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FREE ASTRONOMY magazine

Bi-monthly magazine of scientific and technical information ✶ January-February 2017 issue

234 odd signals from the Galaxy

Stellar system caught in act of forming close multiples

ESO telescopes help reinterpret brilliant explosion

ALMA measures size of planets' seeds

Watchers of the skies

LR experiment, the biological hypothesis strengthens

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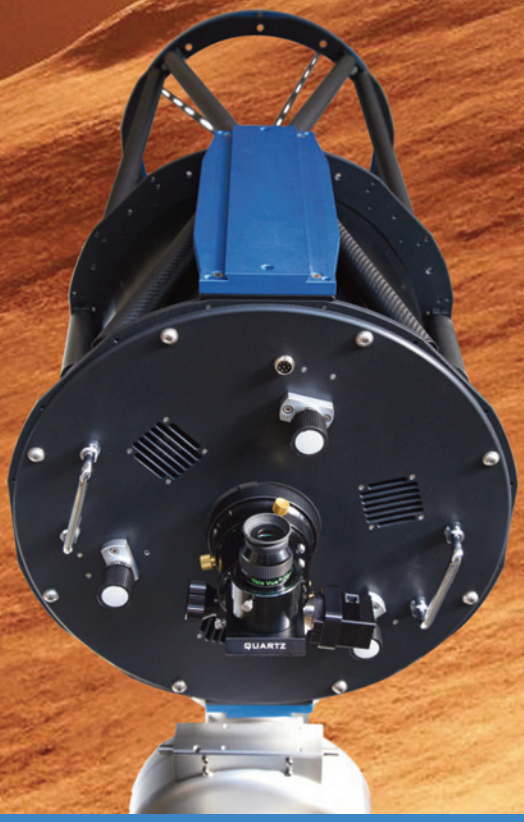

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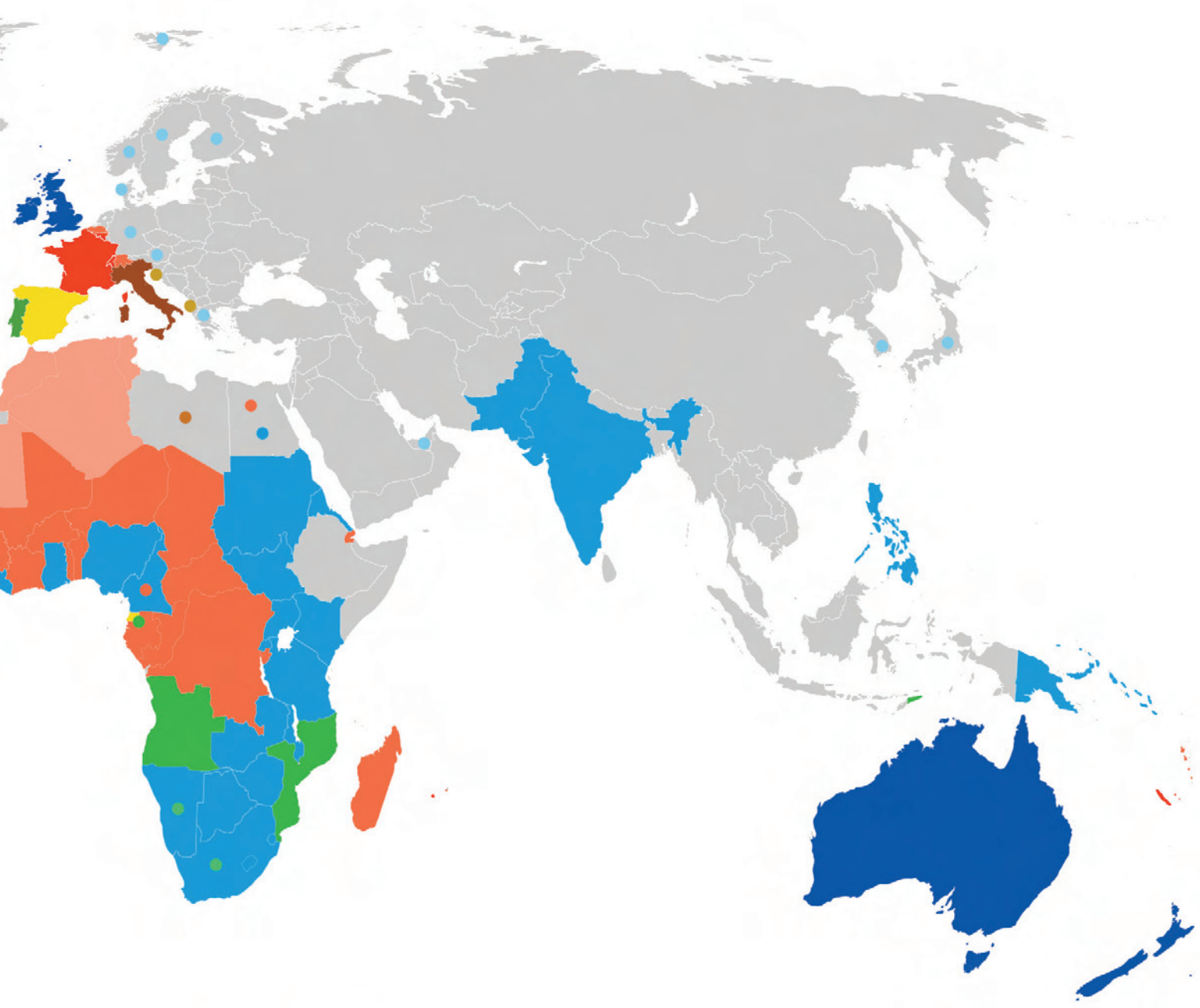
SUMMARY

editorial

Gimme 5!

Dear readers,
as you can see, from this issue, our magazine is freely available online also in Spanish, thanks to the co-operation of some eager amateur astronomers who have joined our increasingly numerous and solid group. So let's welcome with great pleasure the 'Universo' magazine.
In terms of astronomical information, there isn't on our planet another publishing initiative comparable to this. Undoubtedly, this is not an easy task, and adding three language versions in just one year was nothing short of remarkable.
Seeing amateur astronomers of various nationalities and unknown to each other before, enthusiastically throwing themselves in the undertaking of making this magazine available in various languages, it is a form of payback for all the unimaginable efforts made thus far in order to offer to our countless readers a scientifically reliable, culturally useful and socially enriching informative tool.



ADAPTED FROM GOOGLE MAPS AND WIKIPEDIA DATA

But we didn't just add a language spoken by half a billion people. We also implemented a major upgrade to the software used to generate the browsable format, now based on HTML5 technology, which makes our magazine even more enjoyable on any type of computer or mobile device and with any operating system.
It goes without saying that we are already looking much further ahead, even if 5 language versions are de facto a kind of physiological limit beyond which our project can be expected to grow and evolve by listening and sharing any external initiative consistent with our sphere of activity.
The search has already begun...

