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A probe two steps from the Sun

A new transit in front of KIC 8462852

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- Moon spotted around third largest dwarf planet
- Collapsing star gives birth to a black hole
- White dwarf shows how gravity can bend starlight

Looking for an alien past

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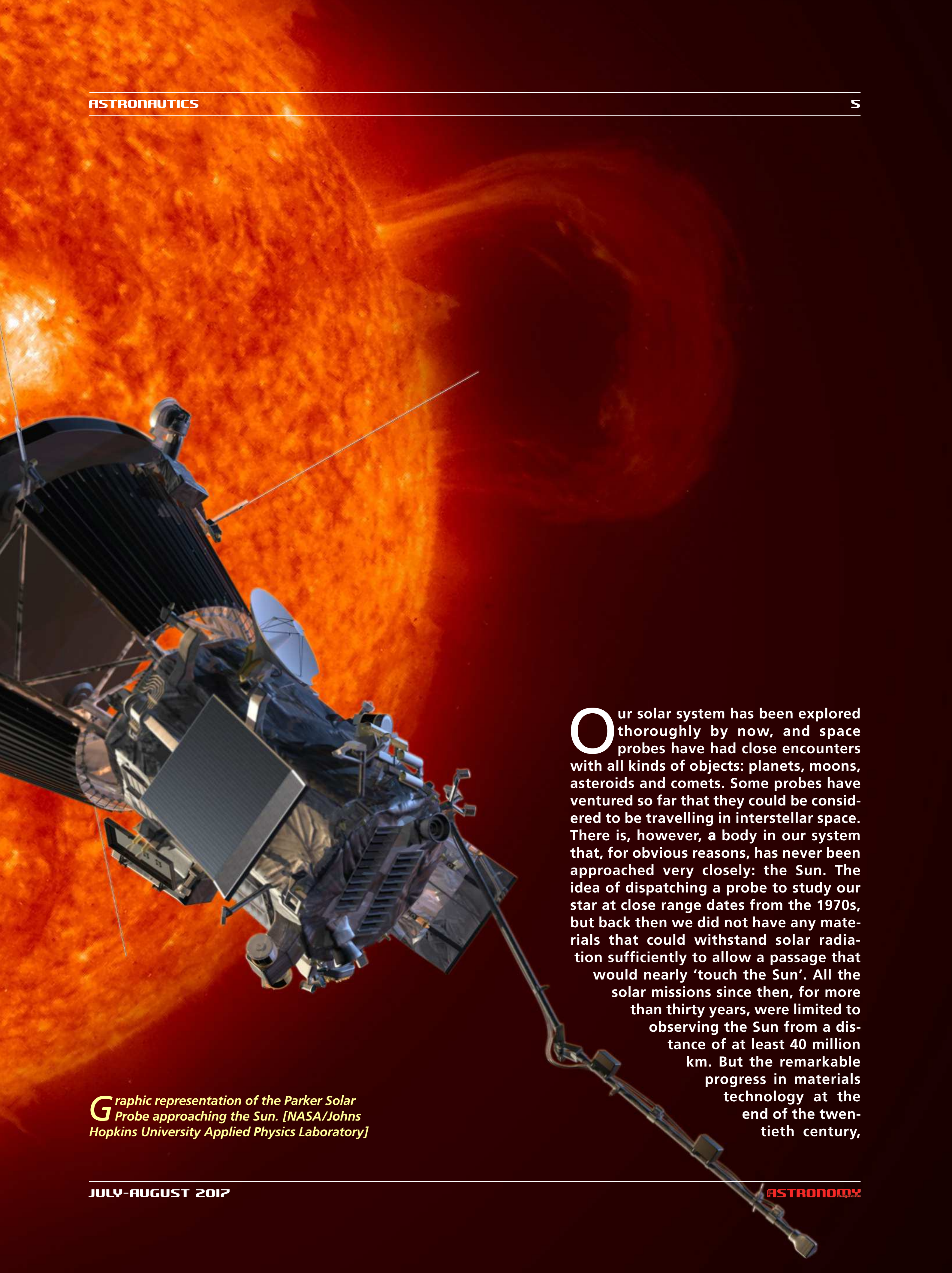
SUMMARY

A probe two steps from the Sun

by Michele Ferrara

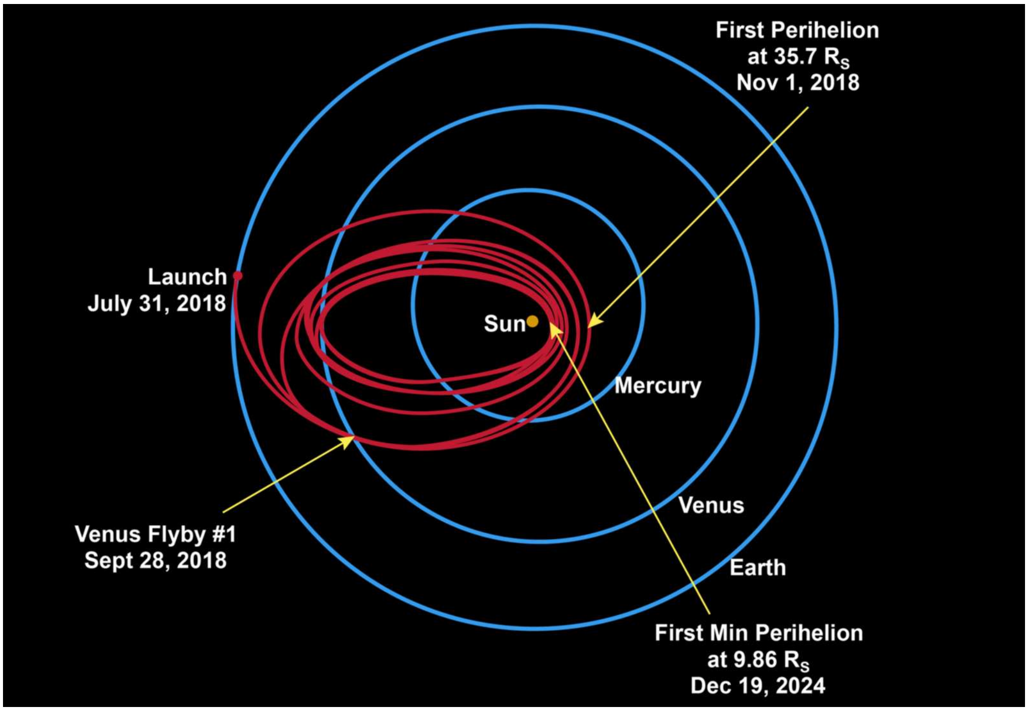
Within a few years we will be able to forecast reasonably far in advance when solar storms will erupt, so we can significantly limit their interference with human activities. To improve our knowledge of this powerful phenomenon, a probe will study the solar corona and the solar wind from within – an extreme mission by any standard.



Graphic representation of the Parker Solar Probe approaching the Sun. [NASA/Johns Hopkins University Applied Physics Laboratory]

Our solar system has been explored thoroughly by now, and space probes have had close encounters with all kinds of objects: planets, moons, asteroids and comets. Some probes have ventured so far that they could be considered to be travelling in interstellar space. There is, however, a body in our system that, for obvious reasons, has never been approached very closely: the Sun. The idea of dispatching a probe to study our star at close range dates from the 1970s, but back then we did not have any materials that could withstand solar radiation sufficiently to allow a passage that would nearly 'touch the Sun'. All the solar missions since then, for more than thirty years, were limited to observing the Sun from a distance of at least 40 million km. But the remarkable progress in materials technology at the end of the twentieth century,

and even more so in the early twenty-first century, have convinced engineers and scientists that sending a spacecraft within a relatively short distance from the Sun is no longer a fantasy but an achievable undertaking. Thus began the planning for a NASA project known as Solar Probe 2005, which anticipated sending a car-sized probe to the Sun equipped with a series of scientific instruments and experiments to make definitive contributions to solving the two great enigmas that have bothered solar physicists since the 1950s — and still bother them. The first is the hellish temperature of the solar corona, which reaches millions of degrees, while the photosphere (the scorching surface of the Sun that we see in white light) does not even reach 6000°C, a seeming paradox that has yet to be explained despite



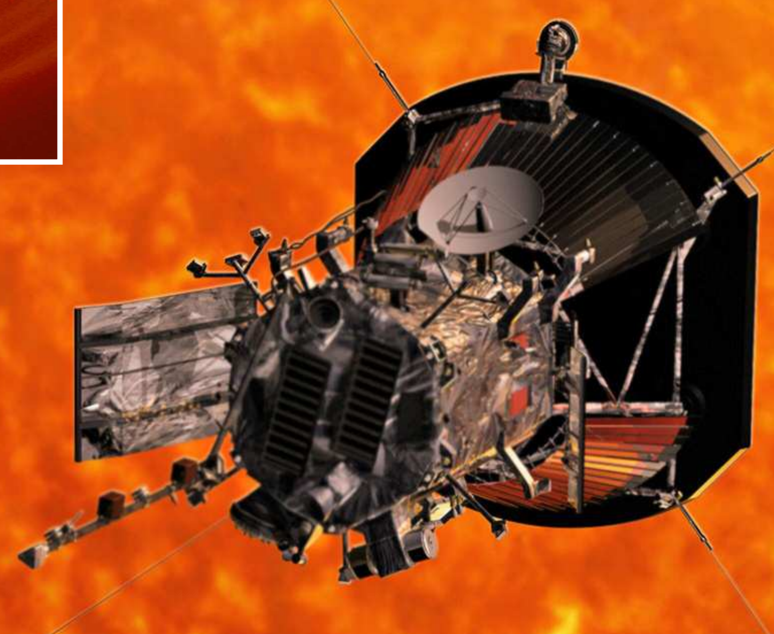
The Parker Solar Probe leaves the Earth after separating from its carrier rocket, a scene that will take place between 31 July and 19 August 2018. [JHU/APL] Below left, a rough diagram of the trajectory that the probe will trace to approach the Sun multiple times. [NASA/JHUAPL]

At right, an animated sequence of the Parker Solar Probe mission. Below, Eugene Parker receives the first scale model of the probe bearing his name, handed to him by Nicola Fox, the mission's Project Scientist. [NASA/JHUAPL]

the many theories proposed and even though our star has been studied in the last decade at a high enough resolution to reveal previously unknown small-scale structures. The second mystery involves the physical mechanism underlying the acceleration of the solar wind. It is currently unknown, but discovering it is of primary importance in protecting some of our most important businesses and even human health from the so-called 'space weather'. The Solar Probe 2005 mission planned a very long trajectory of approach to the Sun with gravitational assistance from Jupiter, entering a solar polar orbit and performing no more than two flybys with our star at a little less than 3 million km from the photosphere, which is within the outer corona.

As often happens in space projects, delays, reshuffling and improvements have transformed the mission's initial formulation, which until a few months ago had been called Solar Probe Plus and was recently renamed Parker Solar Probe in honour of ninety-year-old Eugene Parker, professor emeritus at the University of Chicago and a 1950s pioneer in the study of solar wind, which he described for the first time in an article in *The Astrophysical Journal* in 1958. At the time, Parker was a young professor at the Enrico Fermi Institute who asserted that the Sun released a constant flow of radiation, high-energy particles, plasma and magnetic fields, and that all of these influenced the planets and interplanetary space.

Sixty years of research amply proved Parker right, but the mechanism that triggers and maintains that flow is, as mentioned above, still almost entirely unknown, and Parker himself is impatient to learn when the mission bearing his name (the only one named after a living person) will provide the coveted answer.



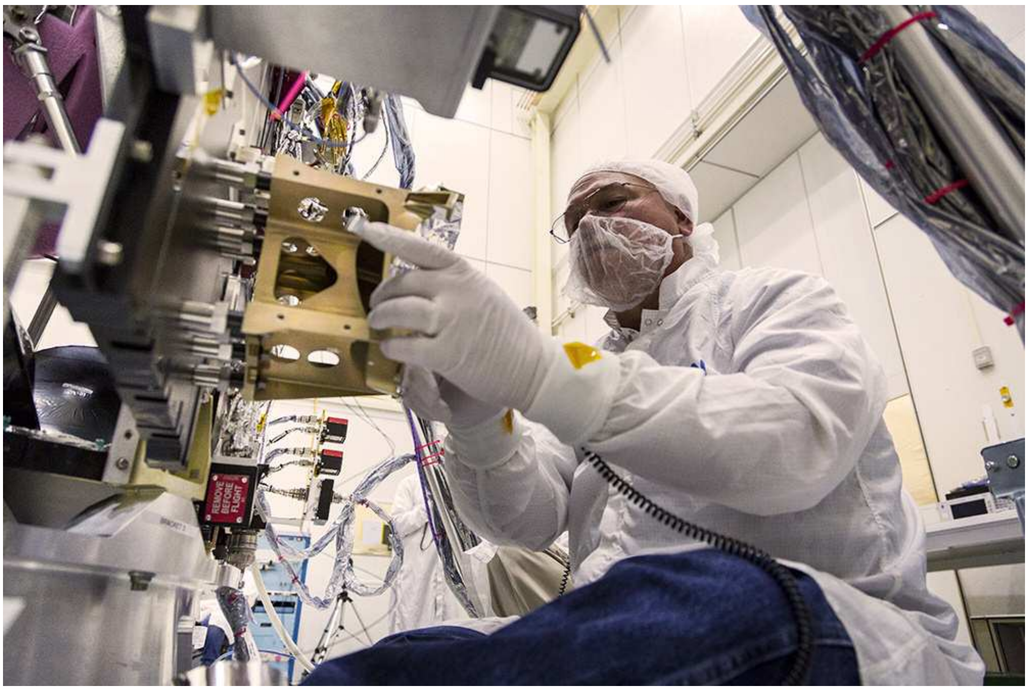
In the background and in the inset, two theoretical views of the Parker Solar Probe mission. [NASA/JHUAPL]

The wait should not be long, because the updated schedule for this NASA mission includes launching the probe (from Florida's Kennedy Space Center, with a Delta 4-Heavy rocket manufactured by United Launch Alliance) within a 20-day window that opens 31 July 2018. The length of the mission, the probe's route and the strategy to bring it close to its goal are totally different than in the initial project. The Parker Solar Probe will orbit the Sun at least 24 times, staying close to the ecliptic plane. Thanks to seven gravity assists with Venus, the perihelia will be reduced each time until the probe transits at about 6 million km (3.7 million miles) from the photosphere, a minimum distance that it will reach six and half years after launch, or in the first few months of 2025, the year when the nominal mission is set to conclude. No probe has ever come closer to the Sun than seven times this distance. Six million km may sound like a safe distance, where the infernal temperature of the solar corona is reduced to very little. Nevertheless, the

Trailer of the mission featuring the Parker Solar Probe. [NASA/JHUAPL]

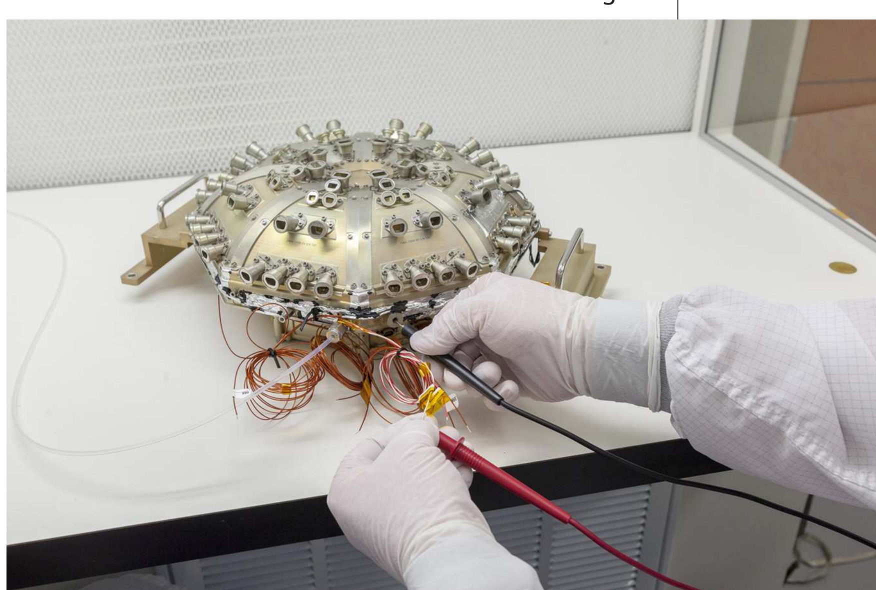
Parker Solar Probe will find itself in an environment where temperatures will reach or even exceed 1400°C (2500°F), and it will be constantly exposed to the fury of the solar wind and all its devastating elements. The estimated level of radiation that the probe will have to withstand is almost 500 times greater than is typical in the Earth's orbit. To defend the spacecraft and the scientific instruments it will carry, NASA engineers designed a special carbon-composite heat shield, 11.5 cm (4.5") thick, that will be kept facing the Sun, while safe behind it the instrumentation will collect data and images of the dynamics of the gases and magnetic fields as well as the type and energy of the solar wind particles. Only the solar panels will extend beyond the heat shield, but to avoid damaging them, engineers plan to close them during the nearest approaches to our star and then re-open them during the less dangerous parts of the orbits.

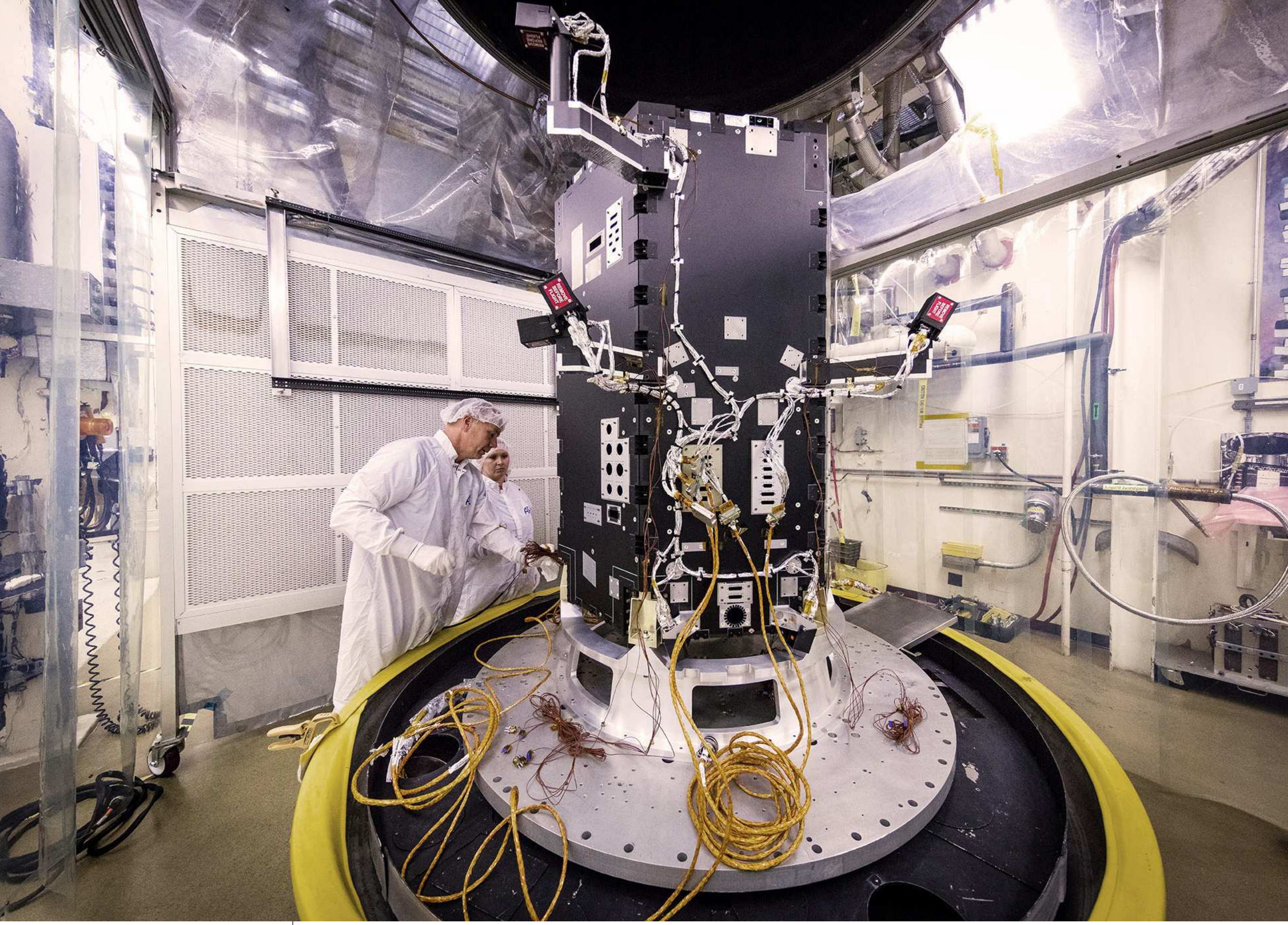
The main instruments/experiments hosted on board the Parker Solar Probe are the



