources of energy are wood and fossil fuels; it is therefore very probable that a very ancient industrial civilization may have done what we still do today: burn wood, coal, oil and natural gas to move machines and produce heat. As we all know, in the long run, this solution alters the balance between some elements that make up atmospheric gases. A similar effect, though less dramatic, may come from the agricultural exploitation of the land and the systematic use of fertilizers.
The continuation of all these activities over time generates anomalies in the abundances of the isotopes of carbon, oxygen, hydrogen, and nitrogen, and in the amount of greenhouse gases that derive from these elements, such as carbon dioxide, methane and nitrous oxide.



This spherical concretion, unearthed in Bosnia a few years ago, could suggest the discovery of an artifact created by an unknown civilization. Instead, it is a natural, and not all that rare, geological formation. [Dado Ruvic/Reuters/Newscom]

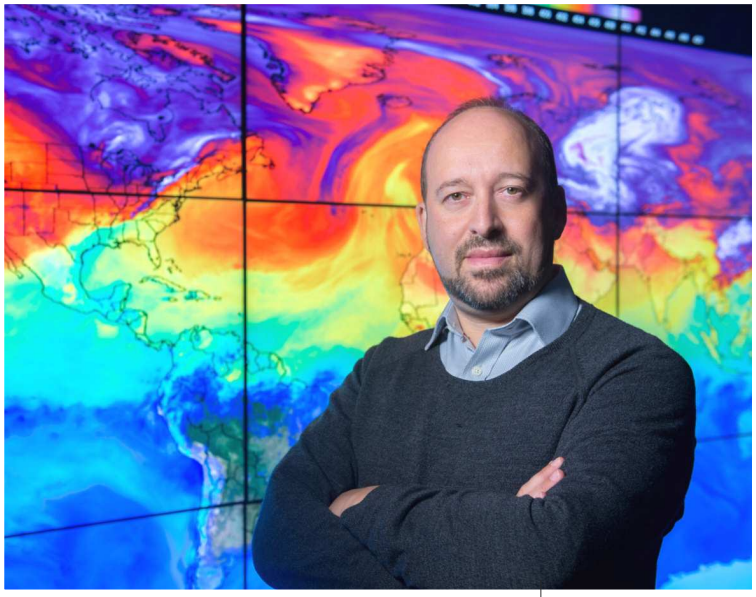
Let's see how Schmidt and Frank address these issues in the IJA article: *"Since the mid-18th Century, humans have released over 0.5 trillion tons of fossil carbon via the burning of coal, oil and natural gas (Le Quéré et al., 2016), at a rate orders of magnitude faster than natural long-term sources or sinks. In addition, there has been widespread deforestation and addition of carbon dioxide into the air via biomass burning. All of this carbon is biological in origin and is thus depleted in ^{13}C compared to the much larger pool of inorganic carbon (Revelle & Suess, 1957). Thus the ratio of ^{13}C to ^{12}C in the atmosphere, ocean and soils is decreasing with a current change of around -1‰ $\delta^{13}C$ since the pre-industrial (Böhm et al., 2002; Eide et al., 2017) in the surface ocean and atmosphere"*.

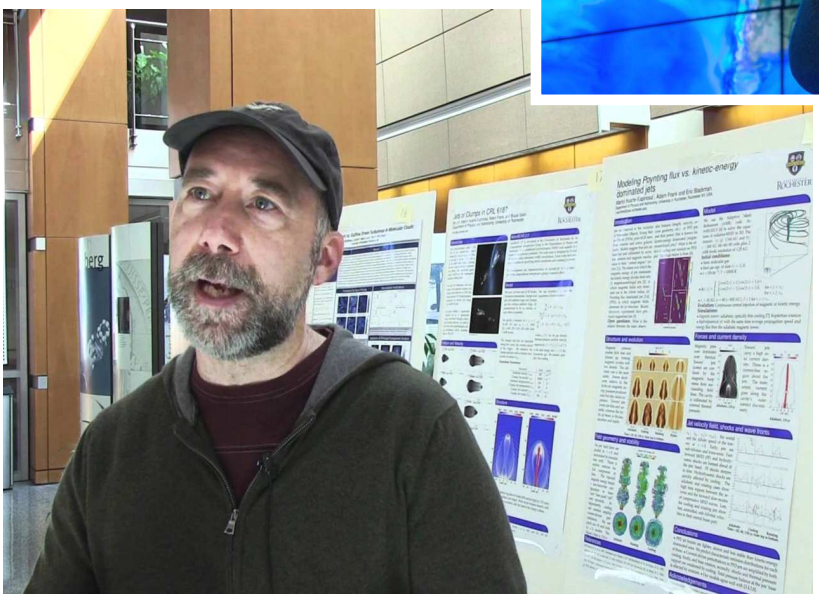
If all this had already happened in a very distant past, the sedimentary layers of that era should retain its traces. But the sediments could be so altered with respect to the previous and following ones as to become themselves evidence. Deforestation and global warming are also the cause of significant soil erosion, either directly, for the felling of trees, or indirectly, for the increase in rainfall due to the greenhouse effect. The eroded soil usually ends up depositing in coastal regions, and a higher stratum per unit of time, with different properties, could indicate an unnatural alteration of the climate. Here's how Schmidt and Frank elaborate on this point: *"In addition to changes in the flux of sediment from land to ocean, the composition of the sediment will also change. Due to the increased dissolution of CO_2 in the ocean as a function of anthropogenic CO_2 emissions, the upper ocean is acidifying (a 26% increase in H+ or 0.1 pH decrease since the 19th Century) (Orr et al., 2005).* […] *As discussed above, nitrogen load in rivers is increasing as a function of agricultural practices. This in turn is leading to more micro-*

bial activity in the coastal ocean which can deplete dissolved oxygen in the water column (Diaz & Rosenberg, 2008), and recent syntheses suggests a global decline already of about 2% (Schmidtko et al., 2017; Ito et al., 2017). This in turn is leading to an expansion of the oxygen minimum zones, greater ocean anoxia, and the creation of so-called 'dead-zones' (Breitburg et al., 2018)".