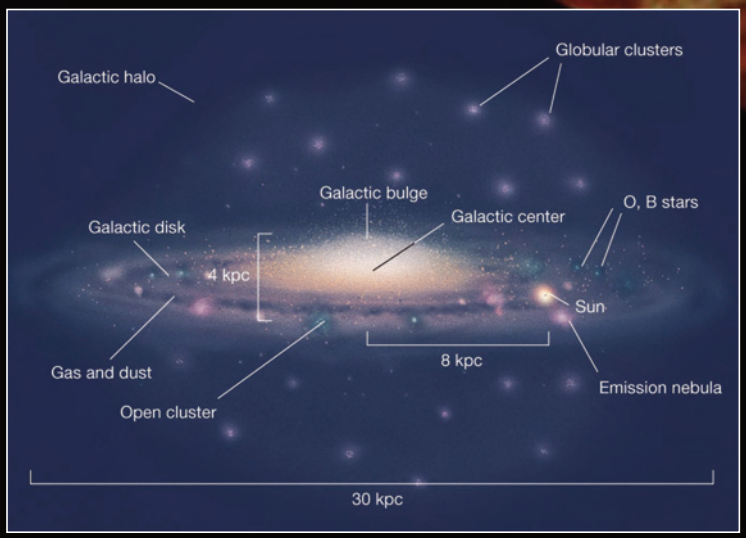
Michele Ferrara

234 odd signals from the Galaxy

by Michele Ferrara

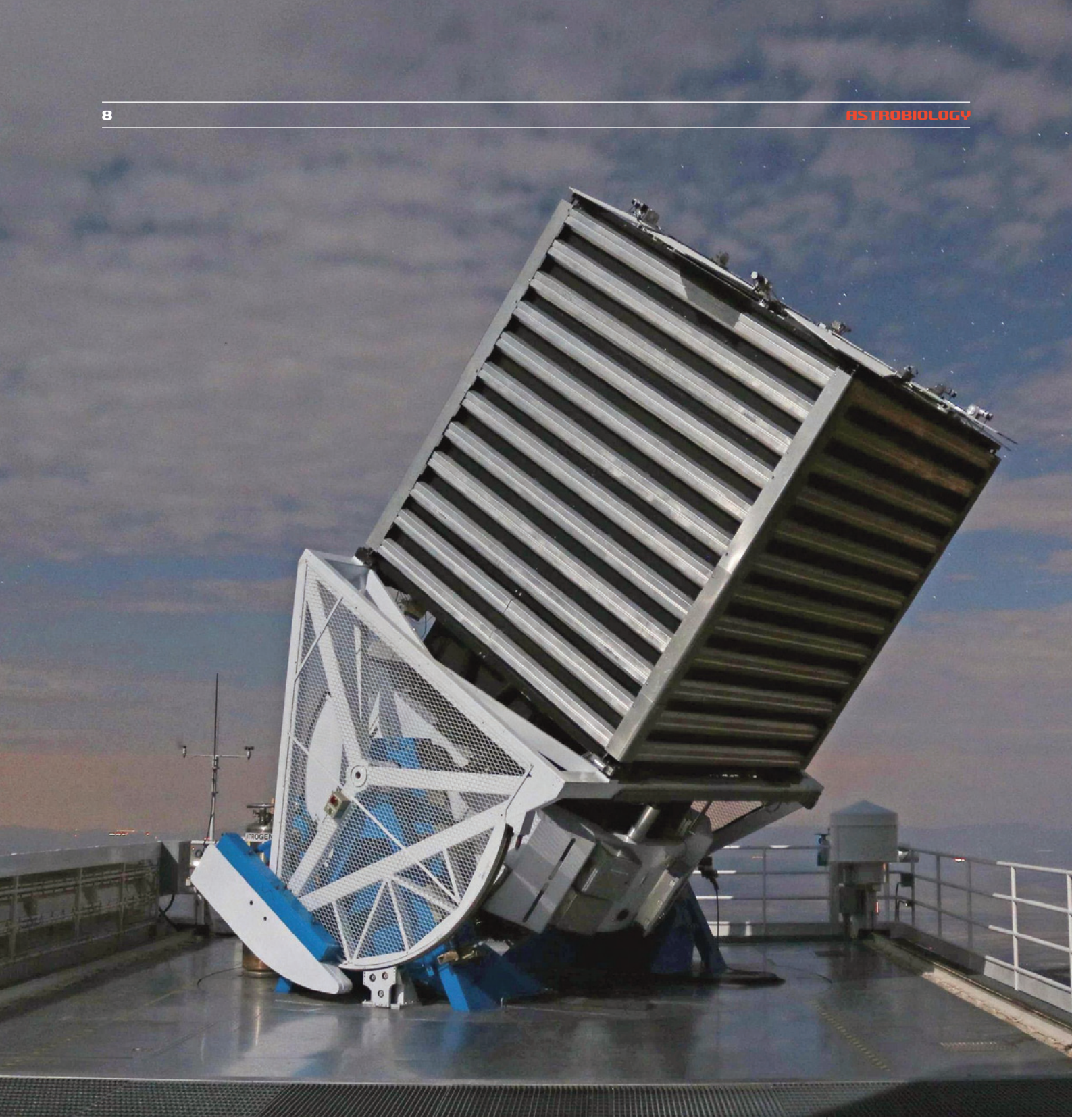
Luckily, for once, the media appear to have missed a good chance to let their imagination run riot about a discovery that does not need any particular hype (since already sensational in its own right) and that — if it were to be confirmed — it would leave mankind dumbfounded, crushing the deeply rooted anthropocentrism that still characterizes it.

In the movie "2001: A Space Odyssey", a black monolith inspires human potential and evolutionary reaction. Perhaps, now, something equally inspiring has been discovered.



In this infographic are shown the main structural components of our Galaxy. The halo is the spheroidal region that is furthest from the disk. Besides hosting most of the globular clusters, the halo contains also the stars from which the mysterious signals arrive.

About ten years ago, Prof. Ermanno F. Borra, of Laval University in Quebec, began to wonder how an evolved extraterrestrial civilization could let other similar civilizations of other worlds know of its existence using a sustainable solution that, most of all, was universally understood. Borra, an expert in optics, suggested a method (partly already



proposed in 2004 by Howard et al.) to emit powerful laser pulses whose duration was so brief as to be measured in nanoseconds (or billionths of a second).
After a thorough theoretical analysis, between 2010 and 2012 Borra published two scientific papers on the subject. In these he showed that a bright object which emits pulsed signals separated by shorter constant times of 10^{-10} seconds, generates periodic spectral modulations (expressed in frequency units) detectable in the spectrum of the object itself.
According to Borra, this property could be used by a possible extraterrestrial intelligence (ETI) to emphasize the artificial na-

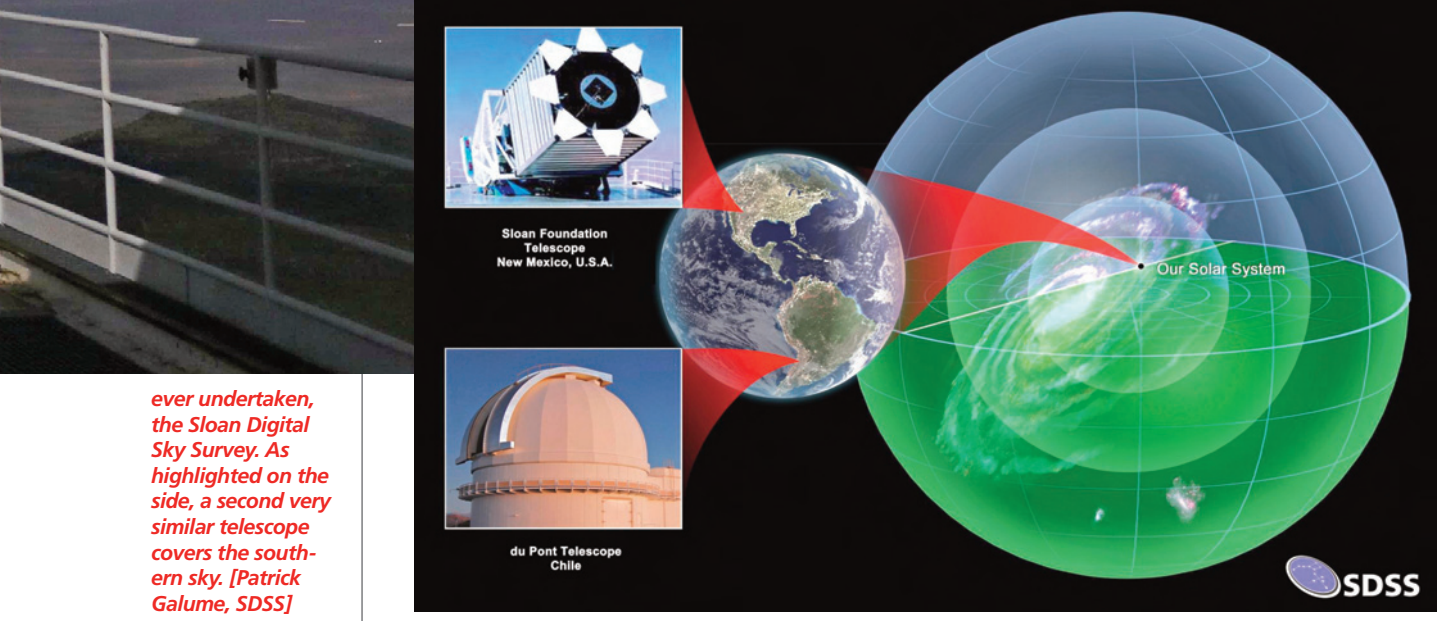
Since 2000, this 2.5 metres f/5 Ritchey-Chrétien telescope is being used to observe the northern hemisphere as part of one of the most ambitious projects

Right, a time-lapse video of one night of operations at the SDSS telescope. During the night, an observer changes the cartridge to observe a new set of stars or galaxies roughly every hour. Each cartridge contains hundreds of fiber-optic cables plugged into holes in a large aluminum plate. Each fiber observes a single star or galaxy. TIn the video, the period in which the sky is bright is during full Moon, not daytime; the Moon (not the Sun) rises shortly before the end of the video. [John Parejko (Yale University) and the SDSS collaboration]

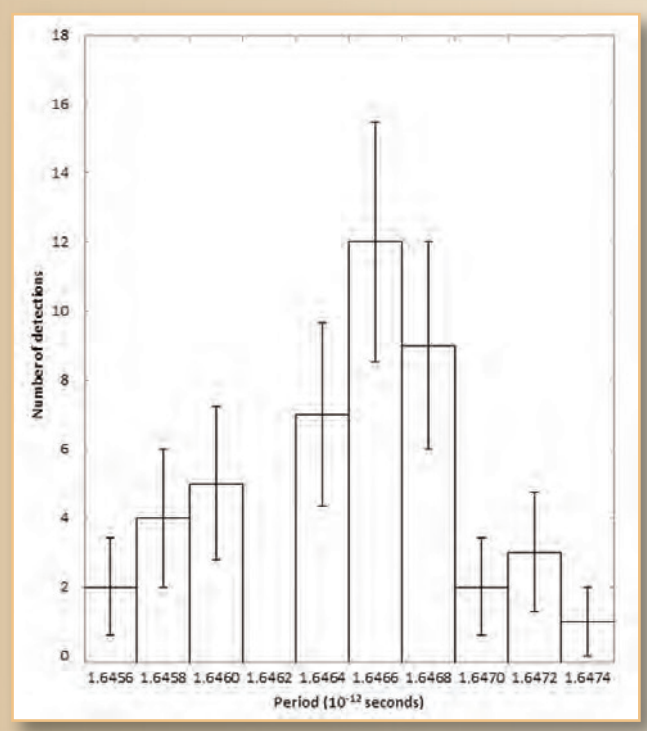
https://www.youtube.com/watch?v=AHsS57NMQjE

ture of the signal purposely emitted in order to communicate its existence. To increase the contrast of the signal with respect to the noise of the spectrum, the ETI would choose an optimal ratio between the number of pulses and the interval separating them. The theoretical analysis performed by the Laval University physicist shows that two powerful laser pulses separated by an interval between 10^{-10} and 10^{-15} seconds are optimal for modulating a stellar spectrum with periodic structures (frequency peaks) such that they can be detectable even within spectra with medium-resolution.