At left and below, scenes from the fine tuning and installation of one of the scientific instruments for the solar probe, the Energetic Particle Instrument-Low Energy. [NASA/JHUAPL]

Wide Field Imager from the Naval Research Laboratory (Washington, D.C.); the Solar Wind Electrons Alphas and Protons Investigation of the Smithsonian Astrophysical Observatory (Cambridge, Massachusetts); the Fields Experiment of the Space Sciences Laboratory at the University of California (Berkeley); and the Integrated Science Investigation of the Southwest Research Institute (San Antonio, Texas). We will summarise the tasks that each will perform. The Wide Field Imager will take visible light photographs of the densest gaseous structures that form in the solar wind and are sent out into interplanetary space. Although this instrument produces 2D images, thanks to the fast motion of the probe itself (its anticipated greatest speed is more than 700,000 km/h) and thanks to special software, multiple frames can be used to build 3D images to be integrated with the data from the other instruments. The Solar Wind Electrons Alphas and Protons Investigation will count the electrons, protons and ions of helium present in the solar wind and will measure their properties. Scientists expect to capture some particles in a special container for direct analysis. The Fields Experiment will take measurements of the electrical and mag-





The primary structure of the Parker Solar Probe (with its propulsion system) is prepared for thermal vacuum tests that simulate conditions in space. [NASA/JHUAPL]

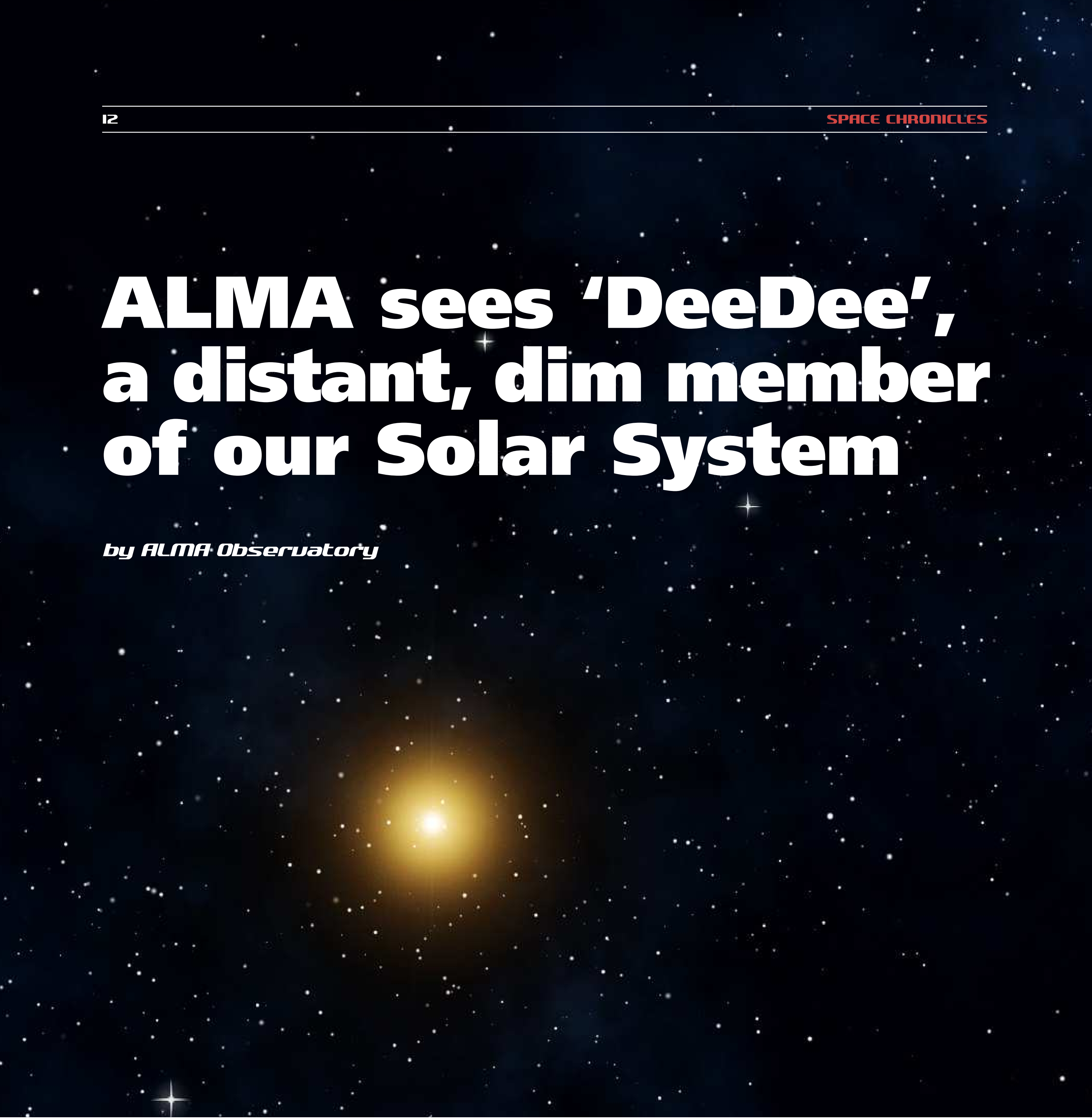
netic field, the radio emissions and the shock waves moving in the plasma of the solar corona. The experiment will also reveal the grains of dust whose energy will be recorded when they strike the probe's antenna. The Integrated Science Investigation consists of two instruments that will inventory the chemical elements that compose the solar atmosphere and will use a mass spectrometer to weigh and classify the ions surrounding the probe.

All the experiments, observations and measurements that the Parker Solar Probe will perform several times from its privileged position will allow us, among other things, to make significant advances in our knowledge of the conditions necessary for the solar atmosphere to generate those mighty magnetic storms that, when aimed at the Earth, can cause various kinds of damage. The intense radiation carried on those occasions by a stronger than usual solar wind can knock the more exposed satellites offline, disturb telecommunications, damage power grids and even threaten the health of aviators and astronauts.

Today, our ability to forecast far enough in advance the triggers for solar storms is quite limited, because we don't have good ways to measure directly and precisely the local magnetic fields in the active regions or the densities and temperatures in the coronal plasma.

By the time we are aware of the instability of an active region and a break in its magnetic field, the storm will be under way imminently. Within just a day the menace can reach Earth, and often this forecast is too short to allow us to take adequate countermeasures.

Being able to reveal variations in local physical conditions on a small scale (which we are entirely unable to observe from Earth), the Parker Solar Probe will tell us what the early warning signs are for magnetic storms and which parameters to consider when developing new methods and techniques to forecast with a reassuring margin the storms brewing in space weather. Knowing these dynamics is essential for planning and carrying out a crewed mission to Mars in safety. ■



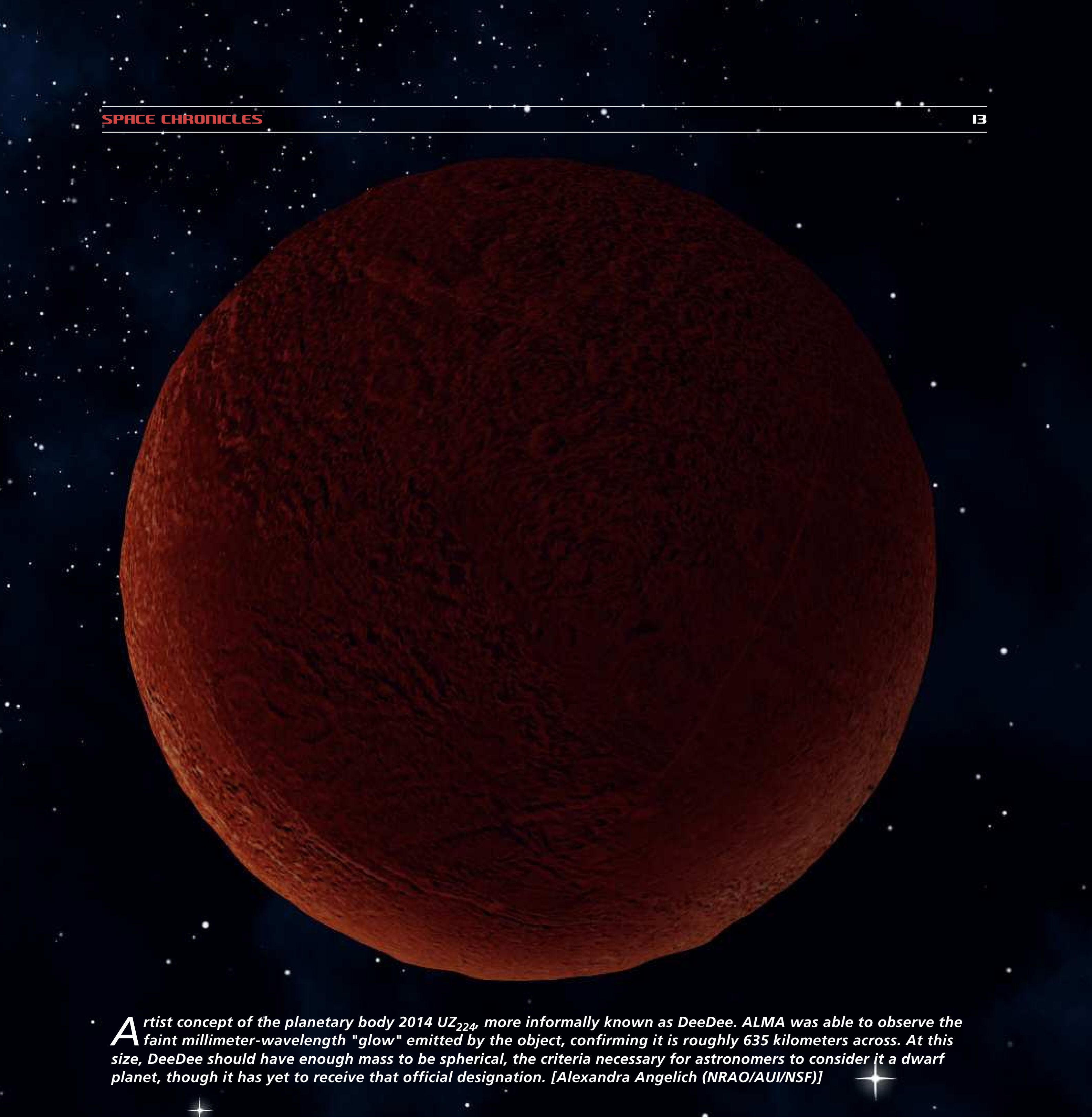
ALMA sees 'DeeDee', a distant, dim member of our Solar System

by ALMA Observatory

Using the Atacama Large Millimeter/submillimeter Array (ALMA), astronomers have revealed extraordinary details about a recently discovered far-flung member of our Solar System, the planetary body 2014 UZ_{224}, more informally known as DeeDee. At about three times the current distance of Pluto from the Sun, DeeDee is the second most distant known trans-Neptunian object (TNO) with a confirmed orbit, surpassed only by the dwarf planet Eris.

Astronomers estimate that there are tens-of-thousands of these icy bodies in the outer Solar System beyond the orbit of Neptune.

The new ALMA data reveal, for the first time, that DeeDee is roughly 635 kilometers across, or about two-thirds the diameter of the dwarf planet Ceres, the largest member of our asteroid belt. At this size, DeeDee should have enough mass to be spherical, the criteria necessary for astronomers to consider it a

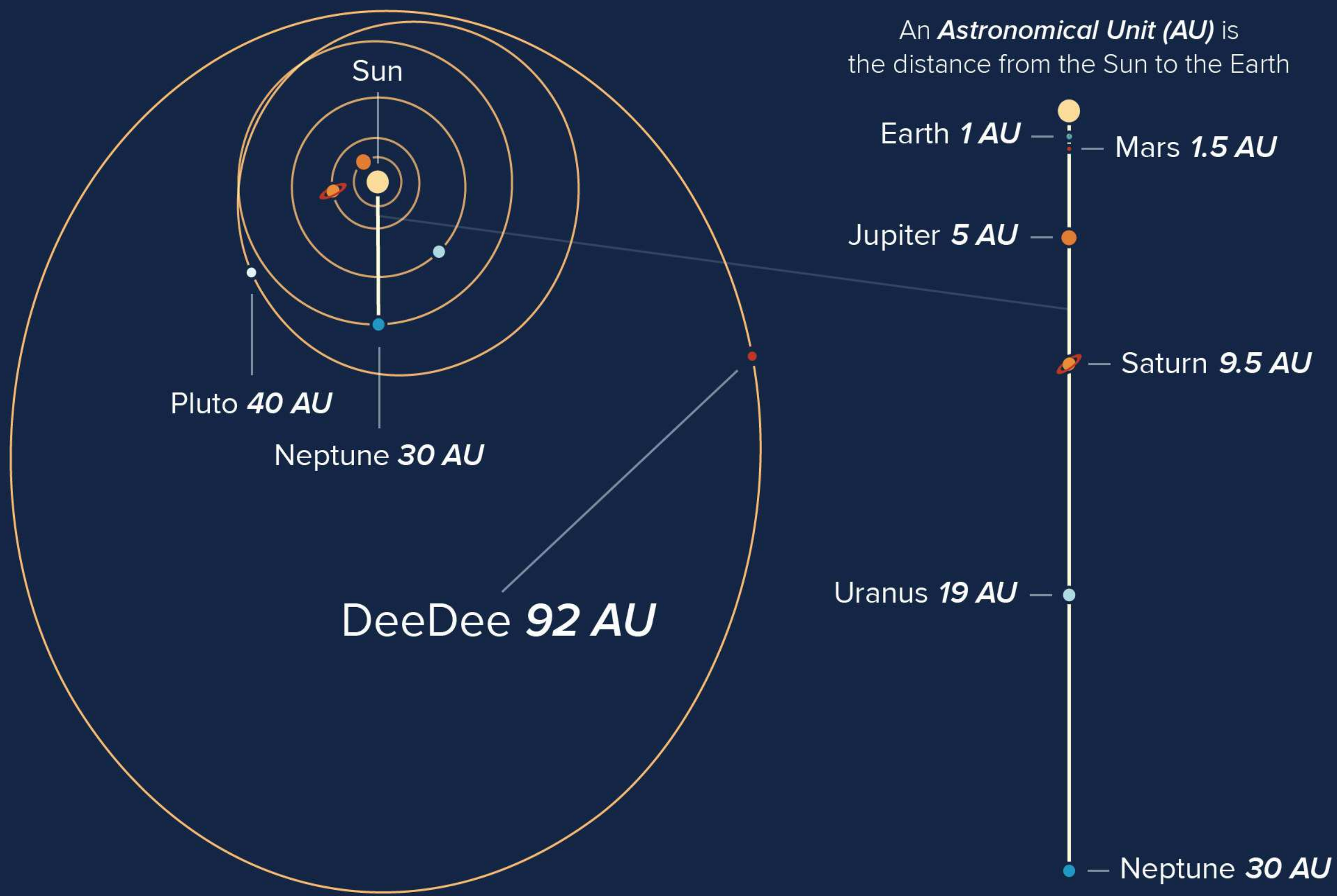


Artist concept of the planetary body 2014 UZ_{224}, more informally known as DeeDee. ALMA was able to observe the faint millimeter-wavelength "glow" emitted by the object, confirming it is roughly 635 kilometers across. At this size, DeeDee should have enough mass to be spherical, the criteria necessary for astronomers to consider it a dwarf planet, though it has yet to receive that official designation. [Alexandra Angelich (NRAO/AUI/NSF)]

dwarf planet, though it has yet to receive that official designation.

"Far beyond Pluto is a region surprisingly rich with planetary bodies. Some are quite small, but others have sizes to rival Pluto and could possibly be much larger," said David Gerdes, a scientist with the University of Michigan and lead author on a paper appeared in *The Astrophysical Journal Letters*. *"Because these objects are so distant and dim, it's incredibly difficult to even detect them, let alone study them in any detail. ALMA, however, has unique capabilities that enabled us to learn exciting details about these distant worlds."*

Currently, DeeDee is about 92 astronomical units (AU) from the Sun. An astronomical unit is the average distance from the Earth to the Sun or about 150 million kilometers. At this tremendous distance, it takes DeeDee more than 1,100 years to complete one orbit. Light from DeeDee takes nearly 13 hours to reach

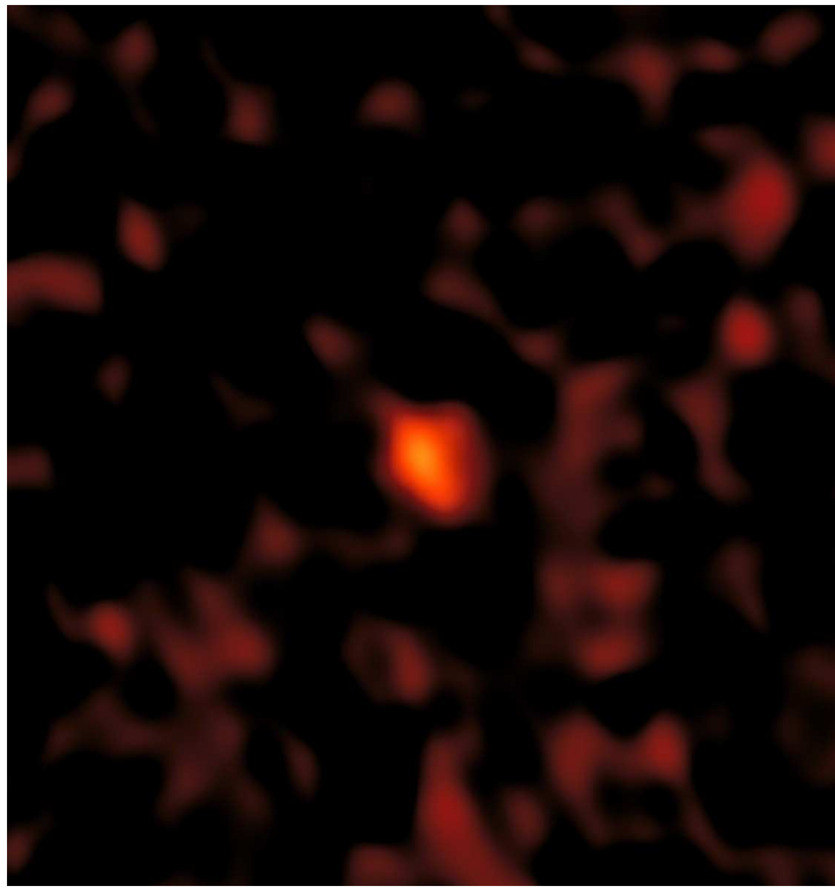


Orbits of objects in our Solar System, showing the current location of the planetary body 'DeeDee'. [Alexandra Angelich (NRAO/AUI/NSF)]

Earth. Gerdes and his team announced the discovery of DeeDee in the fall of 2016. They found it using the 4-meter Blanco telescope at the Cerro Tololo Inter-American Observatory in Chile as part of ongoing observations for the Dark Energy Survey, an optical survey of about 12 percent of the sky that seeks to understand the as-yet mysterious force that is accelerating the expansion of the universe.The Dark Energy Survey produces vast troves

Size comparisons of objects in our solar system, including the recently discovered planetary body 'DeeDee'. [Alexandra Angelich (NRAO/AUI/NSF)]

ALMA image of the faint millimeter-wavelength "glow" from the planetary body 2014 UZ_{224}, more informally known as DeeDee. At three times the distance of Pluto from the Sun, DeeDee is the second most distant known TNO with a confirmed orbit in our Solar System. [ALMA (ESO/NAOJ/NRAO)]



of astronomical images, which give astronomers the opportunity to also search for distant Solar System objects. The initial search, which includes nearly 15,000 images, identified more than 1.1 billion candidate objects. The vast majority of these turned out to be background stars and even more distant galaxies. A small fraction, however, were observed to move slowly across the sky over successive observations, the telltale sign of a TNO.