Schmidt and Frank also went so far as to suggest a geological layer that has characteristics very similar to those the Anthropocene will leave, that of the Paleocene/Eocene transition 56 million years ago.

Obviously, further checks will be needed to exclude any natural processes.





The authors of the Silurian Hypothesis: Gavin Schmidt, NASA GISS (above) and Adam Frank, University of Rochester.

Summing up, if on our planet there are traces of a previous industrial civilization, those traces are indirect and must be sought out in the form of alterations of the ecosystem in the sedimentary layers of epochs not farther than 400 million years ago and probably much closer to us.

However, the two researchers also note that various natural phenomena may have mitigated those traces, and that even a few natural events can mimic them.

Furthermore, it is not possible to predict the thickness of the sediments in which the markers hide, a value that can vary both due to the speed with which sediments settle and the length of the period of disfigurement of the ecosystem.

In this regard, we conclude with a keen consideration of Schmidt and Frank:

"There is an interesting paradox in considering the Anthropogenic footprint on a geological timescale. The longer human civilization lasts, the larger the signal one would expect in the record. However, the longer a civilization lasts, the more sustainable its practices would need to have become in order to survive. The more sustainable a society (e.g. in energy generation, manufacturing, or agriculture) the smaller the footprint on the rest of the planet. But the smaller the footprint, the less of a signal will be embedded in the geological record. Thus the footprint of civilization might be self-limiting on a relatively short time-scale." ■


Nane rosse e
rovescio della
SpaceShipTwo, u
colpo all'astrona
privata
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS HAPPENING
FREE ASTRONOMY magazine
Bi-monthly magazine of scientific and technical information ✶ March-April 2015
LA RIVISTA MULTIMEDIALE GRATUITA DI ASTRONOMIA CHE TI AGGIORNA SUGLI ULTIMI AVVENIMENTI EXTRATERRESTRI
l'ASTROFILO
bimestrale di informazione scientifica e tecnica • settembre-ottobre 2015 • € 0,00
2 PUNTO 0
rprendente
LUTONE
LIFE
ON
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS
FREE ASTRONOMY magazine
Bi-monthly magazine of scientific and technical information ✶ November-Decem
Even today
here is lif
MÉDIA LIVRE QUE MANTÉM-TE A PAR DO QUE ESTÁ A ACONTECER NO ESPAÇO
TÍCIA do ESPAÇO
revista bimestral de informação cientifica e técnica
nova face
LE MAGAZINE MULTIMÉDIA GRATUIT QUI VOUS TIENT AU COURANT DE L'ACTUALITÉ SPATIALE
MACRO Cosmos
bimestriel d'information scientifique et technique ✶ mars-avril 2016
LES ONDES GRAVITATIONNELLES ENFIN RÉVÉLÉES
Planète Neuf
probabl
A REVISTA MULTIMÉDIA LIVRE QUE MANTÉM-TE A PAR DO QUE ESTÁ A ACONTECER NO ESPA
NOTÍCIA do ESPAÇO
Maio-Junho 2016
revista bimestral de informação cientifica e técn
Mundos cada vez
mais
visíveis
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS HAPPENIN
FREE ASTRONOMY magaz
Bi-monthly magazine of scientific and technical information ✶ July-August 2
Is there an ex
in our solar
The intri
LA RIVISTA MULTIMEDIALE GRATUITA DI ASTRONOMIA CHE TI AGGIORNA SUGLI ULTIMI AVVENIMENTI EXTRATERRESTRI
l'ASTROFILO
bimestrale di informazione scientifica e tecnica • settembre-ottobre 2016 • € 0,00
2 PUNTO 0
Una Terra attorno
a Proxima Centauri
K2: valid
nuovi es
Prospe
inato
MAGAZINE MULTIMÉDIA GRATUIT QUI VOUS TIENT AU CO
MACRO Cos
mestriel d'information scientifique et
chnique ✶ Novembre-Décembre 2016
La seconde p
grosse
LA REVISTA GRATUITA DE ASTRONOMÍA QUE TE MANTIENE ACTUALIZADO SOBRE TODO LO QUE SUCEDE EN EL ESP
UNIVERSO
Revista bimestral de información científica y técnica ✶ Número de enero-febrero 201
234 señales extrañas
desde la Galaxia
zado formando compañeros cercanos
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS HAPPEN
FREE ASTRO
Bi-monthly magazine of