Given the huge discrepancy between the energy of the stellar spectrum and that of the laser pulses, the effect produced by the latter would go completely unnoticed.



ever undertaken, the Sloan Digital Sky Survey. As highlighted on the side, a second very similar telescope covers the southern sky. [Patrick Galume, SDSS]



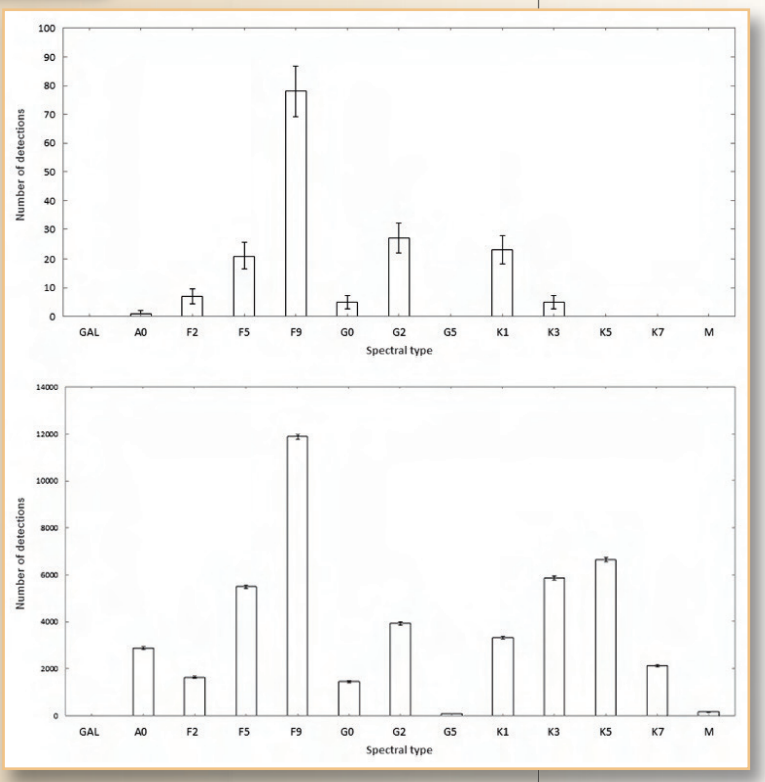
However, by using a specific periodicity, one is able to extract it from the background-spectrum noise by means of an appropriate mathematical tool, the Fourier transform.

In order to get a precise idea of what to look for, Borra conducted a series of computer simulations. He created spectra in which hidden periodic modulations (always in frequency units) were generated by pairs of pulses. He then extracted these with the Fourier transform. Among the factors contributing to form the final signal, the most favourable combination (for a remote observer) is that which has at its base two laser pulses spaced by 10^{-14} seconds and repeated over time at longer intervals.

The distance between successive pairs can be significantly greater and must not necessarily be periodic. Since the device emitting the powerful pulses may require a charging time, Borra and other researchers deemed reasonable an interval of the order of a millionth of a second (10^{-6}) between a pair of pulses and the next.

Once the profile to be identified had been outlined in graphical form, Borra started the search with the assistance of his graduate student Éric Trottier. But where to look for it?

Whereas with our current technology we could introduce in the solar spectrum a signal detectable up to about 1000 light-years away, it is likely that a more advanced civilization than our own could do even better. It is thus possible to reach as far as several thousand light-years away from Earth, preferably in an environment populated by stars several billion years old, namely those most likely to host planets inhabited by ETI. As the innermost part of the galactic halo seemed appropriate to their needs, Borra and Trottier decided to look for that kind of periodic modulations inside about 2.5 million spectra recorded by the Sloan Digital Sky Survey (SDSS). The survey observed simultaneously



The graph on the left demonstrates the range of the most concentrated signals pairs detected in a particular sample of stellar spectra. In the graph below, we can see the star-type relating to the sample of the previous graph. The one lower down shows, according to their spectral type, the number of stars contained in the Sloan Extension for Galactic Understanding and Exploration, that were examined by the Canadian researchers. [Borra & Trottier, 2016]

Above and right, views of the Alexandre Vachon Pavillon, at Laval University, where Borra and Trottier conducted their study on the SDSS stellar spectra. [Stéphane Groleau, UL]

approximately 360,000 faint stars of the galactic halo, from distances of 10 to 60 kpc away from Earth (i.e. from just over 30,000 to less than 200,000 light-years). This lengthy work produced surprising results, published in November in the *Publications of the Astronomical Society of the Pacific*, which show that in the spectra of 234 stars frequency peaks were detected consistent with those foreseen by Borra in case of signals voluntarily generated by ETI.

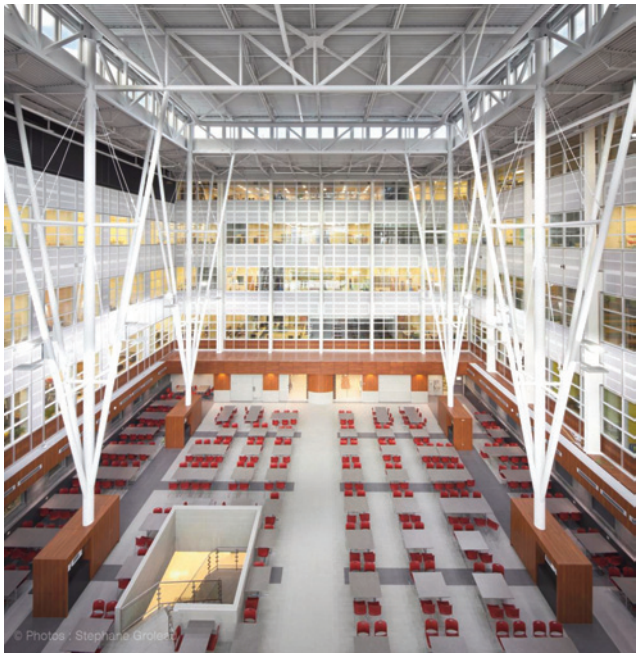
Does this mean that the two researchers of the Laval University have revealed the existence of (at least) 234 alien civilizations in the Galaxy? At the moment no one can answer this question, but we can only review the arguments of the skeptics and the factual findings of the research. Skeptics point out that these periodic spectral modulations may be artefacts generated by the data-processing procedure. However, they may also be due to exotic physical or chemical processes linked to particular stars.

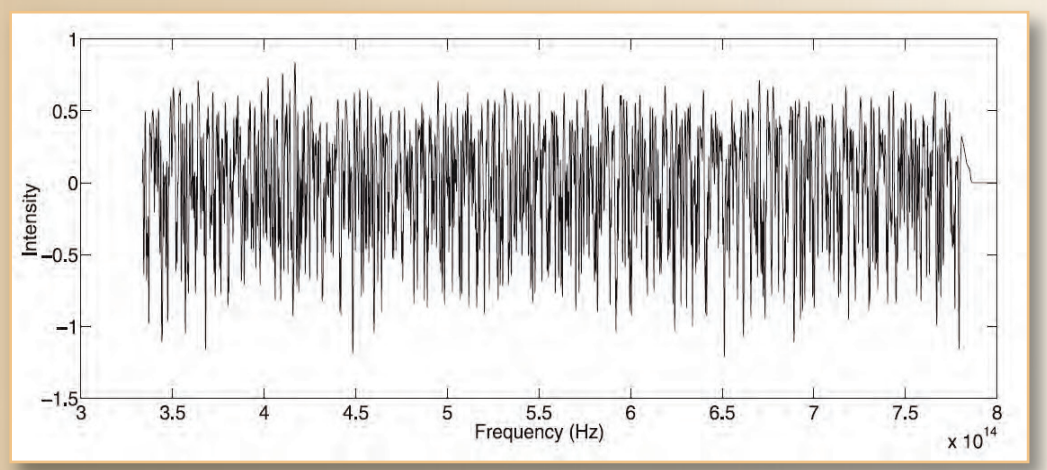
In addition, why should all of these hypothetical civilizations transmit similar signals, with the same separation times and all simultaneously?

Let us now summarise the more open-minded arguments:

• The proportion between the number of stars with a "suspected" spectrum and the total of the stars inves-tigated is around 1:1500. Given that we now know that the vast majority of stars have planets, it would not be unreasonable to hypothesize that one out of 1500 could host ETI.

• The spectra of the 234 stars in question are all included in the F2 to K1 range, virtually centred on the spectral range of the Sun (type G2).





• The 234 stars displaying the mysterious signal represent only 1% of those analyzed and belonging to the aforementioned spectral range. Therefore, if the frequency peaks were artefacts generated by the instruments or the mathematical processing procedure, it would not explain how these may have acted selectively only on a small part of these specific spectral types.

