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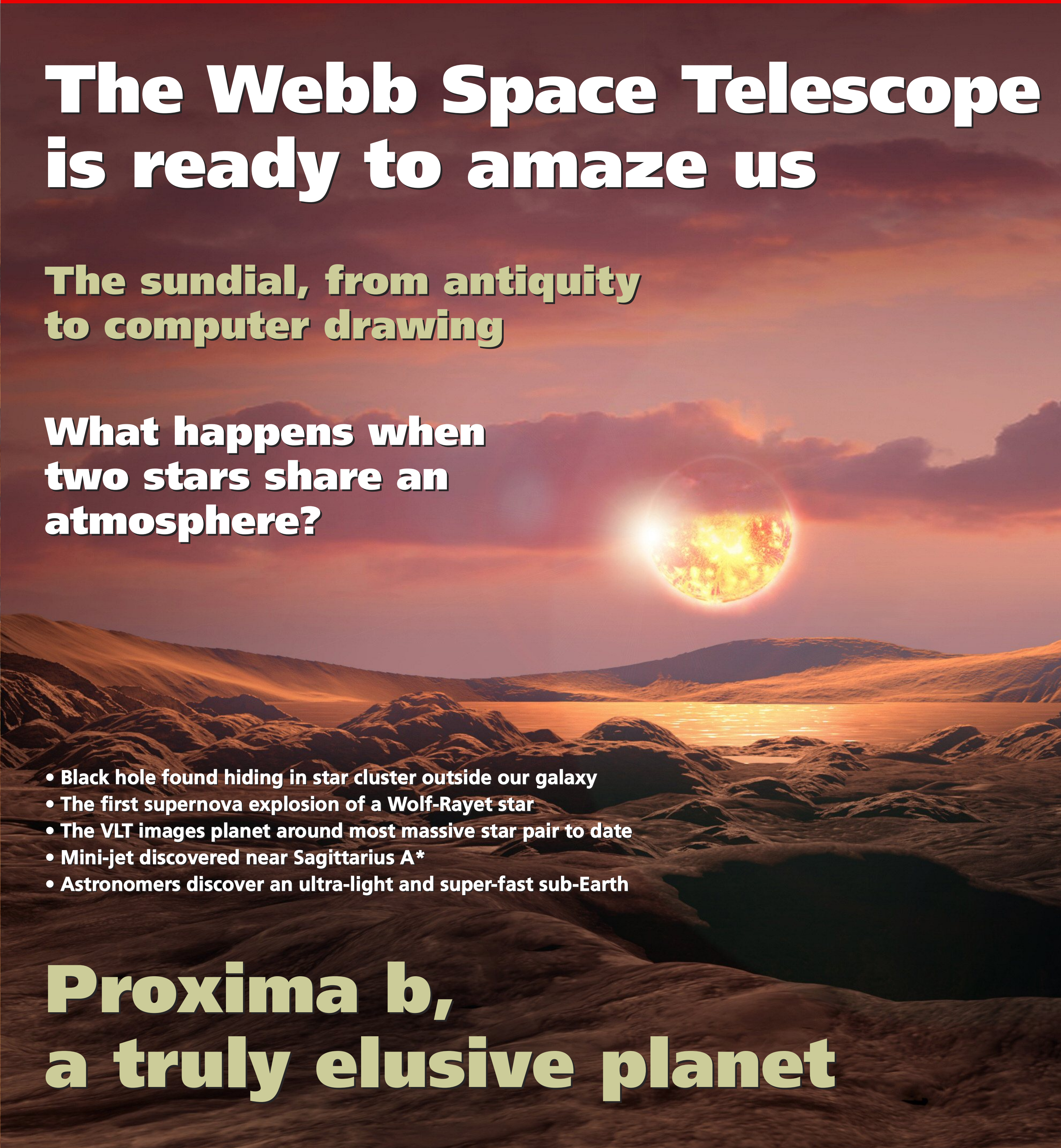

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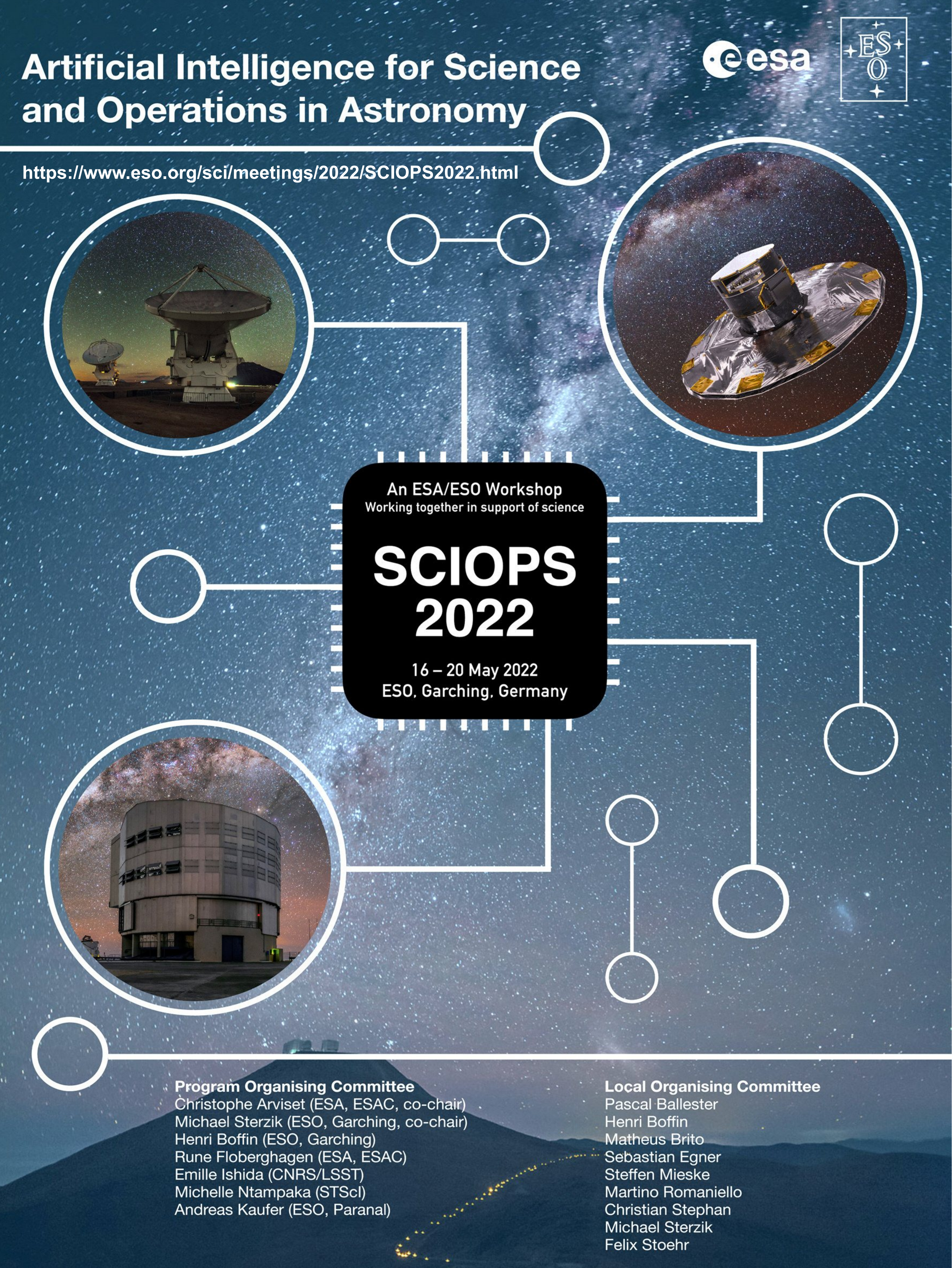

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Editor in chief
Michele Ferrara

Scientific advisor
Prof. Enrico Maria Corsini

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The Webb Space Telescope is ready to amaze us

by Damian G. Allis
NASA Solar System Ambassador

"It has to work" was the opening statement from a 2010 article in *Nature* ominously titled *"The telescope that ate astronomy."* A telescope that, at launch on December 25th of last year, was over its initial budget by nearly 20-fold. 15 years late and subject to multiple delays and launch rescheduling. A major redesign in 2005. A move to cancel the project completely within the U.S. House of Representatives in 2011. Damage discovered to its delicate sunshield during inspections and a practice deployment in 2018. Concerns about excessive vibrations during recent Ariane 5 rocket launches that risked either another delay of launch or the small possibility of damage from a "less than fully nominal" delivery to space. A NASA-reported "communication issue between the observatory and the launch vehicle system" just days prior to its final scheduled launch.

Artist conception of the James Webb Space Telescope. [Adriana Manrique Gutierrez, NASA Animator]

But enough about its time here on Earth – with the cost overruns, criticisms, and controversies surrounding its development, fabrication, testing, naming, and launch all accounted for over its 25-year history, NASA and its collaborators (the European Space Agency, Canadian Space Agency, and several academic and industrial organizations) have successfully launched what is arguably the most important telescope ever deployed in the history of space science.

Now in a halo orbit around the Sun-Earth L2 (second Lagrange) point, a distance 930,000 miles (1,500,000 km) from Earth, the James Webb Space Telescope (JWST) has been delivered, unfurled, and unfolded. It is currently in the process of cooling down before calibration, where it will perform minute adjustments to its 18 hexagonal mirror segments to make the now-famous honeycomb-shaped array act as a single mirror. These adjustments are performed by actuators capable of motions as small as 10 nanometers – 1/10,000th the width of a human hair and a fraction of the wavelengths of light that Webb was designed to detect. The alignment process will take three to five months to complete before the telescope is officially ready to start doing the data collection its developers and proponents have been waiting so long to begin. If all goes well, Webb observation time is expected to begin this summer. In the meantime, mission specialists will have to be content with HD 84406, a 6th magnitude star in Ursa Major this is being used for alignment and data collection purposes.

In terms of scientific discovery, the expectations are great. The JWST can detect objects 100 times fainter than those observed with the Hubble Space Telescope (HST), itself

This infographic shows how the James Webb Space Telescope deployed after launch. [NASA]

one of the great achievements in the history of astronomy and, arguably, the greatest contribution to science outreach ever created (just consider your desktop background. If it's a galaxy, cluster, nebula, or planet, there's a good chance its JPG or TIFF was obtained from a Hubble gallery). Hubble was designed for observation in the ultraviolet and visible parts of the electromagnetic spectrum, with only very limited capability of observing in the infrared. The absence of a broad, space-based infrared-detecting capability from astronomy's complement of telescopes has only grown with the discoveries in observational astronomy since the launch of Hubble and has been felt even more with the retirements of such telescopes as the ESA's Herschel Space Observatory in 2013 and NASA's Spitzer Space Telescope at the end of 2020. This absence of a space-based infrared observatory is felt across all scales of observation in the universe. One set of targets expected to garner significant Webb time – exoplanets – were only first confirmed to exist at all in 1992, two years after Hubble's launch and two decades after Hubble began development. Because of the red-shifting of wavelengths of light due to the expansion of the universe, there are also objects on the far outskirts of the observable universe which Hubble would have been ideally suited to study – if only we could send it back in time nontrivial fractions of the age of the universe itself. Spitzer provided shining examples in Hubble's own Ultra Deep Field image of very prominent, distant infrared sources that simply do not exist accordingly to Hubble's detectors. These are galaxies that were radiating light in the visible spectrum but have had their photons stretched into the infrared – a problem for one type of telescope

Engineers on the ground remotely orchestrated a complex sequence of deployments in the hours and days immediately after the launch of the James Webb Space Telescope. This animation shows the nominal sequence for these deployments. [NASA's Goddard Space Flight Center]

An artist's view of the mirrors, detectors, and support structures on Webb – all placed on the opposite side of the telescope's sunshields from the Sun, which is shown as a brightening glow to the lower-right. [NASA GSFC/CIL/Adriana Manrique Gutierrez]

we can solve by selecting a telescope dedicated to that longer-wavelength radiation.

As to the science to be performed by the JWTS, high sensitivity in the infrared region of the spectrum means a wealth of observational opportunities. We'll consider the two examples mentioned above.

Readers of this magazine are aware of the complexities of both finding habitable exoplanets and determining whether the detection of life – simple or complex, actively trying to communicate or content in their isolation – is going to be something our current technologies enable. Like brown dwarfs, comets, Kuiper belt objects, debris disks, planets in our own Solar System, and any new objects yet to be discovered (all of these objects also being future Webb targets), exoplanets are not shining prominently like the stars they orbit or have been set adrift from. Their emission is stronger in the infrared than the visible. Because of this, there is more information to be obtained, and more to be learned, by collecting data at these longer wavelengths. The problem, of course, is the proximity of these planets to their host stars, which have made direct imaging of most exoplanets all but impossible. Webb combines greater sensitivity than ever available with onboard coronagraphs on its NIRCam and MIRI instruments to both "block out" the associated star and directly image exoplanets in the infrared. This is something that observation from the ground on Earth is made complicated by due to the very molecules that have made life possible at all – water vapor and carbon dioxide in our atmosphere, which absorb the very same infrared wavelengths we want to measure.

If we take the span of 100 million years to be a chapter in a history book of the universe, we currently find ourselves at a distant Chapter 138. Despite only having started to read backwards to uncover the plot of the book from somewhere near the very end of the very last sentence of this current chapter, we've made remarkable progress at skimming through nearly all of the chapters, albeit with some great difficulty in turning the book back to its intro-

An artist's side-on view of the equipment bus and solar panels, five stacked sunshields, and the honeycomb mirror array and detectors. [NASA GSFC/CIL/Adriana Manrique Gutierrez]

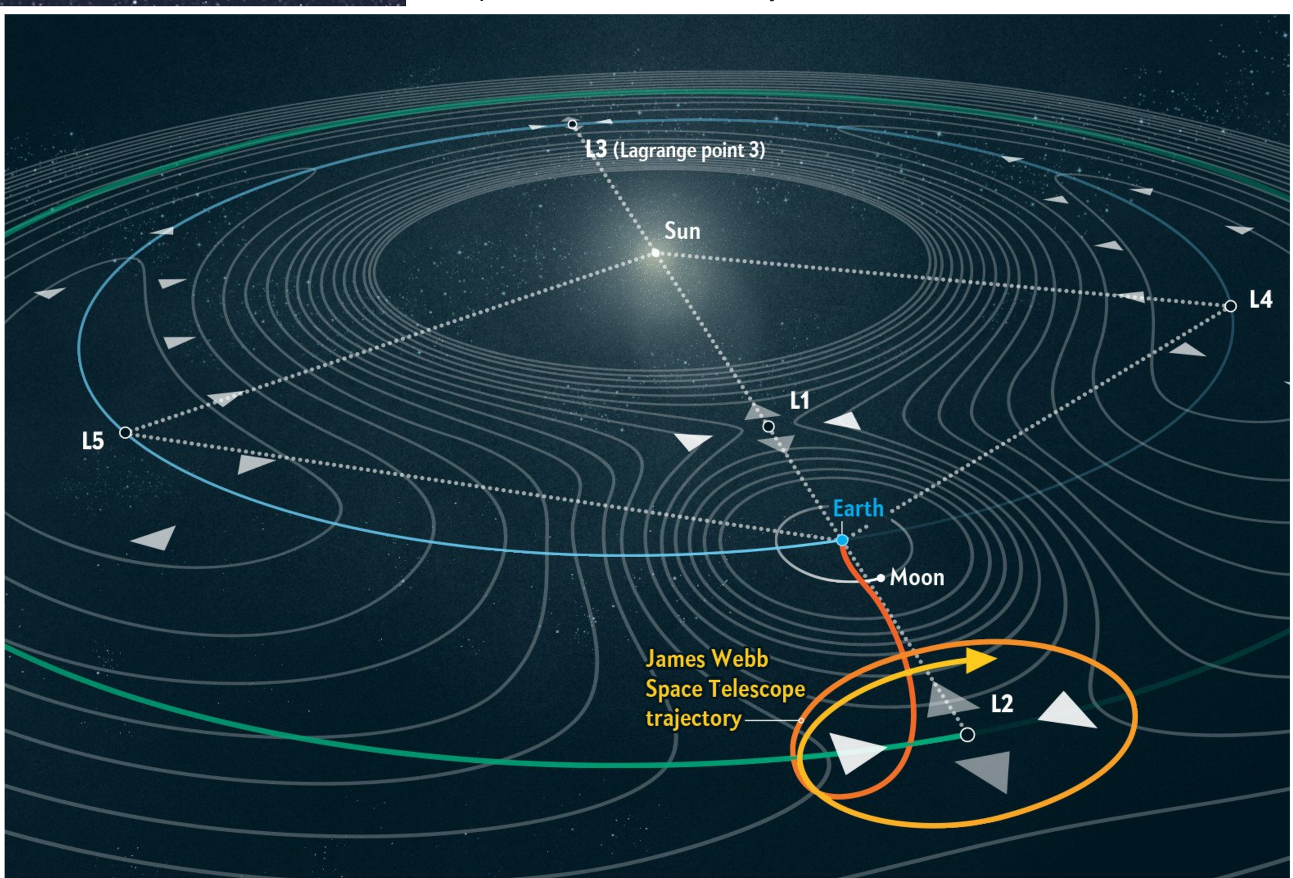
duction. Hubble, for instance, has just taken us back to Chapter Four, a redshift of about z=11. The Cosmic Background Explorer, or COBE, gave us a notion of the shape of the book binding through its measurement of the cosmic background radiation. Webb gives us access to Chapters Two and Three, corresponding to a redshift of z=20, a time 180 million years after the Big Bang when the first stars are theorized to have already been formed but before gravity drew them together into the first galaxies. This process, from stars to galaxies within the architecture of the early cosmos, will hopefully be revealed in detail by Webb.

In terms of design and implementation, Webb's greatest strength for astronomy – infrared sensitivity – is also its greatest challenge for engineers. Just as one would not find much success trying to measure the cosmic microwave background from the inside of a running microwave oven, nor to try to use a 12" Dobsonian telescope to observe distant galaxies (nor arguably anything dimmer than Saturn) during their noontime lunch break, the usability of an infrared telescope is limited dramatically by its proximity to both infrared-emitting objects and to the heat being generated by its own electronics. The seeing from the ground for infrared astronomy is poor on its best days, as Earth's atmosphere is not only being actively heated by the Sun but is also itself an excellent infrared absorber of radiation coming from any object

within and beyond. High-altitude observatories, such as the Infrared Telescope Facility in Hawaii, and very-high-altitude observatories, such as the flying Stratospheric Observatory for Infrared Astronomy (SOFIA), are solutions to the problem, but are limited compared to having an infrared telescope that is completely isolated from all nearby heat sources.

The solution to all of Webb's problems is location, both in terms of the location of the telescope itself, as well as the placement of all onboard equipment capable of producing enough heat to set off the detectors. Joseph-Louis Lagrange identified five locations at which three bodies could exist at stable locations with respect to one another as they orbit. In these special cases of the famous "three-body problem" in physics, solutions work when two of the bodies are massive and the third is diminutive by comparison – a case for which the Sun-Earth-JWST combination certainly applies. At L2, JWST finds itself in a reasonably stable orbit with the Sun, Earth, and Moon all on one side of the telescope – meaning the sunshield can protect the onboard detectors from the heat being emitted or reflected from all three celestial bodies. At the other four Lagrange points, JWST would either be

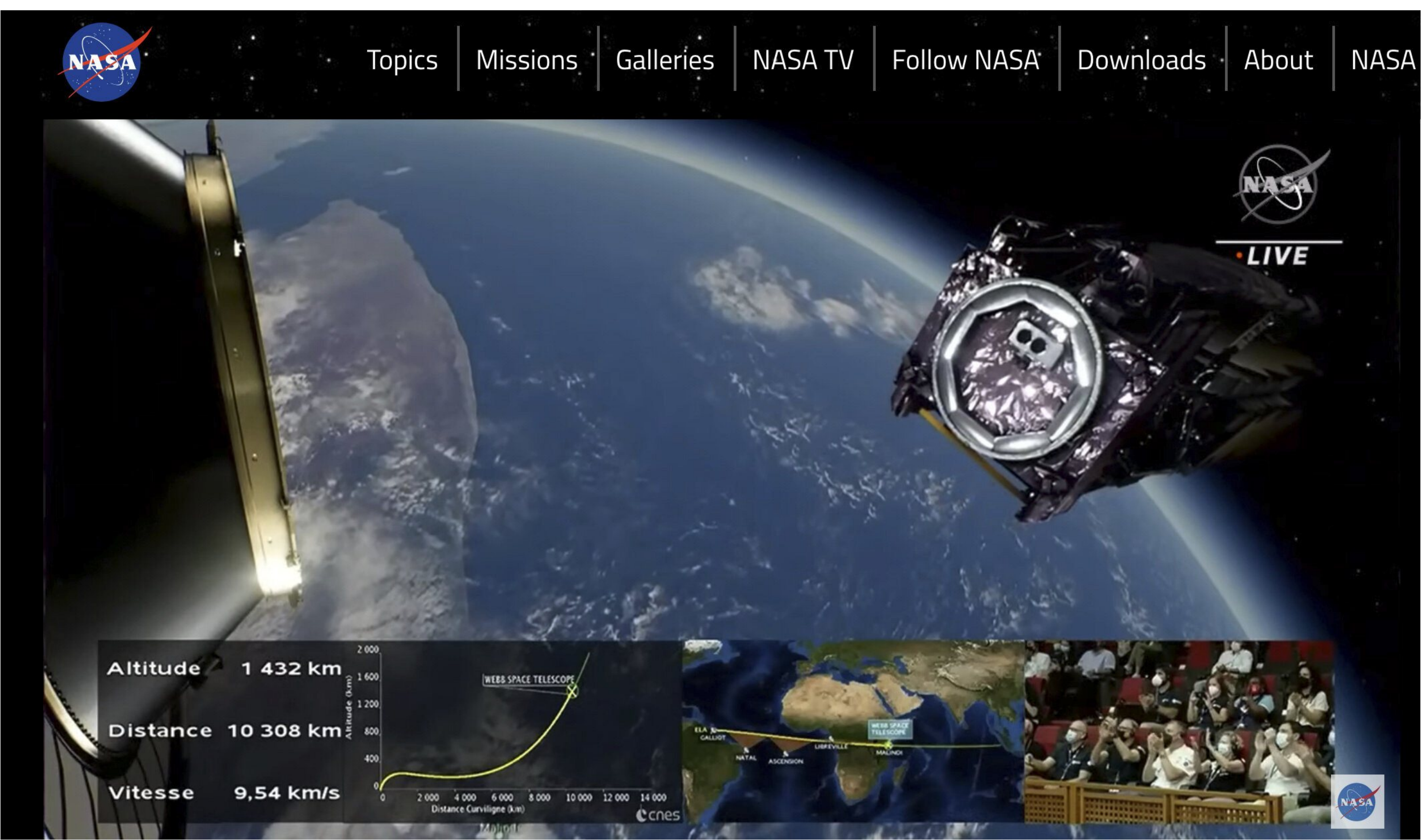
The trajectory followed by the James Webb Space Telescope to reach its special placement around the Lagrangian point L2. Distances are not to scale. [Matthew Twombly]



directly between the Sun and Earth, leading/training the Earth in its orbit (and exposed to both bodies), or completely on the other side of the Sun. In the arrangement at L2 and with its massive sunshield in place and oriented back towards the Sun, the limits of the telescope sensitivity are determined by other nearby celestial sources – for which a source as faint as zodiacal light is a primary limiter. Its placement at L2 also means that gravity alone will do the work of moving the scope to study the universe and only relatively small adjustments will be required with its onboard thrusters to maintain Webb's halo orbit. Despite the massive sunshield sandwiched between the mirrors and we observers, the JWST geometry still allows it to observe any part of 40% of the universe at any one time. With this wide access, JWST can observe any point in the IR-observable universe – with the notable exception of any location within the Sun-JWST radius, of course – in just the six months it takes it and ourselves to make one-half orbit around the Sun.