One such object was identified on 12 separate images. The astronomers informally dubbed it DeeDee, which is short for Distant Dwarf.

The optical data from the Blanco telescope enabled the astronomers to measure DeeDee's distance and orbital properties, but they were unable to determine its size or other physical characteristics. It was possible that DeeDee was a relatively small member of our Solar System, yet reflective enough to be detected from Earth. Or, it could be uncommonly large and dark, reflecting only a tiny portion of the feeble sunlight that reaches it. Both scenarios would produce identical optical data.

Since ALMA observes the cold, dark universe, it can detect the heat – in the form of millimeter-wavelength light – emitted naturally by cold objects in space. The heat signature from a distant Solar System object would be directly proportional to its size. *"We calculated that this object would be incredibly cold, only about 30 Kelvin, just a little above absolute zero,"* said Gerdes.

While the reflected visible light from DeeDee is only about as bright as a candle seen halfway the distance to the Moon, ALMA could quickly home in on the planetary body's heat signature and measure its brightness in the millimeter-wavelength light.

This allowed astronomers to determine that it reflects only about 13 percent of the sunlight that hits it. That is about the same reflectivity of the dry dirt found on a baseball infield.

By comparing these ALMA observations to the earlier optical data, the astronomers had the information necessary to calculate the object's size. *"ALMA picked it up fairly easily,"* said Gerdes. *"We were then able to resolve the ambiguity we had with the optical data alone."*

Objects like DeeDee are cosmic leftovers from the formation of the Solar System. Their orbits and physical properties reveal important details about the formation of planets, including Earth.

This discovery is also exciting because it shows that it is possible to detect very distant, slowly moving objects in our Solar System. The researchers note that these same techniques could be used to detect the hypothesized "Planet Nine" that may reside far beyond DeeDee and Eris. *"There are still new worlds to discover in our cosmic backyard,"* concludes Gerdes. *"The Solar System is a rich and complicated place."* ■

A new look at the Crab Nebula

by NRAO

Astronomers produced this dramatic new, highly-detailed image of the Crab Nebula by combining data from telescopes spanning nearly the entire breadth of the electromagnetic spectrum, from the long waves seen by the Karl G. Jansky Very Large Array (VLA) to the extremely short waves seen by the orbiting Chandra X-Ray Observatory.

The Crab Nebula, the result of a bright supernova explosion seen by Chinese and other astronomers in the year 1054, is some 6,500 light-years from Earth. At its center is a superdense neutron star, rotating once every 33 milliseconds, shooting out rotating lighthouse-like beams of radio waves and light — a pulsar.

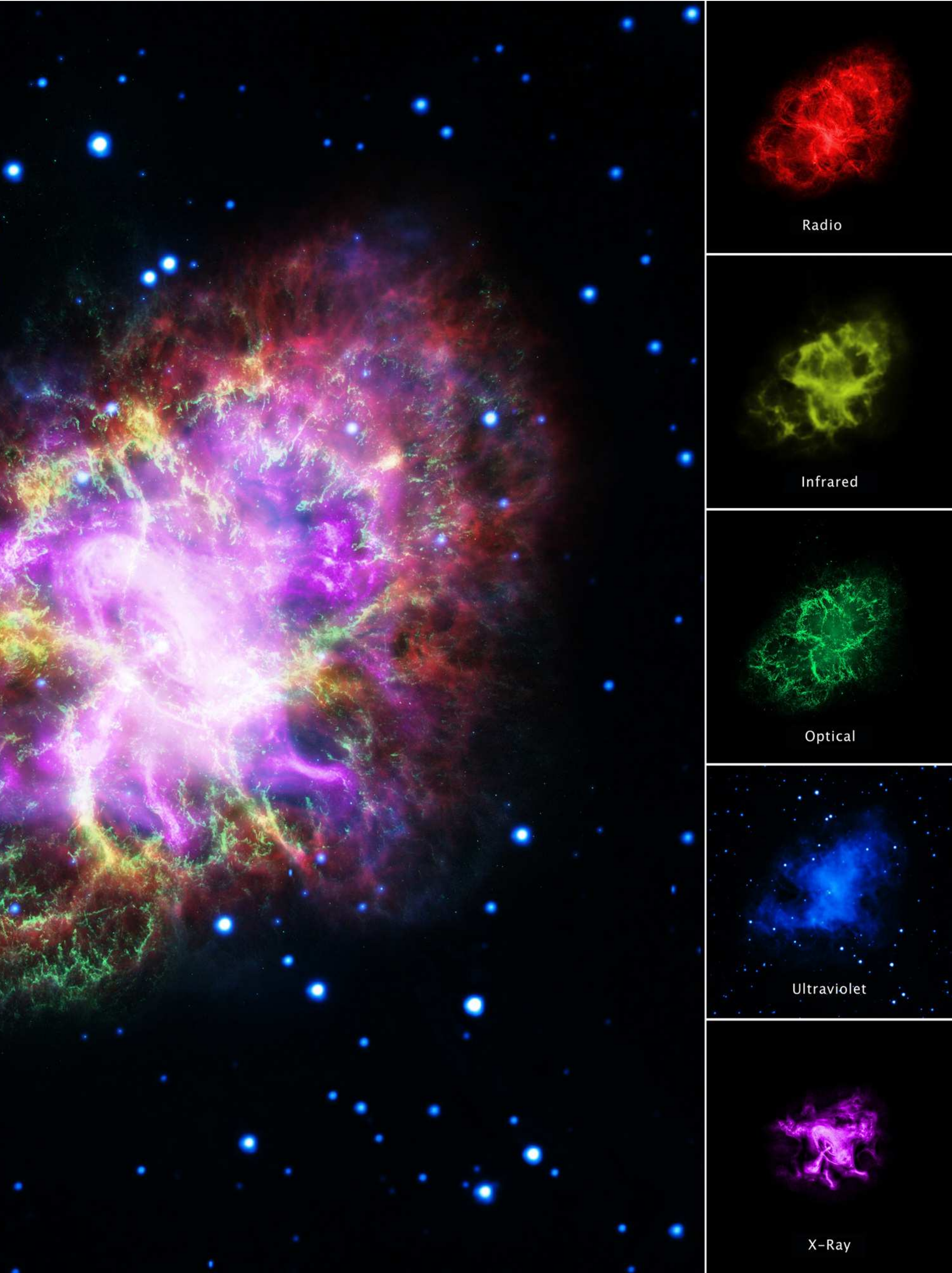
The nebula's intricate shape is caused by a complex interplay of the pulsar, a fast-moving wind of particles coming from the pulsar, and material originally ejected by the supernova explosion and by the star itself before the explosion.

This image combines data from five different telescopes: The VLA (radio) in red; Spitzer Space Telescope (infrared) in yellow; Hubble Space Telescope (visible) in green; XMM-Newton (ultraviolet) in blue; and Chandra X-Ray Observatory (X-ray) in purple. The new VLA, Hubble, and Chandra observations all were made at nearly the same time in November of 2012. A team of scientists led by Gloria Dubner of IAFE, the National Council of Scientific Research (CONICET), and the University of Buenos Aires in Argentina then made a detailed analysis of the newly-revealed details in a quest to gain new insights into the complex physics of the object. They are reporting their findings in *The Astrophysical Journal*.

New details from the study show interactions between fast-moving particles and magnetic fields similar to structures seen on the Sun, other features seen to appear at multiple wavelengths, and structures that may indicate features near the star before it exploded.

Two separate jets of material from near the pulsar appear in the X-ray and the radio images. *"Comparing these new images, made at different wavelengths, is providing us with a wealth of new detail about the Crab Nebula. Though the Crab has been studied extensively for years, we still have much to learn about it,"* Dubner said.

Combined image with, to the side, individual wavelength thumbnails. [G. Dubner (IAFE, CONICET-University of Buenos Aires) et al.; NRAO/ AUI/NSF; A. Loll et al.; T. Temim et al.; F. Seward et al.; Chandra/CXC; Spitzer/JPL-Caltech; XMM-Newton/ ESA; and Hubble/STScI]


Radio
Infrared
Optical
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Ripples in the Cosmic Web

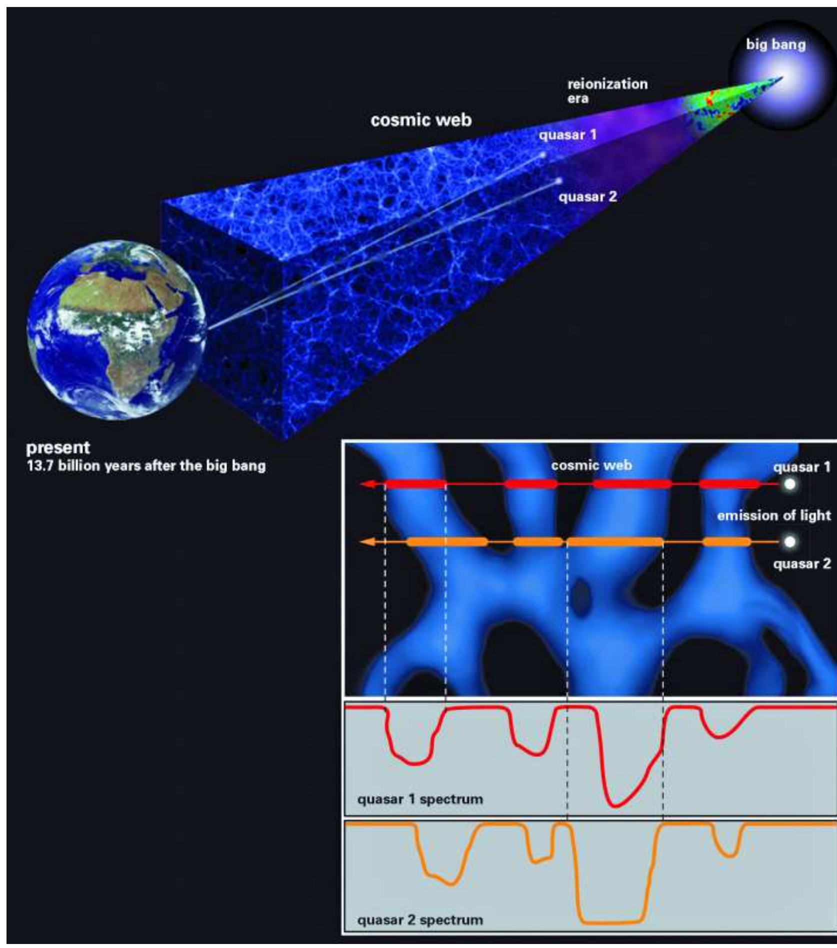
by Keck Observatory

Astronomers for the first time have measured small ripples in the cosmic web using W. M. Keck Observatory images of rare double quasars. The most barren regions of the Universe are the far-flung corners of intergalactic space. In these vast expanses between the galaxies there is just one solitary atom per cubic meter — a diffuse haze of hydrogen gas left over from the Big Bang. On the largest scales, this diffuse material is arranged in a vast network of filamentary structures known as the "cosmic web," its tangled strands spanning billions of light years and accounting for the majority of atoms in the Universe.

Now, a team of astronomers has made the first measurements of small-scale ripples in this primeval hydrogen gas. Although the regions of cosmic web they studied lie nearly 11 billion light years away, they were able to measure variations in its structure on scales 100,000 times smaller, comparable to the size of a single galaxy. The results appeared in the journal *Science*.

Intergalactic gas is so tenuous that it emits no light of its own. Instead astronomers study it indirectly by observing how it selectively absorbs the light coming from faraway sources known as quasars.

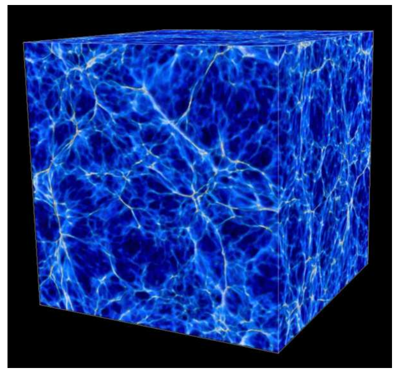
Quasars constitute a brief hyperluminous phase of the galactic lifecycle powered by the infall of matter onto a galaxy's central supermassive black hole. Quasars act like cosmic lighthouses — bright, distant beacons that allow astronomers to study intergalactic atoms residing between the location of the quasar and the Earth. But because these hyperluminous episodes last only a tiny fraction of a galaxy's lifetime, quasars are correspondingly rare on the sky and are typically separated by hundreds of millions of light years from each other. In order to probe the cosmic web on much smaller length scales, the astronomers exploited a fortuitous cosmic coincidence: They identified exceedingly rare pairs of quasars right next to each other on the sky and measured subtle differences in the absorption



Schematic representation of the technique used to probe the small-scale structure of the cosmic web using light from a rare quasar pair. The spectra (bottom right) contain information about the hydrogen gas the light has encountered, as well as the distance of that gas. [Springel et al. (2005) (Cosmic Web) / J. Neidel, MPIA] of intergalactic atoms measured along the two sightlines. *"Pairs of quasars are like needles in a haystack. In order to find them we combed through images of billions of celestial objects, millions of times fainter than what the naked eye can see,"* explains Joseph Hennawi, an associate professor at University of California Santa Barbara's Department of Physics. Hennawi pioneered the application of algorithms from 'machine learning', a branch of artificial intelligence, to efficiently locate quasar pairs in the massive amounts of data produced by digital imaging surveys of the night sky.

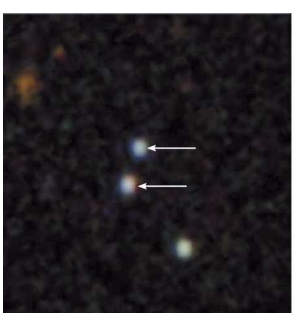
Once identified, the quasar pairs were observed with the largest telescopes in the world, including the 10-meter telescopes at the W. M. Keck Observatory on Maunakea, Hawaii. The University of California (UC) is a founding partner of Keck Observatory, and UC astronomers have access to its telescopes.

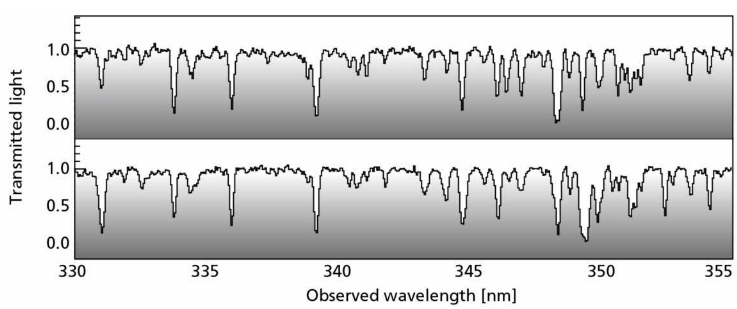
The discovery team gathered a majority of the data using the Low Resolution Imaging Spectrometer (LRIS), a faint-light instrument on the Keck I telescope capable of taking spectra and images of the most distant known objects in the Universe, along with the Echellette Spectrograph and Imager (ESI) on Keck II to capture high-resolution spectra of the rare double quasars.



Volume rendering of the output from a supercomputer simulation showing part of the cosmic web, 11.5 billion years ago. This and other models of the universe were generated and directly compared with quasar pair data in order to measure the small-scale ripples in the cosmic web. The cube is 24 million light years on a side. [J. Onorbe / MPIA]

"One of the biggest challenges was developing the mathematical and statistical tools to quantify the tiny differences we measured in this new kind of data," said lead author Alberto Rorai, Hennawi's former PhD student, who is now a postdoctoral researcher at Cambridge University. Rorai developed these tools as part of the research for his doctoral degree, and applied them to spectra of quasars obtained with Hennawi and other colleagues.





Spectra of both members of a close quasar pair used in the study. The subtle differences in the absorption features between the two sight lines allow the researchers to probe the small-scale structure of the cosmic web. [J. Onorbe / MPIA]

The astronomers compared their measurements to supercomputer models that simulate the formation of cosmic structures from the Big Bang to the present.

"The input to our simulations are the laws of physics and the output is an artificial Universe, which can be directly compared to astronomical data," said co-author Jose Oñorbe, a postdoctoral researcher at the Max Planck Institute for Astronomy who led the supercomputer simulation effort. *"I was delighted to see that these new measurements agree with the well-established paradigm for how cosmic structures form."*

On a single laptop, these complex calculations would have required almost 1,000 years to complete, but modern supercomputers enabled the researchers to carry them out in just a few weeks. *"One reason these small-scale fluctuations are so interesting is that they encode information about the temperature of gas in the cosmic web just a few billion years after the Big Bang,"* explained Hennawi.

Astronomers believe that the matter in the Universe went through phase transitions billions of years ago, which dramatically changed its temperature. These phase transitions, known as cosmic re-ionization, occurred when the collective ultraviolet glow of all stars and quasars in the Universe became intense enough to strip electrons off atoms in intergalactic space.

How and when re-ionization occurred is one of the biggest open questions in the field of cosmology, and these new measurements provide important clues that will help narrate this chapter of the history of the Universe. ■

A new transit KIC 8462852

by Michele Ferrara

Star KIC 8462852 could have remained an unsolved mystery for a long time, but there is already an opportunity to solve it once and for all. A few months ago, the star underwent a new reduction in brightness, one that could finally be observed with instruments powerful enough to see what was passing in front of the disc. It will be some time before we see the results of these observations, but we can review the situation in the meantime.