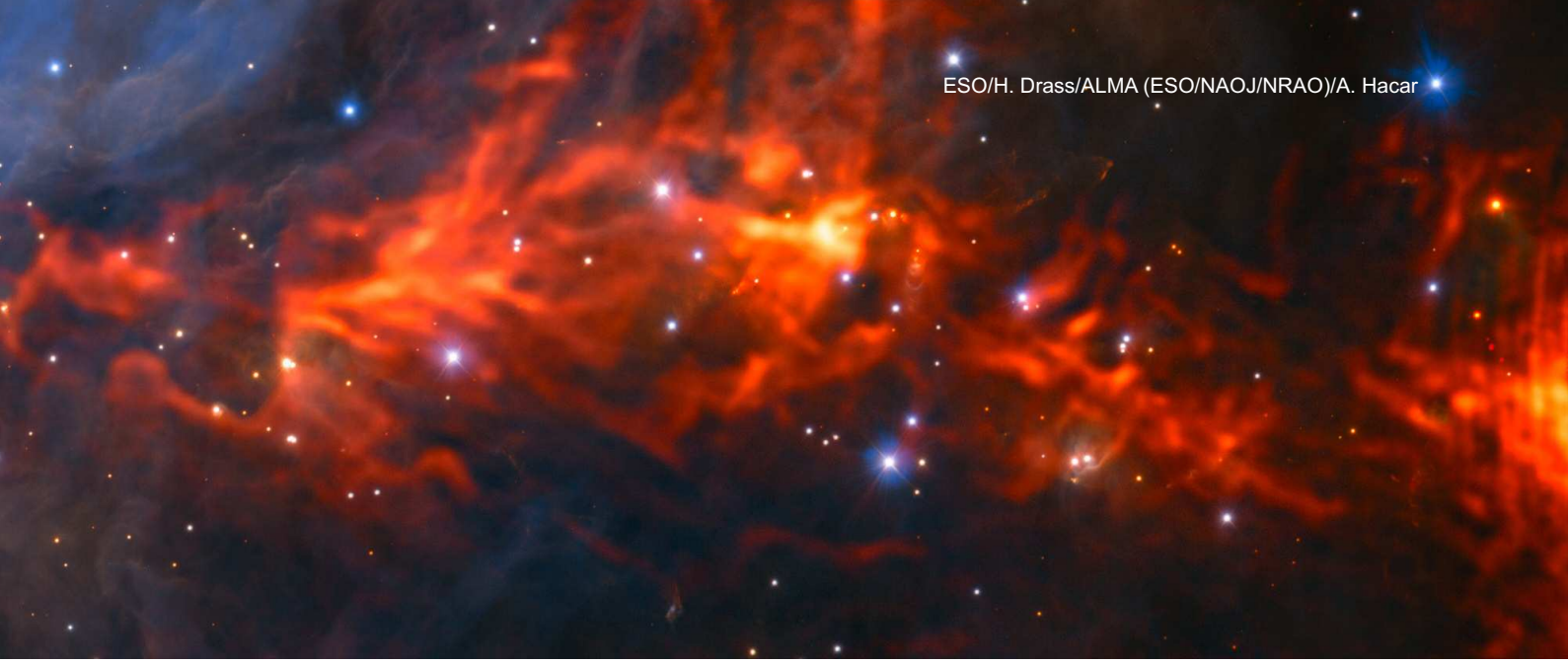
ALMA reveals inner web of stellar nursery

by ALMA Observatory

This spectacular and unusual image shows part of the famous Orion Nebula, a star formation region lying about 1350 light-years from Earth. It combines a mosaic of millimetre-wavelength images from the Atacama Large Millimeter/submillimeter Array (ALMA) and the IRAM 30-metre telescope, shown in red, with a more familiar infrared view from the HAWK-I instrument on ESO's Very Large Telescope, shown in blue. The group of bright blue-white stars at the upper-left is the Trapezium Cluster — made up of hot young stars that are only a few million years old.

The wispy, fibre-like structures seen in this large image are long filaments of cold gas, only visible to telescopes working in the millimetre wavelength range. They are invisible

The squared area in the image on the side is the same as the ALMA image above. [ESO]



at both optical and infrared wavelengths, making ALMA one of the only instruments available for astronomers to study them. This gas gives rise to newborn stars — it gradually collapses under the force of its own gravity until it is sufficiently compressed to form a protostar — the precursor to a star.

The scientists who gathered the data from which this image was created were studying these filaments to learn more about their structure and make-up. They used ALMA to look for signatures of diazenylium gas, which makes up part of these structures. Through doing this study, the team managed to identify a network of 55 filaments.

The Orion Nebula is the nearest region of massive star formation to Earth, and is therefore studied in great detail by astronomers seeking to better understand how stars form and evolve in their first few million years. ESO's telescopes have observed this interesting region multiple times.This image combines a total of 296 separate individual datasets from the ALMA and IRAM telescopes, making it one of the largest high-resolution mosaics of a star formation region produced so far at millimetre wavelengths. Earlier mosaics of Orion at millimetre wavelengths had used single-dish telescopes, such as APEX. The new observations from ALMA and IRAM use interferometry to combine the signals from multiple, widely-separated antennas to create images showing much finer detail. ■

This video starts with a broad view of the sky and zooms in on the familiar constellation of Orion (The Hunter). We then get a closeup view of the Orion Nebula star formation region. In the final sequence we see the strange red filaments of cool gas that ALMA has revealed. [ESO, N. Risinger (skysurvey.org), H. Drass, A. Hacar, ALMA (ESO/NAOJ/NRAO). Music: Johan B. Monell]

Kepler solves the mystery of fast and furious explosions

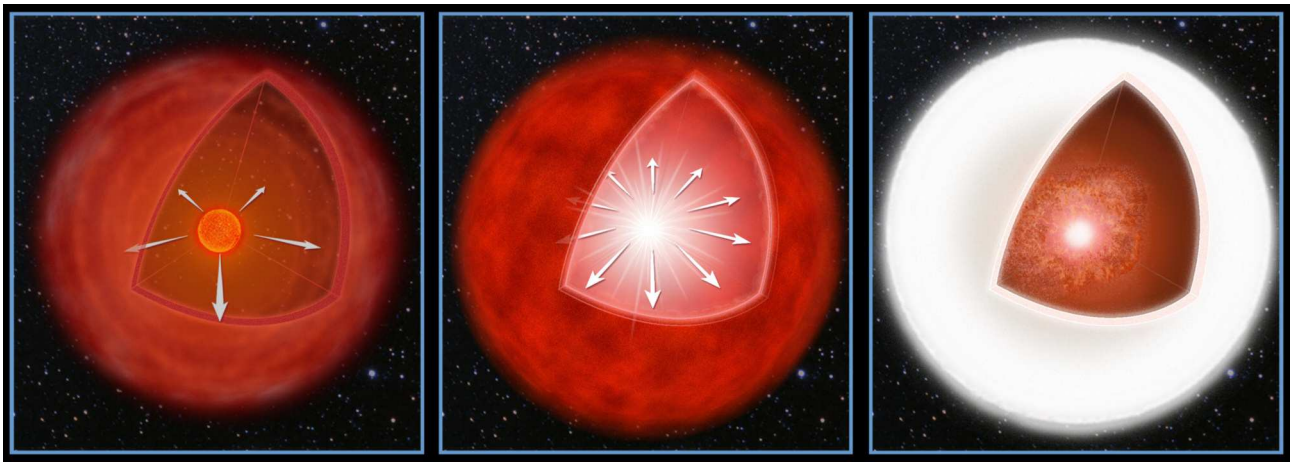
by NASA/ESA

The universe is full of mysterious exploding phenomena that go boom in the dark. One particular type of ephemeral event, called a Fast-Evolving Luminous Transient (FELT), has bewildered astronomers for a decade because of its very brief duration.