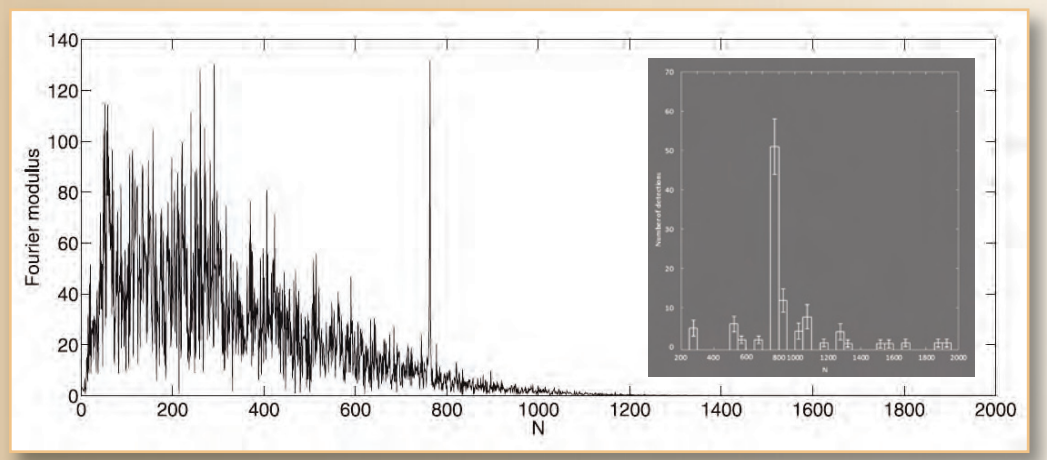
• It seems unlikely that the signals detected could be artefacts associated with the collection or analysis of data, given that considerations on the signal-to-noise ratio predict that these signals should mostly be identified in the brightest spectra, which is not the case.

• It is almost impossible that the signals discovered could be produced by periodic stellar pulsations, since in those environments the masses of matter cannot expand and contract in times on the order of nanoseconds (or close to $1.65 \cdot 10^{-12}$ seconds to be precise).

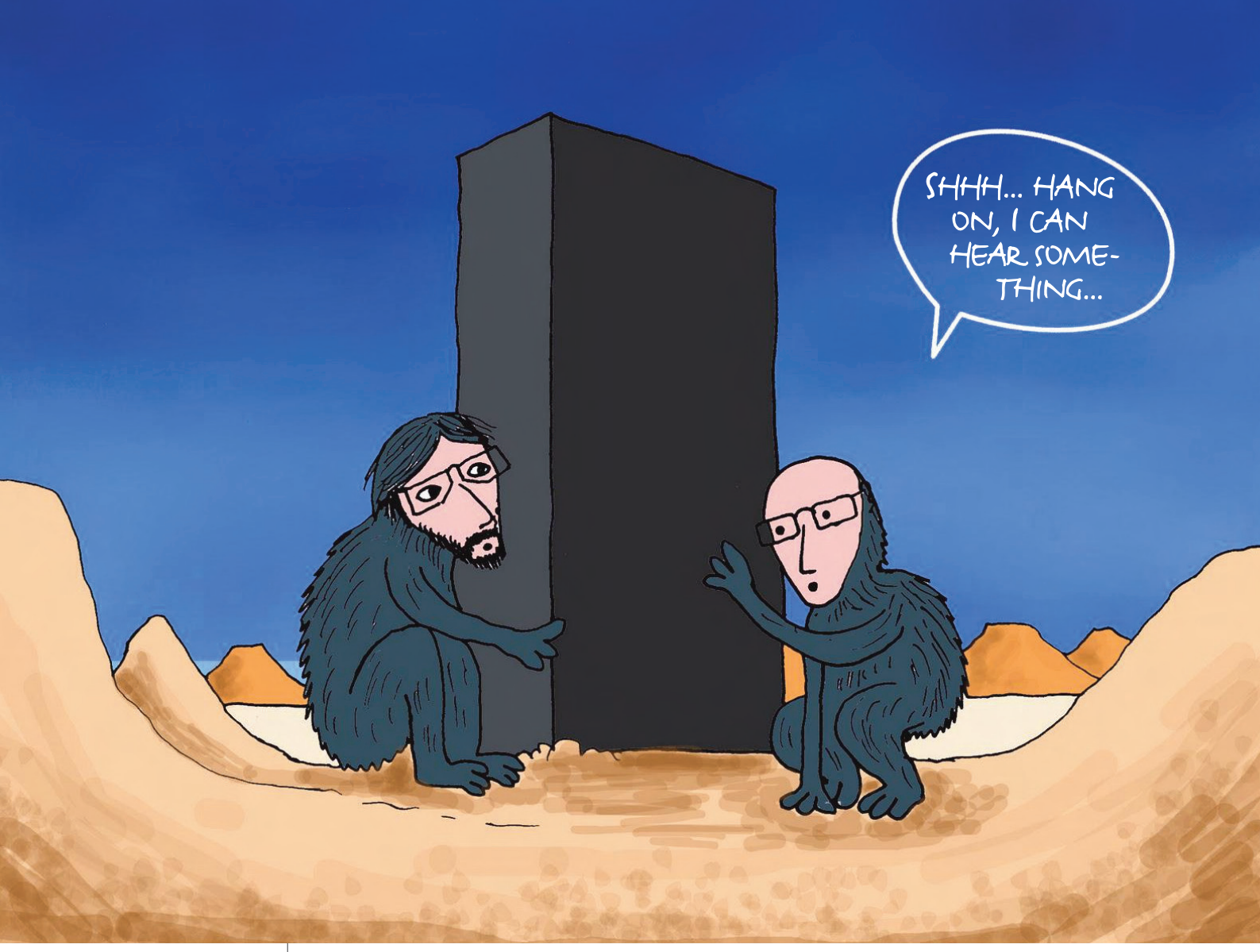
• None of the numerous spectra of non-stellar objects (quasars and galaxies of small angular size) analyzed as a reference to check for possible artefacts have shown the signals detected in the 234 stars.

• The likelihood that the detected signals could be due to statistical fluctuations is ~10^{-20}, while the probability that they are due to random fluctuations is <10^{-16}, and the probability that they are due to noise is $5 \cdot 10^{-27}$.

Borra and Trottier also tend to exclude effects that at first glance may affect the shape and location of the spectral lines, and thus the strength and position of the



To the left is Borra's computer-simulated frequency spectrum, in which is hidden the signal that a highly developed civilization could expediently add to the spectrum of its own star to communicate with other civilizations. Below we can see the results of the simulation processed with the Fourier transform. The isolated frequency peak is the expected signal. Its location coincides perfectly with what has been observed for the 234 stars highlighted by the Canadian researchers' study, the results of which are summarized in the greyish box. [Borra & Trottier, 2016]



This sketch, which hints at a scene from the movie "2001: A Space Odyssey", clearly illustrates the level the human species would be compared to the hypothetical civilization which might have emitted the signals discovered by Borra and Trottier.

signal generated by the Fourier transform. Chemical composition, temperature, gravity, and rotational speed would not be significant for the production of the signal. Only the radial velocity could affect the results, but for the stars in question it should be greater than 300 km/s in 99% of cases. Instead, the vast majority of the SDSS stellar sources examined by the two researchers have radial velocities below such level. To be precise, these speeds are between –150 and +120 km/s, based on a random sample of the distribution of the number of halo stars depending on the radial velocity.

In conclusion, the question remains open, awaiting new works focused on individual suspected stars. An initial observation campaign is currently being planned as part of the Breakthrough Listen Initiative.

This project, launched at the beginning of 2016, aims to search for intelligent life in the cosmos using a 2.4 metres optical telescope, the Automated Planet Finder at Lick Observatory in California, to thoroughly investigate some of the stars reported by Borra and Trottier.

If a natural explanation for this phenomenon cannot be found, we will have to find what is behind the similarity and simultaneity of these voluntary transmissions from ETIs hundreds or thousands light-years away from each other.

Perhaps it is an "obligatory" stage in the evolutionary path of a planetary civilization. Or, taking a cue from science fiction (which often anticipates reality), there could well exist in the Galaxy some sort of interplanetary federation, in which several ETIs communicate with each other by some millennia by inputting signals in the stellar spectra and modulating them in a Morse code manner. Due to the great interstellar distances, these would essentially be a one-way communications, something similar to news bulletins on the current state of each planet. If this were the scenario, we earthly beings would only be a primitive civilization facing its own black monolith. ■

Tangled threads weave through cosmic oddity

by ESA/NASA

NGC 4696 is a member of the Centaurus galaxy cluster, a swarm of hundreds of galaxies all sitting and bound together by gravity, about 150 million light-years from Earth and located in the constellation of Centaurus.

Despite the cluster's size, NGC 4696 still manages to stand out from its companions — it is the cluster's brightest member, known for obvious reasons as the Brightest Cluster Galaxy. This puts it in the same category as some of the biggest and brightest galaxies known in the Universe. Even if NGC 4696 keeps impressive company, it has a further distinction: the galaxy's unique structure. Previous observations have revealed curling filaments that stretch out from its main body and carve out a cosmic question mark in the sky, the dark tendrils encircling a brightly glowing centre.