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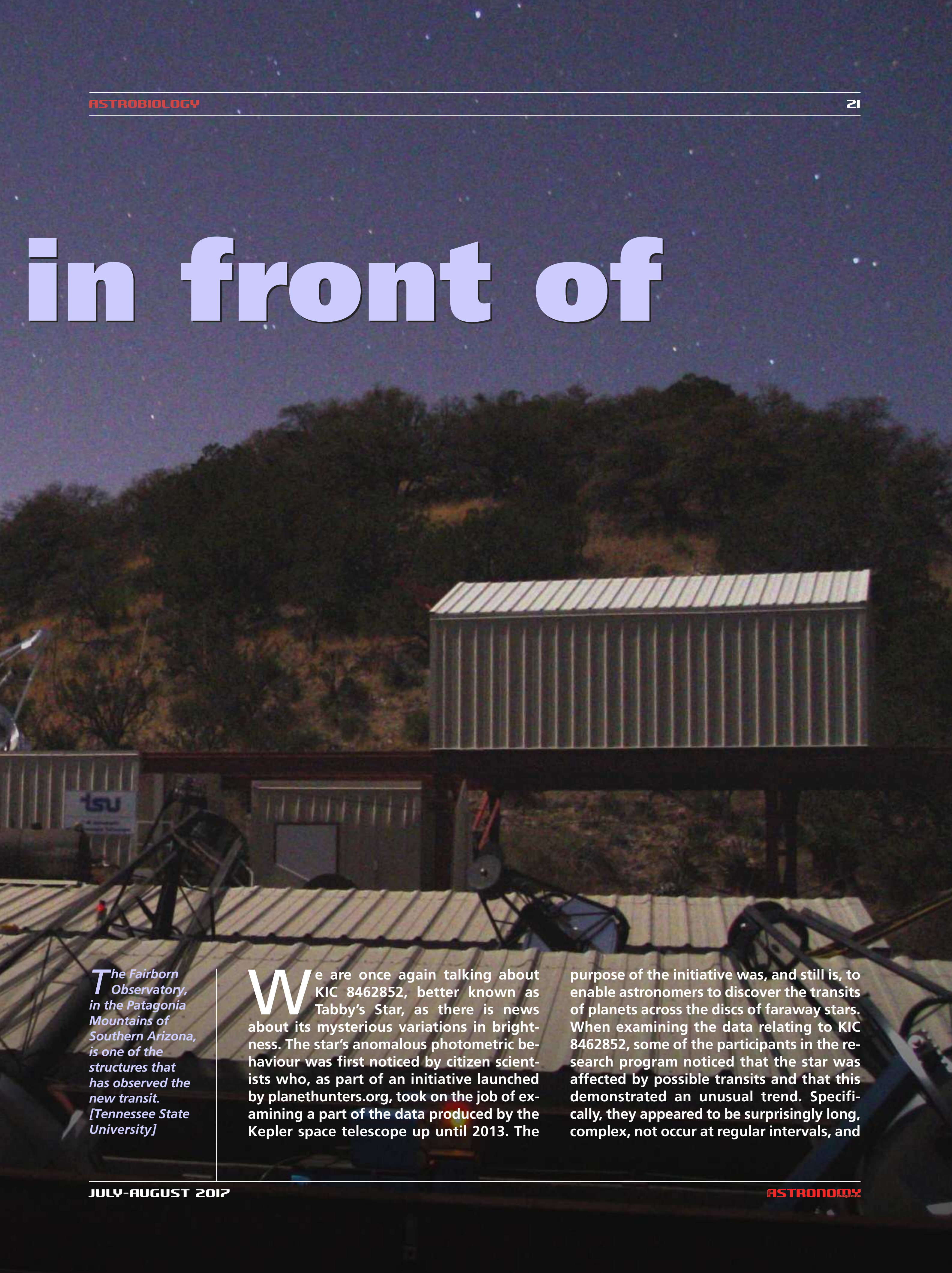
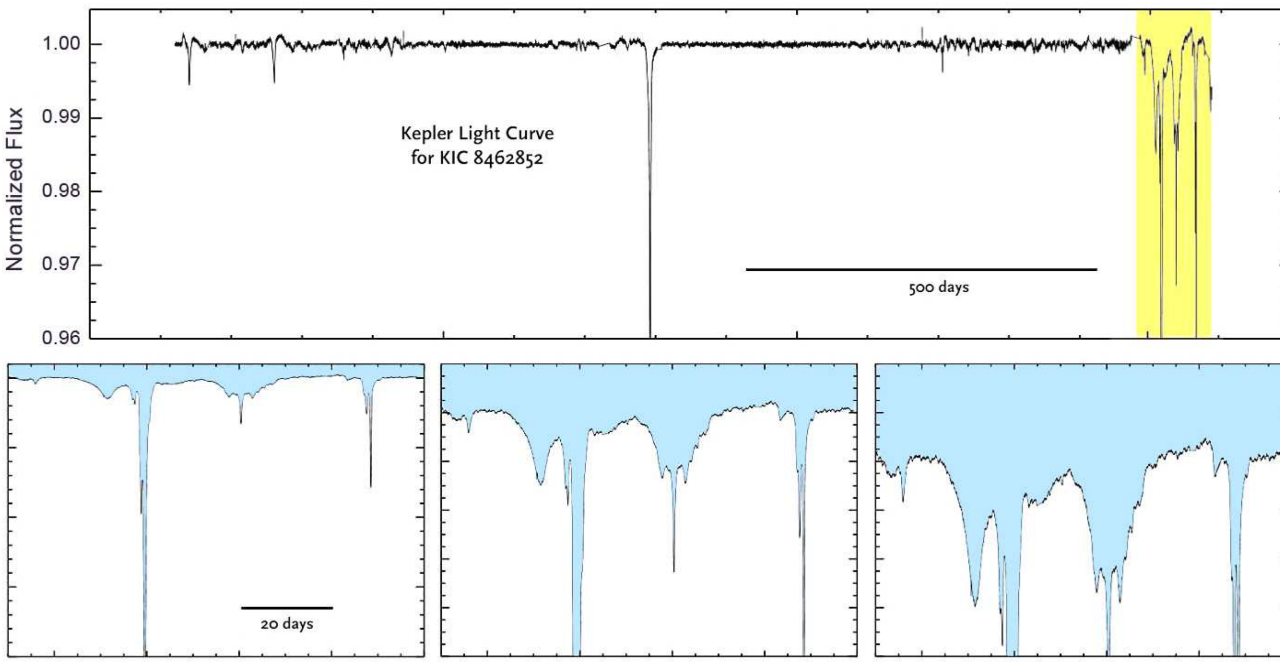


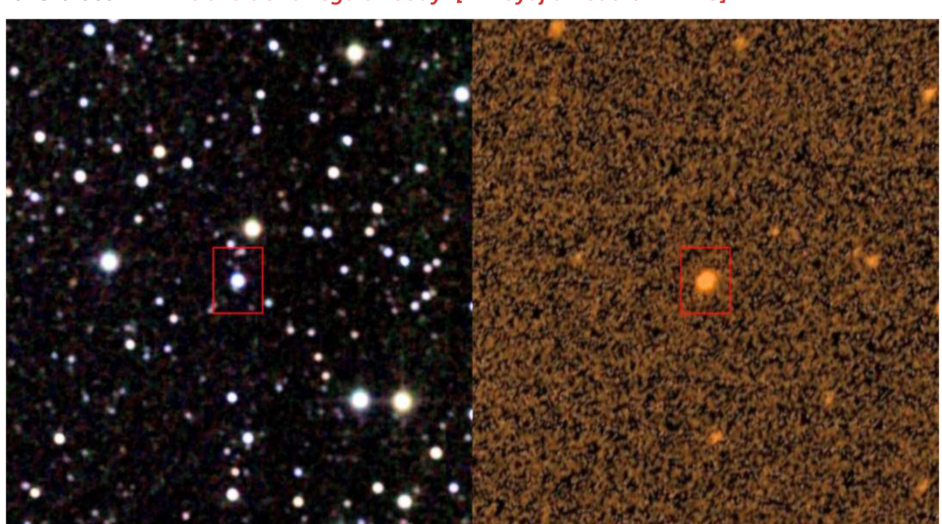
The Fairborn Observatory, in the Patagonia Mountains of Southern Arizona, is one of the structures that has observed the new transit. [Tennessee State University]

We are once again talking about KIC 8462852, better known as Tabby's Star, as there is news about its mysterious variations in brightness. The star's anomalous photometric behaviour was first noticed by citizen scientists who, as part of an initiative launched by planethunters.org, took on the job of examining a part of the data produced by the Kepler space telescope up until 2013. The purpose of the initiative was, and still is, to enable astronomers to discover the transits of planets across the discs of faraway stars. When examining the data relating to KIC 8462852, some of the participants in the research program noticed that the star was affected by possible transits and that this demonstrated an unusual trend. Specifically, they appeared to be surprisingly long, complex, not occur at regular intervals, and



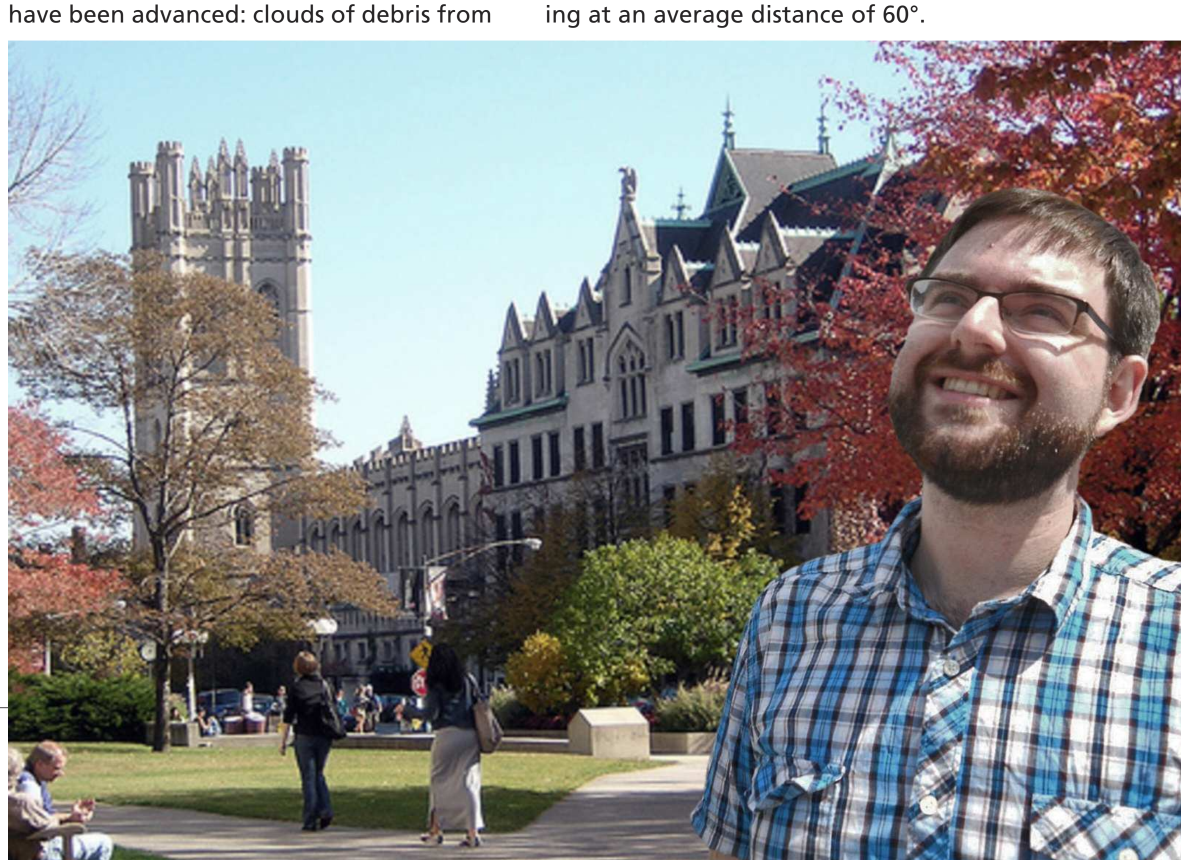
The highest graphic shows KIC 8462852's light curve in the 4 years that it was observed by the Kepler space telescope (2009 to 2013). The falls of light at the end of the curve, highlighted in yellow, are shown at different scales in the three windows here above.
The irregularity of the variations in light is such that it excludes the transit of a regular body. [T. Boyajian et al./MNRAS]

to have a minimum brightness that was sometimes incredibly profound.
In 2015, when Tabetha Boyajian (now at Louisiana State University, but working at Yale University at the time of the discovery), coordinator of the program, gathered this data and transformed it into a light curve, she realized she had not seen anything like it in any other star. The transits seemed to occur in groups and appeared as if they were in part produced by groups of gigantic objects. The lowest of the of the lows recorded was equivalent to the simultaneous transit of twenty planets as large as Jupiter in front of our Sun! Intrigued by the oddity of KIC 8462852, a few groups of researchers have begun to evaluate other photometric data that covers longer periods, something which has further complicated the already complex scenario by showing a slow weakening of the light over the centuries. In the last two



KIC 8462852 in infrared (2MASS survey, left) and in ultraviolet (GALEX). This apparently ordinary star is actually one of the most enigmatic objects in the Galaxy. Its true nature is, however, a few steps from being revealed. [IPAC/NASA (infrared); STScI/NASA (ultraviolet)]

years, very different hypotheses for interpreting the strange photometry of the star have been advanced: clouds of debris from destroyed planets, large masses of interstellar dust, enormous starspots, swarms of comets and artificial megastructures. Apart from this last hypothesis (without a doubt the boldest), all of the others were undermined by the size and intensity of the transits and, above all, of the weakening of the star over a long period. This last obstacle appears insurmountable even for one of the most recent hypothesis (in fact a variation of scenarios already proposed), presented in the *Monthly Notices of the Royal Astronomical Society* by a team of researchers led by Ballesteros (University of València). This study claims that the profound low of 2011, during which the star lost 15% of its brightness, could be attributed to the transit of a planet five times as big as Jupiter and encircled by an impressive system of rings. It would be precisely the structure and tilt of the rings, combined with the geometry of the transit, that made the latter asymmetrical. According to Ballesteros and colleagues, the series of less profound lows recorded by Kepler in 2013 could be explained by the existence of a large population of Trojan asteroids (similar to those of Jupiter, but on a much larger scale), which would follow the hypothetical gigantic planet in its orbit, remaining at an average distance of 60°.



Tabetha Boyajian is the head researcher in the study of the star and is also the source of its nickname, Tabby. Alongside is Benjiamin Montet, near the University of Chicago, where he works. He is one of the astronomers who has demonstrated KIC 8462852's variations in light over a long period.

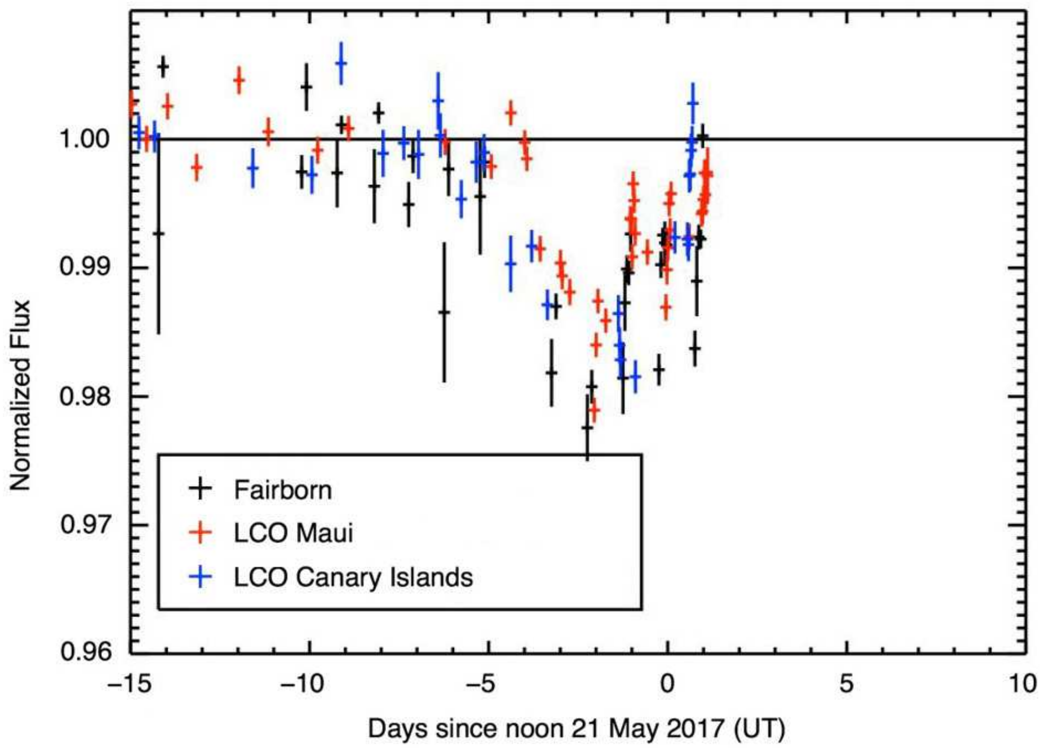
If this is the case and if, as occurs in our solar system, KIC 8462852's planet also has two groups like the Trojan asteroids, the one preceding the planet along its orbit should move across the stellar disc of KIC 8462852 in 2021, two years before the planet would be expected to transit again. As a whole, Ballesteros' team's hypothesis is no more convincing than the others. In fact, it would bring into play scenarios that so far have never been encountered in reality. However, it has the advantage of making a sufficiently precise forecast, which will determine its validity or inconsistency (if the question is not resolved first). And this is not the first time that researchers have predicted possible transits in front of KIC 8462852's disc. A previous hypothesis involved a collision between two planets in a distant orbit around 240 million km from the star, with a period of about 750 days. Such a scenario suggested that the clouds of debris produced by the event and responsible for the deepest of the reductions in light, would once again transit with less conspicuous effects (because of the dispersion of the debris) in May of 2017.

However, the prediction had not seemed particularly believable, because the planetary collision hypotheses was, from the be-

At the centre of the picture are the domes of the twin Keck telescopes, used in the study of the transit of last May. [W. M. Keck Obs.]

The Hobby-Eberly Telescope, another large instrument used for observing KIC 8462852's recent fall of light. [Marty Harris/ McDonald Observatory]

This graphic shows the photometric data of KIC 8462852 collected from three stations of the Las Cumbres Observatory over the course of the most recent transit. The time interval on the X-axis is 25 days and centred on 21 May (= 0). The Y-axis shows the change in comparison to normal brightness (= 1.00). The fall of light is very obvious. [T. Boyajian et al.]



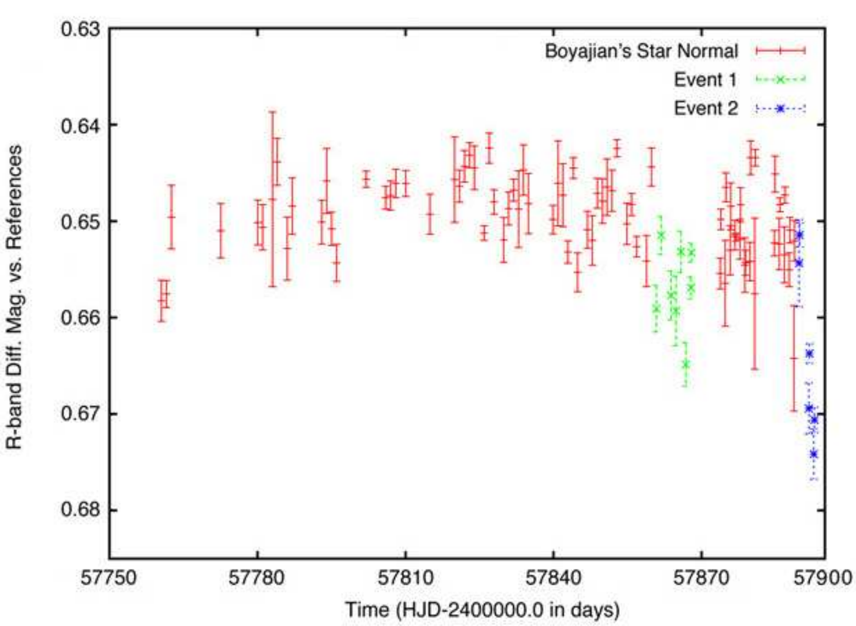
ginning, one of the weakest and most controversial. It was not, for example, capable of explaining other most modest reductions in light and imposed strong restrictions on the dynamics and timing of the event. In the end, it was calculated (by Boyajian and her colleagues) that Kepler could have had a reasonable probability of registering the effects of a collision between planets, over the period in which it was observing KIC 8462852, only if that kind of event occurs thousands of times in the life of a star, something which is not the case. After some technical problems in 2013 forced NASA to revise the Kepler mission, KIC 8462852 was no longer monitored systematically, and it is only within the last year that Tabetha Boyajian succeeded in raising the funds necessary to begin a program for the long-term observation of the star using the Las Cumbres Observatory Global Telescope Network (LCOGT). This global network consists of 18 robotic instruments, distributed over 6 sites that are distant enough from each other to allow continuous monitoring of KIC 8462852's brightness. On 24 April, one of these telescopes, belonging to the Fairborn Observatory in Arizona (managed by Tennessee State University), recorded a slight weakening of the star, within the margins of instrumental error, that disappeared over the course of a week, with the brightness returning to its normal levels (magnitude of +11.7).

However, it is only a month later that happened what astronomers hoped to be able to study directly. On 18 May, KIC 8462852's brightness began to decrease substantially, losing 2% in a single day. It was the first obvious reduction in light since 2013. Between 19 and 21 May the light from the star appeared to weaken by 3% compared to the previous weeks. Between 21 and 22 May the transit was over and everything returned to normal. For the first time, KIC 8462852's variations in brightness had been observed in real time. Surprisingly, this would seem to show that the planetary collision hypothesis was correct. But is that really the case or was it just a lucky coincidence? To find an answer, and to know if the mystery will finally be solved, will take several months, that is the time researchers need to analyse the photometric and spectroscopic data, and to draft the scientific articles in which they will present the results. The material collected in the few days of the minimum is abundant and of high-quality. Indeed, the observation campaign was also conducted with numerous high-powered professional instruments, among them some of the largest optical and radio telescopes in the world: the two 10-meter Keck telescopes in Hawaii; the 11.1×9.8-meter Hobby-Eberly telescope in Texas; the 8.4-meter (×2) Large Binocular Telescope and the 6.5-meter Multiple Mirror Telescope in Arizona; the 100-meter radio telescope in Green Bank, West Virginia; the 1227 m² Allen Telescope Array in California. The most eagerly awaited data is obviously the data relating to spectroscopic observations (carried out by a dozen different instruments), because it will settle various aspects of the question. Its physics-based interpretation will provide, for example, information about the nature of the material in transit and will make it possible to estimate a limit value for the mass of a possible object with large dimensions related to the recent reduction in light.