Now, NASA's Kepler Space Telescope — designed to go hunting for planets across our galaxy — has also been used to catch FELTs in the act and determine their nature. They appear to be a new kind of supernova that gets a brief turbo boost in brightness from its surroundings.

Kepler's ability to precisely sample sudden changes in starlight has allowed astronomers to quickly arrive at this model for explaining FELTs, and rule out alternative explanations.

Researchers conclude that the source of the flash is from a star after it collapses to explode as a supernova. The big difference is that the star is cocooned inside one or more shells of gas and dust. When the tsunami of explosive energy from the blast slams into the shell, most of the kinetic energy is immediately converted to light. The burst of radiation lasts for only a few days



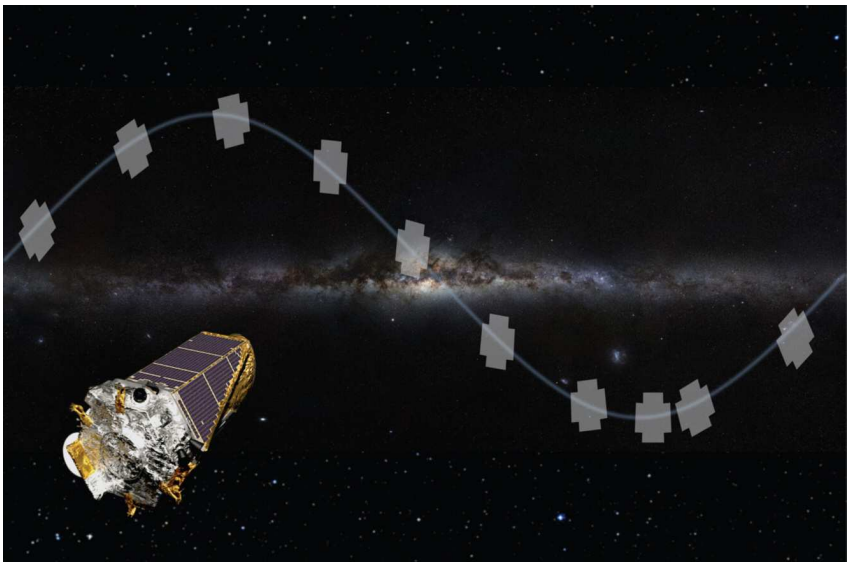
This illustration shows a proposed model for a mysterious astronomical event called a Fast-Evolving Luminous Transient (FELT). In the left panel, an aging red giant star loses mass via a stellar wind. This balloons into a huge gaseous shell around the star. In the center panel, the massive star's core implodes to trigger a supernova explosion. In the right panel, the supernova shockwave plows into the outer shell, converting the kinetic energy from the explosion into a brilliant burst of light. The flash of radiation lasts for only a few days — one-tenth the duration of a typical supernova explosion. [NASA, ESA, and A. Feild (STScI)]

— one-tenth the duration of a typical supernova explosion.

Over the past decade several FELTs have been discovered with timescales and luminosities not easily explained by traditional supernova models. And, only a few FELTs have been seen in sky surveys because they are so brief. Unlike Kepler, which collects data on a patch of sky every 30 minutes, most other telescopes look every few days.

Therefore they often slip through undetected or with only one or two measurements, making understanding the physics of these explosions tricky. In the absence of more data, there have been a variety of theories to explain FELTs: the afterglow of a gamma-ray burst, a supernova boosted by a magnetar (neutron star with a powerful magnetic field), or a failed Type Ia supernova.

Then along came Kepler with its precise, continuous measurements that allowed astronomers to record more details of the FELT event. *"We collected an awesome light curve,"* said Armin Rest of the Space Telescope Science Institute in Baltimore, Maryland. *"We were able to constrain the mechanism and the properties of the blast. We could exclude alternate theories and arrive at the dense-shell model explanation. This is a new way for massive stars to die and distribute material back into space."*