To solve the problem of radiation from internal components, JWST used the same solution – move the entire equipment bus to the Sun-side of the five sunshields, leaving the telescope optics, detectors, and support structures almost completely isolated from the hardware doing the movement, data processing, and communications with the NASA Deep Space Network. With the five sunshields and additional radiators in place, the mirrors and detectors can all be kept under 50 K (-223 °C, or -370 °F) by the 5th layer, below the temperature at which any of the

In this photo provided by NASA, the James Webb Space Telescope is separated in space on Saturday, Dec. 25, 2021. The instrument soared from French Guiana on South America's northeastern coast, carried by a European Ariane 5 rocket into the Christmas morning sky. The $10 billion infrared observatory is intended as the successor to the aging Hubble Space Telescope. [NASA via AP]



NASA's James Webb Space Telescope separates from its Ariane 5 rocket with the bright blue Earth in the background in this view captured after its launch on Dec. 25, 2021. [NASA TV]

components might begin radiating infrared energy and corrupting the observations. This approach of engineering a reflective cooling system into the design is in stark contrast to the approach taken with Spitzer, where liquid helium cooling was employed to keep the detectors cold – a method that certainly kept the telescope cold enough for IR observations, but which also then greatly reduced the usability of the scope to the time it took to deplete the helium. The one onboard cryocooler on Webb, a necessary addition for the Mid-InfraRed Instrument (MIRI) to achieve ultra-cold conditions (7 K) at its detectors, employs a pulse-tube cooling approach that has no moving parts and requires no chemical refrigerant, meaning no unwanted vibrations through the telescope and a cryocooler lifetime that is expected to well-exceed the operational lifetime of the telescope itself.

A final word on finality. Much has been mentioned about JWST and how "it has to work." Unlike Hubble, which benefited greatly from two service missions and actual astronauts to perform the procedures, JWST is nowhere near what anyone would describe as a repair-accessible location. Hubble remains about 540 km (335 mi) away from us at any given time, a distance one could cover on a highway in a long afternoon on a single charge for some electric cars now on the market. From Thomas Zurbuchen (NASA Science Mission Directorate) on down, no one has offered the proposal (serious or otherwise) that an issue with Webb could be resolved with a mission, crewed or otherwise. The only clear sign of optimism for any type of visitation to JWST before the end of its operational lifetime is a reported refueling port. Interestingly, a web search for this port will take you to many space news websites discussing the manners of approach and dangers to the sunshields of refueling through robotic missions, but none of these sites end in nasa.gov. Concerns about a failure in such a complicated undertaking as an unfolding telescope in space ignores, of course, the fact that NASA excels at one-way missions. In most respects, almost every mission beyond the Earth-Moon system is one-way and, by nature, "has to work."

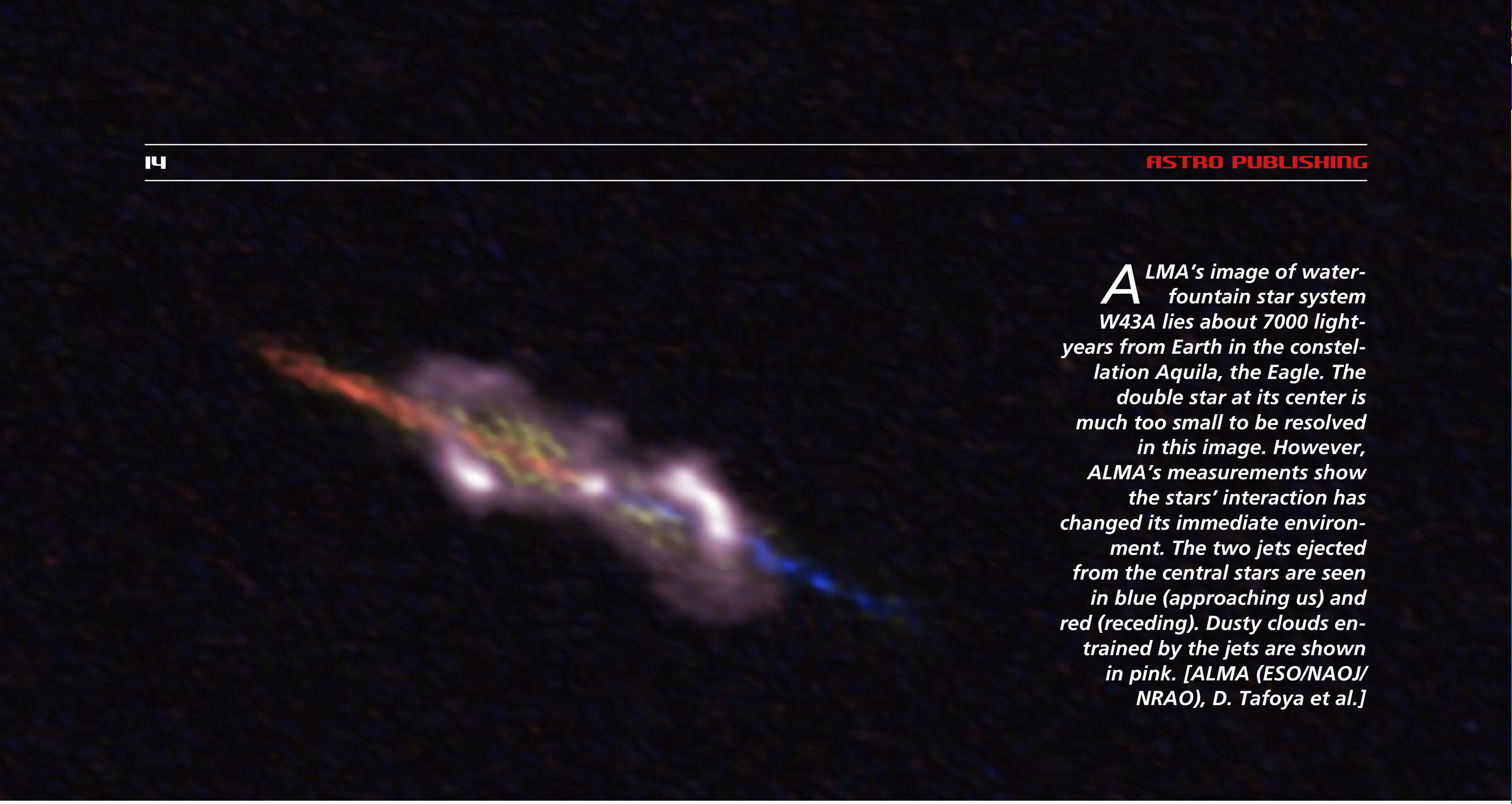
While the JWST is a modern (albeit expensive) and complicated engineering feat, no one can deny the great successes of the Voyagers, Cassini, various Mars missions, New Horizons, and the many other probes either retired or still actively doing great science. This is all to say that the "flawless" and "perfect" descriptors of the launch and unfolding of JWST are welcome from NASA, but not a surprise. With its deployment complete and no expectation of technical issues from here on out, the JWST is nearly ready to begin what could be two decades of groundbreaking observations. The great expectations cover nearly the entirety of the history of the universe itself, from the earliest stars to the possible detections of life-compatible conditions in our own celestial neighborhood. ■

What happens when two stars share an atmosphere?

by ALMA Observatory
Nicolás Lira

Using the gigantic telescope ALMA in Chile, a Chalmers-led team of scientists studied 15 unusual stars in our galaxy, the Milky Way, the closest 5000 light-years from Earth. Their measurements show that all the stars are double.
All have recently experienced a rare phase that is poorly understood but probably leads to many other astronomical phenomena. Their results are published in the scientific journal *Nature Astronomy*. By directing ALMA towards each star and measuring light from different molecules close to each star, the researchers hoped to find clues to their backstories. Nicknamed "water fountains," these stars were known to astronomers because of intense light from water molecules – produced by unusually dense and fast-moving gas. Located 5000 m above sea level in Chile, the ALMA is sensitive to light with wavelengths around one millimeter, invisible to human eyes, but ideal for looking through the Milky Way's layers of dusty interstellar clouds towards dust-enshrouded stars. *"We were extra curious about these stars because they seem to be blowing out quantities of dust and gas into space, some in the form of jets with speeds up to 1.8 million kilometers per hour. We thought we might find out clues to how the jets were being created, but instead, we found much more than that"*, says Theo Khouri, first author of the new study.
The scientists used the telescope to measure signatures of carbon monoxide (CO) molecules in the light from the stars and compared

A pair of stars at the start of a common envelope phase. In this artist's impression, we get a view from very close to a binary system in which two stars have just started to share the same atmosphere. The bigger star, a red giant star, has provided a huge, cool atmosphere that only just holds together. The smaller star orbits ever faster around the stars' center of mass, spinning on its axis and interacting dramatically with its new surroundings. The interaction creates powerful jets that throw out gas from its poles and a slower-moving ring of material at its equator. [Danielle Futselaar, artsource.nl]



ALMA's image of water-fountain star system W43A lies about 7000 light-years from Earth in the constellation Aquila, the Eagle. The double star at its center is much too small to be resolved in this image. However, ALMA's measurements show the stars' interaction has changed its immediate environment. The two jets ejected from the central stars are seen in blue (approaching us) and red (receding). Dusty clouds entrained by the jets are shown in pink. [ALMA (ESO/NAOJ/NRAO), D. Tafoya et al.]

signals from different atoms (isotopes) of carbon and oxygen. Unlike its sister molecule, carbon dioxide (CO_2), carbon monoxide is relatively easy to discover in space and is a favorite tool for astronomers.

"Thanks to ALMA's exquisite sensitivity, we were able to detect the very faint signals from several different molecules in the gas ejected by these stars. When we looked closely at the data, we saw details that we weren't expecting to see", says Theo Khouri.

The observations confirmed that the stars were all blowing off their outer layers. But the proportions of the different oxygen atoms in the molecules indicated that the stars were in another respect not as extreme as they had seemed, explains team member Wouter Vlemmings, an astronomer at Chalmers.

"We realized that these stars started their lives with the same mass as the Sun or only a few times more. Now our measurements showed that they have ejected up to 50% of their total mass just in the last few hundred years. Something flamboyant must have happened to them", he says.

Why were such small stars come losing so much mass so quickly? The evidence all pointed to one explanation, the scientists concluded.

These were all double stars, and they had all just been through a phase in which the two stars shared the same atmosphere, one star entirely embraced by the other.

"In this phase, the two stars orbit together in a sort of cocoon. This phase, we call it a 'common envelope' phase, is really brief and only lasts a few hundred years. In astronomical terms, it's over in the blink of an eye", says team member Daniel Tafoya.

Most stars in binary systems simply orbit around a common center of mass. These stars, however, share the same atmosphere. It can be a life-changing experience for a star and may even lead to the stars merging completely.

Scientists believe that this sort of intimate episode can lead to some of the sky's most spectacular phenomena. Understanding how it happens could help answer some of the astronomers' most important questions about how stars live and die, Theo Khouri explains.

"What happens to cause a supernova explosion? How do black holes get close enough to collide? What's makes the beautiful and symmetric objects we call planetary nebulae? Astronomers have suspected for many years that common envelopes are part of the answers to questions like these. Now we have a new way of studying this momentous but mysterious phase", he says.

Understanding the typical envelope phase will also help scientists study what will happen in the very distant future, when the Sun too will become a more extensive, cooler star – a red giant – and engulf the innermost planets.

"Our research will help us understand how that might happen, but it gives me a more hopeful perspective. When these stars embrace, they send dust and gas out into space that can become the ingredients for coming generations of stars and planets, and with them the potential for new life", says Daniel Tafoya.

Since the 15 stars seem to be evolving on a human timescale, the team plans to keep monitoring them with ALMA and with other radio telescopes. With the future telescopes of the SKA Observatory, they hope to study how the stars form their jets and change their surroundings. They also hope to find more – if there are any. *"Actually, we think the known 'water fountains' could be almost all the systems of their kind in the whole of our galaxy. If that's true, then these stars are the key to understanding the strangest, most wonderful, and most important process that two stars can experience in their lives together"*, concludes Theo Khouri. ■

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Black hole found hiding in star cluster outside our galaxy

by ESO - Bárbara Ferreira

Using the European Southern Observatory's Very Large Telescope (ESO's VLT), astronomers have discovered a small black hole outside the Milky Way by looking at how it influences the motion of a star in its close vicinity.

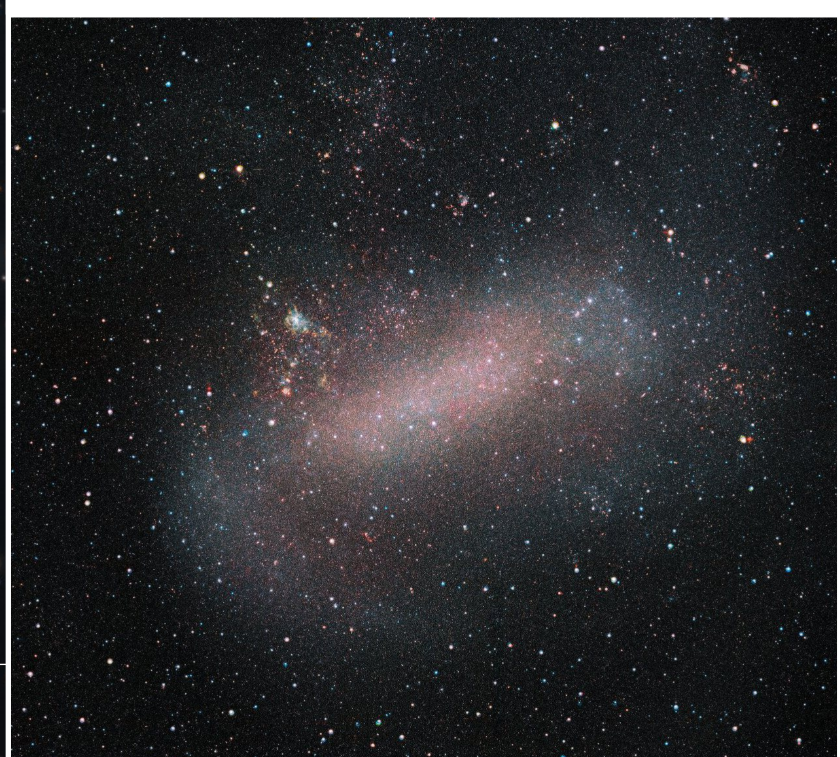
This is the first time this detection method has been used to reveal the presence of a black hole outside of our galaxy. The method could be key to unveiling hidden black holes in the Milky Way and nearby galaxies, and to help shed light on how these mysterious objects form and evolve.

The newly found black hole was spotted lurking in NGC 1850, a cluster of thousands of stars roughly 160,000 light-years away in the Large Magellanic Cloud, a neighbour galaxy of the Milky Way.

"Similar to Sherlock Holmes tracking down a criminal gang from their missteps, we are looking at every single

This artist's impression shows a compact black hole 11 times as massive as the Sun and the five-solar-mass star orbiting it. The two objects are located in NGC 1850, a cluster of thousands of stars roughly 160,000 light-years away in the Large Magellanic Cloud, a Milky Way neighbour. The distortion of the star's shape is due to the strong gravitational force exerted by the black hole. Not only does the black hole's gravitational force distort the shape of the star, but it also influences its orbit. By looking at these subtle orbital effects, a team of astronomers were able to infer the presence of the black hole, making it the first small black hole outside of our galaxy to be found this way. For this discovery, the team used the Multi Unit Spectroscopic Explorer (MUSE) instrument at ESO's Very Large Telescope in Chile. [ESO/M. Kornmesser]

A remarkable image of the Large Magellanic Cloud, one of our nearest galactic neighbours, taken by ESO's VISTA telescope. [ESO/VMC Survey]



star in this cluster with a magnifying glass in one hand trying to find some evidence for the presence of black holes but without seeing them directly," says Sara Saracino from the Astrophysics Research Institute of Liverpool John Moores University in the UK, who led the research published in the *Monthly Notices of the Royal Astronomical Society*. "The one uncovered now is just one of the wanted criminals, but when you

This image shows NGC 1850, a cluster of thousands of stars roughly 160,000 light-years away in the Large Magellanic Cloud, a Milky Way neighbour. The reddish filaments surrounding the cluster, made of vast clouds of hydrogen, are believed to be the remnants of supernova explosions. The image is an overlay of observations conducted in visible light with ESO's Very Large Telescope (VLT) and NASA/ESA's Hubble Space Telescope (HST). The VLT captured the wide field of the image and the filaments, while the central cluster was imaged by the HST. [ESO, NASA/ESA/R. Gilmozzi/S. Casertano, J. Schmidt]

have found one, you are well on your way to discovering many others, in different clusters." This first "criminal" tracked down by the team turned out to be roughly 11 times as massive as our Sun. The smoking gun that put the astronomers on the trail of this black hole was its gravitational influence on the five-solar-mass star orbiting it.

Astronomers have previously spotted such small, "stellar-mass" black holes in other galaxies by picking up the X-ray glow emitted as they swallow matter, or from the gravitational waves generated as black holes collide with one another or with neutron stars.

However, most stellar-mass black holes don't give away their presence through X-rays or gravitational waves. "*The vast majority can only be unveiled dynamically,*" says Stefan Dreizler, a team member based at the University of Göttingen in Germany. *"When they form a system with a star, they will affect its motion in a subtle but detectable way, so we can find them with sophisticated instruments."*

This dynamical method used by Saracino and her team could allow astronomers to find many more black holes and help unlock their mysteries. *"Every single detection we make will be important for our future understanding of stellar clusters and the black holes in them,"* says study co-author Mark Gieles from the University of Barcelona, Spain.

The detection in NGC 1850 marks the first time a black hole has been found in a young cluster of stars (the cluster is only around 100 million years old, a blink of an eye on astronomical scales). Using their dynamical method in similar star clusters could unveil even more young black holes and shed new light on how they evolve. By comparing them with larger, more mature black holes in older clusters, astronomers would be able to understand how these objects grow by feeding on stars or merging with other black holes. Furthermore, charting the demographics of black holes in star clusters improves our understanding of the origin of gravitational wave sources.

To carry out their search, the team used data collected over two years with the Multi Unit Spectroscopic Explorer (MUSE) mounted at ESO's VLT, located in the Chilean Atacama Desert. *"MUSE allowed us to observe very crowded areas, like the innermost regions of stellar clusters, analysing the light of every single star in the vicinity. The net result is information about thousands of stars in one shot, at least 10 times more than with any other instrument,"* says co-author Sebastian Kamann, a long-time MUSE expert based at Liverpool's Astrophysics Research Institute. This allowed the team to spot the odd star out whose peculiar motion signalled the presence of the black hole. Data from the University of Warsaw's Optical Gravitational Lensing Experiment and from the NASA/ESA Hubble Space Telescope enabled them to measure the mass of the black hole and confirm their findings.