Clearly, professionals and amateur astronomers remain on alert for possible, additional transits across the disc of KIC 8462852. According to David Kipping of Columbia University, the transit last May could be the first episode in a series of similar events. There also seem to be similarities between the light curve of this last event and that of the previous transits observed by Kepler, something that would support the scenario in which the same object passes repeatedly in front of the stellar disc.

It is easy to foresee that this will not be the last opportunity to talk about the enigmatic star KIC 8462852. ■

David Kipping, astronomer at Columbia University, has suggested that the transit of the same May could be the first in a new series. [Kris Snibbe/Harvard University]



The preliminary analysis of the data collected shows a possible initial drop on 24 April (Event 1). On 18 May, a more significant reduction in light (Event 2) began, which put a vast network of telescopes on alert. [T. Boyajian et al.]

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Spirals inside a dust gap of a young star forming disk

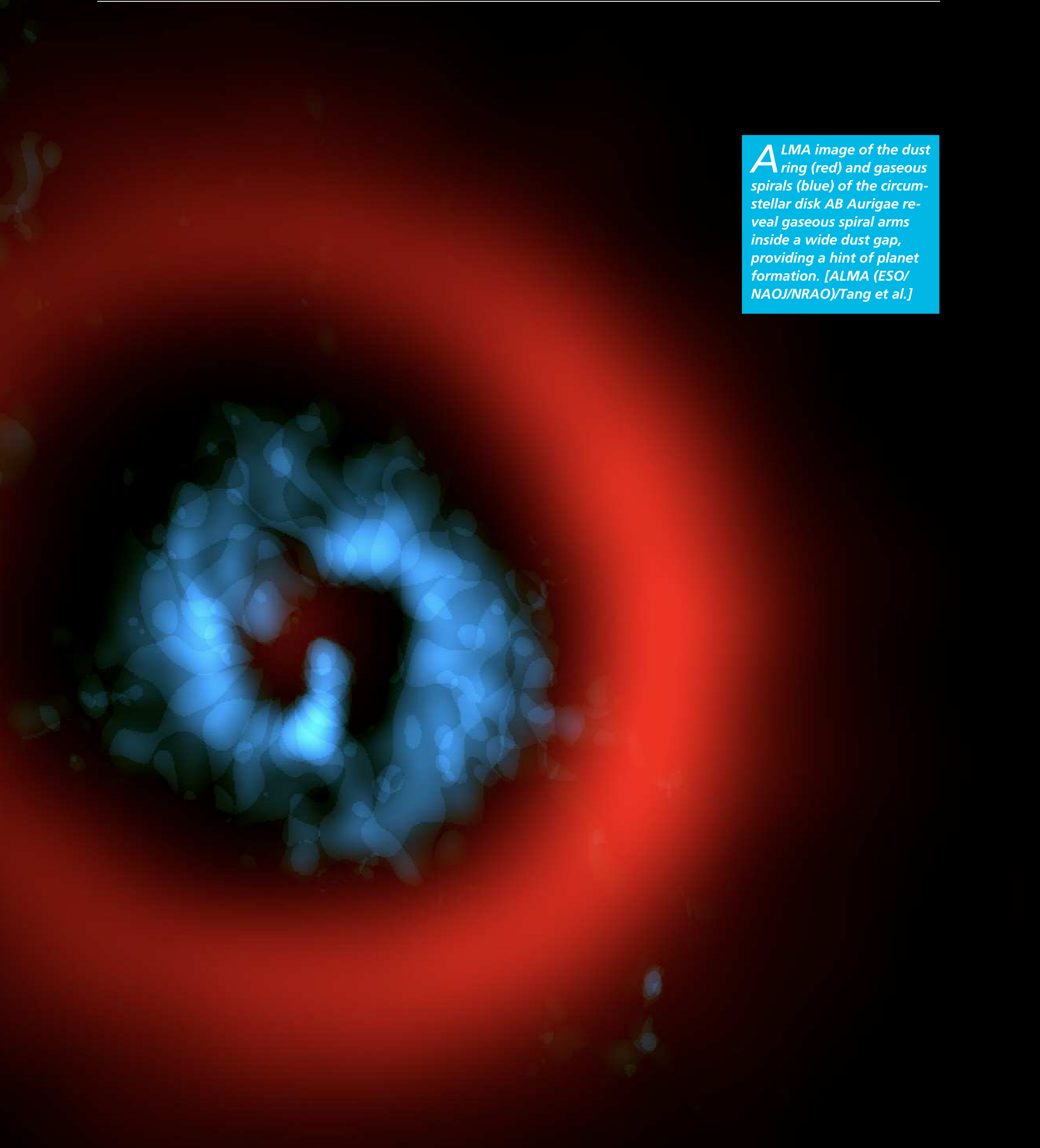
by ALMA Observatory

Planets form within disks composed of dust grains and gas. Planets can gather dust grains from their orbits, resulting in dust gaps or cavities, and can also cause spiral waves within the parental disks based on theoretical predictions. To understand where and when planets can form at early stages, ALMA's capability of seeing disk material with high resolution can depict smoking-gun evidence of infant planets hidden in disks. Both dust gaps and spirals have been seen separately in a handful of disks. The new ALMA images of AB Aurigae clearly depict gas spirals inside a wide dust gap.

These first reported gas spirals within a dust gap might indicate that there are at least 2 planets within this system. One planet at a distance of 80 astronomical units (au; the distance between the Sun and Earth) from the star is required to create the sharp dust ring. An additional planet at 30 au or closer from the star is required to produce such spirals.

These gas spirals further provide an additional dimension to our understanding of planet-disk interaction. Spirals previously seen in the near infrared image appear at the inner edge of the newly detected gas spirals. This can happen when the gas spirals are puffed up and thus scatter more stellar light at locations closer to the star.

The kinematics of gas within the spirals mostly follows the disk rotation. It is only at the putative planet location at 30 au from the star that gas has higher velocities, suggesting streaming motions near the planet. ■



ALMA image of the dust ring (red) and gaseous spirals (blue) of the circumstellar disk AB Aurigae reveal gaseous spiral arms inside a wide dust gap, providing a hint of planet formation. [ALMA (ESO/NAOJ/NRAO)/Tang et al.]

Moon spotted around third largest dwarf planet

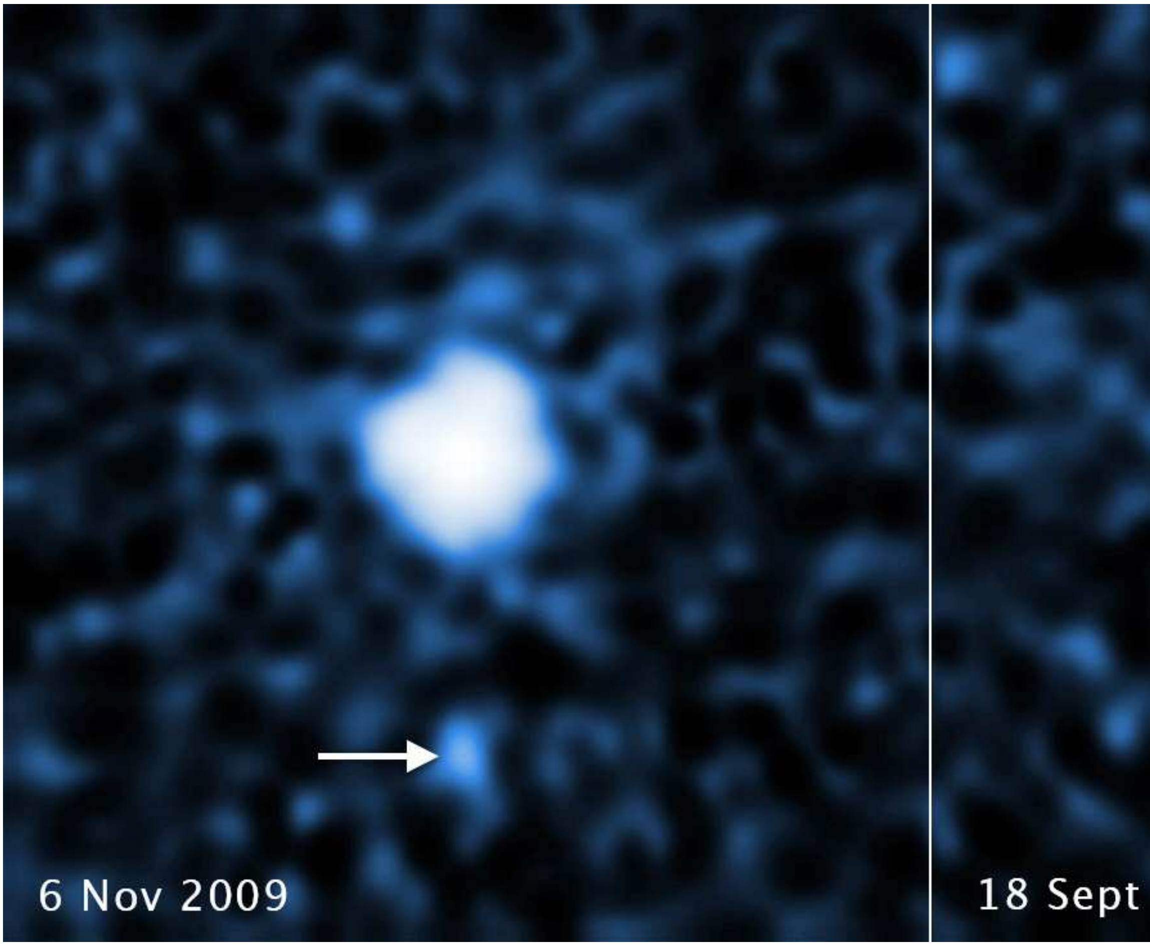
by NASA/ESA

The combined power of three space observatories, including NASA's Hubble Space Telescope, has helped astronomers uncover a moon orbiting the third largest dwarf planet, catalogued as 2007 OR_{10}. The pair resides in the frigid outskirts of our solar system called the Kuiper Belt, a realm of icy debris left over from our solar system's formation 4.6 billion years ago.

With this discovery, most of the known dwarf planets in the Kuiper Belt larger than 600 miles across have companions. These bodies provide insight into how moons formed in the young solar system.

"The discovery of satellites around all of the known large dwarf planets — except for Sedna — means that at the time these bodies formed billions of years ago, collisions must have been more frequent, and that's a constraint on the formation models," said Csaba Kiss of the Konkoly Observatory in Budapest, Hungary. He is the lead author of the science paper announcing the moon's discovery. *"If there were frequent collisions, then it was quite easy to form these satellites."*

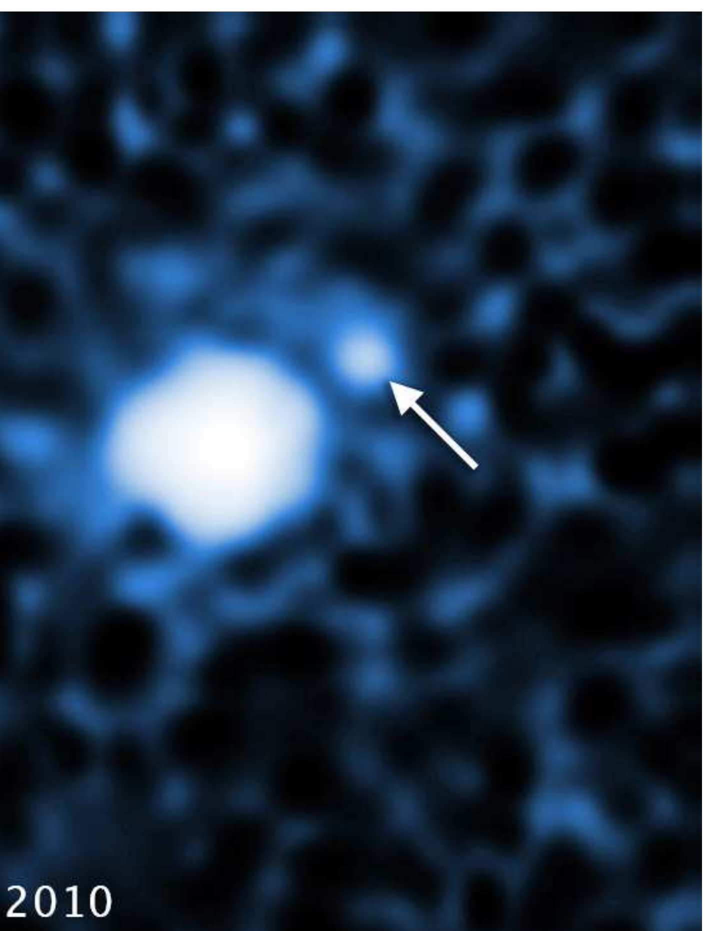
The objects most likely slammed into each other more often because



they inhabited a crowded region. *"There must have been a fairly high density of objects, and some of them were massive bodies that were perturbing the orbits of smaller bodies,"* said team member John Stansberry of the Space Telescope Science Institute in Baltimore, Maryland. *"This gravitational stirring may have nudged the bodies out of their orbits and increased their relative velocities, which may have resulted in collisions."* But the speed of the colliding objects could not have been too fast or too slow, according to the astronomers. If the impact velocity was too fast, the smash-up would have created lots of debris that could have escaped from the system; too slow and the collision would have produced only an impact crater.

Collisions in the asteroid belt, for example, are destructive because objects are traveling fast when they smash together. The asteroid belt is a region of rocky debris between the orbits of Mars and the gas giant Jupiter. Jupiter's powerful gravity speeds up the orbits of asteroids, generating violent impacts.

The team uncovered the moon in archival images of 2007 OR_{10} taken by Hubble's Wide Field Camera 3. Observations taken of the dwarf planet by NASA's Kepler Space Telescope first tipped off the astronomers of the possibility of a moon circling it. Kepler revealed that 2007 OR_{10} has a slow rotation period of 45 hours. *"Typical rotation periods for Kuiper Belt Objects are under 24 hours,"* Kiss said. *"We looked in the Hubble archive because the slower rotation period could have been caused by the gravitational tug of a moon. The initial investigator missed the moon in the Hubble images because it is very faint."*



These two images, taken a year apart, reveal a moon orbiting the dwarf planet 2007 OR_{10}. Each image, taken by the Hubble Space Telescope's Wide Field Camera 3, shows the companion in a different orbital position around its parent body. 2007 OR_{10} is the third-largest known dwarf planet, behind Pluto and Eris, and the largest unnamed world in the solar system. The pair is located in the Kuiper Belt, a realm of icy debris left over from the solar system's formation. The dwarf planet is about 950 miles across; the moon is estimated to be 150 miles to 250 miles in diameter. 2007 OR_{10}, like Pluto, follows an eccentric orbit, but it is currently three times farther than Pluto is from the Sun. [NASA, ESA, C. Kiss (Konkoly Observatory), and J. Stansberry (STScI)]

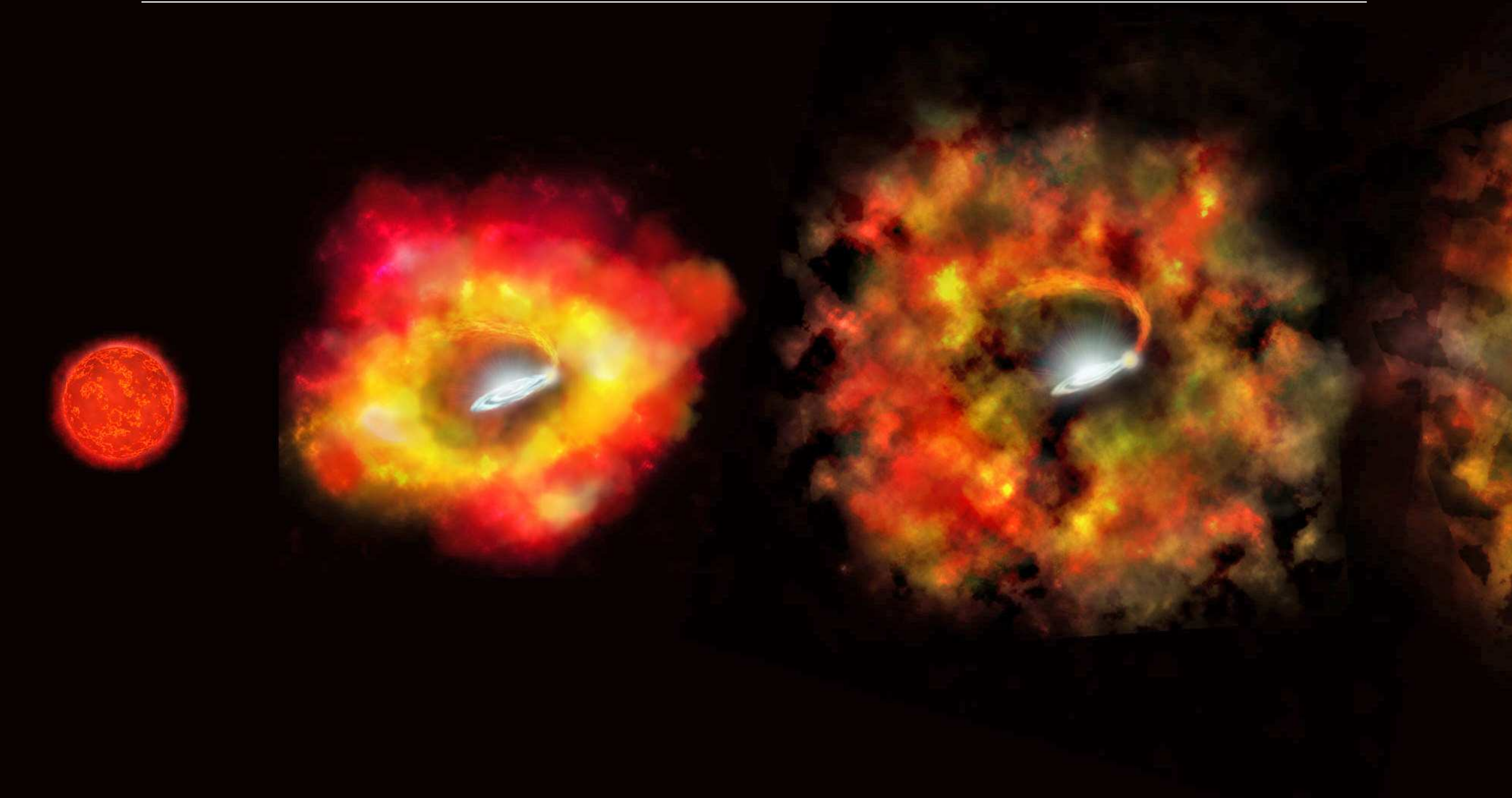
The astronomers spotted the moon in two separate Hubble observations spaced a year apart. The images show that the moon is gravitationally bound to 2007 OR_{10} because it moves with the dwarf planet, as seen against a background of stars. However, the two observations did not provide enough information for the astronomers to determine an orbit.

"Ironically, because we don't know the orbit, the link between the satellite and the slow rotation rate is unclear," Stansberry said.

The astronomers calculated the diameters of both objects based on observations in far-infrared light by the Herschel Space Observatory, which measured the thermal emission of the distant worlds. The dwarf planet is about 950 miles across, and the moon is estimated to be 150 miles to 250 miles in diameter. 2007 OR_{10}, like Pluto, follows an eccentric orbit, but it is currently three times farther than Pluto is from the sun.

2007 OR_{10} is a member of an exclusive club of nine dwarf planets. Of those bodies, only Pluto and Eris are larger than 2007 OR_{10}. It was discovered in 2007 by astronomers Meg Schwamb, Mike Brown, and David Rabinowitz as part of a survey to search for distant solar system bodies using the Samuel Oschin Telescope at the Palomar Observatory in California.

The team's results appeared in *The Astrophysical Journal Letters*.



Collapsing star gives birth to a black hole

by NASA/ESA

Astronomers have watched as a massive, dying star was likely reborn as a black hole. It took the combined power of the Large Binocular Telescope (LBT), and NASA's Hubble and Spitzer space telescopes to go looking for remnants of the vanquished star, only to find that it disappeared out of sight. It went out with a whimper instead of a bang.

The star, which was 25 times as massive as our Sun, should have exploded in a very bright supernova. Instead, it fizzled out—and then left behind a black hole.

"Massive fails" like this one in a nearby galaxy could explain why astronomers rarely see supernovae from the most massive stars, said Christopher Kochanek, professor of astronomy at The Ohio State University and the Ohio Eminent Scholar in Observational Cosmology.