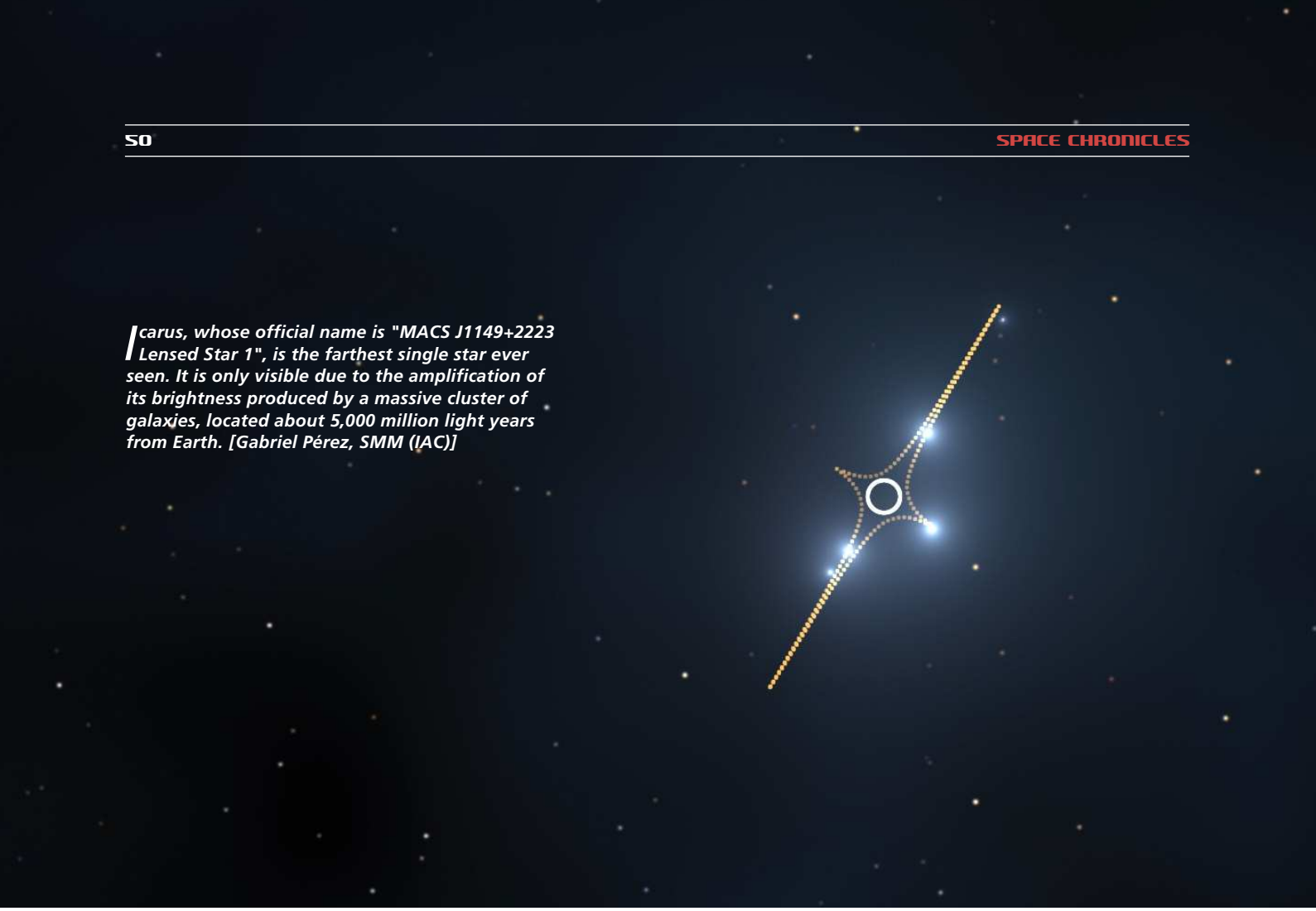
K2 follow-on mission. Artist concept of Kepler spacecraft and fields of view across our galaxy. [NASA]

This video illustrates four ways in which a massive star can explode. [NASA]

"With Kepler, we are now really able to connect the models with the data," he continued. *"Kepler just makes all the difference here. When I first saw the Kepler data, and realized how short this transient is, my jaw dropped. I said, 'Oh wow!'"*

"The fact that Kepler completely captured the rapid evolution really constrains the exotic ways in which stars die. The wealth of data allowed us to disentangle the physical properties of the phantom blast, such as how much material the star expelled at the end of its life and the hypersonic speed of the explosion. This is the first time that we can test FELT models to a high degree of accuracy and really connect theory to observations," said David Khatami of the University of California at Berkeley and Lawrence Berkeley National Laboratory.

This discovery is an unexpected spinoff of Kepler's unique capability to sample changes in starlight continuously for several months. This capability is needed for Kepler to discover extrasolar planets that briefly pass in front of their host stars, temporarily dimming starlight by a small percent. The Kepler observations indicate that the star ejected the shell less than a year before it went supernova. This gives insight into the poorly understood death throes of stars — the FELTs apparently come from stars that undergo "near-death experiences" just before dying, belching out shells of matter in mini-eruptions before exploding entirely. ■



Icarus, whose official name is "MACS J1149+2223 Lensed Star 1", is the farthest single star ever seen. It is only visible due to the amplification of its brightness produced by a massive cluster of galaxies, located about 5,000 million light years from Earth. [Gabriel Pérez, SMM (IAC)]

Hubble discovers the most distant star ever observed

by IAC

If we could travel halfway across the Universe, we would find a huge star, christened Icarus, that was found after its discovery to be the most distant star from Earth. Normally, it would be impossible to detect it, even using the most powerful telescopes currently available, were it not for a quirk of nature that had amplified its brightness such that it could be detected with the Hubble Space Telescope. The discovery has also helped to test a new theory of dark matter and to study what clusters of galaxies are made of. The results of this study were published in the journal *Nature Astronomy*.

Icarus is located in a spiral galaxy that is so far from Earth that its light has taken 9000 million years to reach us. According to Patrick Kelly, a researcher from the University of Minnesota and leader of the team, *"This is the first time we've seen an individual star so far away. We can see very distant galaxies, but this star is a hundred times more distant than the next farthest star that we can observe, unless we include supernova explosions as stars."*

The cosmic quirk that has allowed us to see this star is a phenomenon

known as 'gravitational lensing'. The gravity of an extremely massive cluster of galaxies acts like a giant cosmic magnifying glass that amplifies the light from the most distant objects. The gravitational lens that has enabled us to see Icarus is created by the galaxy cluster known as MACS J1149+2223, located some 5000 million light years from Earth.

Combining this lens with Hubble's resolution and sensitivity has enabled an analysis to be performed of this distant star.

The research team that has participated in this study includes, among other workers, José M. Diego of the Instituto de Física de Cantabria (IFCA), Steven Rodney of the University of South Carolina, Columbia (USA), Pablo G. Pérez González of the Universidad Complutense de Madrid (UCM), Tom Broadhurst of the University of the País Vasco (UPV), and Ismael Pérez Fournon (IAC and ULL). Patrick Kelly and his coworkers detected sudden changes in the star's brightness, produced by the microlens brought about by the gravitational effect of stars belonging to the cluster.