ESO's Extremely Large Telescope in Chile, set to start operating later this decade, will allow astronomers to find even more hidden black holes. *"The ELT will definitely revolutionise this field,"* says Saracino. *"It will allow us to observe stars considerably fainter in the same field of view, as well as to look for black holes in globular clusters located at much greater distances."* ■

This animation explains the method used by a team of astronomers to discover a small black hole outside of our galaxy — the first to be found using this technique. They discovered it in the star cluster NGC 1850, an image of which appears at the start of the animation. The researchers used the Multi Unit Spectroscopic Explorer (MUSE) instrument at ESO's Very Large Telescope in Chile to analyse the spectra of thousands of stars in the cluster at the same time. Spectra (represented in the video by colourful bars) show the light emitted by the stars at different wavelengths and contain information about their chemical composition, temperature and velocity. The animation then focuses on one of the spectra, that of a star five times as massive as our Sun. The dark lines in its spectrum — due to different chemical elements — oscillate back and forth towards blue and red colours. This means that the star is periodically moving towards and away from us. This allowed the astronomers to infer the presence of the eleven-solar-mass black hole influencing the star's orbit with its strong gravitational force. [ESO/L. Calçada, NASA/ESA/M. Romaniello. Acknowledgement: J.C. Muñoz-Mateos]

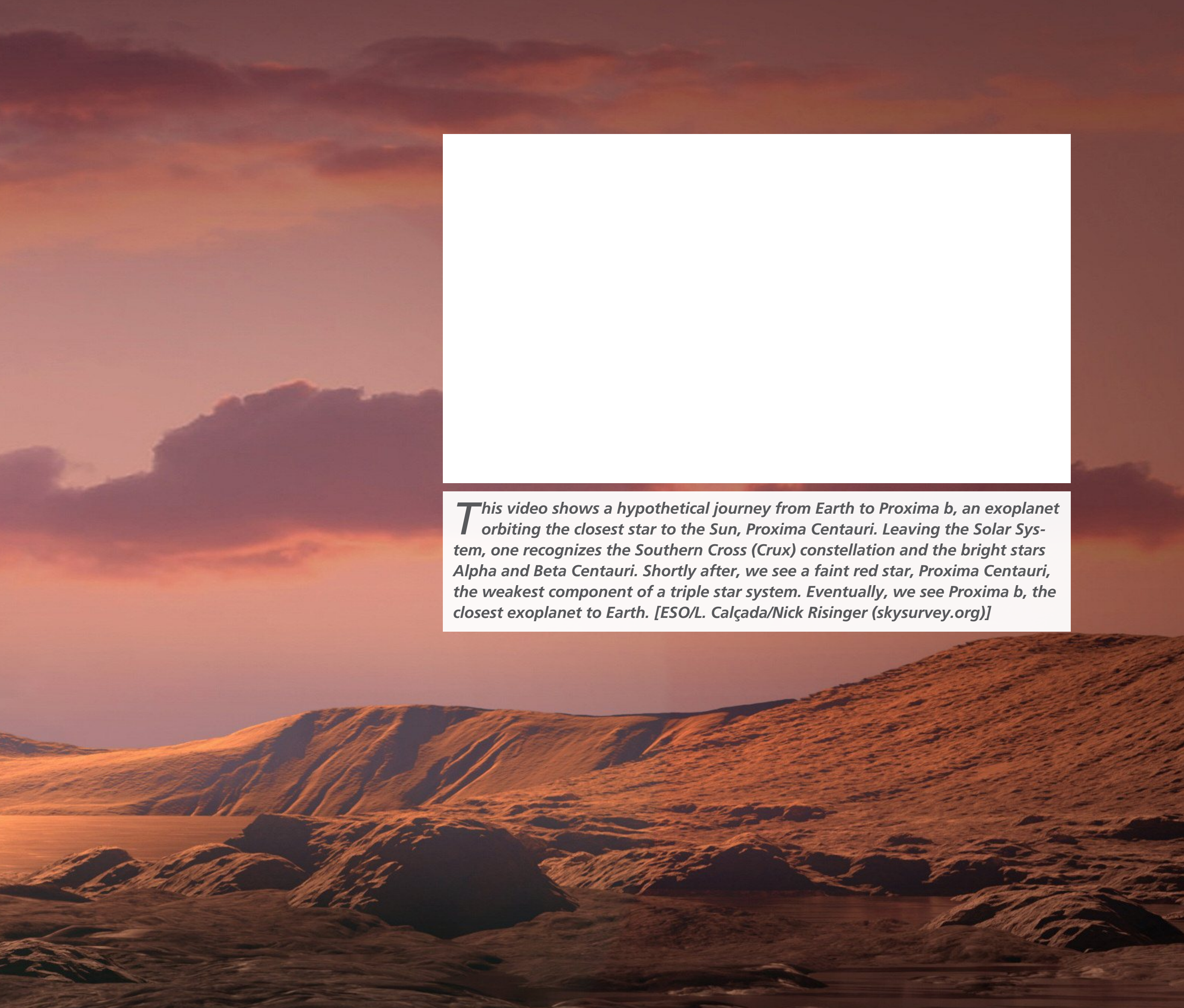
Proxima b, a truly elusive planet

by Michele Ferrara

revised by Damian G. Allis
NASA Solar System Ambassador

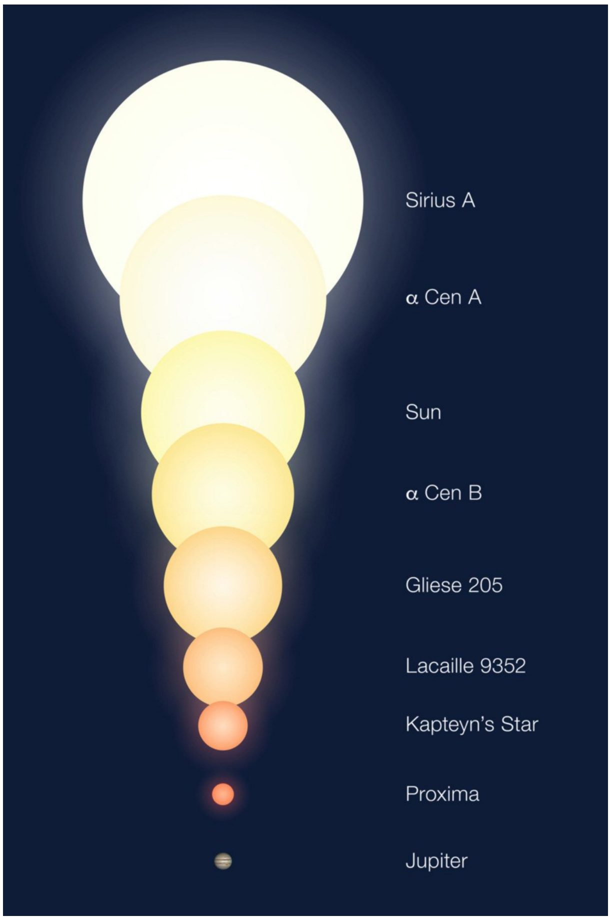
One of the most studied stars in the entire sky is Proxima Centauri, the closest star to our Solar System, located at a distance of "just" 4.24 light-years. We know that it is a red dwarf (spectral class M5.5V) with a mass and a diameter almost ten times smaller than those of the Sun. Despite its tiny size, Proxima Centauri shows much more intense magnetic activity than our star, which manifests itself mainly through the recurrent emission of white light flares. For our Sun, this highly energetic phenomenon occurs a few times per century. In the case of Proxima Centauri, at least a couple of white light flares occur each day, a quantity that considerably complicates photometric and spectroscopic studies of the star. This is a feature that almost all red

A hypothetical landscape for the planet Proxima b, dominated by the looming presence of its star, Proxima Centauri. Like many red dwarfs, Proxima Centauri also manifests its magnetic activity in the form of frequent flares that flood the surrounding planets with deadly radiation. [NASA/Ames Research Center/Daniel Rutter]



This video shows a hypothetical journey from Earth to Proxima b, an exoplanet orbiting the closest star to the Sun, Proxima Centauri. Leaving the Solar System, one recognizes the Southern Cross (Crux) constellation and the bright stars Alpha and Beta Centauri. Shortly after, we see a faint red star, Proxima Centauri, the weakest component of a triple star system. Eventually, we see Proxima b, the closest exoplanet to Earth. [ESO/L. Calçada/Nick Risinger (skysurvey.org)]

dwarfs have in common, including not only the youngest ones, but also those several billions of years old. This is precisely the case for Proxima Centauri, which, at about five billion years old, makes it only a little older than the Sun.
If a star's magnetic activity heavily affects the stability of its light curve and the position of its spectral lines, it goes without saying that that star is not an ideal target in the search for exoplanets, the presence of which is almost systematically inferred through minute dips in starlight during transits in front of the stellar disk or through slight oscillations of the host star's spectral lines. Nevertheless, discovering one or more planets in orbit around the closest star to the Solar System has been a primary goal for astronomers for decades. This type of research reached its milestone in 2016 when, overcoming all the difficulties posed by the "noise" produced by the flares, a team of astronomers led by Guillem Anglada-Escudé (Instituto de Ciencias del Espacio, Barcelona) discovered the first planet of that star, designated Proxima b. The discovery was made by finding a periodicity of 11.2 days in the star's radial

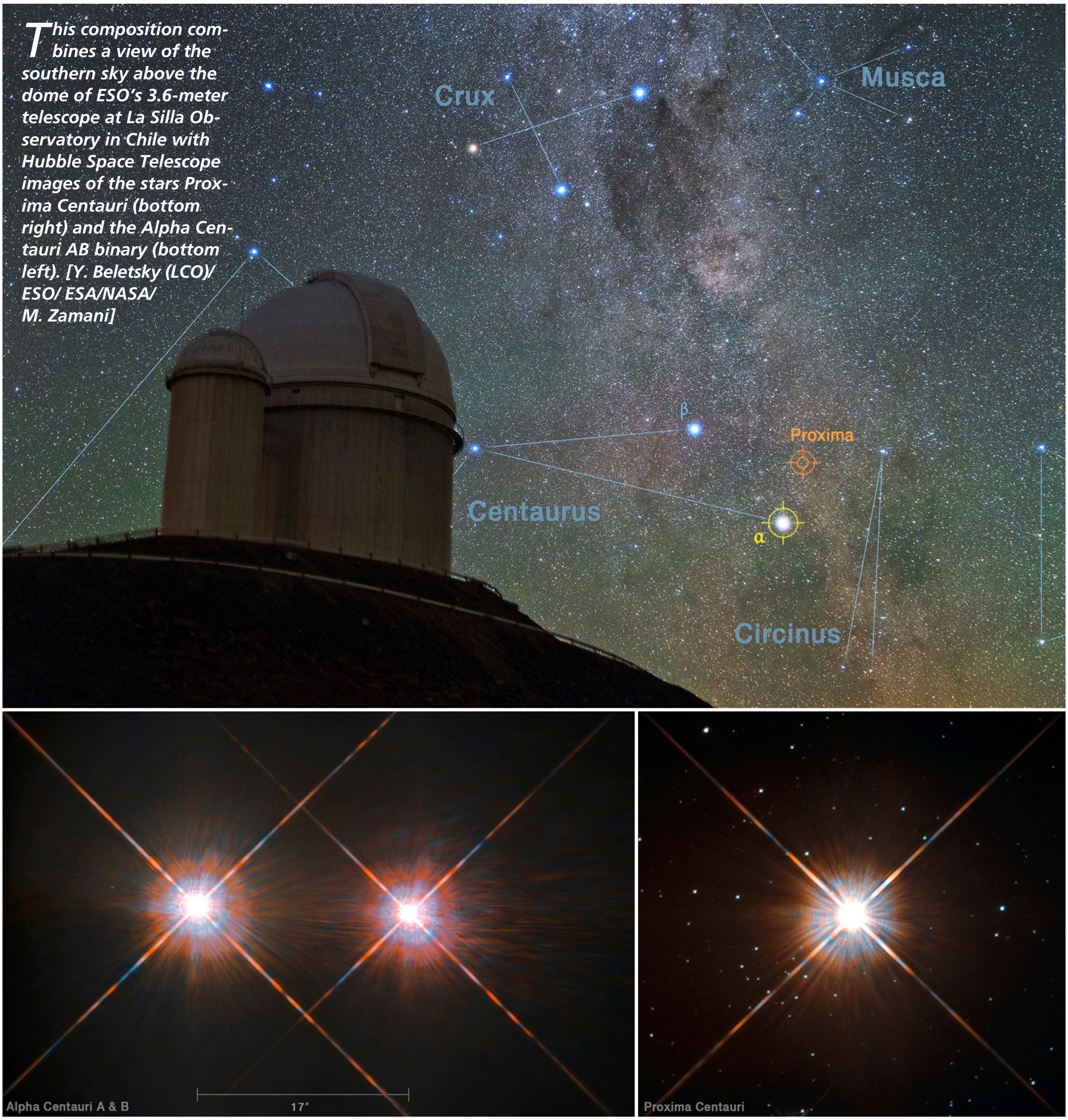


The relative sizes of several objects, including the three (known) members of the Alpha Centauri triple system and some other stars for which angular sizes were measured with the Very Large Telescope Interferometer (VLTI) of the ESO Paranal Observatory. For comparison, the Sun and Jupiter are also shown. [ESO]

velocity variations, which manifested themselves by way of the aforementioned oscillations of the spectral lines. While magnetic activity generates non-periodic random variations that do not move the geometric center of the star, a planet with an orbit not orthogonal to the line of sight physically moves the star towards the observer and in the opposite direction, generating a periodic signal in the spectrum. The challenge of the Anglada-Escudé team was to be able to extract this signal (the orbital period) from the noise. The extent of the oscillation of the spectral lines, combined with the known mass of Proxima Centauri, made it possible to calculate the minimum mass of the planet, which was determined to be equal to 1.3 times that of the Earth. From the orbital period, it was then possible to trace the star-planet distance, which is 0.048 astronomical units (7.2 million km or 4.5 million mi). These values were a sensation soon after their calculation because they suggested that Proxima b may be a rocky planet that surely orbits in the habitable zone of Proxima Centauri, a zone that extends from 0.023 to 0.054 astronomical units from the center of the star. Let's recall that the term "habitable zone" means the region around a star where liquid water can exist on the surface of a planet.

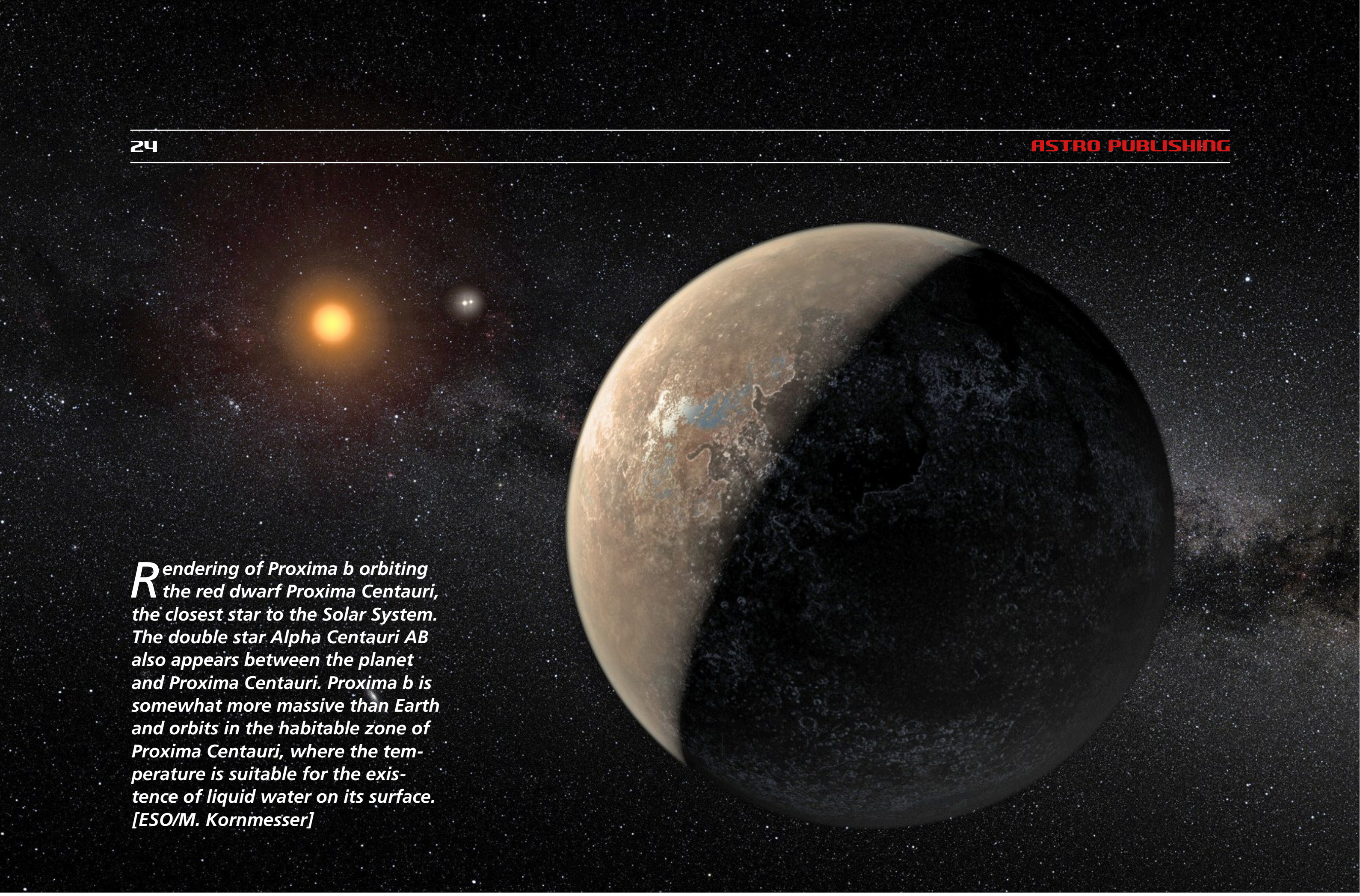
Guillem Anglada-Escudé, the astronomer who, with his team, discovered Proxima b. [Universitat de Barcelona]

In short, its size and positioning give hope that Proxima b is the closest exoplanet that has the essential requirements to host life. However, this scenario is made extremely unlikely by several factors. The first is the exuberant magnetic activity of Proxima Centauri, which continually storms the planet with deadly streams of ultraviolet and X-ray radiation. The second is the real mass of the planet itself, which might actually be twice that of the Earth if the planet is far above or below the line of sight at the closest and furthest points from the Earth. In fact, when we talk about "minimum mass" from calculations of exoplanet orbits, we mean the mass the planet would have if its orbit led it to intersect the Earth-star junction - it is much more likely that that specific configuration is not the actual one, making the mass of the planet only a bounded variable.
Precisely knowing the mass of Proxima b would allow us to better frame the typology of the planet, but the known mass alone would not be sufficient to distinguish between a small rocky planet, an ocean world, or a mini-Neptune. In other words, mass alone does not tell us whether a planet is about the



This composition combines a view of the southern sky above the dome of ESO's 3.6-meter telescope at La Silla Observatory in Chile with Hubble Space Telescope images of the stars Proxima Centauri (bottom right) and the Alpha Centauri AB binary (bottom left). [Y. Beletsky (LCO)/ ESO/ ESA/NASA/ M. Zamani]

size of the Earth or not, much less whether it is potentially habitable. To obtain this information, it is indispensable to also know the diameter of the planet. There are essentially two ways to do this: getting a direct image with an angular resolution sufficient to measure the apparent size of the planet (with the distance known, you can calculate the actual size) or record its transit in front of the stellar disk and deduce the diameter from the percentage of the eclipsed photosphere (with the diameter and the

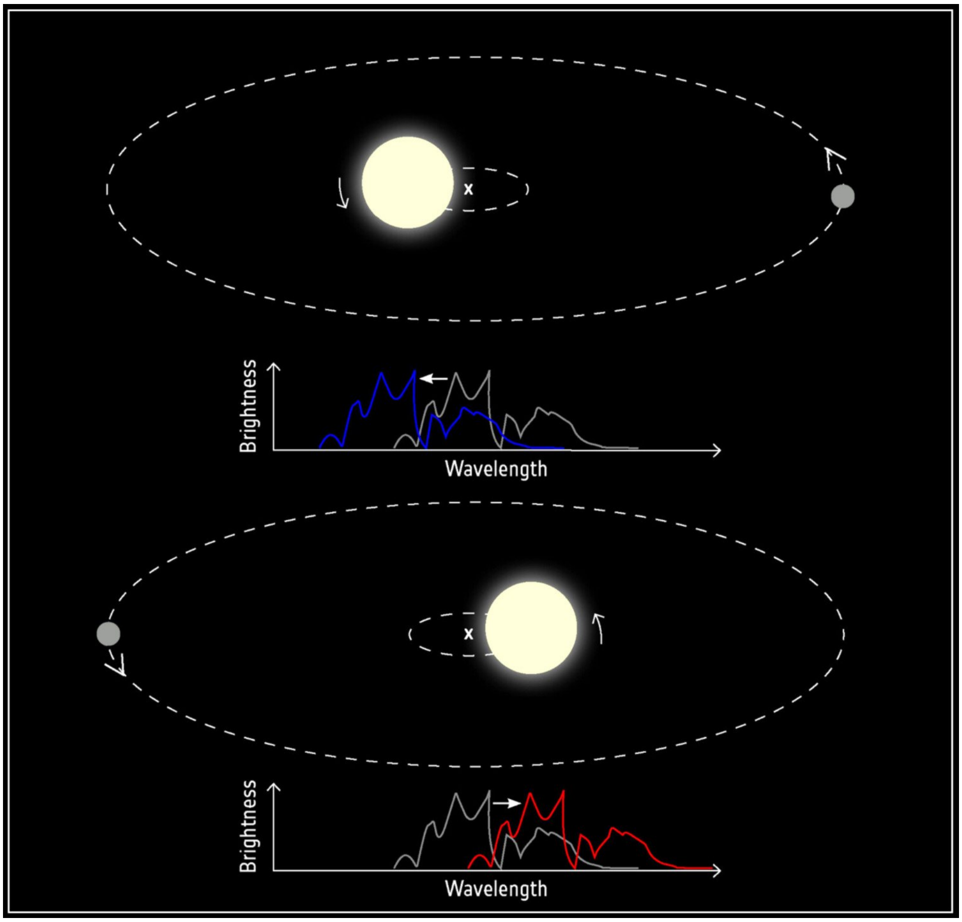


Rendering of Proxima b orbiting the red dwarf Proxima Centauri, the closest star to the Solar System. The double star Alpha Centauri AB also appears between the planet and Proxima Centauri. Proxima b is somewhat more massive than Earth and orbits in the habitable zone of Proxima Centauri, where the temperature is suitable for the existence of liquid water on its surface. [ESO/M. Kornmesser]