An international team of scientists, led by astronomers from the University of Cambridge, UK, have now used new observations from the NASA/ESA Hubble Space Telescope to explore this thread-like structure in more detail. They found that each of the dusty filaments has a width of about 200 light-years, and a density some 10 times greater than the surrounding gas. These filaments knit together and spiral inwards towards the centre of NGC 4696, connecting the galaxy's constituent gas to its core. In fact, it seems that the galaxy's core is actually responsible for the shape and positioning of the filaments themselves. At the centre of NGC 4696 lurks an active supermassive black hole. This floods the galaxy's inner regions with energy, heating the gas there and sending streams of heated material outwards.

It appears that these hot streams of gas bubble outwards, dragging the filamentary material with them as they go. The galaxy's magnetic field is also swept out with this bubbling motion, constraining and sculpting the material within the filaments.

At the very centre of the galaxy, the

This picture, taken by Hubble's Wide Field Camera 3 (WFC3), shows NGC 4696, the largest galaxy in the Centaurus Cluster. The new images taken with Hubble show the dusty filaments surrounding the centre of this huge galaxy in greater detail than ever before. These filaments loop and curl inwards in an intriguing spiral shape, swirling around the supermassive black hole at such a distance that they are dragged into and eventually consumed by the black hole itself. [NASA, ESA/Hubble, A. Fabian]

This ground-based image shows the galaxy NGC 4696 and its surroundings. [NASA, ESA, Digitized Sky Survey 2 and Davide De Martin]

http://www.spacetelescope.org/videos/heic1013a/

This video zooms on NGC 4696, the largest galaxy in the Centaurus Cluster (galaxy cluster Abell 3526) as seen with the NASA/ESA Hubble Space Telescope. [ESA/Hubble, NASA, ESO/Digitized Sky Survey 2 and S. Brunier]

filaments loop and curl inwards in an intriguing spiral shape, swirling around the supermassive black hole at such a distance that they are dragged into and eventually consumed by the black hole itself.

Understanding more about filamentary galaxies such as NGC 4696 may help us to better understand why so many massive galaxies near to us in the Universe appear to be dead; rather than forming newborn stars from their vast reserves of gas and dust, they instead sit quietly, and are mostly populated with old and aging stars. This is the case with NGC 4696. It may be that the magnetic structure flowing throughout the galaxy stops the gas from creating new stars. ■

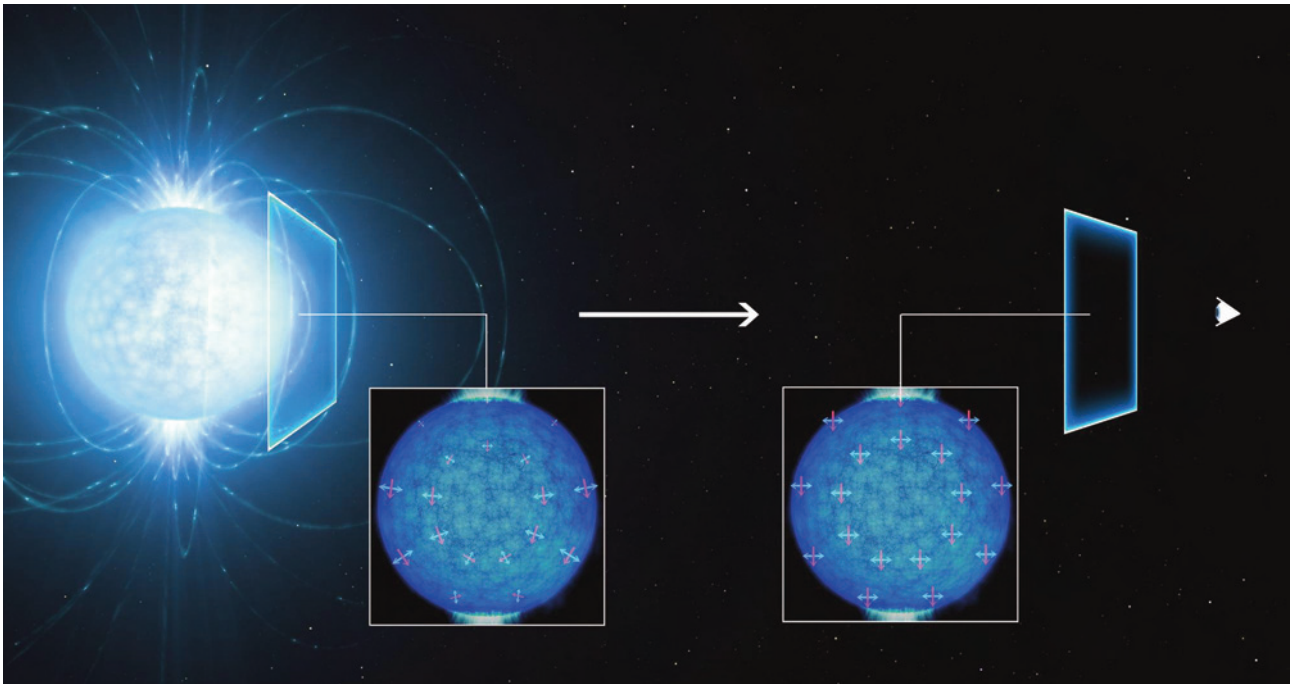
First signs of weird quantum property of empty space?

by ESO

A team led by Roberto Mignani from INAF Milan (Italy) and from the University of Zielona Gora (Poland), used ESO's Very Large Telescope (VLT) at the Paranal Observatory in Chile to observe the neutron star RX J1856.5-3754, about 400 light-years from Earth.

This object is part of the group of neutron stars known as the Magnificent Seven. They are known as isolated neutron stars (INS), which have no stellar companions, do not emit radio waves (like pulsars), and are not surrounded by progenitor supernova material.

Despite being amongst the closest neutron stars, its extreme dimness meant the astronomers could only observe the star with visible light using the FORS2 instrument on the

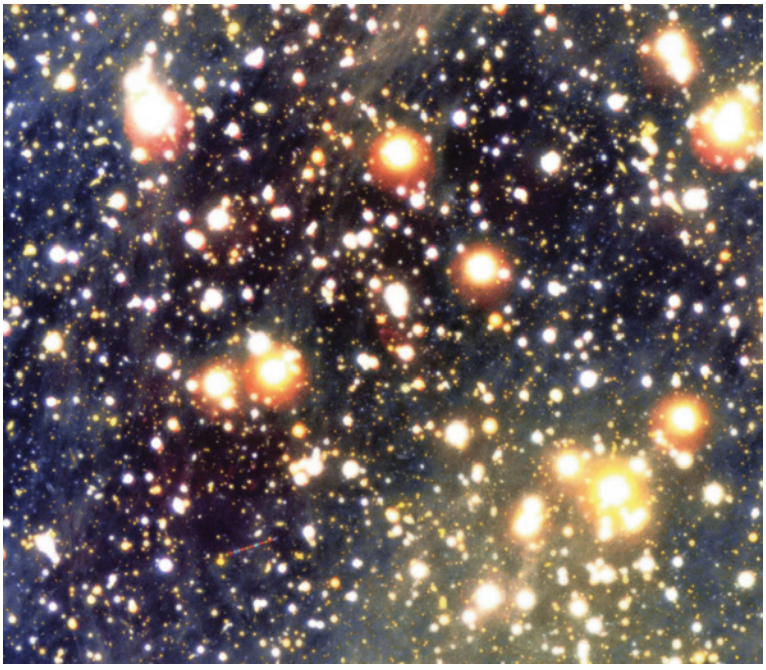


This artist's view shows how the light coming from the surface of a strongly magnetic neutron star (left) becomes linearly polarised as it travels through the vacuum of space close to the star on its way to the observer on Earth (right). The polarisation of the observed light in the extremely strong magnetic field suggests that the empty space around the neutron star is subject to a quantum effect known as vacuum birefringence, a prediction of quantum electrodynamics (QED). This effect was predicted in the 1930s but has not been observed before. [ESO/L. Calçada]

VLT, at the limits of current telescope technology. Neutron stars are the very dense remnant cores of massive stars — at least 10 times more massive than our Sun — that have exploded as supernovae at the ends of their lives. They also have extreme magnetic fields, billions of times stronger than that of the Sun, that permeate their outer surface and surroundings. These fields are so strong that they even affect the properties of the empty space around the star. Normally a vacuum is thought of as completely empty, and light can travel through it without being changed.

But in quantum electrodynamics (QED), the quantum theory describing the interaction between photons and charged particles such as electrons, space is full of virtual particles that appear and vanish all the time. Very strong magnetic fields can modify this space so that it affects the polarisation of light passing through it. Mignani explains: *"According to QED, a highly magnetised vacuum behaves as a prism for the propagation of light, an effect known as vacuum birefringence."*

Among the many predictions of QED, however, vacuum birefringence so far lacked a direct experimental demonstration. Attempts to detect it in the laboratory have not yet succeeded in the 80 years since it was predicted in a paper by Werner Heisenberg (of uncertainty principle fame) and Hans Heinrich Euler.



Colour composite photo of the sky field around the lonely neutron star RX J1856.5-3754 and the related cone-shaped nebula. It is based on a series of exposures obtained with the multi-mode FORS2 instrument at VLT Kueyen through three different optical filters. The trail of an asteroid is seen in the field with intermittent blue, green and red colours. RX J1856.5-3754 is exactly in the centre of the image. [ESO]

"This effect can be detected only in the presence of enormously strong magnetic fields, such as those around neutron stars. This shows, once more, that neutron stars are invaluable laboratories in which to study the fundamental laws of nature." says Roberto Turolla (University of Padua, Italy).