Although its official designation is MACS J1149+2223 Lensed Star 1, the team decided to name the star after the character in Greek mythology who flew too close to the Sun with wings and feathers made of wax. Just like Icarus, the light from this star, on its journey towards Earth, passed so close to a Sun-like star in the intergalactic region of the MACS J1149+2223 cluster that its brightness was amplified by a factor of about 2000, thus attaining the glory of its Greek namesake.

"We were able to establish that Icarus is a blue supergiant star, a type of star that is much bigger, more massive, hotter and possibly thousands of times brighter than the Sun. But, at its great distance, it would be impossible to observe it as an individual star, even with the Hubble, were it not for the gravitational lens phenomenon," comments Ismael Pérez Fournon.

Pablo Pérez González (UCM) explains, *"Until 2016 it was only possible to observe individual stars in galaxies close to the Milky Way. Today, we are witnessing an individual star, very like Rigel, which is halfway across the Universe, and which, indeed, no longer exists."*

The detection of Icarus with the Hubble was so extraordinary that, when it was discovered, telescopes worldwide started to observe it. In Spain, special observing time was applied for on the Gran Telescopio Canarias (GTC), the largest optical-infrared telescope in the world.

It turned out, according to Pérez González, that the GTC *"was the only telescope to detect this star so distant from Earth, given that Icarus is so faint."*

The discovery of Icarus is exceptional not only in terms of the detection of such a distant star. Detecting the amplification of an individual star's brightness enables us to study the nature of the cluster's dark matter content, thus putting to the test a theory of the nature of the dark matter of the cluster that shows that most of it is in the form of primordial black holes. According to José M. Diego (IFCA), first author of the theoretical paper accompanying the *Nature Astronomy* article, *"If the dark matter consisted of black holes similar to those detected by LIGO (Laser Interferometer Gravitational-Wave Observatory), the signal observed from Icarus would have been very different, which enables us to discard these types of candidates."*

Artistic simulation of Icarus (MACS J1149+2223 Lensed Star 1). [Gabriel Pérez, SMM (IAC)]

Tome Broadhurst (UPV) adds, "this type of study will in future enable us to set limits on other dark matter models, such as those that postulate superlight particles of matter and their quantum effects."

Also, in May 2016, another image appeared next to Icarus that seems to suggest that we are not dealing with an individual star. We could instead be talking about a binary system, with two stars in orbit around each other. ■

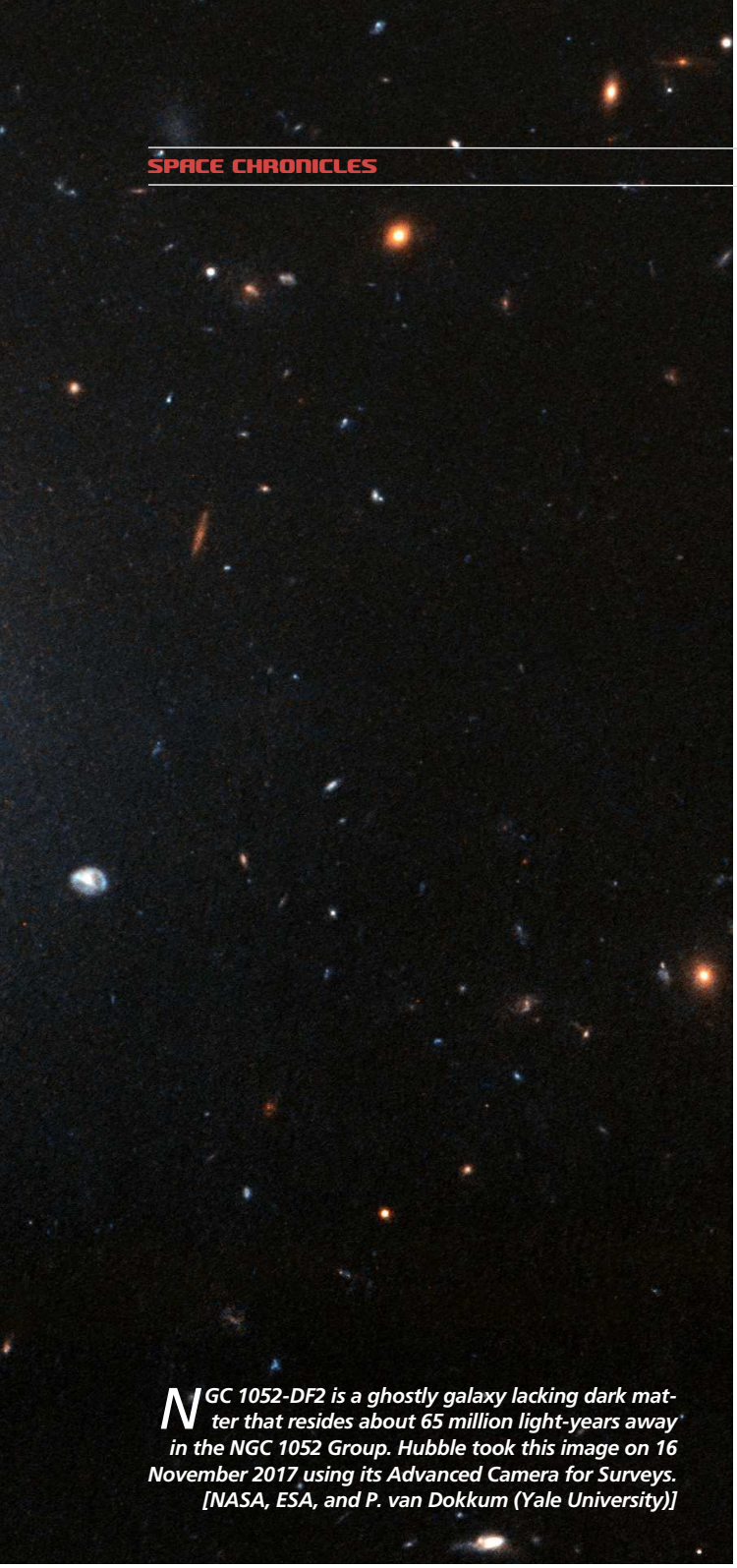
First galaxy in the local Universe without dark matter

by NASA/ESA

Galaxies and dark matter go together like peanut butter and jelly. You typically don't find one without the other.