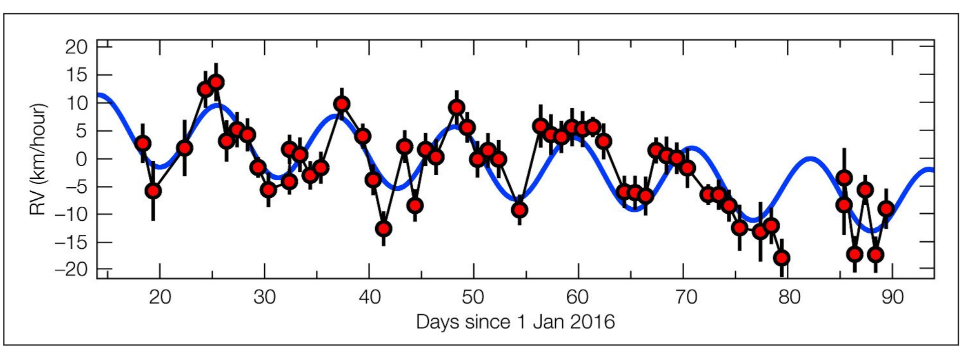
brightness of the star both known). In the case of Proxima b, as well as for all other known exoplanets, the first way is not feasible due to the impossibility, with current instruments, of obtaining planetary images larger than a pixel.
Furthermore, many of those planets are very close to their stars (especially true for red dwarfs) and it is impossible to “extract” them from the dazzling starlight. Almost always practicable is, however, the second way, that of transits on stellar disks, which, even so, are geometrically rare.
At this point, the question we must ask ourselves is the following: for at least a short stretch of its orbit, does Proxima b pass in front of the Proxima Centauri disk as observed from Earth? Astronomers have been asking this question from the very first day of the planet’s discovery. If Proxima b were observed in transit, we would immediately have confirmation that its mass coincides with the minimum estimated one, and we could easily deduce the diameter, identifying the planetary type with sufficient precision. Spectroscopic observations could also tell us if the planet has an atmosphere and which gases it is mainly composed of; to accomplish this, it is sufficient (but not simple) to subtract from the stellar spectrum acquired during a transit the one acquired out of transit: the difference is indicative of the gases that make up the planetary atmosphere (if one exists).
Unfortunately, as previously mentioned, Proxima Centauri is very noisy

This video takes the viewer on a journey at 20% the speed of light to the nearest star, Proxima Centauri. The planet Proxima b is visible, orbiting its star every 11.2 days. This planet is located within the star’s habitable zone, which means that liquid water may exist on its surface. [PHL @ UPR Arecibo, ESO. Music by Lyford Rome]

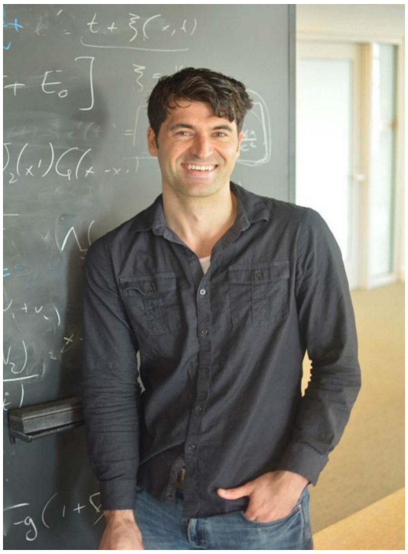
An exoplanet can be detected through an oscillation in the movement of its star, caused by the gravitational attraction of the planet itself on the star as they orbit around their common center of mass. When viewed from afar, the star seems to approach and move away from the observer. The movement makes the light of the star appear slightly bluer when it moves towards the observer and slightly redder when it moves away. This change in frequency is known as the Doppler Effect. Most of the early discoveries of exoplanets took place by exploiting this effect. [ESA]



both photometrically and spectroscopically, allowing it to easily hide the signal produced by any Proxima b transits. Nevertheless, if the planet transits, it does so every 11.2 days, a frequency that in the long run could bring out the signal. If it were possible to regularly record the transits, there would be the opportunity to carry out more in-depth spectroscopic analyses and reveal the possible presence of biosignatures – molecules potentially linked to the presence of life, such as oxygen and methane. This opportunity, referring precisely to the planet in the habitable zone closest to the Solar System, has lately prompted many teams of researchers to study Proxima Centauri assiduously to confirm or definitively exclude the transits of Proxima b. The first team was the Anglada-Escudé team, which analyzed a number of the star's light curves available in 2016 but found no evidence of transits. Those same researchers, considering the orbital separation of the planet, calculated that the



This graph shows the movement of Proxima Centauri with respect to the Earth in the first months of 2016. In one part of its orbit, the star approaches the Earth at about 5 km/h, then in another part it moves away at the same velocity. This regular pattern of radial velocity variation repeats itself over a period of 11.2 days. [ESO/G. Anglada-Escudé]



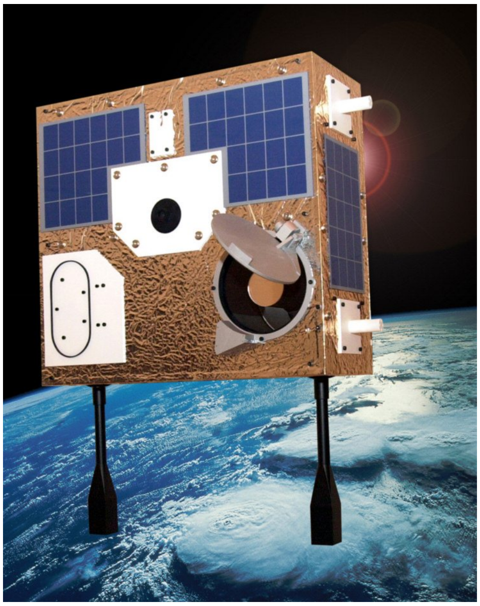
David Kipping, the astronomer who, while examining MOST observations with his team, highlighted two candidates transiting the Proxima Centauri disk. [Columbia University]

geometric probability that Proxima b transits is about 1.5%.

In 2017, a team led by David Kipping (Columbia University, Department of Astronomy) reworked Proxima Centauri observations collected over 40 days between 2014 and 2015 with the MOST Space Telescope, a very high-precision instrument measuring just 15 cm in diameter (MOST stands for Microvariability and Oscillation of Stars). Although this study did not reveal a photometric periodicity directly attributable to Proxima b, two isolated signals of candidate transits were identified with the expected depth for the transit of a body of similar size.

Again in 2017, a team led by Yiting Li (Pennsylvania State University) presented the data obtained by observing Proxima Centauri for 23 nights with a 30 cm robotic telescope at the Las Campanas Observatory. The research was inconclusive regarding Proxima b, but a transit candidate was identified, perhaps attributable to a second planet (not necessarily to one of the more recently discovered planets).

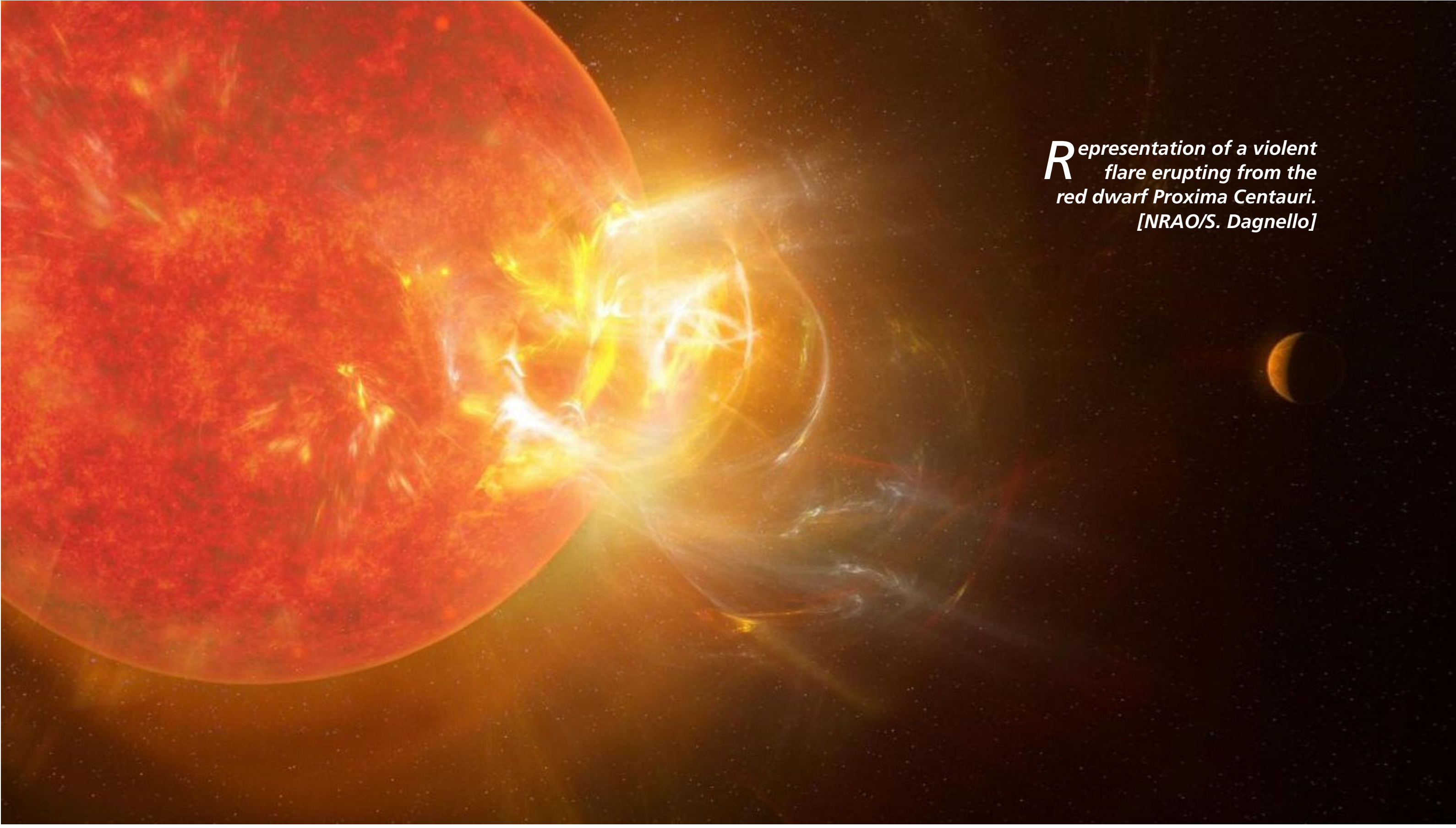
In 2018, a team led by Hui-Gen Liu (Nanjing University, School of Astronomy and Space Science) published the results of 10 days of photometric monitoring of Proxima Centauri with the Bright Star Survey Telescope at Zhongshan Station, Antarctica. Also in this case, a signal was found with the characteristics of a planetary transit and consistent with the orbital parameters of Proxima b deduced from the variations in the radial velocity of its star, but the confidence level of the detected signal was not particularly high. Once again, the photometric noise produced by Proxima Centauri's magnetic activity was deleterious.



Graphic depiction of the MOST Space Telescope orbiting the Earth. [Canadian Space Agency]

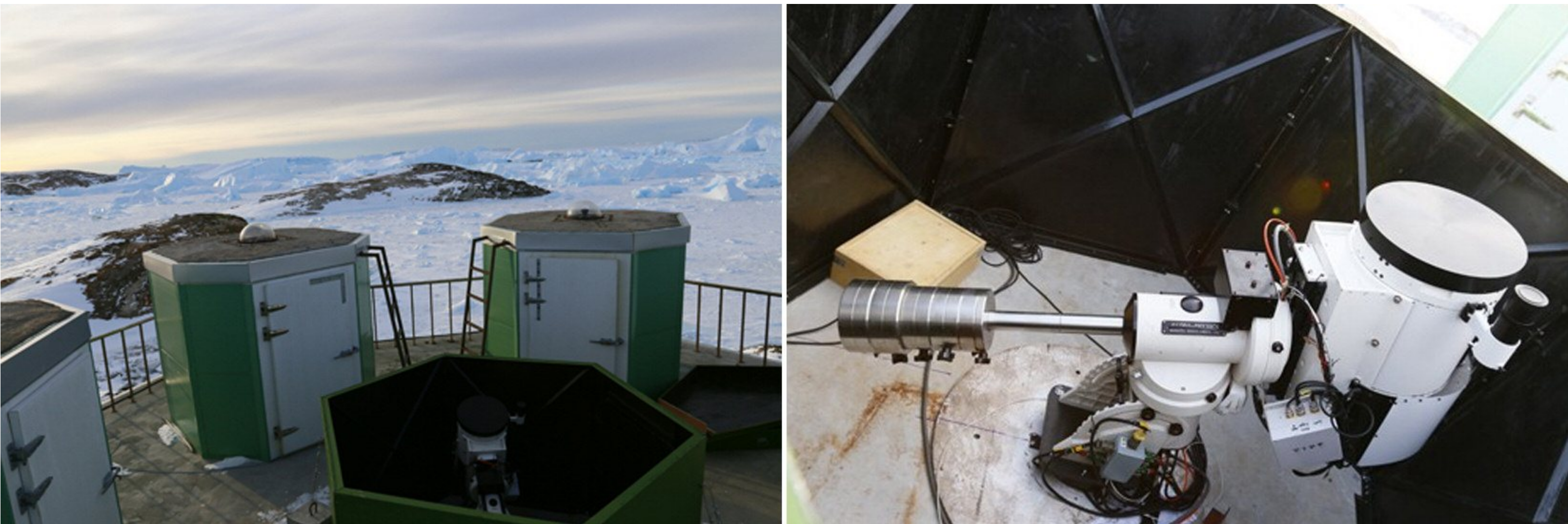
Another study published in 2018 was that of David Blank's team (James Cook University, North Queensland, Australia), who reworked over 300 observations of Proxima Centauri, collected by different telescopes around the world, in the period

Transiting exoplanets are detected as they pass in front of their star, causing a drop in starlight visible to a distant observer. The transit is repeated with a cadence that depends on the time taken by the exoplanet to orbit around its star. For example, under ideal conditions, any alien observer of our Solar System would have to wait one of our years to see a repeat of the Earth's transit in front of the Sun. [ESA]

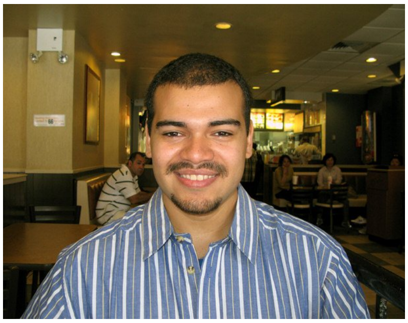


Representation of a violent flare erupting from the red dwarf Proxima Centauri. [NRAO/S. Dagnello]

2006-2017. Despite the amount and variety of data, the team failed to pinpoint any transit candidates, while they easily confirmed the star's considerable and unpredictable photometric variability.
A selection of the highest quality light curves already reworked by Blank and colleagues became, in 2019, the database on which a different team led by Dax Feliz (Vanderbilt University, Nashville, TN) worked. These researchers focused their analysis on orbital periods in the 1-to-30-day range. To better evaluate the sensitivity threshold of their investigation methods, they included in the database some series of "synthetic" signals with different properties, easily recognizable if detected in the photometric noise. The team was thus able to establish that the mathematical procedures to which the real database was subjected had a sensitivity useful for detecting transits with a depth of five thousandths of a magnitude, a value just sufficient to show Proxima b. However, from this minimum value up, no periodic event similar to a transit was highlighted.
Also in 2019, a work by James Jenkins (Department of Astronomy, Universidad de Chile) and colleagues was published that was based on data from the Spitzer Infrared Space Telescope. Observations at the 4.5 micron wavelength over 48 hours did not reveal any transit on schedule, despite the benefit of the repeated stellar flares of Proxima Centauri appearing less prominent in the infrared. Spitzer's sensitivity would certainly have shown the transit of a planet with a minimum diameter of no less than 40% the Earth's. By considering the minimum mass estimated for Proxima b, it is practically impossible that it could be so small: even a diameter for a planet of just under 0.9 earth diameters would require that that planet be entirely composed of iron!
To dispel residual doubts that Proxima b does not pass in front of its star, a team led by Emily Gilbert (University of Chicago, Department of Astronomy and Astrophysics) collected and analyzed photometric observations of Proxima Centauri made by the Transiting Exoplanet Survey Satellite (TESS) in the periods of April-June 2019 and April-May 2021, for a total of almost 80 days



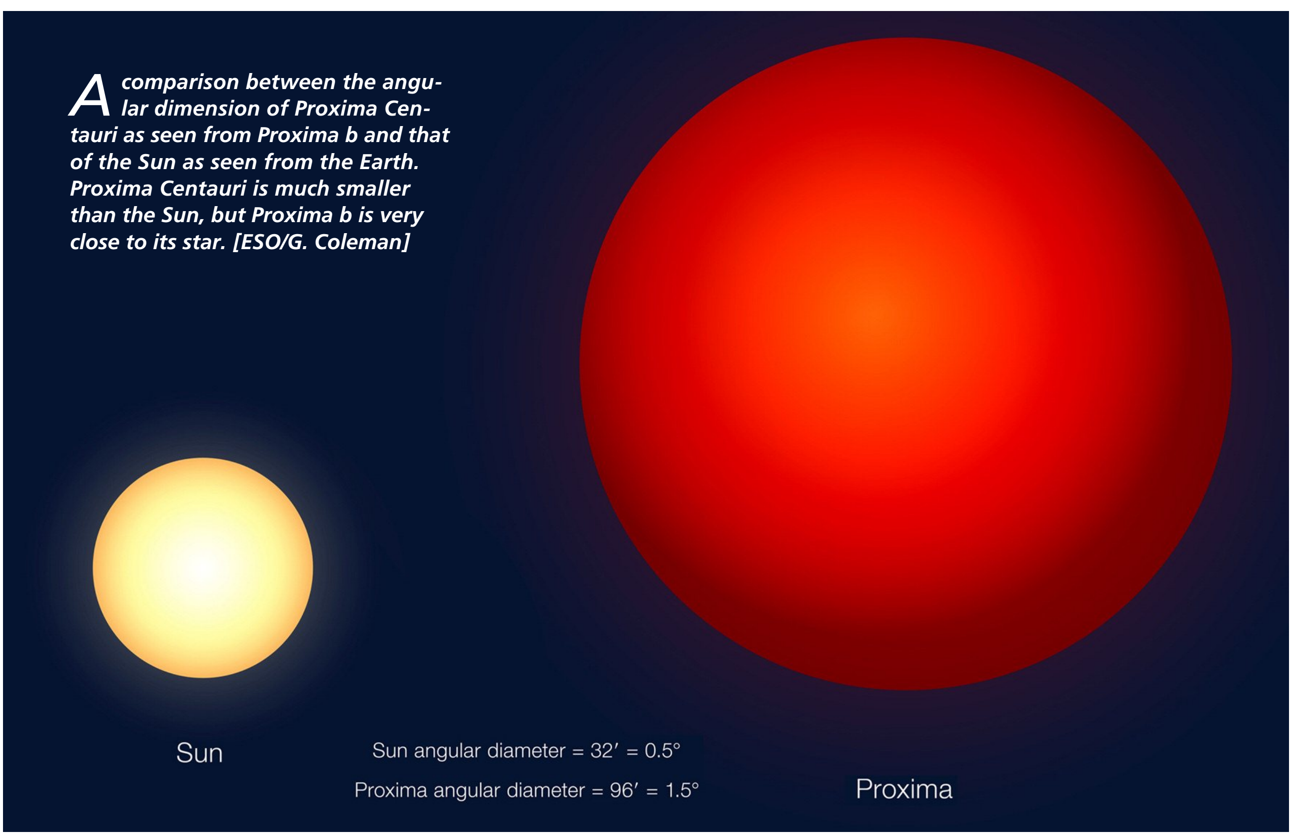
The Bright Stars Survey Telescope (BSST) from Zhongshan Station, Antarctica. [Chinese Center of Antarctic Astronomy]



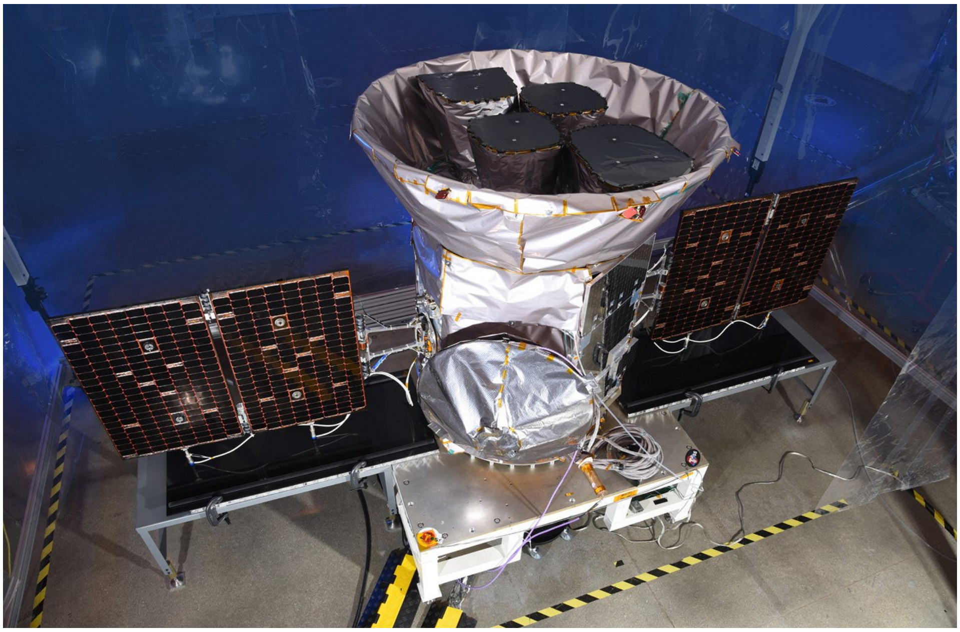
Dax Feliz, the researcher who, with his team, has shown that there are no transiting planets around Proxima Centauri capable of reducing its brightness by more than five thousandths of a magnitude. [Vanderbilt University]

of observations. The task of TESS is to observe the whole sky in the visible and near-infrared to discover planets with frequent transits in front of stars relatively close to the Sun. Of about 200,000 targets, TESS has collected high-precision photometric data with a cadence of two minutes in both periods considered, as well as with the new cadence mode of just 20 seconds in the most recent period. Despite such intense photometry, it could still be difficult to correctly interpret the evolution of Proxima Centauri flares and isolate signals potentially attributable to planetary transits. Additionally, James Davenport (University of Washington's Department of Astronomy) and colleagues had suggested in 2016 that the star's light curve could even be dominated by the superposition of numerous flares of varying energies, a scenario that would make it almost impossible to extract the very weak signal of a transit from the noise despite

Emily Gilbert is the author of one of the most recent and most accurate Proxima Centauri photometry studies. With her team, she established that, around the closest star to the Solar System, there are no transiting planets with a diameter larger than 40% of Earth's. [University of Chicago]



A comparison between the angular dimension of Proxima Centauri as seen from Proxima b and that of the Sun as seen from the Earth. Proxima Centauri is much smaller than the Sun, but Proxima b is very close to its star. [ESO/G. Coleman]



NASA's Transiting Exoplanet Survey Satellite (TESS) during final tuning in the laboratory (left) and pictured as it travels its wide orbit around the Earth (below). [Orbital ATK]

that signal being both periodic and frequent. To mitigate the problems from that noise, Gilbert's team has integrated a new methodology into the planet's search algorithms that includes modeling of stellar activity, allowing them to predict the photometric behavior of flares. By subtracting the theoretical light curve of the modeled flares from that of the star, it becomes possible to clean up the stellar photometry of some noise produced by the photospheric activity. However, this procedure is easier to describe than to apply, especially if the photometry includes the co-evolution of several flares of different energies. To reduce the margin of uncertainty, the team also "injected" artificial transits into Proxima Centauri's light curves to test the sensitivity of the method regarding possible real transits and to determine under what circumstances they can be detected. Once again, the result was that any transits that might be occurring are not of planets with a diameter greater than 0.4 Earth diameters. Furthermore, this latest study established that the existence of transiting planets larger than Mars in the habitable zone of the star (where the orbital periods are 6-27 days) is extremely unlikely.