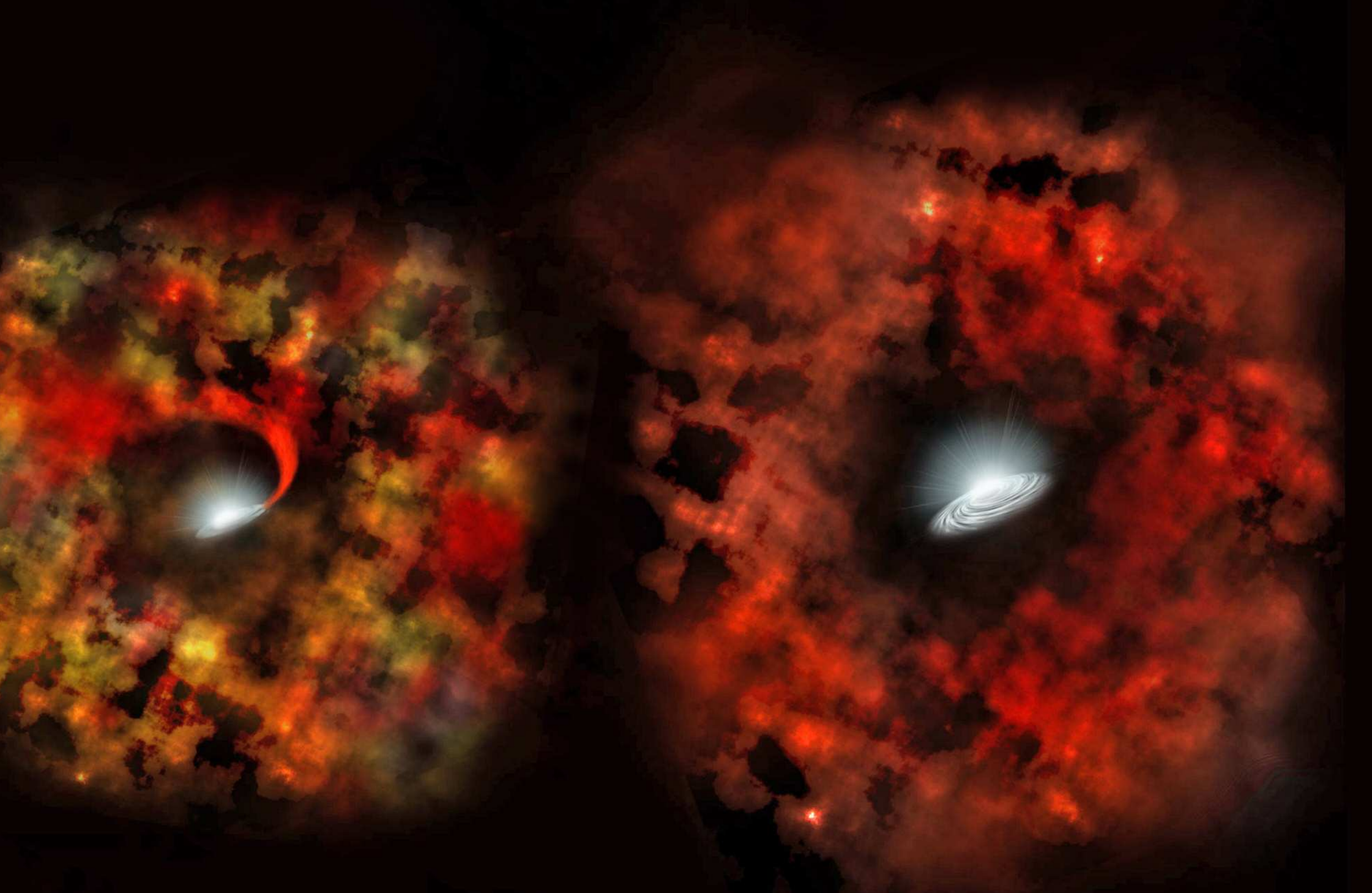
As many as 30 percent of such stars, it seems, may quietly collapse into black holes — no supernova required.

"The typical view is that a star can form a black hole only after it goes supernova," Kochanek explained. *"If a star can fall short of a supernova and still make a black hole, that would help to explain why we don't see supernovae from the most massive stars."*

He leads a team of astronomers who published their latest results in the *Monthly Notices of the Royal Astronomical Society*.

Among the galaxies they've been watching is NGC 6946, a spiral galaxy 22 million light-years away that is nicknamed the "Fireworks Galaxy" because supernovae frequently happen there — the last one was SN 2017eaw, discovered on May 14th. Starting in 2009, one particular star, named N6946-BH1, began to brighten weakly. By 2015, it appeared to have winked out of existence.

After the LBT survey for failed supernovas turned up the star, astronomers aimed the Hubble and Spitzer space telescopes to see if it



This illustration shows the final stages in the life of a supermassive star that fails to explode as a supernova but instead implodes under gravity to form a black hole. From left to right: the massive star has evolved to a red supergiant, the envelope of the star is ejected and expands, producing a cold, red transient source surrounding the newly formed black hole. Some residual material may fall onto the black hole, as illustrated by the stream and the disk, potentially powering some optical and infrared emissions years after the collapse. [NASA, ESA, and P. Jeffries (STScI)]

was still there but merely dimmed. They also used Spitzer to search for any infrared radiation emanating from the spot. That would have been a sign that the star was still present, but perhaps just hidden behind a dust cloud. All the tests came up negative. The star was no longer there. By a careful process of elimination, the researchers eventually concluded that the star must have become a black hole.

It's too early in the project to know for sure how often stars experience massive fails, but Scott Adams, a former Ohio State student who recently earned his Ph.D. doing this work, was able to make a preliminary estimate.

"N6946-BH1 is the only likely failed supernova that we found in the first seven years of our survey. During this period, six normal supernovae have occurred within the galaxies we've been monitoring, suggesting that 10 to 30 percent of massive stars die as failed supernovae," he said. *"This is just the fraction that would explain the very problem that motivated us to start the survey, that is, that there are fewer observed supernovae than should be occurring if all massive stars die that way."*

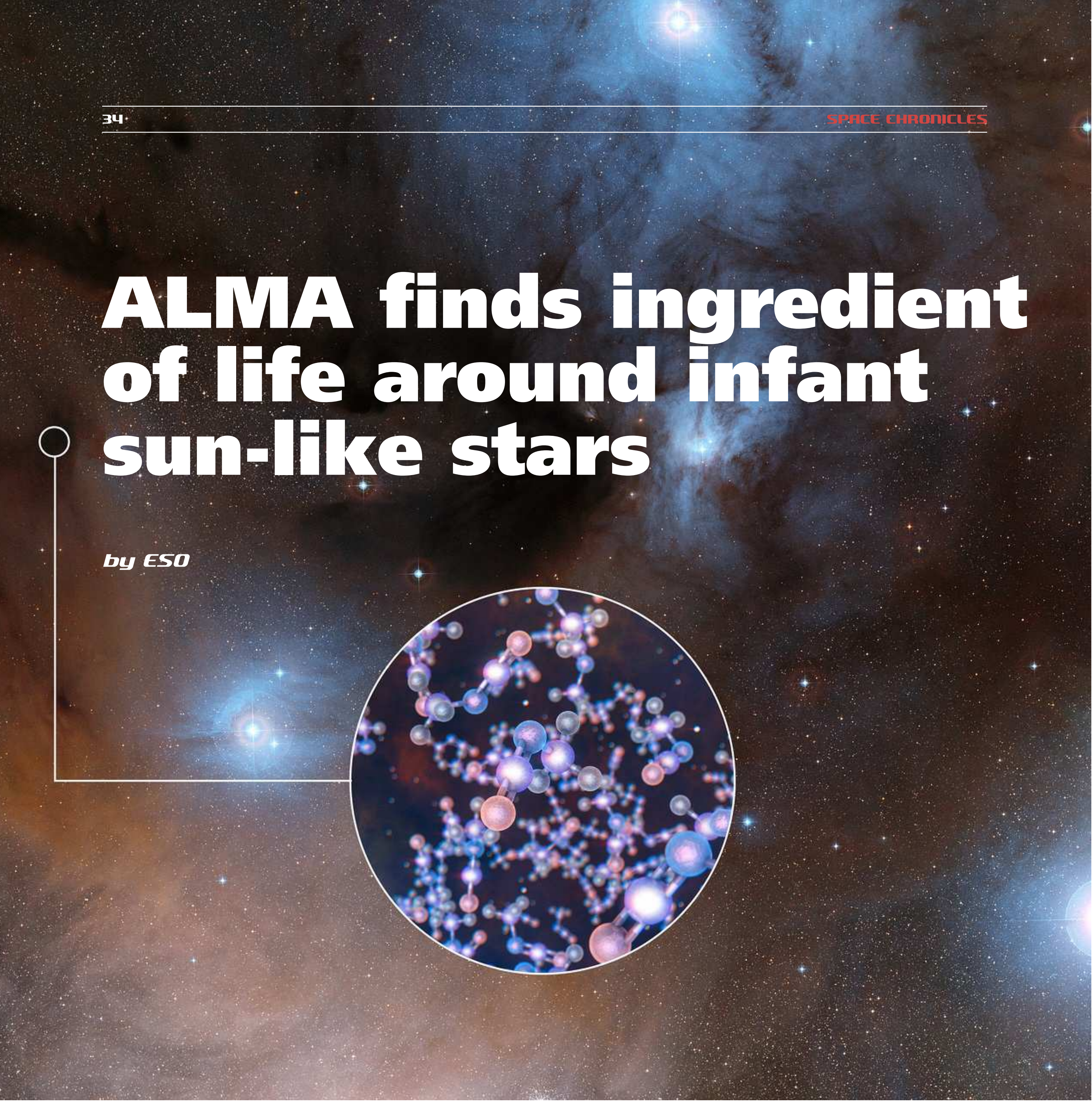
To study co-author Krzysztof Stanek, the really interesting part of the discovery is the implications it holds for the origins of very massive black holes — the kind that the LIGO experiment detected via gravitational waves. (LIGO is the Laser Interferometer Gravitational-Wave Observatory.) It doesn't necessarily make sense, said Stanek, professor of astronomy at Ohio State, that a massive star could undergo a supernova — a process which entails blowing off much of its outer layers — and still have enough mass left over to form a massive black hole on the scale of those that LIGO detected.

"I suspect it's much easier to make a very massive black hole if there is no supernova," he concluded.

Adams is now an astrophysicist at Caltech. Other co-authors were Ohio State doctoral student Jill Gerke and University of Oklahoma astronomer Xinyu Dai. Their research was supported by the National Science Foundation.

ALMA finds ingredient of life around infant sun-like stars

by ESO



ALMA has observed stars like the Sun at a very early stage in their formation and found traces of methyl isocyanate — a chemical building block of life. This is the first ever detection of this prebiotic molecule towards a solar-type protostar, the sort from which our Solar System evolved. The discovery could help astronomers understand how life arose on Earth. This image shows the spectacular region of star formation where methyl isocyanate was found. The insert shows the molecular structure of this chemical. [ESO/Digitized Sky Survey 2/L. Calçada]

Two teams of astronomers have harnessed the power of the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile to detect the prebiotic complex organic molecule methyl isocyanate in the multiple star system IRAS 16293-2422. A complex organic molecule is defined in astrochemistry as consisting of six or more atoms, where at least one of the atoms is carbon. Methyl isocyanate contains carbon, hydrogen, nitrogen and oxygen atoms in the chemical configuration CH_3NCO.

This video summarizes the discovery made by the two teams using the Atacama Large Millimeter/submillimeter Array. [ESO]

One team was co-led by Rafael Martín-Doménech at the Centro de Astrobiología in Madrid, Spain, and Víctor M. Rivilla, at the INAF-Osservatorio Astrofisico di Arcetri in Florence, Italy; and the other by Niels Ligterink at the Leiden Observatory in the Netherlands and Audrey Coutens at University College London, United Kingdom.

"This star system seems to keep on giving! Following the discovery of sugars, we've now found methyl isocyanate. This family of organic molecules is involved in the synthesis of peptides and amino acids, which, in the form of proteins, are the biological basis for life as we know it," explain Niels Ligterink and Audrey Coutens.

The system was previously studied by ALMA in 2012 and found to contain molecules of the simple sugar glycolaldehyde, another ingredient for life.

ALMA's capabilities allowed both teams to observe the molecule at several different and characteristic wavelengths across the radio spectrum. The team led by Rafael Martín-Doménech used new and archive data of the protostar taken across a large range of wavelengths across ALMA's receiver Bands 3, 4 and 6. Niels Ligterink and his colleagues used data from the ALMA Protostellar Interferometric Line Survey (PILS), which aims to chart the chemical complexity of IRAS 16293-2422 by imaging the full wavelength range covered by ALMA's Band 7 on very small scales, equivalent to the size of our Solar System.

The teams found the unique chemical fingerprints located in the warm, dense inner regions of the cocoon of dust and gas surrounding young stars in their earliest stages of evolution. Each team identified and isolated the signatures of the complex organic molecule methyl isocyanate. The teams carried out spectrographic analysis of the protostar's light to determine the chemical constituents. The amount of methyl isocyanate they detected — the abundance — with respect to molecular hydrogen and other tracers is comparable to previous detections around two high-mass protostars (i.e. within the massive hot molecular cores of Orion KL and Sagittarius B2 North).

They then followed this up with computer chemical modelling and laboratory experiments to refine our understanding of the molecule's origin. Martín-Doménech's team chemically modelled gas-grain formation of methyl isocyanate. The observed amount of the molecule could be explained by chemistry on the surface of dust grains in space, followed by chemical reactions in the gas phase. Moreover, Ligterink's team demonstrated that the molecule can be formed at extremely cold interstellar temperatures, down to 15 Kelvin (–258 degrees Celsius), using cryogenic ultra-high-vacuum experiments in their laboratory in Leiden.

IRAS 16293-2422 is a multiple system of very young stars, around 400 light-years away in a large star-forming region called Rho Ophiuchi in the constellation of Ophiuchus (The Serpent Bearer). The new results from ALMA show that methyl isocyanate gas surrounds each of these young stars.

Earth and the other planets in our Solar System formed from the material left over after the formation of the Sun. Studying solar-type protostars can therefore open a window to the past for astronomers and allow them to observe conditions similar to those that led to the formation of our Solar System over 4.5 billion years ago.

Rafael Martín-Doménech and Víctor M. Rivilla, lead authors of one of the papers, comment: *"We are particularly excited about the result because these protostars are very similar to the Sun at the beginning of its lifetime, with the sort of conditions that are well suited for Earth-sized planets to form. By finding prebiotic molecules in this study, we may now have another piece of the puzzle in understanding how life came about on our planet."*

Niels Ligterink is delighted with the supporting laboratory results: *"Besides detecting molecules we also want to understand how they are formed. Our laboratory experiments show that methyl isocyanate can indeed be produced on icy particles under very cold conditions that are similar to those in interstellar space This implies that this molecule — and thus the basis for peptide bonds — is indeed likely to be present near most new young solar-type stars."*

Looking for

by Michele Ferrara

The images in this article, real works of art by well-known space illustrators, have been selected to depict hypothetical scenarios which could have actually occurred in our planetary system in the very remote past, and of which traces could still exist. A new branch of scientific research, space archaeology, concerns itself with these themes and might one day turn our view of the world upside down.

an alien past

Artwork by Malte Langheim

Most of those who communicate science to the public no longer venture into “minefields” where it is difficult to identify possible truths, submerged as they are beneath mountains of trash. It sometimes has to be done, however, to prevent topics of undeniable scientific interest and value from becoming the preserve of charlatans and speculators. One of these topics is the possibility that, in the dim and distant past, Earth may have been home – for either short or long periods of time – to representatives of an alien technological civilisation. By the term “alien” we mean here a civilisation which is not necessarily extra-terrestrial, but different from the human one of which we are part, which has as its earliest ancestor (in common with many other contemporary species) the Saccorhytus: a primitive animal just 1 millimetre in size, which appeared about 540 million years ago, at the time of the great explosion of life in the

Cambrian Period, and of which the first fossil has recently been discovered. Inevitably, many people associate the term "alien" with the UFO phenomenon, but the two have virtually nothing in common. The UFO phenomenon is essentially a fashion which emerged at the end of the Second World War and was embraced by all those who, lacking objectivity and/or sufficient scientific knowledge, interpret certain sightings as proof of the existence of extraterrestrial beings.

The facts indicate that none of the tens of thousands of sightings so far reported has ever demonstrated the existence of aliens. Ufology instead feeds a squalid business founded on the ignorance and credulity of the populace, and is used as an opportunistic shortcut by people who are interested in spreading their own opinions without testing them against scientific realities. It is curious that almost all of these sightings have been concentrated in the last 70 years, with a small minority of reports arising in earlier periods of history. Our planet has been here to be explored for around 4 billion years, and it would be bizarre to think that space journeys by various alien technological civilisations (surely more than one, based on the grotesque reports of the self-styled "contactists"), begun in times and places inevitably long distances apart, should have been focussed directly on our planet and right in this most recent, tiny period of time. If we stretch out the 4 billion years along the classic solar calendar, we notice that the last 70 years rep-


Artwork by Angus Mckie

resent the last half second before the stroke of midnight that brings in the New Year on 31 December! If the Earth and the other planetary bodies in our solar system have ever been visited by alien intelligences, it is much more likely that this will have occurred in a remote age, rather than during the "pop" of the Champagne. Objecting that it has been our telecommunications which have attracted hordes of extraterrestrials in recent decades would be naive, given that any message sent into space by us, whether voluntary or involuntary, would be, in terms of the distance it would have travelled, still on the doorstep, astronomically (and astrobiologically) speaking. If we assume that we are not the only technological civilisation in the Galaxy, given that it has been in existence for at least 12 billion years (some of its structures and stars are significantly older), we can reasonably assert that the first technological civilisations appeared and developed within it billions of years before the birth of our solar system. Even if it is impossible for us to imagine the physical, biological and technological knowledge of a civilisation that has managed to prosper for hundreds of thousands, if not millions (in theory, even billions) of years, our current knowledge is enough for us to assume that a long-lasting alien civilisation would certainly be able to send its probes, or even whole colonies, to any habitable (or inhabited) planet in the Galaxy. To get an idea of how that is possible, consider the fact that, with the aid of gravitational slingshots, our fastest probes have reached velocities of around 250,000 km/h. This is certainly a laughable velocity and our probes are undoubtedly primitive, but that is enough to get from one end of the Galaxy to the other in around 400 million years. This period is just 1/30 of the age of our huge star system and so, if there are, or have been, civilisations much more developed than ours, it is not absurd to postulate that there may be traffic out there. Consequently, someone or something may also have arrived in our solar system and have left some form of trace. Based on our limited knowledge, the probabilities that this has really happened are infinitesimally small but not zero. In recent decades, these ideas have been seriously addressed by many scientists, some of them internationally famous; think of Carl Sagan, for example and, more recently, Paul Davies and Jason Wright. These authors have not only acknowledged the possibility of identifying vestiges of civilisations which came here from other planetary systems, but have also considered the eventuality that there may have been an earlier technological civilisation, arising and developing within our solar system, hundreds of millions or even billions of years before the appearance of terrestrial hominids.