Therefore, researchers were surprised when they uncovered a galaxy that is missing most, if not all, of its dark matter. An invisible substance, dark matter is the underlying scaffolding upon which galaxies are built. It's the glue that holds the visible matter in galaxies — stars and gas — together.

"We thought that every galaxy had dark matter and that dark matter is how a galaxy begins," said Pieter van Dokkum of Yale University in New Haven, Connecticut, lead researcher of the Hubble observations. *"This invisible, mysterious substance is the most dominant aspect of any galaxy. So finding a galaxy without it is unexpected. It challenges the standard ideas of how we think galaxies work, and it shows that dark matter is real: it has its own separate existence apart from other components of galaxies. This result also suggests that there may be more than one way to form*



NGC 1052-DF2 is a ghostly galaxy lacking dark matter that resides about 65 million light-years away in the NGC 1052 Group. Hubble took this image on 16 November 2017 using its Advanced Camera for Surveys. [NASA, ESA, and P. van Dokkum (Yale University)]

a galaxy." The unique galaxy, called NGC 1052-DF2, contains at most 1/400th the amount of dark matter that astronomers had expected. The galaxy is as large as our Milky Way, but it had escaped attention because it contains only 1/200th the number of stars. Given the object's large size and faint appearance, astronomers classify NGC 1052-DF2 as an ultra-diffuse galaxy. A 2015 survey of the Coma galaxy cluster showed these large, faint objects to be surprisingly common.

But none of the ultra-diffuse galaxies discovered so far have been found to be lacking in dark matter.

So even among this unusual class of galaxy, NGC 1052-DF2 is an oddball.

Van Dokkum and his team spotted the galaxy with the Dragonfly Telephoto Array, a custom-built telescope in New Mexico they designed to find these ghostly galaxies. They then used the W.M. Keck Observatory in Hawaii to measure the motions of 10 giant groupings of stars called globular clusters in the galaxy. Keck revealed that the globular clusters were moving at relatively low speeds, less than 23,000 miles per hour. Stars and clusters in the outskirts of galaxies containing dark matter move at least three times faster. From those measurements, the team calculated the galaxy's mass. *"If there is any dark matter at all, it's very little,"* van Dokkum explained. *"The stars in the galaxy can account for all the mass, and there doesn't seem to be any room for dark matter."*

The researchers next used NASA's Hubble Space Telescope and the Gemini Observatory in Hawaii to uncover more details about the unique galaxy.

Gemini revealed that the galaxy does not show signs of an interaction with another galaxy. Hubble helped them better identify the globular clusters and measure an accurate distance to the galaxy.

The Hubble images also revealed the galaxy's unusual appearance.

"I spent an hour just staring at the Hubble image," van Dokkum recalled. *"It's so rare, particularly these days after so many years of Hubble, that you get an image of something and you say, 'I've never seen that before.' This thing is astonishing: a gigantic blob that you can look through. It's so sparse that you see all of the galaxies behind it. It is literally a see-through galaxy."*

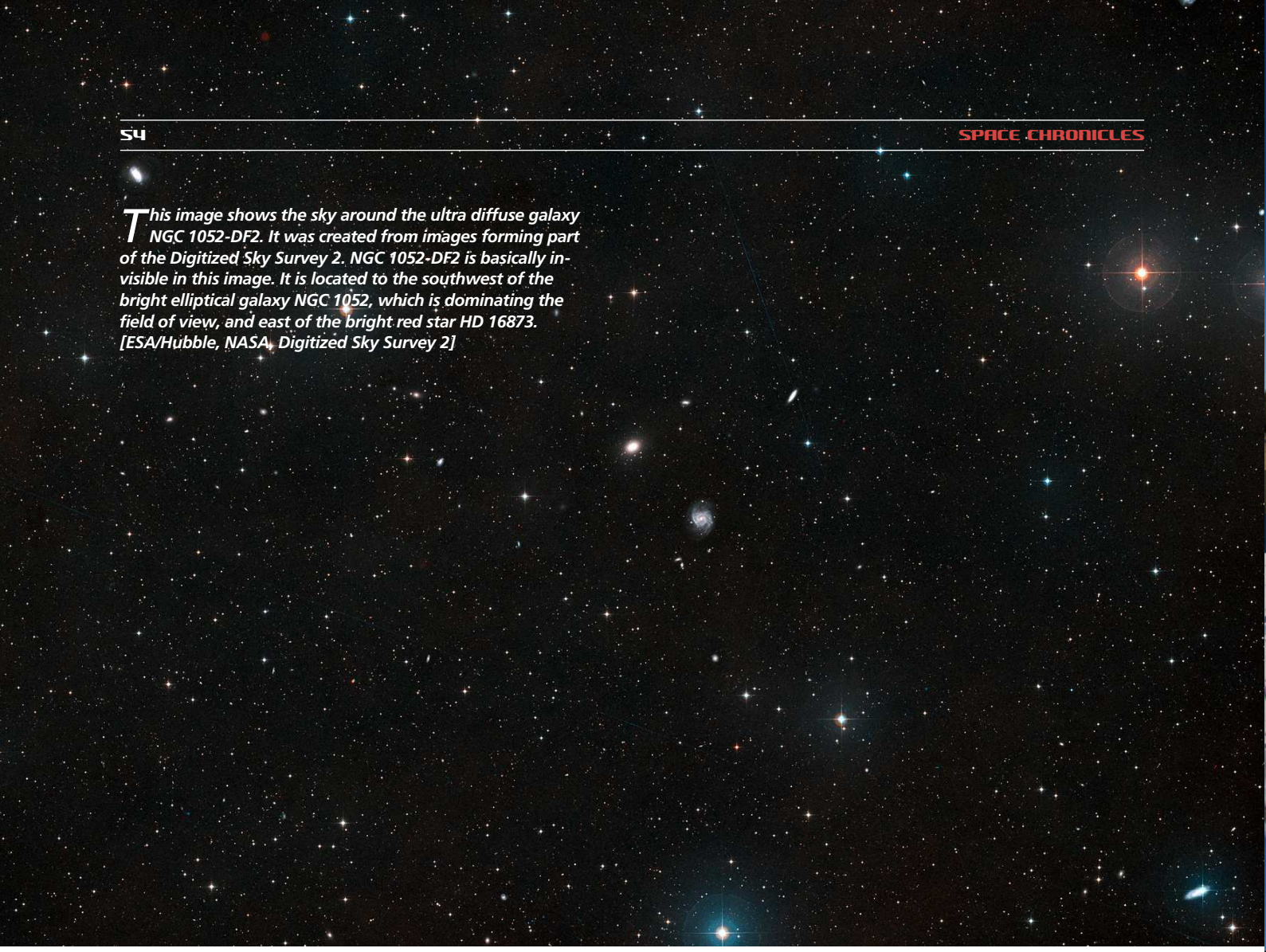
The ghostly galaxy doesn't have a noticeable central region, or even spiral arms and a disk, typical features of a spiral galaxy.