If, as all the research conducted in recent years seem to demonstrate, Proxima b does not pass in front of the Proxima Centauri disk, it will be necessary to take other paths to know something more about this elusive planet. Unfortunately, not even with the new Webb Space Telescope will it be possible to observe the planet directly, although we will still be able to understand if Proxima b has an atmosphere and, therefore, what kind of planet it is. The prerequisites for obtaining this information are remarkable sensitivity to infrared light (which Webb provides) and the fact that the planets orbiting in the habitable zones of red dwarfs are, likely, all gravitationally locked, meaning they always turn the same hemisphere to their star (the period of rotation on its axis and the orbital period coincide, as happens for the Moon). It follows that Webb could detect variations in the thermal emissions from the planet as it moves around the star. Although not directly visible, Proxima b makes a small contribution to the total in-

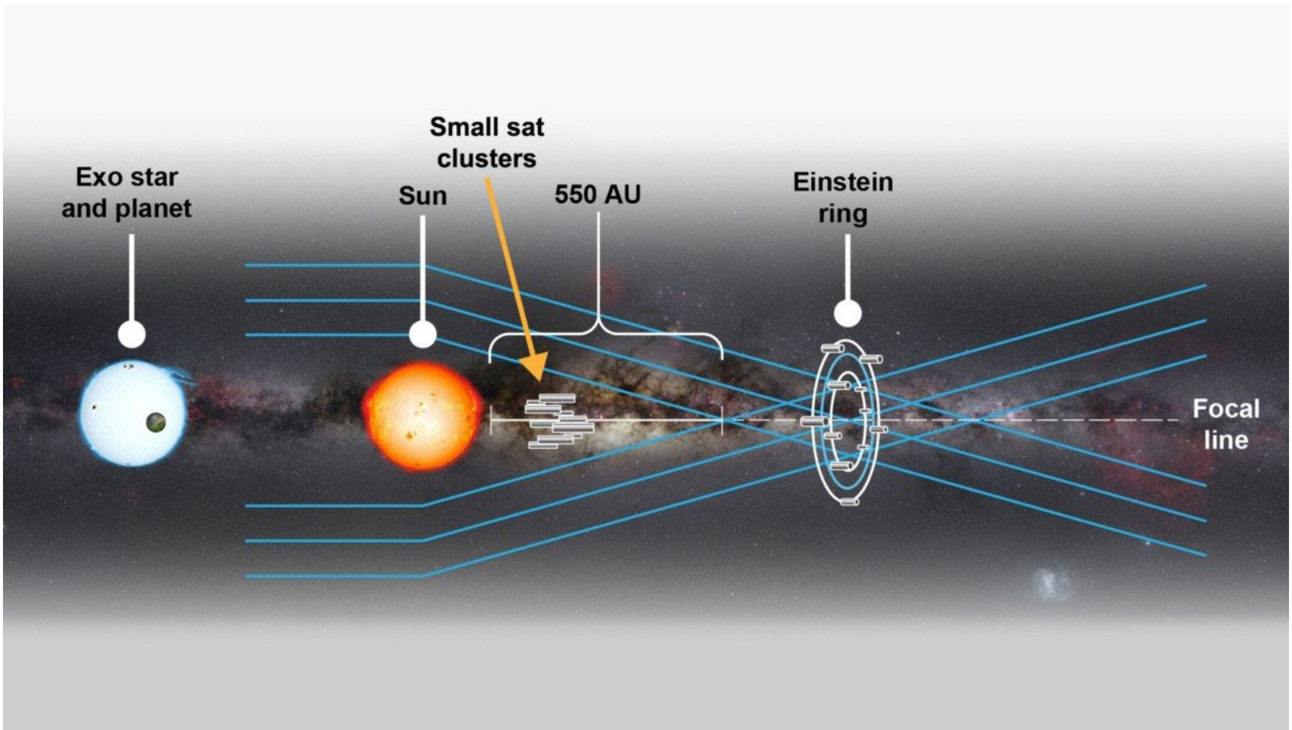


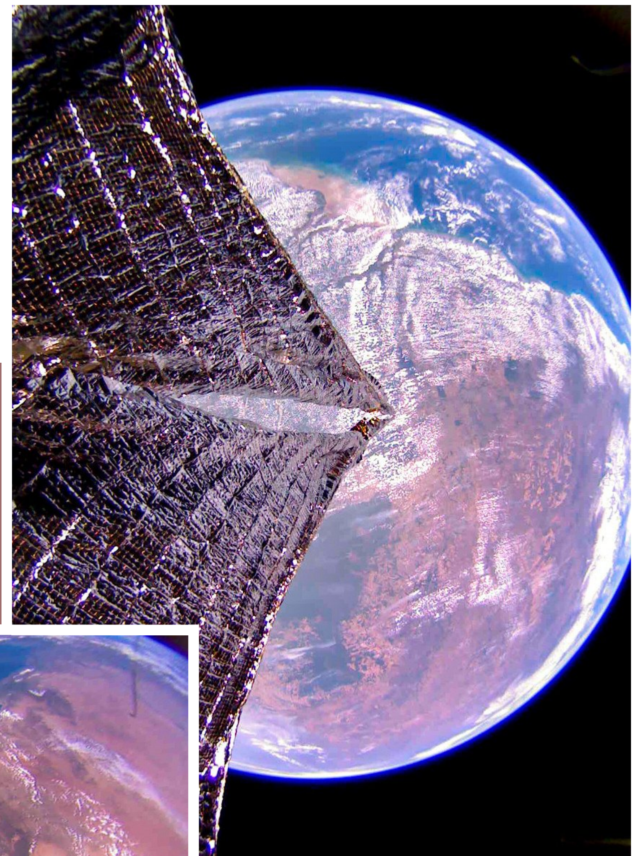
Diagram of the concept of a solar gravitational lens, which could allow a better visualization of potentially habitable exoplanets. The natural lens generates an Einstein Ring, which is a deformed image of the amplified celestial object. With appropriate mathematical procedures it is possible to reconstruct the real image as if the object were being observed closely. [The Aerospace Corporation – Music by Lyford Rome]

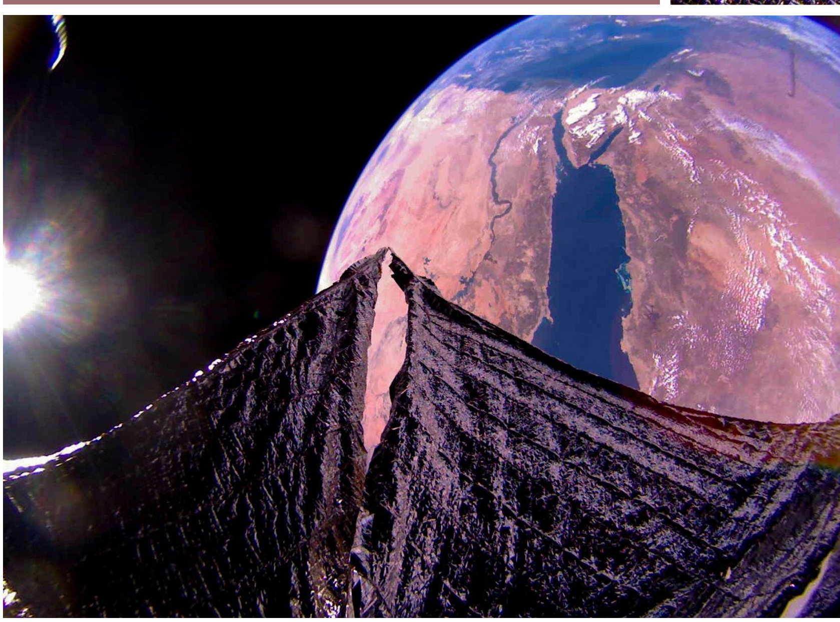
frared emission of the star-planet system, an emission that is certainly greater when it turns the illuminated (and therefore warmer) hemisphere in our direction, and is smaller half an orbit later, when it is the night hemisphere that points towards us. Recording a modest difference in thermal radiation between the two hemispheres would suggest the presence of an atmosphere or an ocean (or both) capable of redistributing the heat received by the star, while a large thermal contrast would indicate that the planet is devoid of atmosphere and substantially arid. Interestingly, the time required for Webb to make this check might be as short as a single orbit of the planet. Avi Loeb and Laura Kreidberg (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) are convinced that if Webb could observe this star-planet system for a couple of months, it would be able to identify the infrared spectral line of ozone (if present), which would then indicate the presence of molecular oxygen in the atmosphere.

All of the attempts to unveil Proxima b summarized thus far are evidently indirect ways of gathering information. Will we ever be able to observe and photograph it directly? From a theoretical point of view, this is possible by exploiting the curvature of space produced by the mass of the Sun. In fact, our star could be used as a gravitational lens and, placing an "eyepiece" at the focus of the unusual lens, the necessary resolution to photograph Proxima b in detail could be reached.

This bizarre but scientifically flawless idea came to a team led by Louis Friedman (The Planetary Society, Pasadena, CA), who published the details last summer. The phenomenon of the gravitational lens was predicted by Albert Einstein over a century ago, was then amply demonstrated, and is now regularly exploited for the study of very distant galaxies that would otherwise be inscrutable without the amplification of their light by large masses (typically galaxies or clusters of galaxies) interposed along the line-of-sight. Compared to the cosmological protagonists of gravitational lensing, the Sun would be a very small lens, but enough to amplify the information coming from the Proxima Centauri system by at least one hundred billion times. To get an idea of the difference from traditional imaging at the distance of that system, it's enough to say that the largest ground-based telescopes can resolve details no smaller than two million kilometers wide, or about 150 times the size of the Earth. At that scale, the image of no exoplanet could occupy more than one single pixel. If, on the other hand, we could use the Sun as if it were the objective of a telescope, we could obtain a resolution of a few kilometers on Proxima b, which would mean mapping the surface in amazing detail.

Beyond all the technical difficulties that such an undertaking would bring, the most relevant problem is reaching the focal line of the "lens," which begins about 550 astronomical units away from the Sun (82 billion km or 51 billion mi). If we consider that the Voyager 1 probe, launched in 1977, has moved away by just over 155 astronomical units, the idea of Friedman and colleagues appears rather utopian, even despite the advances accumulated by astronautics in the last 45 years. However, this same team proposed a solution to shorten the time needed to reach the focal line. The solution consists of using a probe equipped with a large solar sail, a technology that recently has been successfully tested in Earth orbit with LightSail 2. The principle of solar sailing finds the sail propelled (therefore accelerated) by the pressure of solar radiation. The larger the sail and the lighter the load carried, the higher the achievable velocity. The team calculated that a focusing device weighing about 100 kg (220 lb) could arrive at its destination in about a quarter of a century, which is acceptable given the impressive prospects. We cannot predict what from all this possibility will be achieved in the coming decades and what will remain only theory. What is certain is that Proxima b will remain a primary target for many research teams, at least until it is certain (and not just probable) that it is an inhospitable planet for life as we know it.





These images taken by the Planetary Society's LightSail 2 spacecraft show the Red Sea, the Nile River, the Eastern Mediterranean Sea with surrounding areas (below), and northern Brazil (right). The LightSail 2 mission demonstrated that it is possible to accelerate a spacecraft by simply using the pressure of solar radiation, a type of propulsion that could be exploited to reach distant destinations in a few decades, such as the focal line of the solar gravitational lens or the nearest exoplanets. [The Planetary Society]

NORT

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The NortheK Rapido 450 is designed to be disassembled into essential parts for transport in a small car. Each component is equipped with its own case, facilitating transport and assembly. The main element weighs 27 kg. Incorporated mechanical devices and the precise execution of each component allows for the collimation of the optics with extreme ease, maintaining collimation throughout an observation session while eliminating twisting and bending, regardless of the weight of the accessories used. The very thin primary optic allows for rapid acclimatization and ensures thermal stability throughout the night. Two bars equipped with sliding weights allow for the perfect balance of the telescope and accessories. On demand, it is also possible to modify the support to mount the telescope on an equatorial platform. This instrument is composed of aluminum, carbon and steel, each perfectly selected according to strict mechanical standards. It is undoubtedly the best altazimuth Newtonian on the market.

I N S T R U M E N T S - C O

The first supernova explosion of a Wolf-Rayet star

by IAC - Outreach Unit

In the not-so-distant past, the discovery of a supernova – an exploding star – was considered a rare occasion. Today, advanced measuring instruments and analysis methods make it possible to detect fifty such explosions on a daily basis, which has also increased the probability that researchers would be able to spot rarer types of explosions that have so far existed only as theoretical constructs.

Recently, an international team of scientists, led by researcher Avishay Gal-Yam of the Weizmann Institute's Particle Physics and Astrophysics Department, discovered a supernova that has never been observed before. It is an explosion originating from a Wolf-Rayet star, a type of highly evolved massive star that loses a large amount of mass due to intense stellar winds.

A Wolf-Rayet star and the nebula surrounding it captured by the Hubble Space Telescope. Gal-Yam and colleagues are the first to discover a rare-type supernova originating from this star. [NASA/ESA Hubble Space Telescope]

The life spans of massive stars are considered relatively short, a few million years at most. The Sun, in comparison, has a life expectancy of about 10 billion years. The subsequent processes of nuclear fusion at the core of massive stars lead to their stratification, in which the heavy elements are concentrated at the core, and gradually lighter elements compose the outer layers.

Wolf-Rayet stars are particularly massive stars that are missing one or more of the external layers that are made up of lighter elements. In this way, instead of hydrogen – the lightest element – the star's surface is characterized by the presence of helium, or even carbon and heavier elements. One possible explanation for this phenomenon is that strong winds blowing due to high pressure at the star's envelope, disperse its outermost layer, thus causing the star to lose one layer after the other over several hundred thousand years.

Despite their relatively short life spans and their state of progressive disintegration, analysis of the ever-growing number of supernova discoveries has led to the hypothesis that Wolf-Rayet stars simply don't explode – they just quietly collapse into black holes – otherwise, we would have been able to observe one by now. This hypothesis, however, has just been shattered owing to the recent discovery.

Spectroscopic analysis of the light emitted from the explosion led to the discovery of spectral signatures that are associated with specific elements. In this way, the researchers were able to show that the explosion contained carbon, oxygen and neon atoms, the latter an element that has not yet been observed in this manner in any supernova to date. Moreover, the researchers identified that the matter spouting cosmic radiation did not in itself participate in the blast but rather originated from the space surrounding the volatile star. This, in turn, strengthened their hypothesis in favor of strong winds that took part in stripping the star of its outer envelope.

Since this observation is the first of its kind, Gal-Yam states that it may be too early to unequivocally determine the fate of all such stars. *"We can't say at this stage whether all Wolf-Rayet stars end their lives with a bang or not. It might be that some of them do collapse quietly into a black hole,"* he says.

Researchers estimate that the mass that dispersed during the explosion is probably equal to that of the Sun or a slightly smaller star; the star that exploded was significantly heavier – having a mass at least ten times greater than that of the Sun, so scientists wonder where the majority of mass end up.

Gal-Yam suggests a midway scenario, in which both possible fates are fulfilled at the same time: once nuclear fusion is exhausted at the star's core, an explosion takes place that blasts some of the mass into space, while the remaining mass collapses in on itself, forming a black hole. *"One thing's certain,"* says Gal-Yam, *"This is not the 'silent' collapse often referred to in the past."*

The study has used observations made with different telescopes, including the Gran Telescopio Canarias (GTC or Grantecan) located at the Roque de los Muchachos Observatory (Garafía, La Palma).

For Antonio Cabrera Lavers, head of scientific operations at Grantecan and affiliated researcher at the IAC who participated in the study, *"It is worth mentioning that since this discovery was first made, another similar explosion of a Wolf-Rayet star has been observed, implying that this phenomenon is indeed not a single occurrence."* ■

The VLT images planet around most massive star pair to date

by ESO - Bárbara Ferreira

The European Southern Observatory's Very Large Telescope (ESO's VLT) has captured an image of a planet orbiting b Centauri, a two-star system that can be seen with the naked eye. This is the hottest and most massive planet-hosting star system found to date, and the planet was spotted orbiting it at 100 times the distance Jupiter orbits the Sun. Some astronomers believed planets could not exist around stars this massive and this hot — until now.

"Finding a planet around b Centauri was very exciting since it completely changes the picture about massive stars as planet hosts," explains Markus Janson, an astronomer at Stockholm University, Sweden and first author of the new study published in *Nature*.

Located approximately 325 light-years away in the constellation Centaurus, the b Centauri two-star system (also known as HIP 71865) has at least six times the mass of the Sun, making it by far the most massive system around which a planet has been confirmed. Until now, no planets had been spotted around a star more than three times as massive as the Sun.

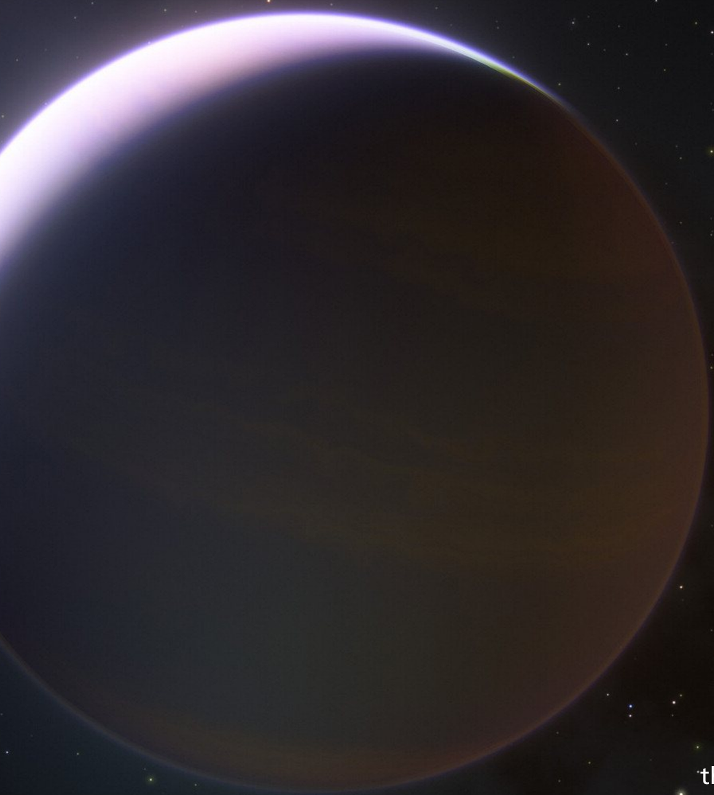
Most massive stars are also very hot, and this system is no exception: its main star is a so-called B-type star that is over three times as hot as the Sun. Owing to its intense temperature, it emits large amounts of ultraviolet and X-ray radiation.

The large mass and the heat from this type of star have a strong impact on the surrounding gas, that should work against planet formation. In particular, the hotter a star is, the more high-energy radiation it produces, which causes the surrounding material to evaporate faster. *"B-type stars are generally considered as quite destructive and dangerous environments, so it was believed that it should be exceedingly difficult to form large planets around them,"* Janson says.

But the new discovery shows planets can in fact form in such severe star systems.