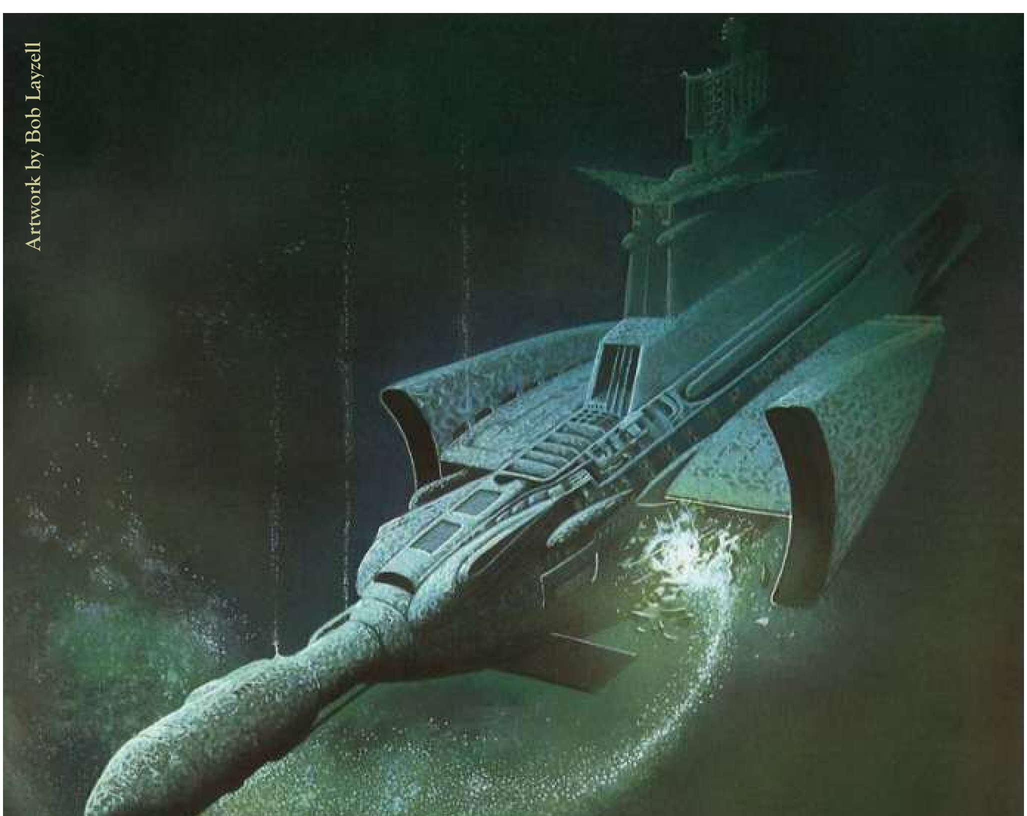
In the first billion years of existence of our planetary system, the environmental conditions pertaining on Venus, Mars and Earth were different from the current ones and, in some respects, similar to each other; we cannot therefore automatically rule out the possibility of all three allowing life to bloom. We only know in broad terms what happened on these three planets in the primordial epoch. On Earth, for example, we cannot say with certainty that in the 3 billion years preceding the huge explosion of life in the Cambrian Period nothing of the kind had happened before. Let us also bear in mind that less than half a billion years could be enough to evolve from humble unicellular organisms organised in colonies, to an animal species capable of travelling to other celestial bodies. When 66 million years ago an asteroid annihilated the dinosaurs (paving the way for the mammals), among them there were already some morphologically very promis-

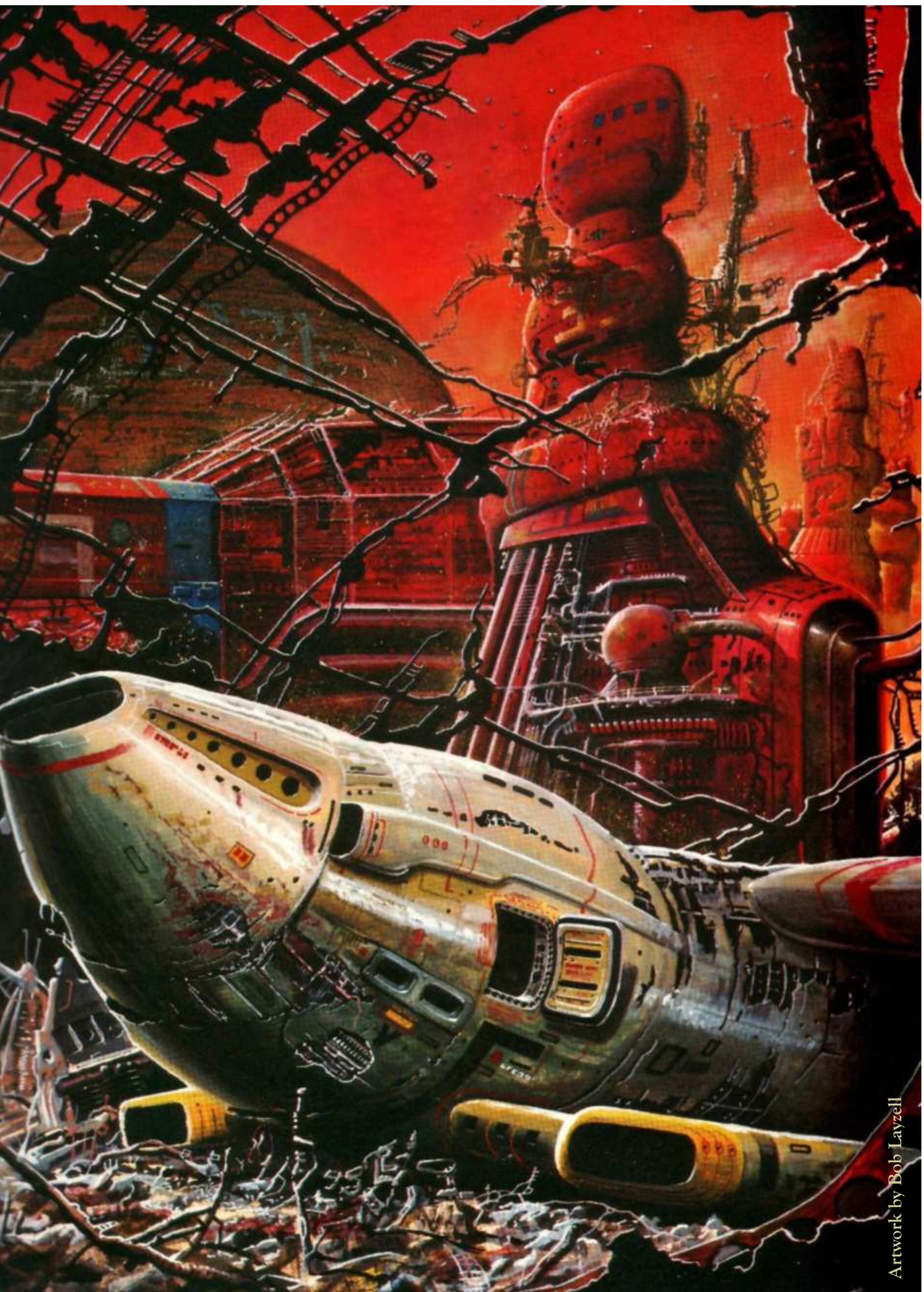

Artwork by Tony Roberts

Artwork by Tony Roberts

ing species from the point of view of possible evolution towards individuals capable of developing a civilisation. How many millions of years would have it taken for them to reach space? Probably fewer than 66.
By today they could have colonised other planetary systems and sent out probes pretty much everywhere in our corner of the Galaxy. Let's say for argument's sake that at least one out of the young Venus, Mars and Earth in the pre-Cambrian era could have been home to a native technological civilisation, or that the solar system had been visited by space ships (and possibly astronauts) from other planetary systems, where, and for what, would we have to look to find evidence? Responding accurately to these questions would presuppose knowledge of the thinking and motivation of completely unknown entities.
We will therefore confine ourselves to some inevitably human hypotheses. The location and type of evidence for a remote alien presence may depend on the purpose of the visit, which we can narrow down to three basic categories: the wish to communicate their own existence to other civilisations; the desire to gather information on other habitable or inhabited planets; the need to obtain supplies of raw materials.
All of these involve activities which could leave traces on rocky surfaces, in the form of space vehicles, scientific instruments, antennae, energy-production equipment, geomorphological changes, geochemical anomalies. How long these traces would last and the extent to which they could be identified would vary according to many factors (not all of them imaginable), such as, for example, structural strength, the materials used, the location and hence their

exposure to specific processes able to remove all traces in the short or long term. If something alien had ever existed on Venus, the greenhouse effect and volcanic activity will have certainly destroyed all traces by now. On Earth, plate tectonics have recycled a significant portion of the crust which existed before the Cambrian period; other geological phenomena and atmospheric agents are also destructive, even over short timescales. Mars would be better adapted to preserve any evidence of aliens, but it could be trapped under metres of sand and ice. The Moon deserves separate consideration, being an ideal observation post for our planet and an ideal place to leave a message intended for a future terrestrial technological civilisation, the existence of which could perhaps be foreseen based on the evolutionary development of the animal species. But the craterisation of the surface of the Moon, even more pronounced going back in time, places obvious and substantial limitations on the conservation of any alien products. Experts in the sector are in agreement in asserting that, in the inner part of the solar system, no artificial structure abandoned on the surface of a planet or on a seabed or in free space (in independent orbit around the Sun or located at a Lagrange point) would be traceable and recognisable for a period greater than around 100 million years.
The forecasts are less pessimistic for some of the rocky moons of the giant planets and for objects in the Kuiper Belt, but to consider these interesting targets from our point of view would presuppose a quite large-scale visit to our planetary system, and in that case there should not be any lack of recognisable evidence even in the nearest main asteroid belt.
If it is not obvious where to look, it is even less obvious what to look for. Up to the above-mentioned 100 million years, large-scale products, such as space ships and per-


Artwork by Bob Layzell



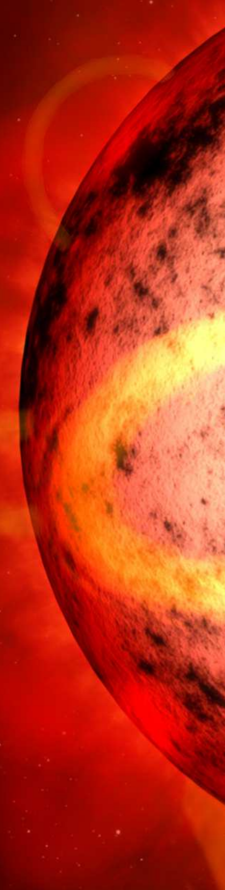
haps permanent bases, could be recognisable. However, the aliens could have decided to leave no trace, so as not to interfere with our evolution (a little like documentary makers do with animals they are filming). Considering a completely different scenario, we could surmise that following the rapid destruction of a technological civilisation within the solar system, all sorts of wreckage may have remained, abandoned who knows where. A similar situation could arise in the case of accidents occurring to space ships arriving from other stars.

On a smaller scale, simply identifying beyond the Earth a small concentration of plutonium, our best source of nuclear energy for space flights, could in itself be a residual trace from a radioisotope thermoelectric generator, once belonging to an alien vehicle. The plutonium present in the solar system at its birth has effectively decayed a very long time ago, so its anomalous presence in concentrated form would be suspicious.

Notwithstanding all the arguments set out so far may appear open to dispute, and although the probabilities of identifying traces left by technological civilisations different to our own are minimal, this has not prevented, for several years to this part, a fair number of researchers (including some real science celebrities) have been examining the high resolution photographic databases of the Moon and Mars, searching for anomalous structures. So far only products manufactured by humans have been identified in these images, but we are only at the beginning of the research and the stakes are truly high. ■

Flares may threaten planet habitability near red dwarfs

by NASA



Cool dwarf stars are hot targets for exoplanet hunting right now. The discoveries of planets in the habitable zones of the TRAPPIST-1 and LHS 1140 systems, for example, suggest that Earth-sized worlds might circle billions of red dwarf stars, the most common type of star in our galaxy. But, like our own Sun, many of these stars erupt with intense flares. Are red dwarfs really as friendly to life as they appear, or do these flares make the surfaces of any orbiting planets inhospitable?

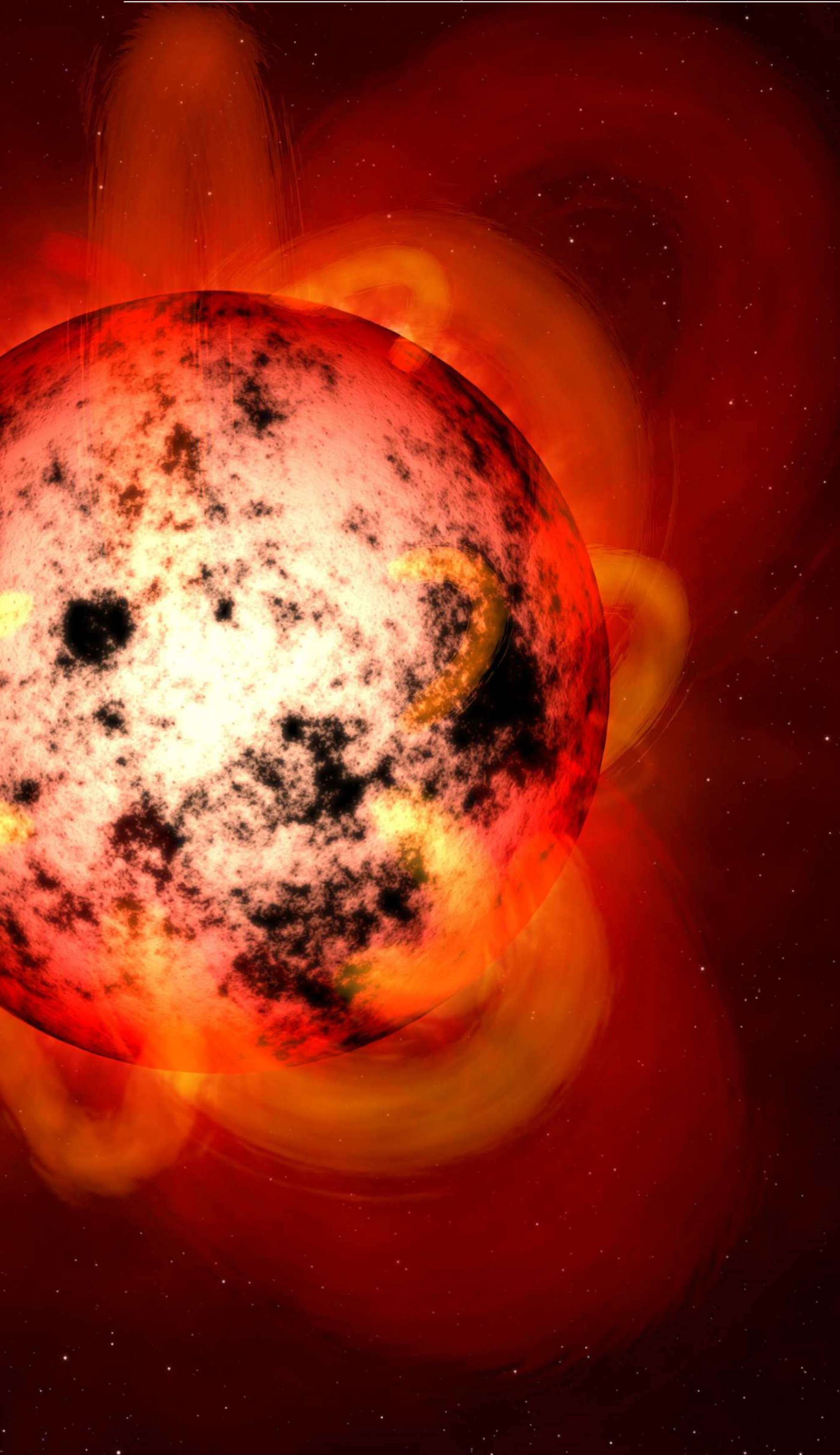
To address this question, a team of scientists has combed 10 years of ultraviolet observations by NASA's Galaxy Evolution Explorer (GALEX) space telescope, looking for rapid increases in the brightness of stars due to flares.

Flares emit radiation across a wide swath of wavelengths, with a significant fraction of their total energy released in the ultraviolet bands where GALEX observed. At the same time, the red dwarfs from which the flares arise are relatively dim in ultraviolet. This contrast, combined with the GALEX detectors' sensitivity to fast changes, allowed the team to measure events with less total energy than many previously detected flares. This is important because, although individually less energetic and therefore less hostile to life, smaller flares might be much more frequent and add up over time to create an inhospitable environment. *"What if planets are constantly bathed by these smaller, but still significant, flares?"* asked Scott Fleming of the Space Telescope Science Institute (STScI) in Baltimore. *"There could be a cumulative effect."*

To detect and accurately measure these flares, the team had to analyze data over very short time intervals. From images with exposure times of nearly half an hour, the team was able to reveal stellar variations lasting just seconds.

First author Chase Million of Million Concepts in State College, Pennsylvania, led a project called gPhoton that reprocessed more than 100 terabytes of GALEX data held at the Mikulski Archive for Space Telescopes (MAST), located at the Space Telescope Science Institute. The team then used custom software developed by Million and Clara Brasseur, also at the institute, to search several hundred red dwarf stars, and they detected dozens of flares. *"We have found dwarf star flares in the whole range that we expected GALEX to be sensitive to, from itty bitty baby flares that last a few seconds, to monster flares that make a star hundreds of times brighter for a few minutes,"* said Million.

The flares GALEX detected are similar in strength to flares produced by



This illustration shows a red dwarf star orbited by a hypothetical exoplanet. [NASA/ESA/G. Bacon (STScI)]

our own Sun. However, because a planet would have to orbit much closer to a cool, red dwarf star to maintain a temperature friendly to life as we know it, such planets would be subjected to more of a flare's energy than Earth. Large flares can strip away a planet's atmosphere. Strong ultraviolet light from flares that penetrates to a planet's surface could damage organisms or prevent life from arising. Currently, team members Rachel Osten and Brasseur are examining stars observed by both the GALEX and Kepler missions to look for similar flares. The team expects to eventually find hundreds of thousands of flares hidden in the GALEX data.

"These results show the value of a survey mission like GALEX, which was instigated to study the evolution of galaxies across cosmic time and is now having an impact on the study of nearby habitable planets," said Don Neill, research scientist at Caltech in Pasadena, who was part of the GALEX collaboration. *"We did not anticipate that GALEX would be used for exoplanets when the mission was designed."*

New and powerful instruments like NASA's James Webb Space Telescope, scheduled for launch in 2018, ultimately will be needed to study atmospheres of planets orbiting nearby red dwarf stars and search for signs of life. But as researchers pose new questions about the cosmos, archives of data from past projects and missions, like those held at MAST, continue to produce exciting new scientific results.

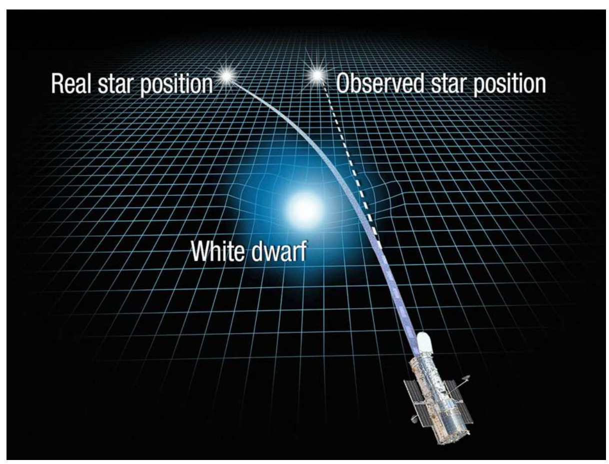
These results were presented in a news conference at the 4-8 June meeting of the American Astronomical Society in Austin, Texas.

White dwarf shows how gravity can bend starlight

by NASA/ESA

Astronomers have used the sharp vision of NASA's Hubble Space Telescope to repeat a century-old test of Einstein's general theory of relativity. The Hubble team measured the mass of a white dwarf, the burned-out remnant of a normal star, by seeing how much it deflects the light from a background star. This observation represents the first time Hubble has witnessed this type of effect created by a star. The data provide a solid estimate of the white dwarf's mass and yield insights into theories of the structure and composition of the burned-out star.

First proposed in 1915, Einstein's general relativity theory describes how massive objects warp space, which we feel as gravity. The theory was experimentally verified four years later when a team led by British astronomer Sir Arthur Eddington measured how much the Sun's gravity deflected the image of a background star as its light grazed the Sun during a solar eclipse, an effect called gravitational microlensing. Astronomers can use this effect to see magnified images of distant galaxies or, at closer range, to measure tiny shifts in a star's apparent position on the sky. Researchers had to wait a century, however, to build telescopes powerful enough to detect this gravitational warping phenomenon caused by a star outside our solar system. The amount of deflection is so small only the sharpness of Hubble could measure it.