After careful analysis of the VLT data, Mignani and his team detected linear polarisation — at a significant degree of around 16% — that they say is likely due to the boosting effect of vacuum birefringence occurring in the area of empty space surrounding RX J1856.5-3754. There are other processes that can polarise starlight as it travels through space. The team carefully reviewed other possibilities — for example polarisation created by scattering off dust grains — but consider it unlikely that they produced the polarisation signal observed. Vincenzo Testa (INAF, Rome, Italy) comments: *"This is the faintest object for which polarisation has ever been measured. It required one of the largest and most efficient telescopes in the world, the VLT, and accurate data analysis techniques to enhance the signal from such a faint star."*

"The high linear polarisation that we measured with the VLT can't be easily explained by our models unless the vacuum birefringence effects predicted by QED are included," adds Mignani.

"This VLT study is the very first observational support for predictions of these kinds of QED effects arising in extremely strong magnetic fields," remarks Silvia Zane (UCL/MSSL, UK).

Mignani is excited about further improvements to this area of study that could come about with more advanced telescopes: *"Polarisation measurements with the next generation of telescopes, such as ESO's European Extremely Large Telescope, could play a crucial role in testing QED predictions of vacuum birefringence effects around many more neutron stars."*

"This measurement, made for the first time now in visible light, also paves the way to similar measurements to be carried out at X-ray wavelengths," adds Kinwah Wu (UCL/MSSL, UK). ■

Stellar system caught in act of forming close multiples

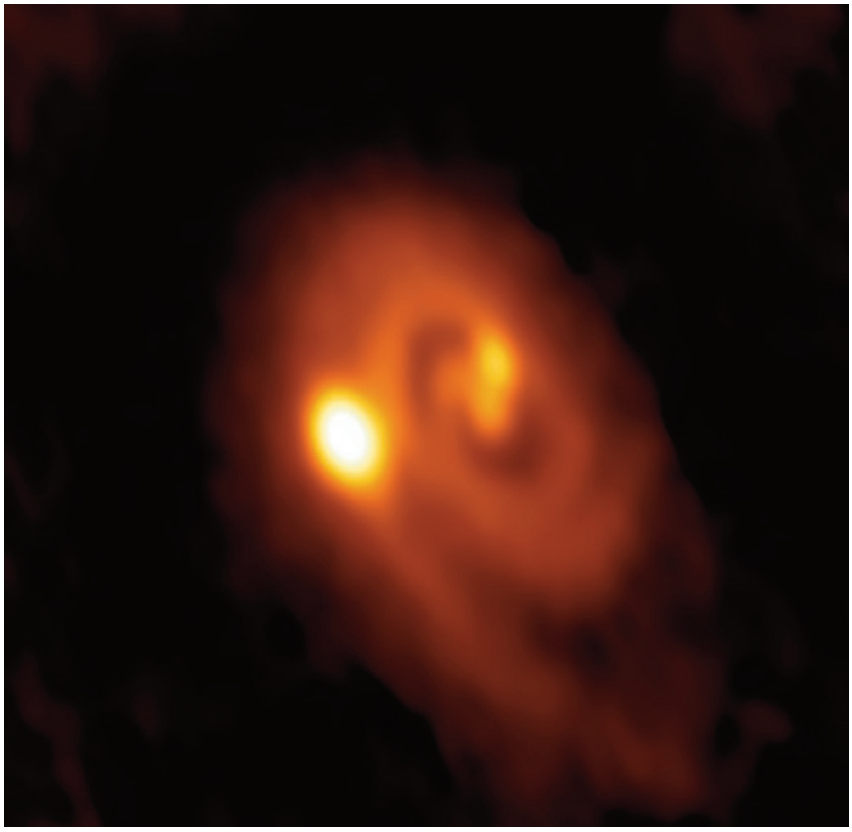
by ALMA Observatory

For the first time, astronomers have seen a dusty disk of material around a young star fragmenting into a multiple-star system. Scientists had suspected such a process, caused by gravitational instability, was at work, but new observations with the Atacama Large Millimeter/submillimeter Array (ALMA) and the Karl G. Jansky Very Large Array (VLA) revealed the process in action.

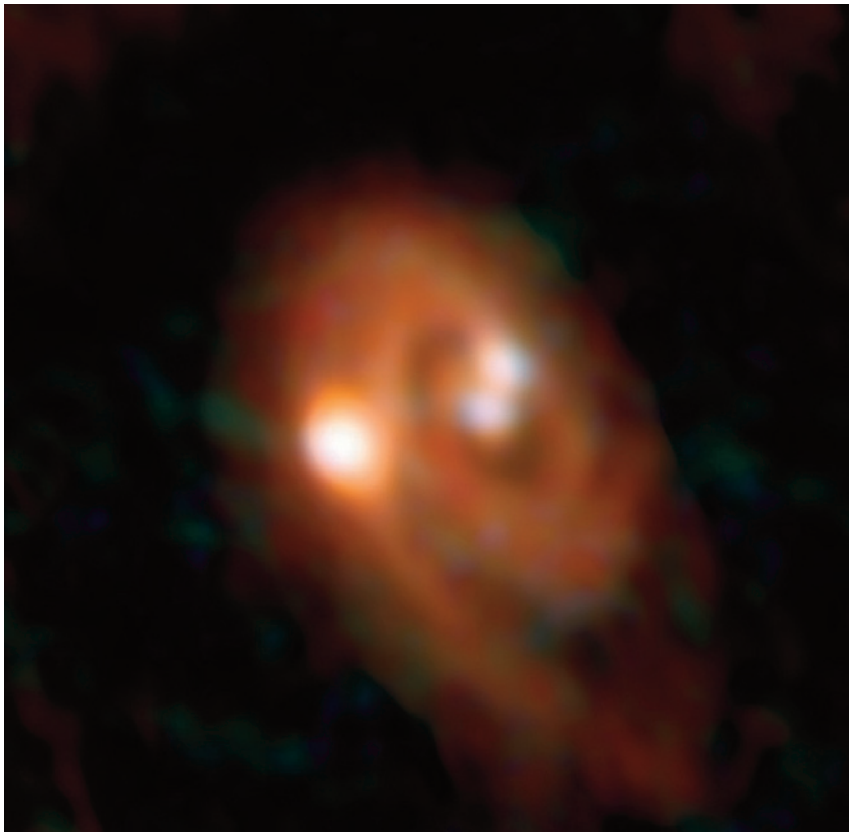
"This new work directly supports the conclusion that there are two mechanisms that produce multiple star systems: fragmentation of circumstellar disks, such as we see here, and fragmentation of the larger cloud of gas and dust from which young stars are formed," said John Tobin, of the University of Oklahoma and Leiden Observatory in the Netherlands.

Stars form in giant clouds of gas and dust, when the tenuous material in the clouds collapses gravitationally into denser cores that begin to draw additional material inward. The infalling material forms a rotating disk around the young star. Eventually, the young star gathers enough mass to create the temperatures and pressures at its center that will trigger thermonuclear reactions.

Previous studies had indicated that multiple star systems tend to have companion stars either relatively close, within about 500 times the Earth-Sun distance, or significantly farther apart, more than 1,000 times that distance. Astronomers concluded that the differences in



ALMA image of the L1448 IRS3B system, with two young stars at the center and a third distant from them. Spiral structure in the dusty disk surrounding them indicates instability in the disk, astronomers said. [Bill Saxton, ALMA (ESO/NAOJ/NRAO), NRAO/AUI/NSF]



Combined ALMA and VLA image of L1448 IRS3B system. [Bill Saxton, ALMA (ESO/NAOJ/NRAO), NRAO/AUI/NSF]

distance result from different formation mechanisms. The more widely-separated systems, they said, are formed when the larger cloud fragments through turbulence, and recent observations have supported that idea.

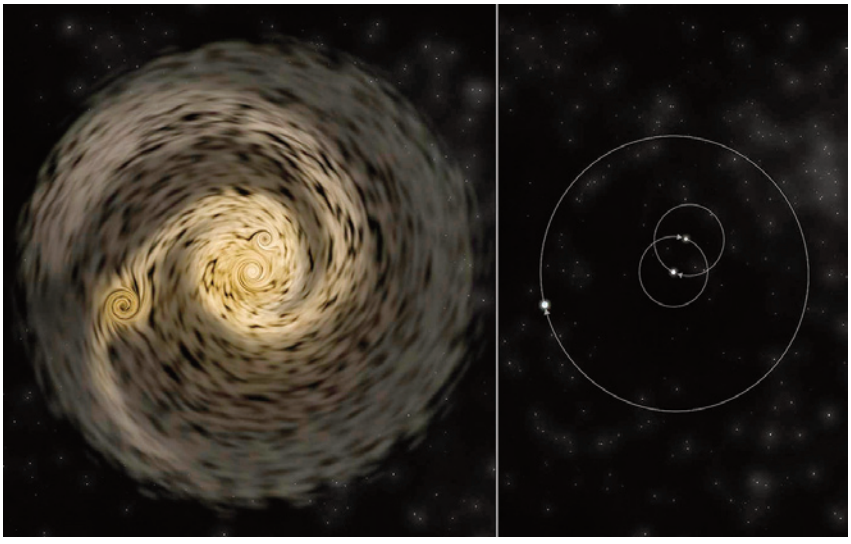
The closer systems were thought to result from fragmentation of the smaller disk surrounding a young protostar, but that conclusion was based principally on the relative proximity of the companion stars.