"The planet in b Centauri is an alien world in an environment that is completely different from what we experience here on Earth and in our Solar System," explains co-author Gayathri Viswanath, a PhD student at Stockholm University. *"It's a harsh environment, dominated by extreme radiation, where everything is on a gigantic scale: the stars are bigger, the planet is bigger, the distances are bigger."*

Indeed, the planet discovered, named b Centauri (AB)b or b Centauri b, is also extreme. It is 10 times as massive as Jupiter, making it one of the most massive planets ever



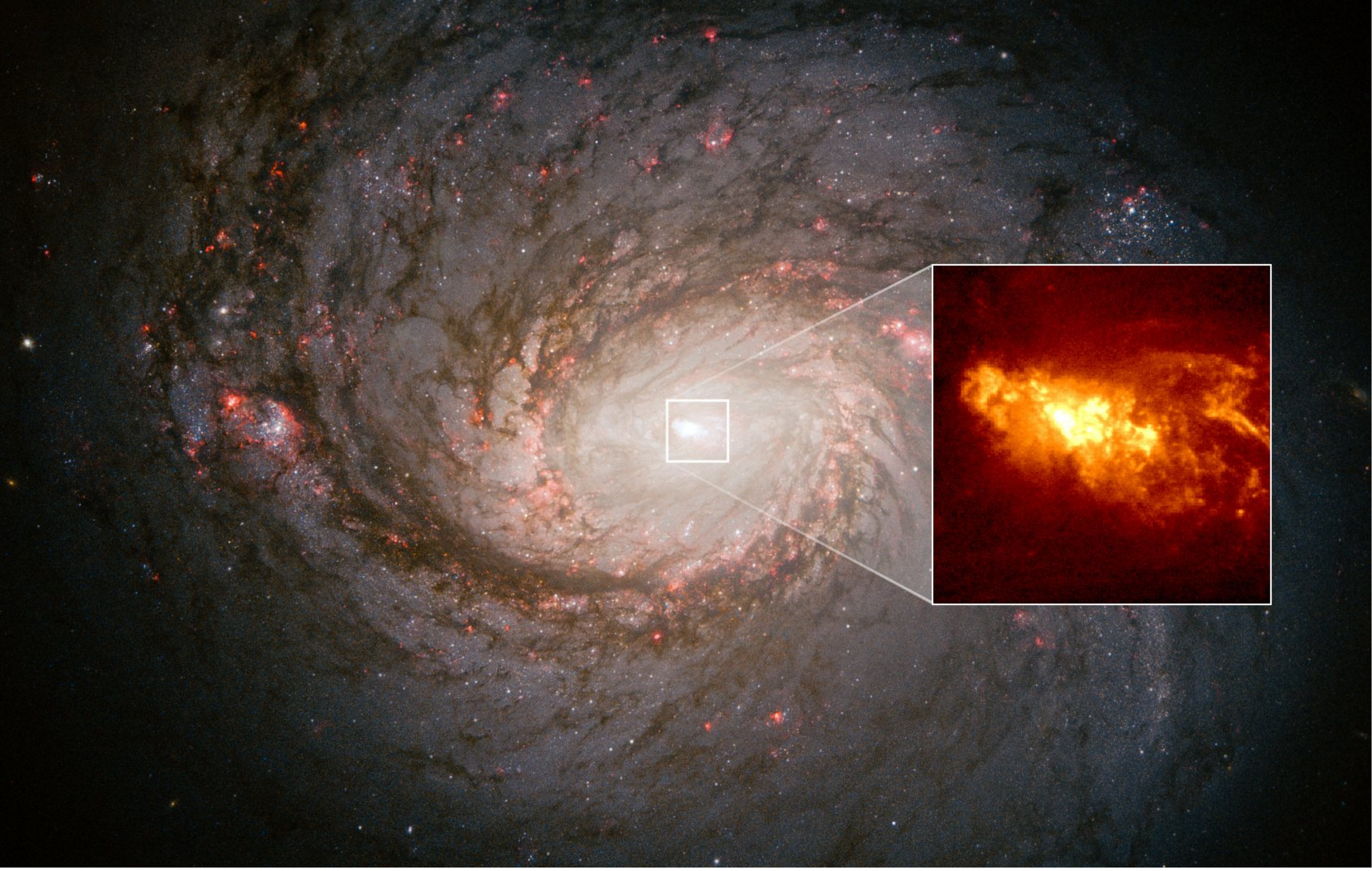
In the background, an artist's impression shows a close up of the planet b Centauri b, which orbits a binary system with mass at least six times that of the Sun. This is the most massive and hottest planet-hosting star system found to date. The planet is ten times as massive as Jupiter and orbits the two-star system at 100 times the distance Jupiter orbits the Sun. [ESO/L. Calçada] On the right, ESO's Very Large Telescope has captured an image of a planet orbiting b Centauri, a pair of stars that can be seen with the naked eye. Find out why this next-door planetary system is extreme in this short video. [ESO]

found. Moreover, it moves around the star system in one of the widest orbits yet discovered, at a distance a staggering 100 times greater than the distance of Jupiter from the Sun. This large distance from the central pair of stars could be key to the planet's survival. These results were made possible thanks to the sophisticated Spectro-Polarimetric High-contrast Exoplanet REsearch instrument (SPHERE) mounted on ESO's VLT in Chile. SPHERE has successfully imaged several planets orbiting stars other than the Sun before, including taking the first ever-image of two planets orbiting a Sun-like star.

However, SPHERE was not the first instrument to image this planet.

As part of their study, the team looked into archival data on the b Centauri system and discovered that the planet had actually been imaged more than 20 years ago by the ESO 3.6-m telescope, though it was not recognised as a planet at the time.

With ESO's Extremely Large Telescope (ELT), due to start observations later this decade, and with upgrades to the VLT, astronomers may be able to unveil more about this planet's formation and features. *"It will be an intriguing task to try to figure out how it might have formed, which is a mystery at the moment,"* concludes Janson.



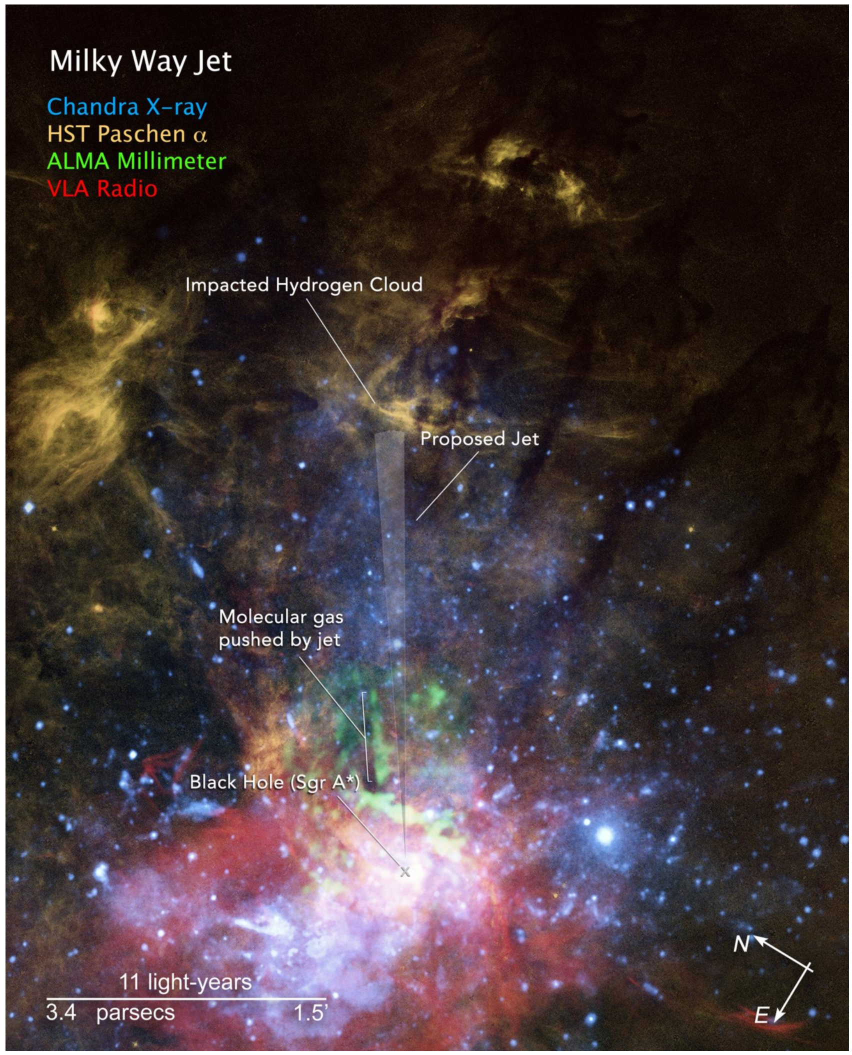
Mini-jet discovered near Sagittarius A*

by NASA/ESA
Ray Villard

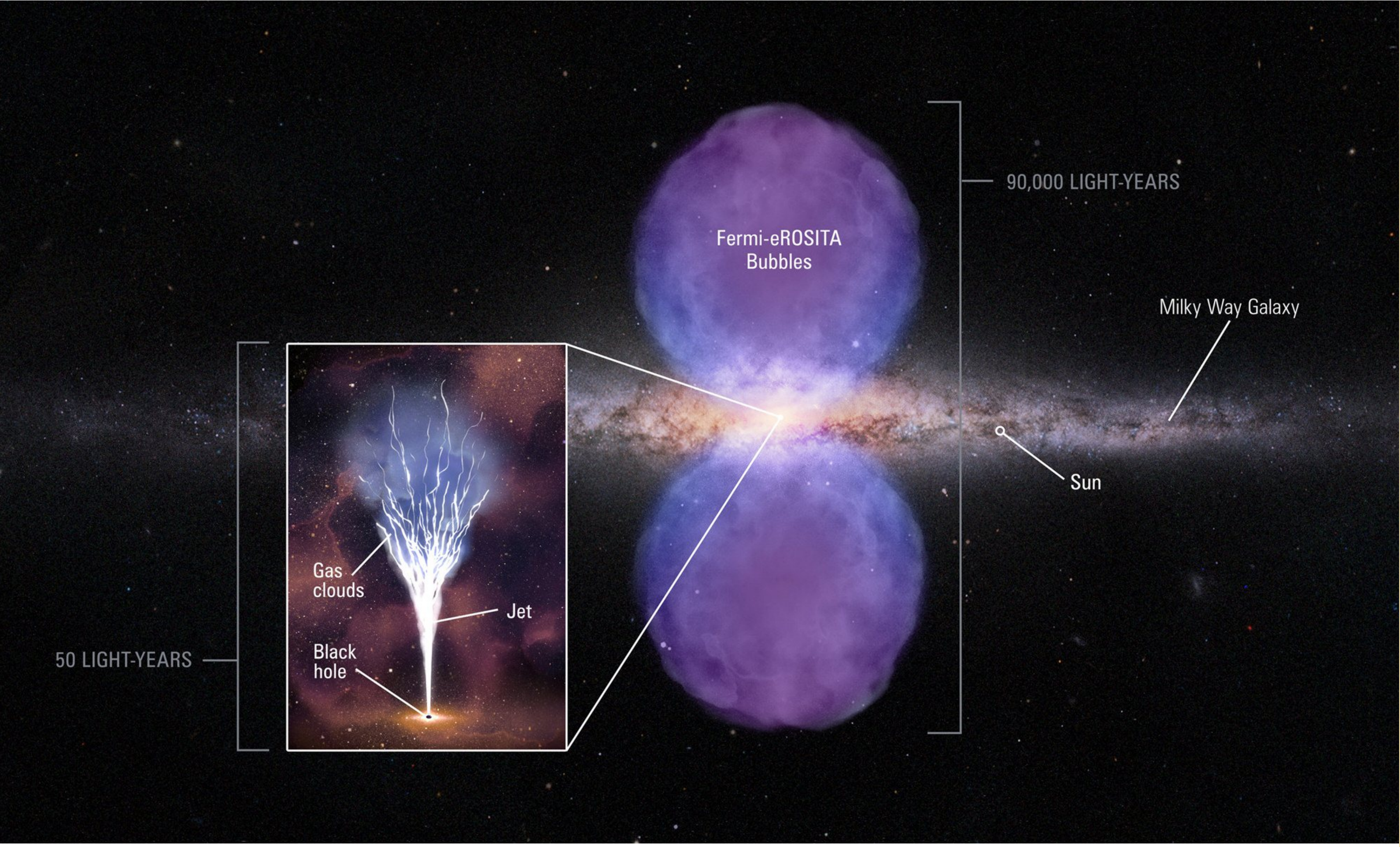
The nearby barred-spiral galaxy NGC 1068 serves as a proxy for helping astronomers understand the fireworks taking place at the center of our Milky Way galaxy, driven by eruptions from a supermassive black hole. Because we live inside the Milky Way, much of our view of the galaxy's center is blocked by intervening clouds of gas and dust. But, looking 47 million light-years away at NGC 1068 gives astronomers a birds-eye view of similar black hole outbursts. The inset Hubble Space Telescope image resolves hydrogen clouds as small as 10 light-years across within 150 light-years of the core. The clouds are glowing because they are caught in a "searchlight" of radiation beamed out of the galaxy's black hole, which is larger and more active than the black hole in the heart of our galaxy. [NASA, ESA, Alex Filippenko (UC Berkeley), William Sparks (STScI), Luis C. Ho (KIAA-PKU), Matthew A Malkan (UCLA), Alessandro Capetti (STScI)]

Our Milky Way's central black hole has a leak. This supermassive black hole (Sagittarius A*) looks like it still has the vestiges of a blowtorch-like jet dating back several thousand years. NASA's Hubble Space Telescope has not photographed the phantom jet but has helped find circumstantial evidence that it is still pushing feebly into a huge hydrogen cloud and then splattering, like the narrow stream from a hose aimed into a pile of sand. This is further evidence that the black hole, with a mass of 4.1 million Suns, is not a sleeping monster but periodically hiccups as stars and gas clouds fall into it. Black holes draw some material into a swirling, orbiting accretion disk where some of the infalling material is swept up into outflowing jets that are collimated by the black hole's powerful magnetic fields. The narrow "searchlight beams" are accompanied by a flood of deadly ionizing radiation. *"The central black hole is dynamically variable and is currently powered down,"* said Gerald Cecil of the University of North Carolina in Chapel Hill. Cecil pieced together, like a jigsaw puzzle, multiwavelength observations from a variety of telescopes that suggest the black hole burps out mini-jets every time it swallows something hefty, like a gas cloud. His multinational team's research has been published in *The Astrophysical Journal*.

In 2013 evidence for a stubby southern jet near the black hole came from X-rays detected by NASA's Chandra X-ray Observatory and radio waves detected by the Jansky Very Large Array telescope in Socorro, New Mexico. This jet too appears to be plowing into gas near the black hole. Cecil was curious if there was a northern counter-jet as well. He first looked at archival spectra of such molecules as methyl alcohol and carbon monosulfide from the ALMA Observatory in Chile (Atacama Large Millimeter/submillimeter Array), which uses millimeter wavelengths to peer through the veils of dust between us and the galactic core. ALMA reveals an expanding, narrow linear feature in molecular gas that can be traced for 15 light-years back towards the black hole. By connecting the dots, Cecil next found in Hubble infrared-wavelength images a glowing, inflating bubble of hot gas that aligns to the jet at a distance of at least 35 light-years from the black hole. His team suggests that the black hole jet has plowed into it, inflating the bubble. These two residual effects of the fading jet are the only visual evidence of it impacting molecular gas. As it blows through the gas the jet hits material and bends along multiple streams. *"The streams percolate out of the Milky Way's dense gas disk,"* said co-author Alex Wagner of Tsukuba University in Japan. *"The jet diverges from a pencil beam into tendrils, like that of an octopus."* This outflow creates a series of expanding bubbles that extend out to at least 500 light-years. This larger "soap bubble" structure has been mapped at various wavelengths by other telescopes. Wagner and Cecil next ran supercomputer models of jet outflows in a simulated Milky Way disk, which reproduced the observations. *"Like in archeology, you dig and dig to find older and older artifacts until you come upon remnants of a grand civilization,"* said Cecil.



This is a composite view of X-rays, molecular gas, and warm ionized gas near the galactic center. The graphic of a translucent, vertical white fan is added to show the suggested axis of a mini-jet from the supermassive black hole at the galaxy's heart. The orange-colored features are of glowing hydrogen gas. One such feature, at the top tip of the jet is interpreted as a hydrogen cloud that has been hit by the outflowing jet. The jet scatters off the cloud into tendrils that flow northward. Farther down near the black hole are X-ray observations of superheated gas colored blue and molecular gas in green. These data are evidence that the black hole occasionally accretes stars or gas clouds, and ejects some of the superheated material along its spin axis. [NASA, ESA, Gerald Cecil (UNC-Chapel Hill)]



This schematic is based on multiwavelength observations of a suspected jet from the massive black hole at the center of our Milky Way galaxy. The wide view shows our galaxy edge-on, with two huge bubbles of plasma glowing in gamma-rays and X-rays. These are evidence for an explosive outburst from the black hole about 2 million years ago. Probing deep into the galaxy's core (inset), astronomers using the Hubble Space Telescope have captured a glowing cloud of hydrogen near the black hole. The interpretation is that the cloud is being hit by a narrow, columnated jet of material that was blasted out of the black hole merely 2000 years ago. The black hole is still active, but on a smaller scale of energy output than previously known outbursts. When the jet slams into the hydrogen knot the outflow scatters into octopus-like tendrils that continue along a trajectory out of our galaxy. [NASA, ESA, Gerald Cecil (UNC-Chapel Hill), Dani Player (STScI)]

Wagner's conclusion: *"Our central black hole clearly surged in luminosity at least 1 millionfold in the last million years. That sufficed for a jet to punch into the Galactic halo."* Previous observations by Hubble and other telescopes found evidence that the Milky Way's black hole had an outburst about 2-4 million years ago. That was energetic enough to create an immense pair of bubbles towering above our galaxy that glow in gamma-rays. They were first discovered by NASA's Fermi Gamma-ray Space Telescope in 2010 and are surrounded by X-ray bubbles that were discovered in 2003 by the ROSAT satellite and mapped fully in 2020 by the eROSITA satellite. Hubble ultraviolet-light spectra have been used to measure the expansion velocity and composition of the ballooning lobes. Hubble spectra later found that the burst was so powerful that it lit up a gaseous structure, called the Magellanic stream, at about 200,000 light-years from the galactic center. Gas is glowing from that event even today. To get a better idea of what's going on, Cecil looked at Hubble and radio images of another galaxy with a black hole outflow. Located 47 million light-years away, the active spiral galaxy NGC 1068 has a string of bubble features aligned along an outflow from the very active black hole at its center.

Cecil found that the scales of the radio and X-ray structures emerging from both NGC 1068 and our Milky Way are very similar. *"A bow shock bubble at the top of the NGC 1068 outflow coincides with the scale of the Fermi bubble start in the Milky Way. NGC 1068 may be showing us what the Milky Way was doing during its major power surge several million years ago."* The residual jet feature is close enough to the Milky Way's black hole that it would become much more prominent only a few decades after the black hole powers up again. Cecil notes that *"the black hole need only increase its luminosity by a hundredfold over that time to refill the jet channel with emitting particles. It would be cool to see how far the jet gets in that outburst. To reach into the Fermi gamma-ray bubbles would require that the jet sustain for hundreds of thousands of years because those bubbles are each 50,000 light years across!"* The anticipated images of the black hole's shadow made with the National Science Foundation's Event Horizon Telescope may reveal where and how the jet is launched. ■

The sundial, from antiquity to computer drawing

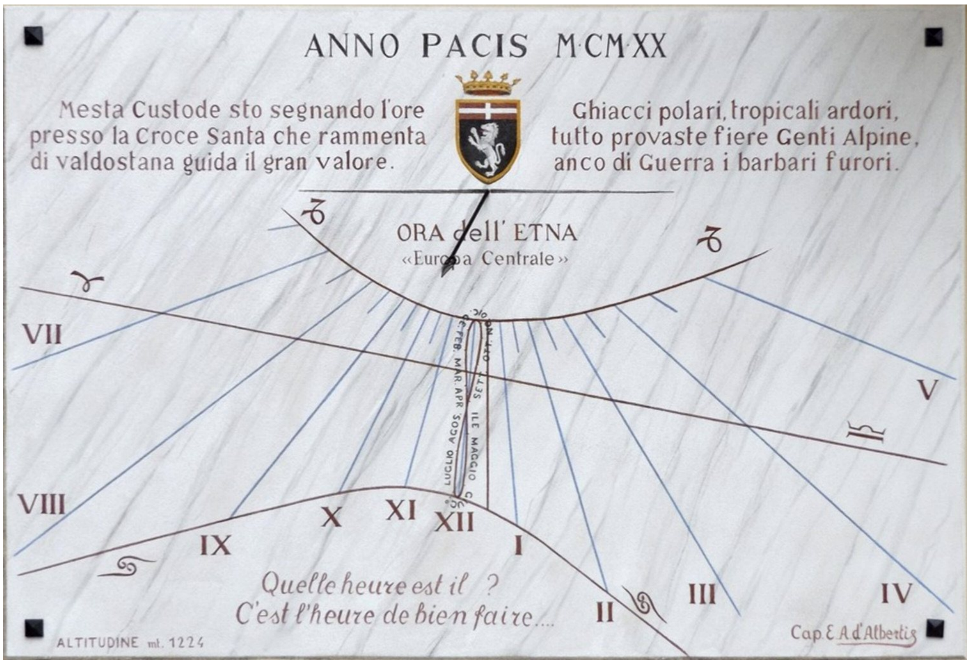
by François Blateyron

translated by Michele Ferrara
and revised by Damian G. Allis
NASA Solar System Ambassador

Ancient and modern civilizations alike share a special bond with the sky and the stars, and in particular with the Sun. In addition to illuminating us, warming us, and providing energy to grow the plants we consume, the Sun provides a temporal reference, allowing the human being to measure the passage of time. The ancients counted 12 hours between sunrise and sunset – a practical measure for

The magnificent sundial at All Souls College in Oxford (United Kingdom). Sundials are often the support for the artistic expression of their creator. [Photo FB]

Multiple sundials installed at the main entrance of Gonville and Caius College, Cambridge, United Kingdom.