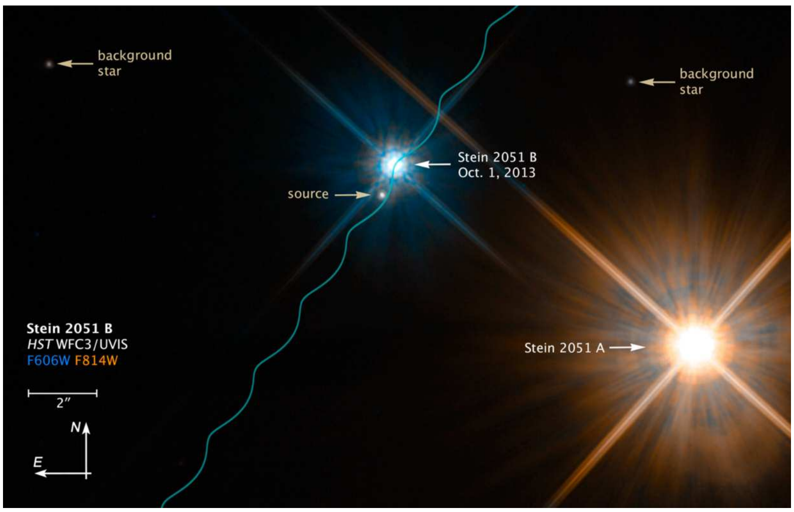


This illustration reveals how the gravity of a white dwarf star warps space and bends the light of a distant star behind it. [NASA, ESA, and A. Feild (STScI)]

Hubble observed the nearby white dwarf star Stein 2051 B as it passed in front of a background star. During the close alignment, the white dwarf's gravity bent the light from the distant star, making it appear offset by about 2 milliarcseconds from its actual position. This deviation is so small that it is equivalent to observing an ant crawl across the surface of a quarter from 1,500 miles away. Using the deflection measurement, the Hubble astronomers calculated that the white dwarf's mass is roughly 68 percent of the Sun's mass. This result matches theoretical predictions. The technique opens a window on a new method to determine a star's mass.

Normally, if a star has a companion, astronomers can determine its mass by measuring the double-star system's orbital motion. Although Stein 2051 B has a companion, a bright red dwarf, astronomers cannot accurately measure its mass because the stars are too far apart.

The stars are at least 5 billion miles apart – almost twice Pluto's present distance from the Sun. *"This microlensing method is a very independent and direct way to determine the mass of a star,"* explained lead researcher Kailash Sahu of the Space Telescope Science Institute (STScI) in Baltimore, Maryland. *"It's like placing the star on a scale: the deflection is analogous to the movement of the needle on the scale."*



This HST image shows the binary star system Stein 2051 on October 1, 2013. Because these stars are relatively close to Earth, only 17 light-years away, they appear to move in the sky relative to the much more distant background stars in several months of observations with Hubble. The wavy blue line traces this motion, due to their true motion relative to the sun combined with the parallax due to the motion of Earth around the sun. Stein 2051 B appeared to pass close enough to one of these background stars, labeled "source" that the light from the source star was bent due to the mass of the white dwarf star. This color image was made by combining images taken in two filters with Hubble's Wide Field Camera 3 (WFC3/UVIS) instrument. [NASA, ESA, and K. Sahu (STScI)]

Sahu presented his team's findings June 7, at the American Astronomical Society meeting in Austin, Texas. The Hubble analysis also helped the astronomers to independently verify the theory of how a white dwarf's radius is determined by its mass, an idea first proposed in 1935 by Indian American astronomer Subrahmanyan Chandrasekhar.

"Our measurement is a nice confirmation of white-dwarf theory, and it even tells us the internal composition of a white dwarf," said team member Howard Bond of Pennsylvania State University in University Park.

Sahu's team identified Stein 2051 B and its background star after combing through data of more than 5,000 stars in a catalog of nearby stars that appear to move quickly across the sky.

Stars with a higher apparent motion across the sky have a greater chance of passing in front of a distant background star, where the deflection of light can be measured.

After identifying Stein 2051 B and mapping the background star field, the researchers used Hubble's Wide Field Camera 3 to observe the white dwarf seven different times over a two-year period as it moved past the selected background star.

This time-lapse movie, made from eight Hubble Space Telescope images, shows the apparent motion of the white dwarf star Stein 2051 B as it passes in front of a distant star. The observations were taken between Oct. 1, 2013, and Oct. 14, 2015. [NASA, ESA, and K. Sahu (STScI)]

The Hubble observations were challenging and time-consuming. The research team had to analyze the white dwarf's velocity and the direction it was moving in order to predict when it would arrive at a position to bend the starlight so the astronomers could observe the phenomenon with Hubble.

The astronomers also had to measure the tiny amount of deflected starlight. *"Stein 2051 B appears 400 times brighter than the distant background star,"* said team member Jay Anderson of STScI, who led the analysis to precisely measure the positions of stars in the Hubble images. *"So measuring the extremely small deflection is like trying to see a firefly move next to a light bulb. The movement of the insect is very small, and the glow of the light bulb makes it difficult to see the insect moving."* In fact, the slight movement is about 1,000 times smaller than the measurement made by Eddington in his 1919 experiment.

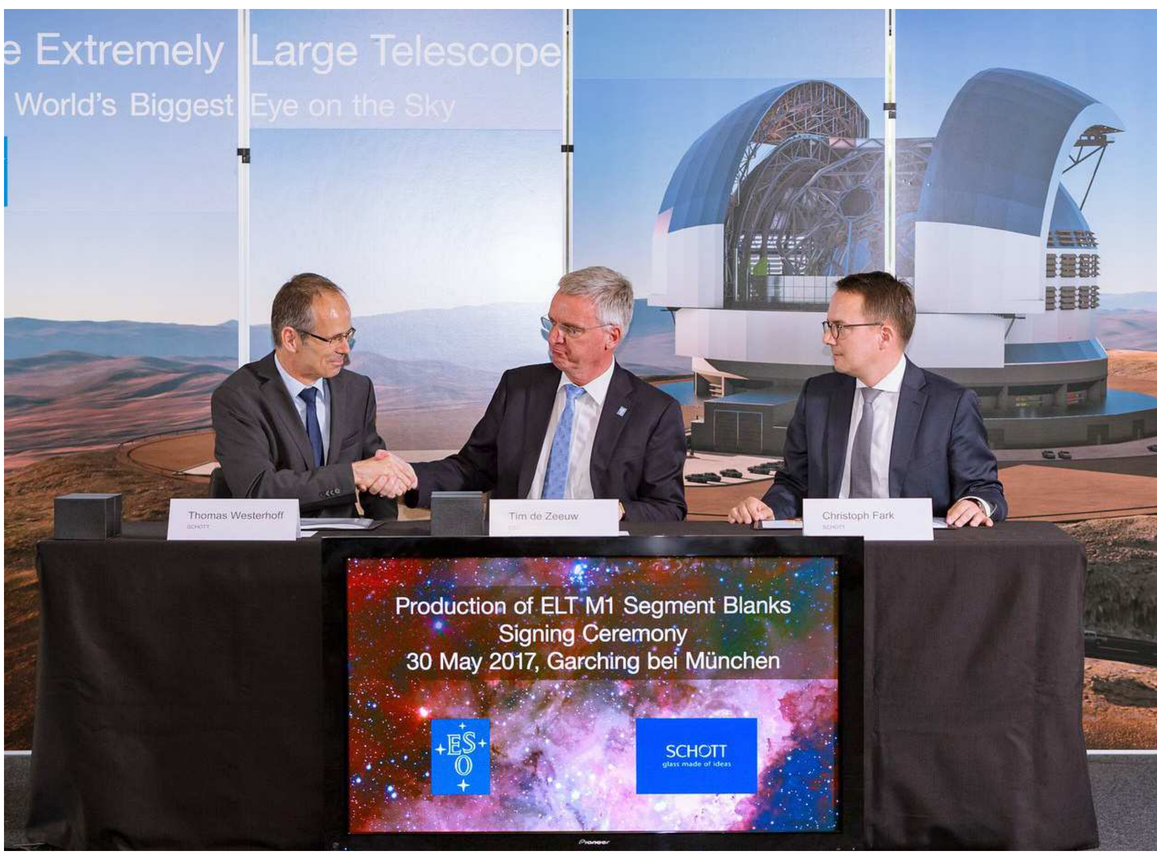
Stein 2051 B is named for its discoverer, Dutch Roman Catholic priest and astronomer Johan Stein. It resides 17 light-years from Earth and is estimated to be about 2.7 billion years old. The background star is about 5,000 light-years away.

The researchers plan to use Hubble to conduct a similar microlensing study with Proxima Centauri, our solar system's closest stellar neighbor. The team's result appeared in the journal *Science* on June 9. ■

ESO signs contracts for the ELT's gigantic primary mirror

by ESO

The unique optical system of ESO's Extremely Large Telescope consists of five mirrors, each of which represents its own significant engineering challenge.
The 39-metre-diameter primary mirror, which will be made up of 798 individual hexagonal segments each measuring 1.4 metres across, will be by far the largest ever made for an optical telescope. Together, the segments will collect tens of millions of times as much light as the human eye.
The ELT primary mirror segments will be installed in a common support structure and equipped with edge sensors — the most accurate ever used in a telescope — that will continuously sense the locations of the ELT primary mirror seg-



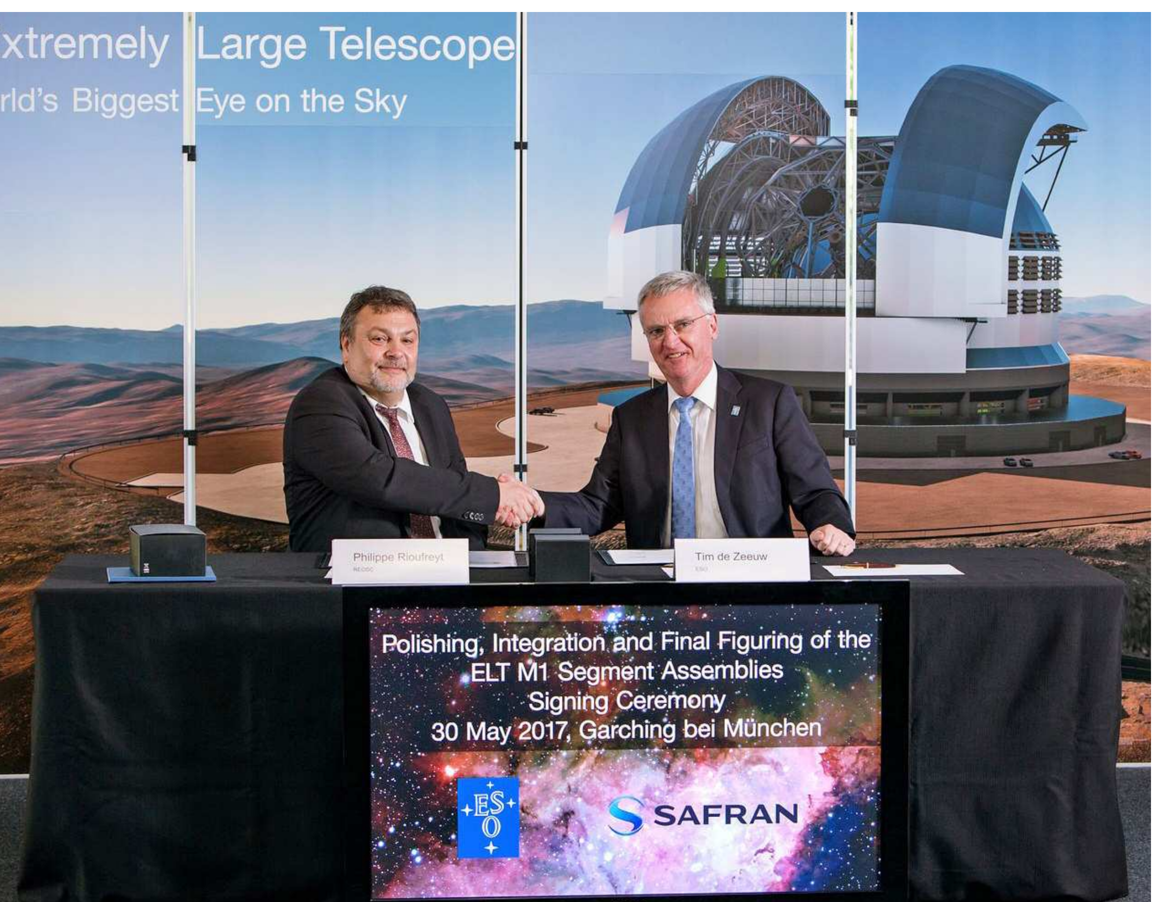
The contracts to manufacture and polish the ELT primary mirror segments were signed on 30 May 2017 by ESO's Director General, Tim de Zeeuw, and senior representatives of SCHOTT and Safran Reosc, a subsidiary of Safran Electronics & Defense, in the presence of key ESO staff members. Above, the first contract is being signed with SCHOTT. Tim de Zeeuw, ESO's Director General, appears in the centre, with Thomas Westerhoff, Director Strategic Marketing Zerodur for SCHOTT, to the left and Christoph Fark, Executive Vice President Advanced Optics of SCHOTT on the right. Next page, the second contract is being signed with Safran Reosc. Tim de Zeeuw, ESO's Director General appears on the right and Philippe Rioufreyt, Chief Executive Officer, Safran Reosc on the left. [ESO/M. Zamani]

An overview of ESO's Extremely Large Telescope. [ESO]

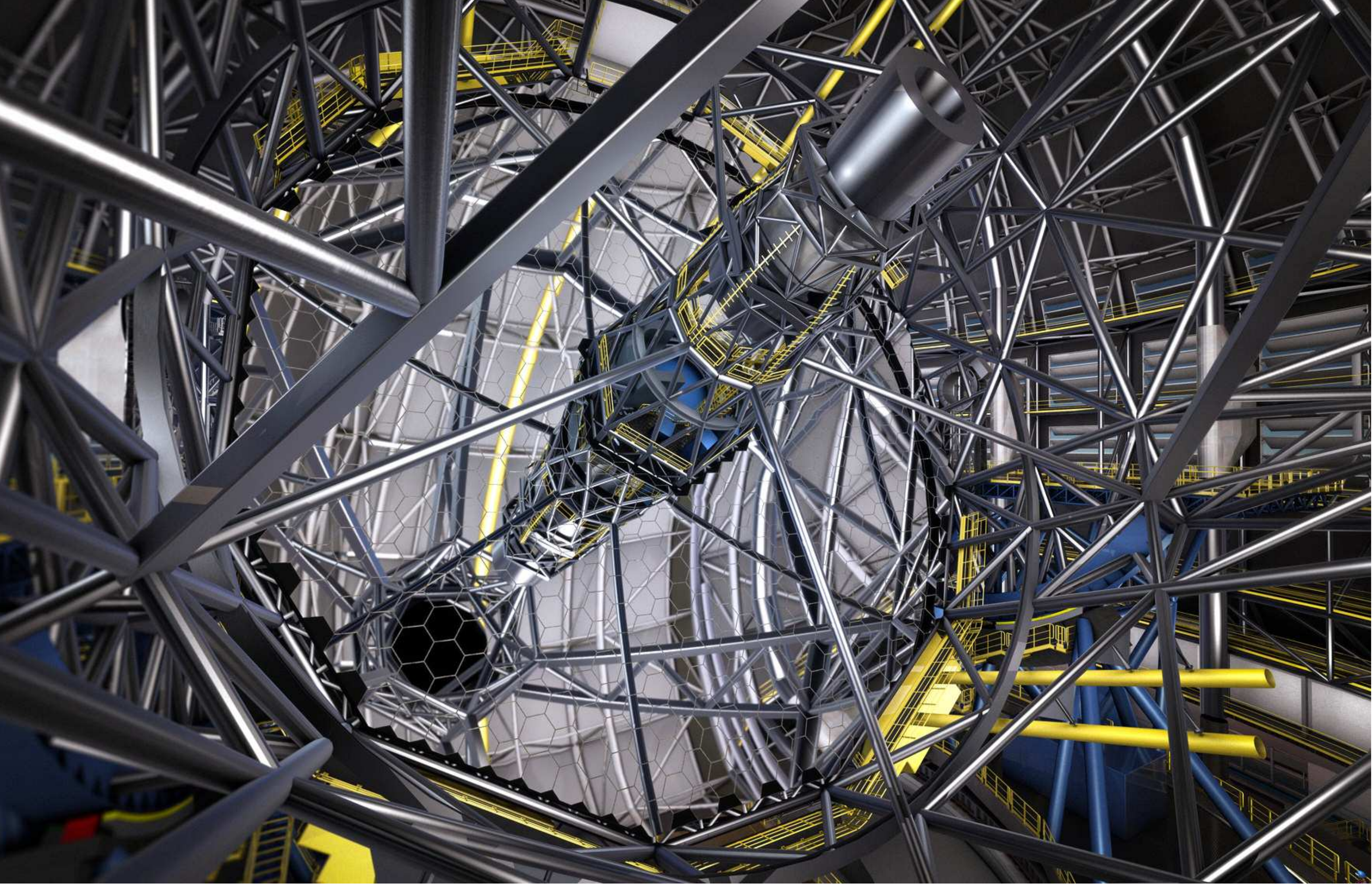
ments relative to their neighbours and allow the segments to work together to form a perfect imaging system.

The contracts to manufacture and polish the ELT primary mirror segments were signed today by ESO's Director General, Tim de Zeeuw, and senior representatives of Schott and Safran Reosc, a subsidiary of Safran Electronics & Defense, in the presence of key ESO staff members. The first contract was signed with Schott by Christoph Fark, Executive Vice President Advanced Optics, and Thomas Westerhoff, Director Strategic Marketing Zerodur. The second contract was signed with Safran Reosc by Philippe Rioufreyt, Chief Executive Officer. Tim de Zeeuw expressed his delight at the current progress with the ELT: *"This has been an extraordinary two weeks! We saw the casting of the ELT's secondary mirror and then, last Friday, we were privileged to have the President of Chile, Michelle Bachelet, attend the first stone ceremony of the ELT.*

And now two world-leading European companies are starting work on the telescope's enormous main mirror, perhaps the biggest challenge of all."



The 798 hexagonal segments that together comprise the ELT's primary mirror will be produced from the low-expansion ceramic material Zerodur® by Schott. Zerodur® is a sophisticated material which has almost no thermal expansion even when subjected to large tem-



This artist's rendering shows the huge segmented primary mirror of the ESO Extremely Large Telescope (ELT). Contracts for the manufacture of the mirror segments were signed on 30 May 2017 at a ceremony at ESO's Headquarters near Munich. The German company SCHOTT will produce the blanks of the mirror segments, and the French company Safran Reosc will polish, mount and test the segments. The contract to polish the mirror blanks is the second-largest contract for the ELT construction and the third-largest contract ESO has ever awarded. [ESO/L. Calçada/M. Kornmesser]

perature fluctuations, is highly chemically resistant, and can be polished to a high standard of finish.

The reflective layer, made of aluminum or silver, will be vapourised onto the extremely smooth surface shortly before the telescope is put into operation. Many well-known telescopes with Zerodur® mirrors have been operating reliably for decades, including ESO's Very Large Telescope in Chile.

Previously Schott was also awarded the contracts for the production of the telescope's giant secondary and tertiary mirrors and the material is also being used for the ELT's deformable quaternary mirror that is currently under construction.

Once the mirror blanks are ready they will be passed to Safran Reosc, to design the mounting interfaces, figure and polish the segments, integrate them into their support systems, and perform optical tests before delivery.

During the polishing process, each segment will be polished until it has no surface irregularity greater than about 10 nanometres — no higher than a ladybird if each segment were as big as France!

To meet the challenge of delivering such a large number of polished segments within seven years, Safran Reosc will build up to a peak production rate of one mirror a day. It will set up a dedicated new facility at its Poitiers plant, specialising in the production of high-tech optical and optronic (electro-optical) equipment. Up to 931 segments will ultimately be produced and polished, including 133 in a maintenance set, allowing for segments to be removed, replaced and recoated on a rotating basis once the ELT is in operation.

The new contract with Safran Reosc is the second-largest contract for the ELT construction and the third-largest contract ESO has ever signed. The two other contracts are those for the Dome and Main Structure of the ELT and the European ALMA Antennas. Safran Reosc will also design, polish and test the ELT's secondary mirror and tertiary mirror, and is currently manufacturing the 2-mm thick deformable shell mirrors that will comprise the ELT's fourth mirror.

Both Schott and Safran Reosc have long and successful involvements with ESO. Together they manufactured many optical components, including the 8.2-metre main mirrors of the four Unit Telescopes of the ESO Very Large Telescope.

The ELT is currently under construction at Cerro Armazones near ESO's Paranal Observatory in northern Chile, and is scheduled to see first light in 2024.