"Now, we've seen this disk fragmentation at work," Tobin said.

Tobin, Kaitlin Kratter of the University of Arizona, and their colleagues used ALMA and the VLA to study a young triple-star system called L1448 IRS3B, located in a cloud of gas in the constellation Perseus, some 750 light-years from Earth. The most central of the young stars is separated from the other two by 61 and 183 times the Earth-Sun distance. All three are surrounded by a disk of material that ALMA revealed to have spiral structure, a feature that, the astronomers said, indicates instability in the disk.

"This whole system probably is less than 150,000 years old," Kratter said. *"Our analysis indicates that the disk is unstable, and the most widely separated of the three protostars may have formed only in the past 10,000 to 20,000 years,"* she added. The L1448 IRS3B system, the astronomers conclude, provides direct observational evidence that fragmentation in the disk can produce young multiple-star systems very early in their development.

"We now expect to find other examples of this process and hope to learn just how much it contributes to the population of multiple stars," Tobin concluded. ■



Artist's conception of how the triple-star system develops. Left, disk of material fragments into separate protostars. Right, the resulting stellar system. [Bill Saxton, NRAO/AUI/NSF]

Watchers of the skies

by Audrey Choné and Jérôme Duprez

A giant flash, a fireball, and thunder noise: here is what inhabitants of Khakassia could witness on 06 December. But bigger threats exist: that's why a fair lot of instruments scout the skies, tracking several new one-million-tons pebbles every day. Should one of them threaten to hit the window, what could we do to thwart fate? Well, a lot actually, provided we have enough time. That's the mission of a network of telescopes and scientists all over the world. A waste of taxpayers' money? Dinosaurs would have a different opinion...

In the background, a tipical example of a bolide (i.e. a fireball, or bright meteor) entering the atmosphere. If enough massive, bolides can reach the surface and for this reason they represent a threat for life.

In the side video the latest relevant bolide plunged last 06 December in the Siberian night skies, in the territory of Khakassia, over the Beisk district.

https://www.youtube.com/watch?v=jw2tk13S794

There is little controversy nowadays on the reasons of the mass extinction at the end of Cretaceous, 66 million years ago. Paleontologists, geologists, and astronomers, agree that an asteroid or comet hammered the Gulf of Mexico close to what is known today as the city of Chicxulub Puerto, releasing eight billion times as much energy as the Hiroshima bombing. The dust lifted up by the impact dimmed sunlight for a few years, possibly a decade, triggering a climate change that proved fatal to many species of cold-blooded animals that had not been killed in the fires and tsunamis that followed the explosion itself.

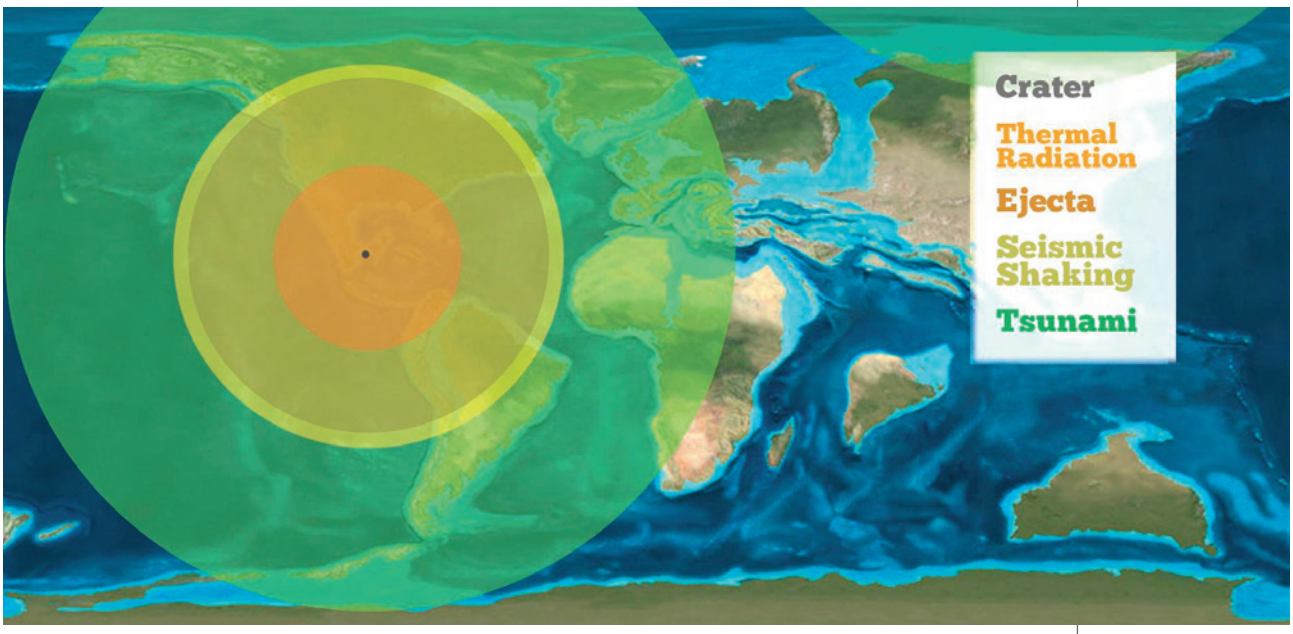
In modern time, an asteroid or a cometary fragment is assumed to be the reason for the 1908 Tunguska event, which caused a detonation heard 1500 km away, and consumed or knocked down millions of trees across an area of at least 20 km of radius.
Even more recently (2013), we can consider it lucky that the fireball that was witnessed crossing the sky over the Russian city of Chelyabinsk, was on a trajectory that ended tangentially enough to Earth surface: the atmospheric friction heated it up and blew it at an altitude of 20 to 25 kilometers. Hundreds of people were injured by broken windows; but on the plus side, the widely

commented videos of the event helped to popularize the dangers of space bodies: forewarned is forearmed.
And forewarned we are. Indeed, the Chelyabinsk fireball showed that, although Hollywood's attention is focused on projectiles that might powder humanity after the dinosaurs, we are far more at risk of meeting a smaller impactor that would destroy a city and take thousands of lives.
By 1991, the International Astronomical Union had already appointed a Working Group focused on NEOs (Near-Earth Objects): a NEO is a space body whose perihelion (point of closest approach to the Sun) is less than 1.3 astronomical unit (au), which may bring it in the vicinity of planet Earth. More scary are the Potentially Hazardous Objects (or PHAs), a subcategory of NEOs whose path comes within 0.05 au of Earth, that is, about 7.5 million km.
The Spaceguard Foundation followed in 1996: hosted by the Instituto di Astrofisica Spaziale, in the National Research Council (CNR) in Rome, its purposes is to establish an international ground network called Spaceguard System to detect, analyze, and follow-up NEOs, refine their trajectory predictions, and identify those that might threaten to impact Earth.

https://www.youtube.com/watch?v=5qJPTjMnwNk

In 2013, maybe pressed by the Chelyabinsk event, the United Nations approved the creation of the International Asteroid Warning Network (IAWN). Much less soporific than its acronym suggests, this network of instruments and researchers publishes a daily report of new NEOs, and works in the background on improving the detection methods, and ensuring efficiency on the alerting system.
The biggest contributor to the extensive detection effort so far has been NASA. The US agency was commissioned in 1998, by the National Congress, to conduct a program

Above, a spectacular reconstruction of the immediate and long-term effects of the impact that wiped out the dinosaurs. [Radek Michalik, David Dolak, Chicago Columbia College] Below, the different direct impact consequences on a planetary scale.



An impressive artistic representation of the explosion which took place in 1908 over the Tunguska region.

whose aim was to detect 90% of the NEOs of 1 km or larger, within ten years. An objective met in 2005, three years in advance. However, this success is deceiving. Granted, the Chicxulub impactor had an estimated diameter of 10 km. But the smaller objects, harder to detect, vastly outnumber the huge ones. In a 2007 report to National Congress on "Near-Earth Object Survey and Deflection Analysis of Alternatives", NASA recommended to improve the system to cover this gap, and to aim for the detection of 90% of the Potentially Hazardous Asteroids of 140 m or larger, a size sufficient to wipe out a city.

Recent advances in the detection of small bodies, and in the subsequent actions, include NASA's Scout software program. Using data gathered from several telescopes, this program, developed by the Jet Propulsion Laboratory (JPL) in Pasadena, California, analyzes the trajectory of any new tiny dot (NASA surveys discover more than five asteroids every night). If an impact risk is determined to be sufficiently high, Scout instructs other telescopes to make fol-

low-up observations, to help refine the orbital data, and reckon the threat. Scout helped determine the trajectory of asteroid 2016 UR_{36}, which passed 1.3 lunar distances (LD) from Earth on last Halloween. More interestingly, it gave the warning 5 days in advance, which is more than the typical hours we have when dealing with small bodies.