The vertical sundial of Guedoz House, in Abbé Henry Square, in Courmayeur (Italy), designed and built by Captain Enrico Alberto D'Albertis in 1920. Deteriorated by the passage of time and urban transformations, this sundial was restored in 2017 based on the original designs. Among the fifteen sundials present in the territory of Courmayeur, this is the most historically important one. [Photo MF]

working in the fields, but whose duration varied between summer and winter. The direction of dawn allowed us to orient ourselves across the seasons and to know when to sow or harvest.
A simple stick planted vertically in the horizontal ground already allows you to identify the direction of sunrise and sunset and to count the hours during the day. This device is a gnomon, the ancestor of sundials. The origin of sundials is lost to antiquity and probably dates back more than 2000 years. After the simple gnomon, the first sundials took the form of either a sphere carved into stone, whose hour lines were spaced 15° (360°/24h) apart, or a vertical sundial with a straight stylus that allowed one to identify the times of prayer, called a canonical sundial. Sundials subsequently became more sophisticated, with the appearance of the polar style, the Babylonian and Italic hours, diurnal arcs, and many other ways of marking certain information related to the Sun.
Some countries are distinguished by the large number of ancient sundials that were created there: in particular, Italy, France, and England. Most of these sundials are now restored and are considered as real elements of the architectural and artistic heritage of their hosting cities. It is enough to spend a few days in many Italian cities, in Saint-Véran in the French Alps, in Oxford in England, or in Prague in the Czech Republic, to see magnificent sundials on many street corners.
Several famous museums have very nice collections of portable or decorative

A "landscape" sundial painted on wood, whose stylus is represented by one of the ski poles! Pragelato, Sestriere (Italy). [Photo FB]

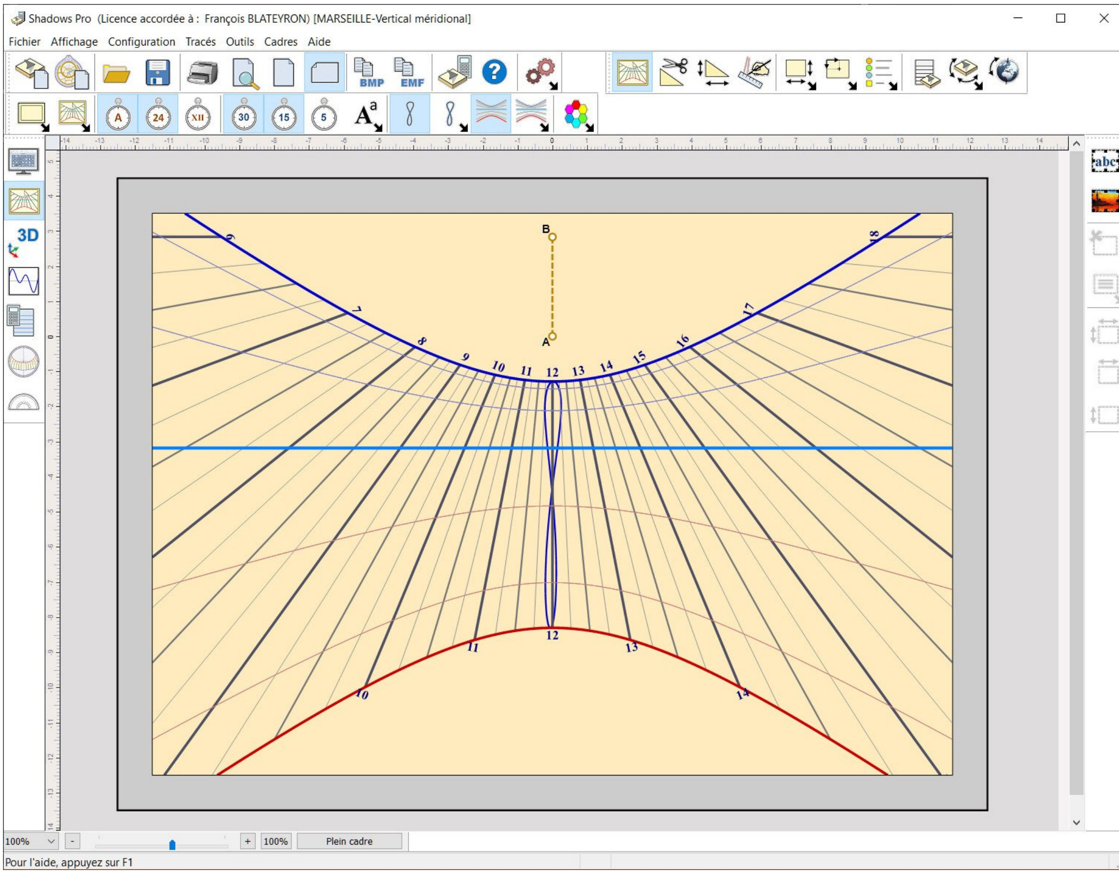
The sundial of the Palais de Justice in Besançon, near Saint-Pierre Square. This sundial is, in fact, a vertical dial that declines in the morning.

sundials. The Louvre Museum and the National Conservatory of Arts and Crafts in Paris, the Galileo Museum in Florence, the Navy Museum in Madrid, the Adler Planetarium in Chicago, the Greenwich Observatory in England, the Munich Science Museum in Germany… Each time, these collections amaze and arouse interest and admiration.

Disappearing into oblivion for a while starting in the nineteenth century due to the spread of mechanical wall and wrist clocks, sundials returned to fascinate the public, thanks in no small part to software and computerized drawing and carving tools. More and more people are installing one at their houses, especially in some regions such as the French and Italian Alps. It is one of the rare subjects that combine science with art or handicraft, as well as with philosophy, with inscribed mottos that often make passersby reflect on their life and the passage of time.

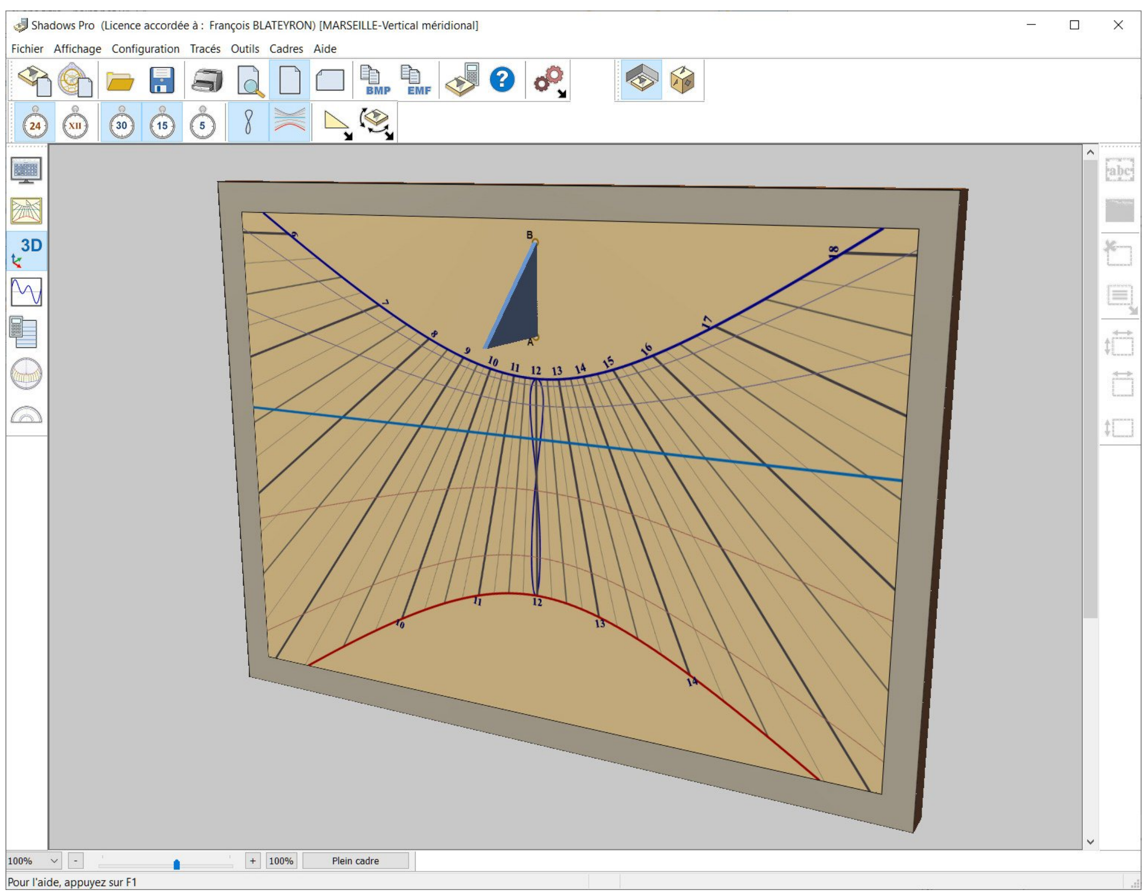
Many books on the subject have been published in the last thirty years, including technical and mathematical, as well as beautiful photographic books that allow, for example, the reader to discover the many sundials of Queyras or the Hautes Alpes. The archives available online also allow one to delve into ancient scriptures by downloading beautiful books from the 17th or 18th centuries and discovering geometric methods richly illustrated with hand engravings.

While it is possible to manually calculate a horizontal or vertical southern sundial, it becomes a bit more complicated to accurately trace a vertical descending sundial, or to trace the sidereal hours and analemmas. Many people dream of making a sundial on their own for their garden or the facade of their house, expressing their talents in painting,



decoration, woodworking, metalworking and so on in the process, but they give up in the face of the technical difficulty of calculating

A sundial drawn with Shadows software for the city of Marseille. Above is the flat drawing; on the right, the animated 3D view. The options are guided by icons and menus.

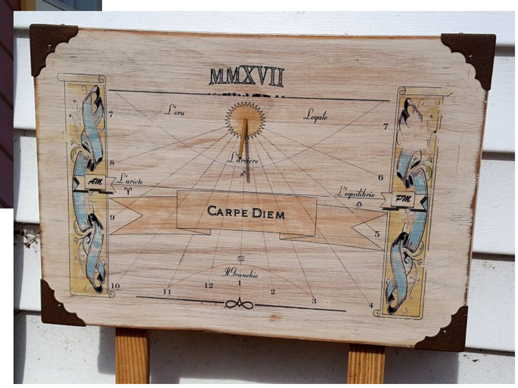


hourly lines. Not infrequently, people think that a sundial should be level and south-oriented. Instead, it is possible to make one with any inclination or orientation, and on any type of support too. This, however, requires specific calculations and knowledge. Fortunately, software comes to our rescue – in particular, the free software Shadows, a digital reference point for many years. Shadows is a program for Windows that takes care of all of the calculations and tracing drawings in 1:1 scale, allowing the user to concentrate on their skills as a creator starting from printed projects. Shadows offers many types of sundials: classic, analemmatic, bifilar, and cylindrical, all valid for any place on Earth.

The software also provides a database of over 5000 predefined locations with their latitude, longitude, and time zone. Of course, it is possible to add new locations, as a sundial must be designed for a precise latitude. Such a personalized sundial, designed for its location and placement, is much more interesting than an industrial one bought from somewhere.

The process of creating a sundial in Shadows is very simple. Once the location has been chosen from the list,

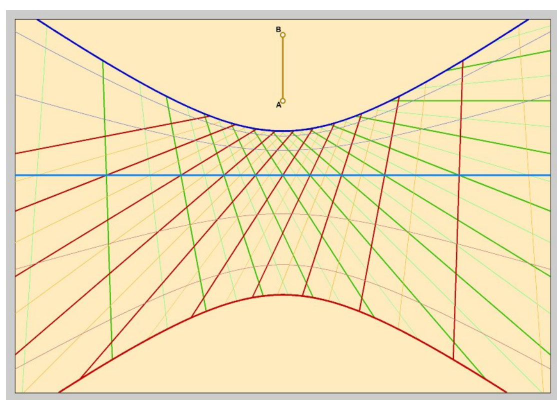
On the left, a vertical sundial made by Heiko De Jong with Shadows, for his house in the Netherlands. Below, a painted wood sundial, made by Mark Mills in Springfield (IL, USA), with the same software.

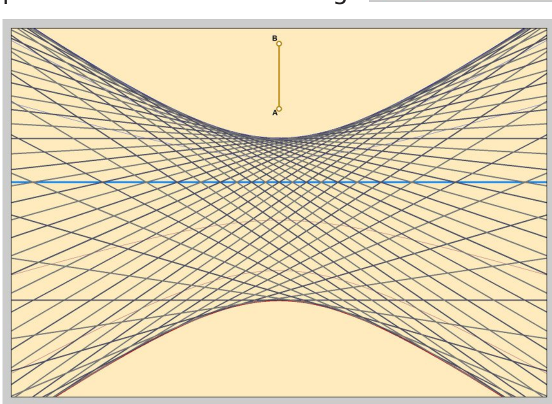


the sundial is displayed on the screen and the user only needs to configure it by changing its size and design options, decorating it with clip art or images, and possibly embellishing it with a personalized motto, or simply choosing an option from the long list provided by the software. Finally, the result can be printed to scale, possibly on several sheets. For large sundials, the coordinates of the points are provided in Excel-compatible tables. The lines can also be exported in vector format (EMF), to allow one to rework them in Corel Draw or Adobe Illustrator, or in DXF format, compatible with CAD software and, from there, engraving machines.

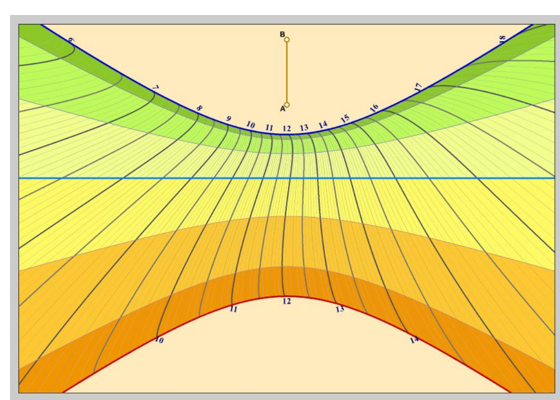
The computer can help a lot, but the user still has to do the practical work of transferring the layout to the final material, as well as assembling the stylus and placing it on the facade of the house or on a column in the garden. The satisfaction of the work done will still be there and can be shared with others.

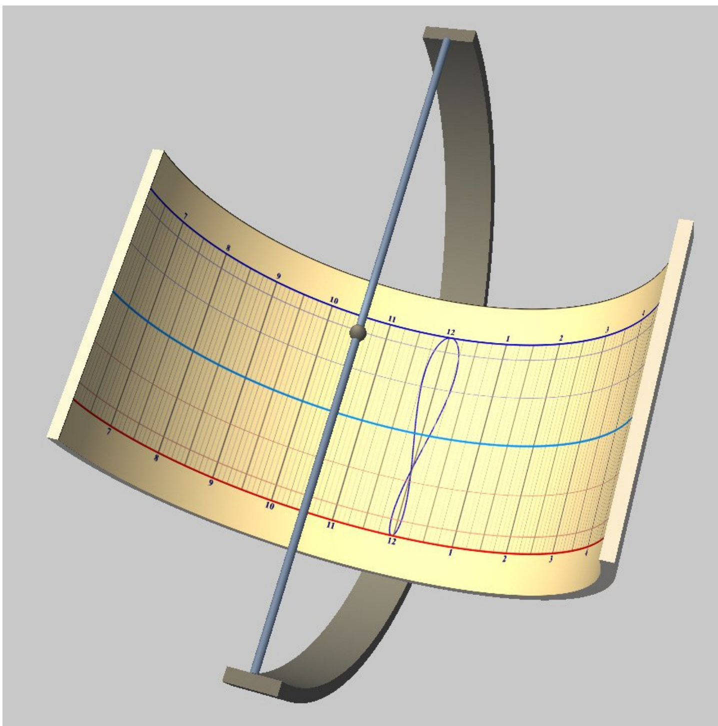
The users' sundials gallery highlights the diversity of layouts and materials. There are horizontal and vertical sundials of any orientation, armillary spheres, portable shepherd sundials, and so on. It is evident how the talent of some can be expressed once the software eliminates the difficulty of the calculations. Furthermore, it is not only the private individual who uses Shadows, but also teachers and professors in their schools for illustrating projects on celestial mechanics or the Solar System, and even professionals who produce sundials in engraved stone, wrought iron or fresco. The Shadows software is used all over the world thanks to its

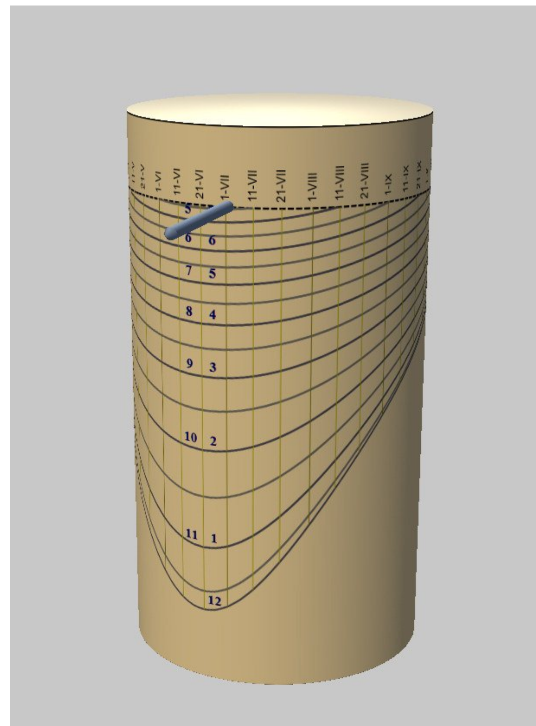




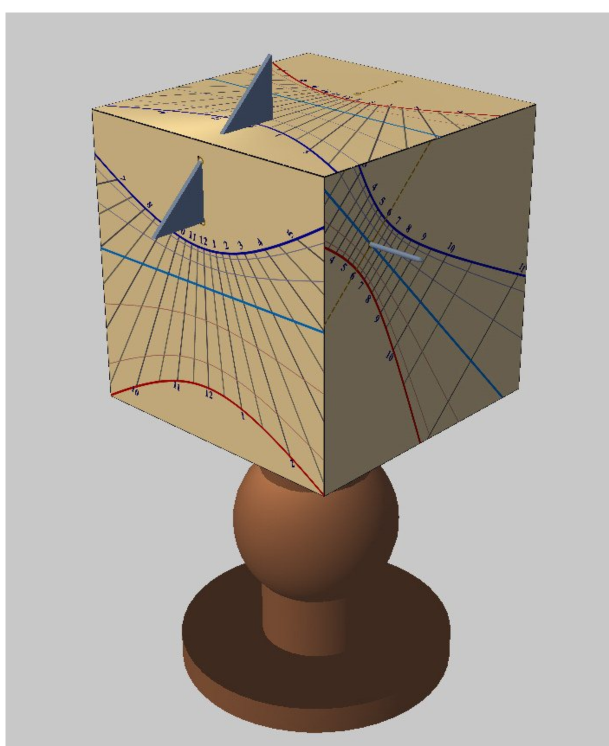
Above, Italic (green lines) and Babylonian (red lines) hours. Left, sidereal hours. Right, mean time and coloring of diurnal arcs.







Above, armillary corona with polar style. Top right, shepherd's cylindrical dial. Opposite, multiple sundials on a cube (5 dials).



translation into 17 languages. Its user manual, over 130 pages long, has been translated into seven languages and can be downloaded for free from the software website.

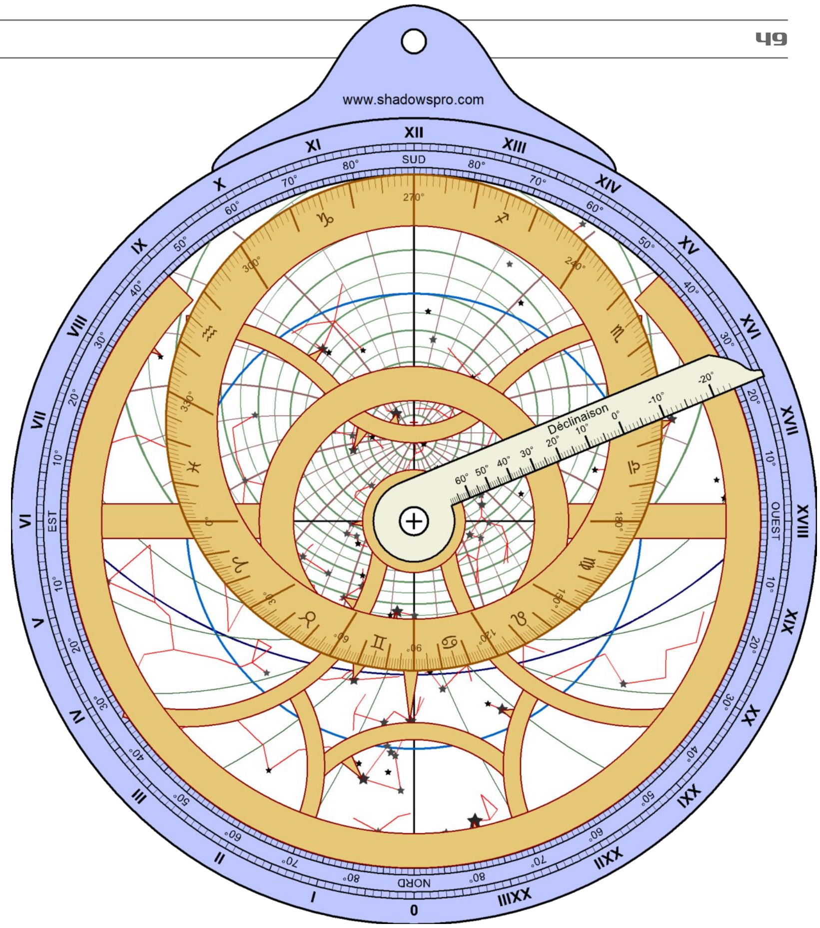
Shadows has been around since 1997 and accessible online since its inception. It was awarded in 2005 the Julien Saget medal, assigned by the Société Astronomique de France.