But it doesn't look like an elliptical galaxy, either. The galaxy also shows no evidence that it houses a central black hole.

Based on the colors of its globular clusters, the galaxy is about 10 billion years old. Even the globular clusters are oddballs: they are twice as large as typical stellar groupings seen in other galaxies.

"It's like you take a galaxy and you only have the stellar halo and globular clusters, and it somehow forgot to make everything else," van Dokkum said. *"There is no theory that predicted these types of galaxies. The galaxy is a complete mystery, as everything about it is strange. How you actually go about forming one of these things is completely unknown."*

But the researchers do have some ideas. NGC 1052-DF2 resides about 65 million light-years away in a collection of galaxies that is domi-



This image shows the sky around the ultra diffuse galaxy NGC 1052-DF2. It was created from images forming part of the Digitized Sky Survey 2. NGC 1052-DF2 is basically invisible in this image. It is located to the southwest of the bright elliptical galaxy NGC 1052, which is dominating the field of view, and east of the bright red star HD 16873. [ESA/Hubble, NASA, Digitized Sky Survey 2]

nated by the giant elliptical galaxy NGC 1052. Galaxy formation is turbulent and violent, and van Dokkum suggests that the growth of the fledgling massive galaxy billions of years ago perhaps played a role in NGC 1052-DF2's dark-matter deficiency.

Another idea is that gas moving toward the giant elliptical NGC 1052 may have fragmented and formed NGC 1052-DF2. The formation of NGC 1052-DF2 may have been helped by powerful winds emanating from the young black hole that was growing in the center of NGC 1052. These possibilities are speculative, however, and don't explain all of the characteristics of the observed galaxy, the researchers said.

The team is already hunting for more dark-matter deficient galaxies. They are analyzing Hubble images of 23 other diffuse galaxies. Three of them appear similar to NGC 1052-DF2.

"Every galaxy we knew about before has dark matter, and they all fall in familiar categories like spiral or elliptical galaxies," van Dokkum said. *"But what would you get if there were no dark matter at all? Maybe this is what you would get."* ■

This video zooms in from a view of the night sky, through the constellation of Cetus (the Whale), to end on the NASA/ESA Hubble Space Telescope observations of the ultra diffuse galaxy NGC 1052-DF2. This is the first galaxy to be found to not have dark matter. [ESA/Hubble, Digitized Sky Survey, Nick Risinger (skysurvey.org)]

TecnoSky

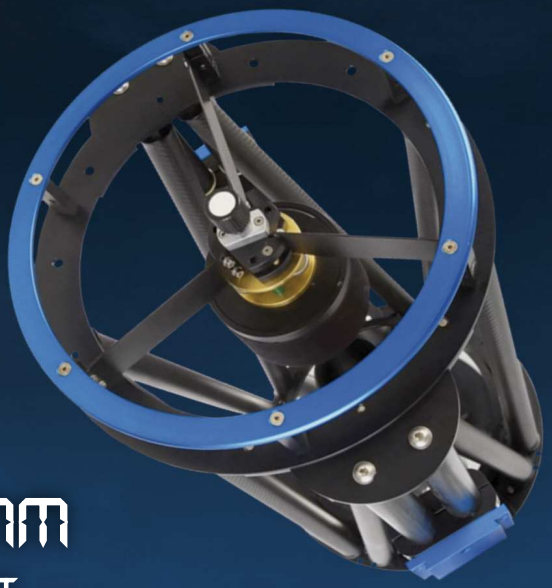
Via Fubine, 79 - Felizzano AL - ITALY - Tel. +39 0131772241
info.oasifelizzano@gmail.com - info@tecnosky.it

astronomy instruments
nature & didactics

www.astrobioparcofelizzano.it
www.facebook.com/LOasiDiFelizzano
http://shop.tecnosky.it
www.facebook.com/Tecnosky-146585525428890

NortheK

Instruments - Composites - Optics



RITCHEY-CHRÉTIEN 250 MM

F/8.5 SUPRAX OPTICS FROM SCHOTT
CARBON STRUCTURE
NORTHEK CELL STABILOBLOK 25
FOCUSER FEATHER TOUCH FTF 2000 2"
WEIGHT 15 KG.

www.northek.it - www.facebook.com/northek.it - info@northek.it - phone +39 01599521