The software has constantly evolved based on user requests, gradually enriching itself through to today, becoming an undisputed model for all amateur gnomonists.

At the end of 2021, the new version 5.0 introduced animated 3D viewing on the screen, which increases the educational potential of the software itself and opens the door to three-dimensional printing.

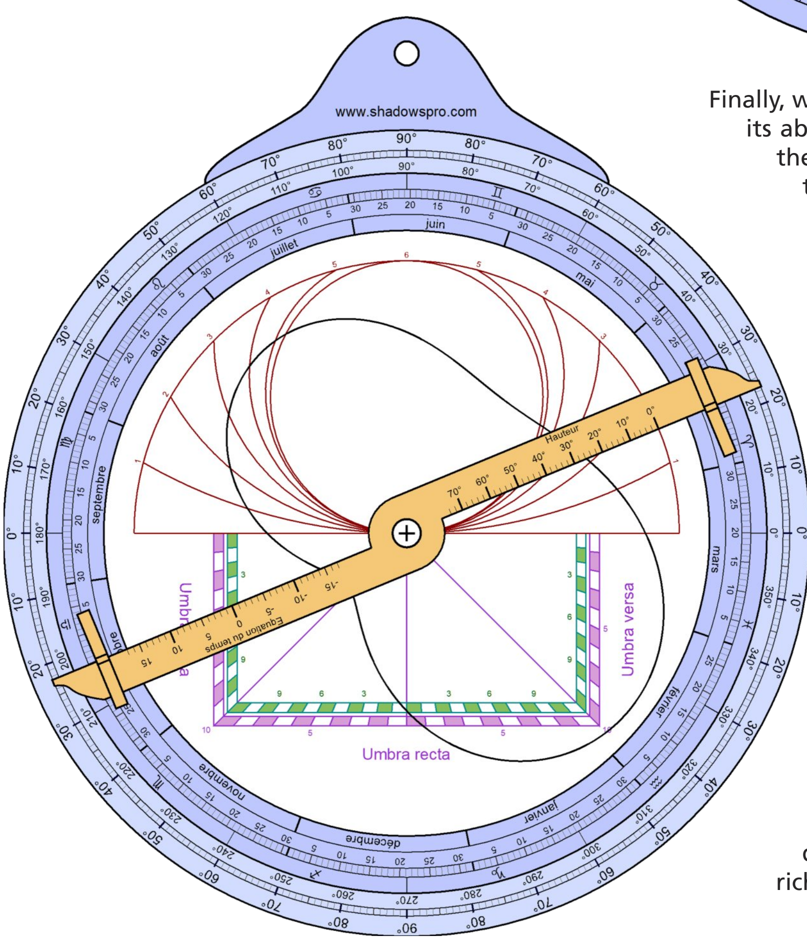
Sundials are fascinating, and you can have fun simulating and animating the shadow of the stylus on the dial on your screen, varying with the time of day or day of the year. This helps to understand the effects of the tilt of the Earth's rotation axis and the eccentricity of the Earth's orbit.

In addition to drawings directly related to the sundials, the software also offers complete ephemeris for the year, calculated for a day or



On the right, the face of a planispheric astrolabe, with its spider and movable ruler. Below, the back of the astrolabe, with the alidade and the square of shadows.

for a specific instant. The solar graph allows you to view the azimuth and height of the Sun during the year based on the time, and to superimpose a horizon mask on it to predict the times in which obstacles will put the observer (or the sundial) in the shade. This tool is used by architects to optimize the orientation of the rooms in a house. Amateur astronomers may be interested in ephemeris, but also in the map of the sky, drawn according to place and time. In short, many features of educational or practical natures are available.



Finally, we recall the other unique feature of Shadows: its ability to simulate three types of astrolabes on the screen, including the superb planispheric astrolabe, all elements of which can be configured and manipulated by mouse.

The program also provides a very simple way to make a functional astrolabe.

The software can be downloaded from https://www.shadowspro.com. Its basic version is free. It comes with a complete and illustrated user manual in PDF format, allowing you to discover all of the features and to understand gnomonics. Interested amateurs can then upgrade to the Shadows Expert or Shadows Pro levels by purchasing a license at a low price (23 or 57 USD).

Amateur astronomers who spend their nights observing and photographing the deep sky can remain in contact with the stars and celestial mechanics by taking an interest in sundials and astrolabes during the day or when the weather conditions are not favorable – providing another topic of interest and wonder of human intelligence in the face of the richness of the universe. ■

Astronomers discover an ultra-light and super-fast sub-Earth

by IAC - Outreach Unit

An international team, including researchers from the Instituto de Astrofísica de Canarias (IAC), has discovered an extrasolar planet with half the mass of the Earth that takes approximately eight hours to orbit its parent star, a red dwarf just under 31 light-years from Earth. Called GJ 367 b, it is one of the lightest among the nearly 5000 exoplanets known today.

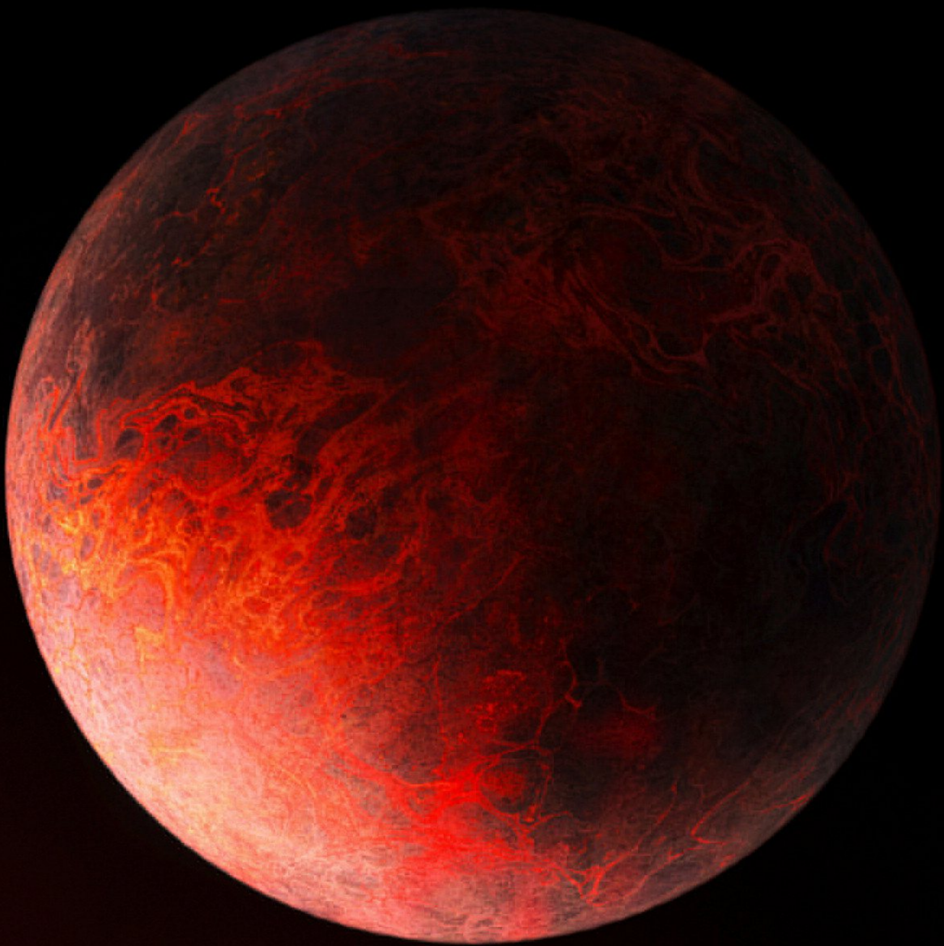
With a diameter of just over 9000 kilometres, this sub-Earth is slightly larger than Mars. The discovery not only demonstrates that it is possible to precisely determine the event the smallest, least massive exoplanets, but also provides a key to understanding how terrestrial planets form and evolve. The study was published in the journal *Science*.

A quarter of a century after the first discovery of an extrasolar planet, the focus has shifted to characterising these planets more precisely, in addition to making new discoveries. At present, it is possible to construct a much more precise profile for most known exoplanets. Many exoplanets were discovered using the transit method – the measurement of minute differences in the emitted light, or its apparent magnitude, of a star as a planet passes in front of it (with respect to the observer). GJ 367 b was also discovered using this method, with the help of NASA's Transiting Exoplanet Survey Satellite (TESS).

With an orbital period of only one-third of an Earth day, GJ 367 b is a fast mover. *"From the precise determination of its radius and mass, GJ 367b is classified as a rocky planet,"* reports Kristine Lam from the Institute of Planetary Research at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR). *"This places it among the sub-Earth sized terrestrial planets and brings research one step forward in the search for a 'second Earth'."*

GJ 367 b belongs to the 'ultra-short period' (USP) group of exoplanets that orbit their star in less than 24 hours. *"We already know a few of these, but their origins are currently unknown,"* says Savita Mathur, a researcher at the IAC and co-author of the article. Moreover, with a rotation period of 48 days for the star, *"it is a very interesting system to study and understand the dynamical evolution of small rocky planets with this orbit,"* explains the researcher.

Following the discovery of this planet using TESS and the transit method, the spectrum of its star was then studied from the ground using the radial velocity method. This technique consists of measuring changes in the position and velocity of a star as it and a surrounding planet orbit their common centre of mass. The variation caused by the gravitational force of the two objects is reflected in a shift in the spectrum of the observed star. In the case of GJ 367 b, the mass was determined using the HARPS instrument on the European Southern Observatory's 3.6m telescope.



An artist's simulation of the subterrestrial planet GJ 367 b. [DLR]

With the meticulous study and combination of different evaluation methods, the radius and mass of the planet were accurately determined: its radius is 72 percent of Earth's radius, and its mass 55 percent of Earth's mass. By determining its radius and mass with an accuracy of 7 and 14 percent respectively, the researchers were also able to draw conclusions about the exoplanet's inner structure. It is a low-mass rocky planet, but has a higher density than the Earth. "*The high density indicates the planet is dominated by an iron core,*" explains Szilárd Csizmadia co-author of the article from the DLR. *"These properties are similar to those of Mercury, with its disproportionately large iron and nickel core that differentiates it from other terrestrial bodies in the Solar System."* However, the planet's proximity to its star means it is exposed to an extreme high level of radiation, more than 500 times stronger than what the Earth experiences.

"The surface temperature could reach up to 1500 degrees Celsius – a temperature at which all rocks and metals would be melted. GJ 367 b therefore cannot be considered a 'second Earth'" notes Enric Pallé, a researcher at the IAC who has also participated in the study.

The parent star of this newly discovered exoplanet, a red dwarf called GJ 367, is only about half the size of the Sun. This was beneficial for its discovery as the transit signal of the orbiting planet is particularly significant. *"Red dwarfs are not only smaller, but also cooler than the Sun. This makes their associated planets easier to find and characterise"*, says Felipe Murgas co-author of the article from the IAC.

Red dwarfsare among the most common stellar objects in our cosmic neighbourhood and are therefore suitable targets for exoplanet research. Researchers estimate that these red dwarfs, also known as 'class M stars', are orbited by an average of two to three planets, each of which is at most four times the size of Earth.

Closest pair of supermassive black holes uncovered

by ESO - Bárbara Ferreira

Using the European Southern Observatory's Very Large Telescope (ESO's VLT), astronomers have revealed the closest pair of supermassive black holes to Earth ever observed. The two objects also have a much smaller separation than any other previously spotted pair of supermassive black holes and will eventually merge into one giant black hole. Located in the galaxy NGC 7727 in the constellation Aquarius, the supermassive black hole pair is about 89 million light-years away from Earth. Although this may seem distant, it beats the previous record of 470 million light-years by quite some margin, making the newfound supermassive black hole pair the closest to us yet.

Supermassive black holes lurk at the centre of massive galaxies and when two such galaxies merge, the black holes end up on a collision course. The pair in NGC 7727 beat the record for the smallest separation between two supermassive black holes, as they are observed to be just 1600 light-years apart in the sky.

"It is the first time we find two supermassive black holes that are this close to each other, less than half the separation of the previous record holder," says Karina Voggel, an astronomer at the Strasbourg Observatory in France and lead author of the study published in *Astronomy & Astrophysics*.

"The small separation and velocity of the two black holes indicate that they will merge into one monster black hole, probably within the next 250 million years," adds co-author Holger Baumgardt, a professor at the University of Queensland, Australia. The merging of black holes like these could explain how the most massive black holes in the Universe come to be.

Voggel and her team were able to determine the masses of the two ob-

This image shows close-up (left) and wide (right) views of the two bright galactic nuclei, each housing a supermassive black hole, in NGC 7727, a galaxy located 89 million light-years away from Earth in the constellation Aquarius. Each nucleus consists of a dense group of stars with a supermassive black hole at its centre. The image on the left was taken with the MUSE instrument on ESO's Very Large Telescope (VLT) at the Paranal Observatory in Chile while the one on the right was taken with ESO's VLT Survey Telescope. [ESO/Voggel et al.; ESO/VST ATLAS team. Acknowledgement: Durham University/CASU/WFAU]

Using the ESO's Very Large Telescope, astronomers have revealed the closest pair of supermassive black holes to Earth ever observed. This video summarises the discovery. [ESO]

jects by looking at how the gravitational pull of the black holes influences the motion of the stars around them. The bigger black hole, located right at the core of NGC 7727, was found to have a mass almost 154 million times that of the Sun, while its companion is 6.3 million solar masses.

It is the first time the masses have been measured in this way for a supermassive black hole pair. This feat was made possible thanks to the close proximity of the system to Earth and the detailed observations the team obtained at the Paranal Observatory in Chile using the Multi-Unit Spectroscopic Explorer (MUSE) on ESO's VLT, an instrument Voggel learnt to work with during her time as a student at ESO. Measuring the masses with MUSE, and using additional data from the NASA/ESA Hubble Space Telescope, allowed the team to confirm that the objects in NGC 7727 were indeed supermassive black holes. Astronomers suspected that the galaxy hosted the two black holes, but they had not been able to confirm their presence until now since we do not see large amounts of high-energy radiation coming from their immediate surroundings, which would otherwise give them away. *"Our finding implies that there might be many more of these relics of galaxy mergers out there and they may contain many hidden massive black holes that still wait to be found,"* says Voggel. *"It could increase the total number of supermassive black holes known in the local Universe by 30 percent."*

The search for similarly hidden supermassive black hole pairs is expected to make a great leap forward with ESO's Extremely Large Telescope (ELT), set to start operating later this decade in Chile's Atacama Desert. *"This detection of a supermassive black hole pair is just the beginning,"* says co-author Steffen Mieske, an astronomer at ESO in Chile and Head of ESO Paranal Science Operations. *"With the HARMONI instrument on the ELT we will be able to make detections like this considerably further than currently possible. ESO's ELT will be integral to understanding these objects."* ■

The Gemini South catches a one-winged butterfly

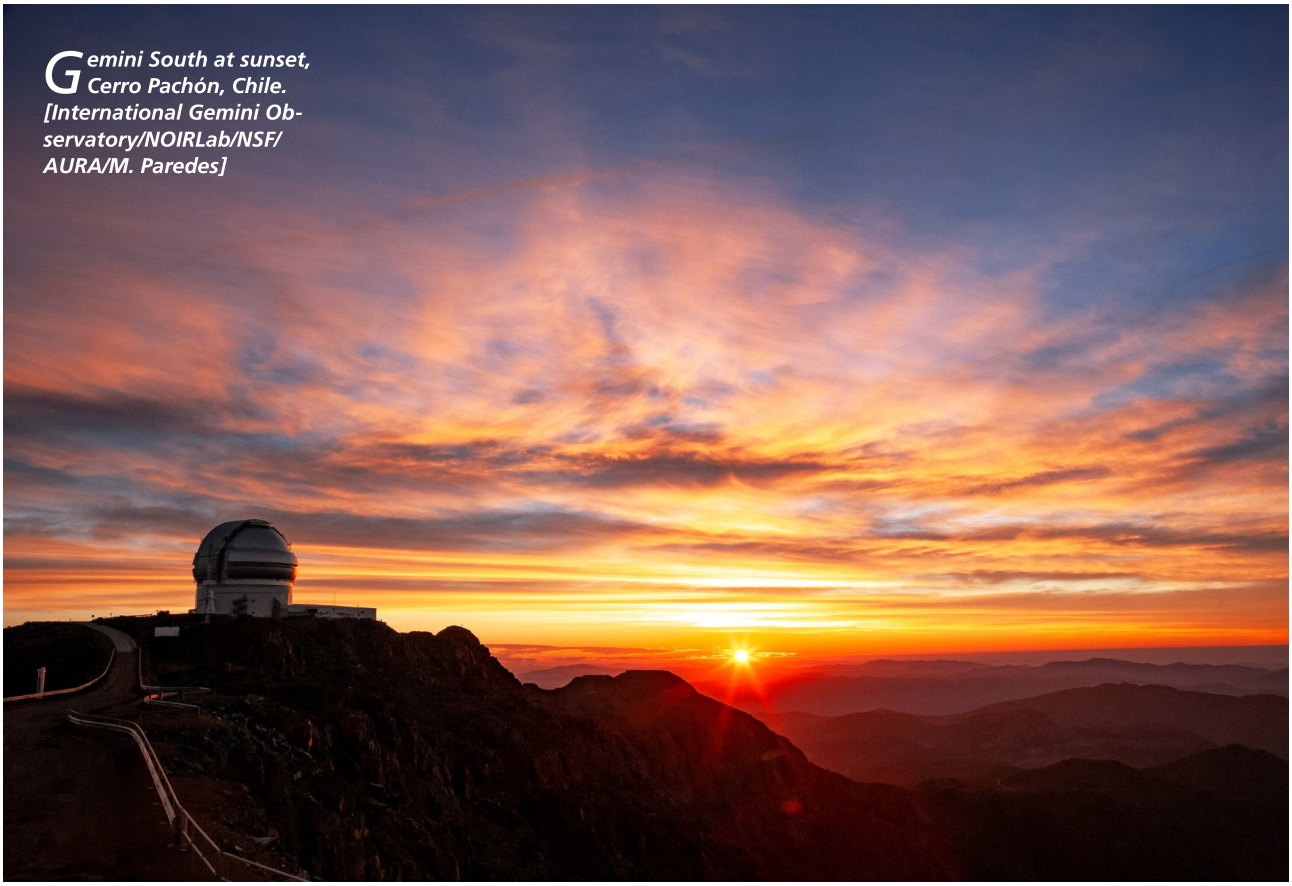
by NOIRLab
Vanessa Thomas

This ethereal image, captured from Chile by the international Gemini Observatory, a Program of NSF's NOIRLab, looks as delicate as a butterfly's wing. It is, however, a nabula located near the center of the mammoth Chamaeleon I dark cloud, one of the nearest star-forming regions in our Milky Way. This breathtaking visible-light image, taken with the Gemini South telescope, looks as though it is ready to flutter off the screen. This apparently wispy object is an outflow of gas known as the Chamaeleon Infrared Nebula – so named because it is bright at some infrared wavelengths of light, although it can also be seen in visible light, as in this view. Hidden at the core of this reflection nebula, and at the center of this image, is the engine of the nebula, a low-mass star (less massive than our Sun) that is eclipsed by a dark vertical band. Even though it is concealed from view, this young, cool star emits streams of fast-moving gas that have carved a tunnel through the interstellar cloud from which the young star formed. Infrared and visible light emitted by the star escapes along this tunnel and scatters off its walls, giving rise to the wispy reflection nebula. The bright red object to the left of the image center marks where some of the fast-moving stream of gas lights up after colliding with slower-moving gas in the nebula. It is known as a Herbig-Haro (HH) object and has the designation HH 909A. Other Herbig-Haro objects have been found along the axis of the star's outflow beyond the edges of the image to the right and left. Astronomers have suggested that the dark band at the center of the Chamaeleon Infrared Nebula is a circumstellar disk — a reservoir of gas and dust orbiting the star. Circumstellar disks are typically associated with young stars and provide the materials needed to build planets. The reason the disk appears as a band rather than a circle in this image is because it is edge-on, only revealing one edge to observers here on Earth. Astronomers believe that the nebula's central star is a young stellar object embedded

This ethereal image, captured from Chile by the international Gemini Observatory, a Program of NSF's NOIRLab, looks as delicate as a butterfly's wing. It is, however, a structure known as the Chamaeleon Infrared Nebula, which is located near the center of the even larger Chamaeleon I dark cloud, one of the nearest star-forming regions in our Milky Way. [International Gemini Observatory/NOIRLab/NSF/AURA]

within the disk. The background nebulosity, appearing in blue in this image, is reflecting light from a nearby star located outside the frame. The Chamaeleon Infrared Nebula resides within the larger Chamaeleon I dark cloud, which is neighbored by the Chamaeleon II and Chamaeleon III dark clouds. These three dark clouds collectively comprise the Chamaeleon Complex, a large area of star formation that occupies almost the entirety of the constellation Chamaeleon in the southern sky. The gorgeous detail in this image is thanks to the southern edition of the twin Gemini Multi-Object Spectrographs (GMOS), located atop Cerro Pachón in Chile at Gemini South, part of the international Gemini Observatory, a Program of NSF's NOIRLab. GMOS has imaging capabilities in addition to being a spectrograph, which makes it a very versatile instrument. *"GMOS-South is the perfect instrument to make this observation, because of its field of view, which can nicely capture the whole nebula, and because of its ability to capture the emission from the nebula's ionized gas,"* said NOIRLab instrument scientist German Gimeno. The image was produced by NOIRLab's Communication, Education & Engagement team as part of the NOIRLab Legacy Imaging Program.

This video zooms in to the Chamaeleon Infrared Nebula, located in the constellation Chamaeleon. [International Gemini Observatory/NOIRLab/NSF/AURA/E. Slawik, D. De Martin/Kwon O Chul]


Gemini South at sunset, Cerro Pachón, Chile. [International Gemini Observatory/NOIRLab/NSF/AURA/M. Paredes]

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