Thanks to the international effort, including the Catalina Sky Survey in Arizona, the Pan-STARRS project in Hawaii, and the European Space Agency's Space Situation Awareness program (SSA), the number of known NEOs increases by about 30 every week, exceeding 15000 (including more than 1500 PHAs), a milestone reached in October 2016!

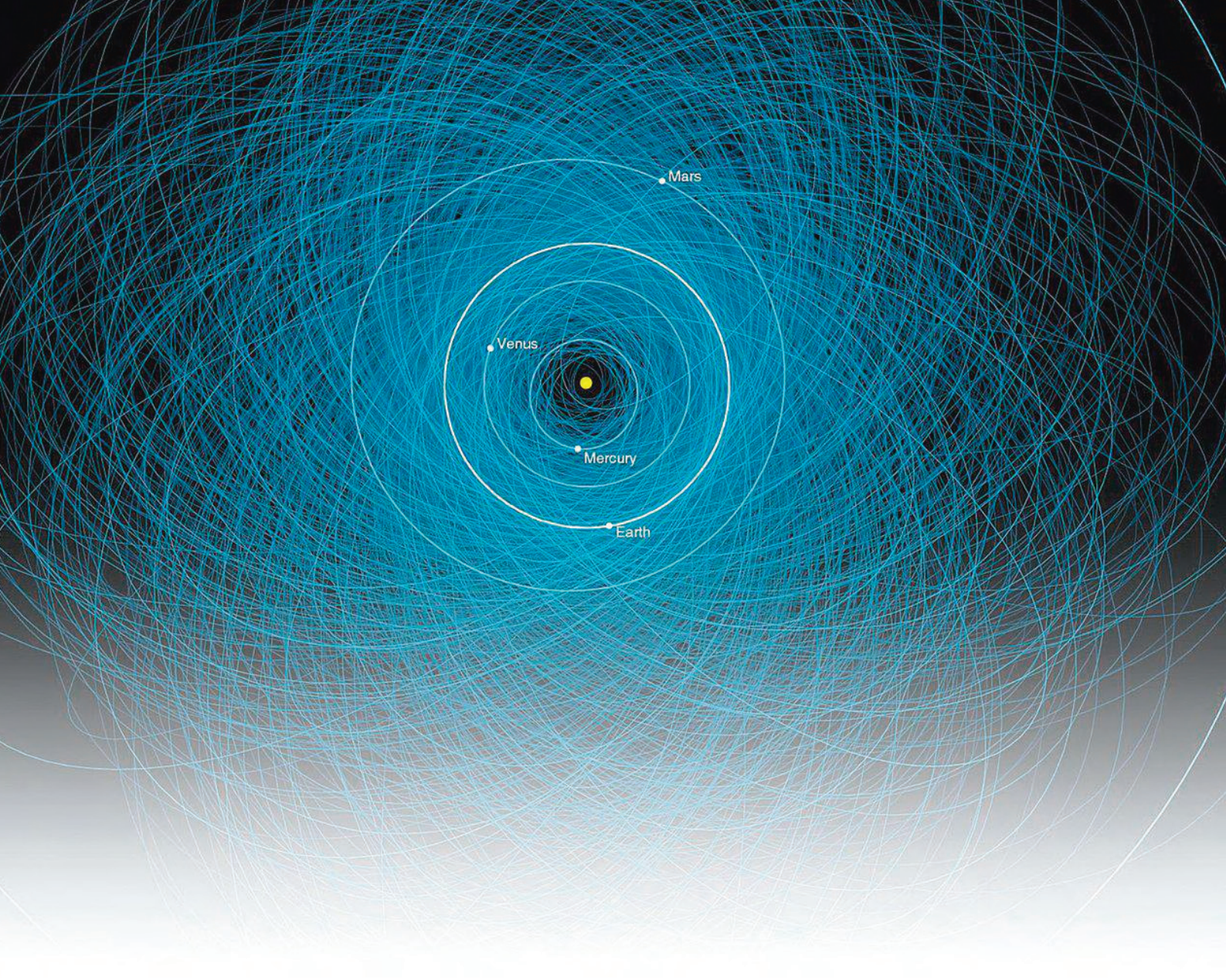
Among PHAs, the largest known is 4179 Toutatis, 4.6 km at it thickest. It toured at 18 lunar distances from Earth on December 2012, and will make a closer pass at 7.7 LD in 2069. But the two most hazardous asteroids are 99942 Apophis and 2000 YK_{66}, in the 300 m large, which will approach Earth under 0.1 and 0.2 LD. Apophis has an estimated probability of 1:1000000 to collide with Earth on the 13 April 2029; worse,

A wonderful photograph of the fireball streaking through the sky above Chelyabinsk, Russia, on 15 February 2013. The small asteroid was about 20 meters wide. [M. Ahmetvaleev] On the left, two historical photographs showing the Tunguska impact effects on the Siberian taiga: only some of the trees just below the point of the explosion remained standing, while all around they were knocked down. About 80 million trees died in that event.

Below, the crater produced into the icy surface of the Lake Chebarkul by the Chelyabinsk impact. The bigger fragment recovered in the lake is showed on the right.

2000 YK_{66} has a 1 on 300 chance to smash into our planet! But mankind has more than 8 centuries to prepare itself and find a solution — the potential killjoy will not crash into the party before 2880!

The work on NEOs at NASA is coordinated by the Planetary Defense Coordination Office… A name that would sound far-fetched if you heard it in a science-fiction movie. Still, this real official institution has the mission to ensure the early detection of PHAs above 30 m (those large enough to survive atmospheric friction and reach the surface of Earth), and accordingly trigger a national or international alert system, as well as coordinate the response to the threat. Indeed the 2007 report to National Congress included a summary of defense techniques — and



fortunately they include more science than fiction.

"Asteroid impacts are the only natural hazard that we can, in principle, entirely eliminate", said Dr David Morrison, from NASA's NEO Program.

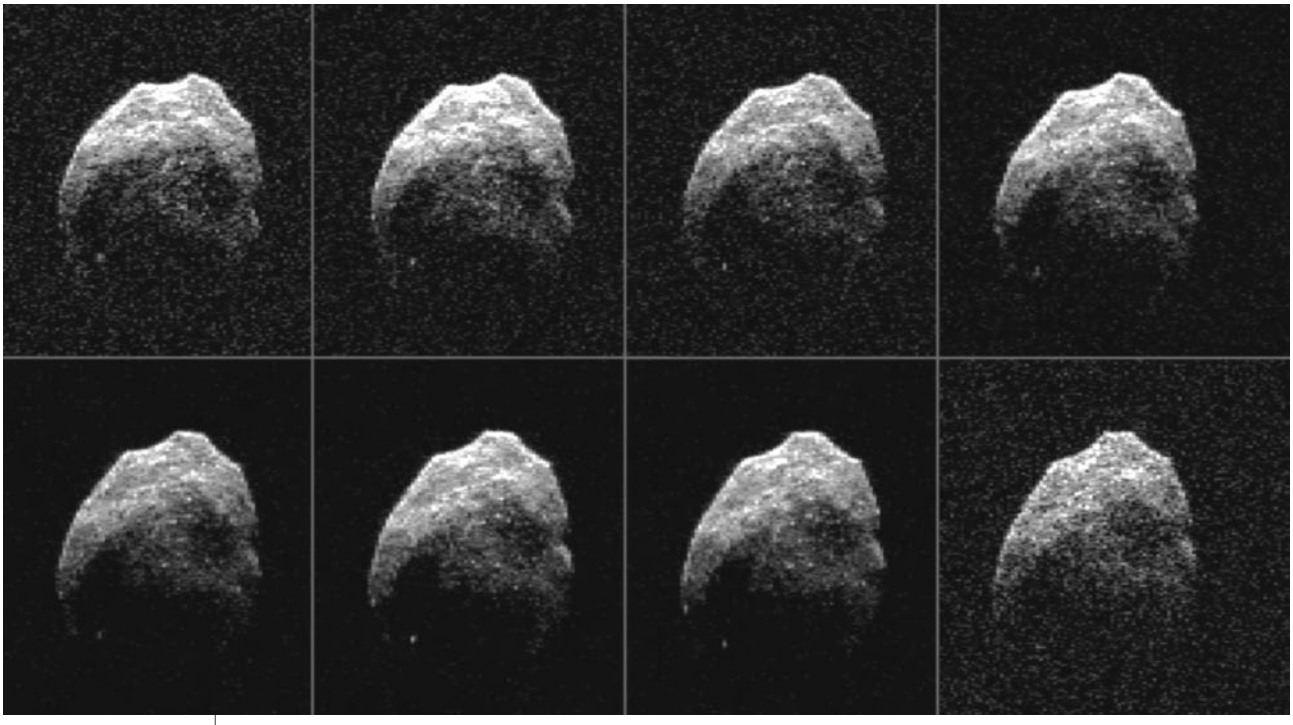
This comforting statement relies on technological factors. But the single most important criterion is time: a few decades would be comfortable to prevent a collision. Let's assume we have 20 years to avoid a 1 km gravel to crash into the windshield. We can eliminate the destructive techniques: a swarm of building-sized rocks would not be a blessing compared to a single flying hill. And using a nuclear bomb to blow up the intruder in space would only add radioactivity to the deadly debris!

So, why not use a trendier clean energy? Solar sails, or white foil clinging to the asteroid's surface, could increase the radiation pressure from the solar wind, and thrust it out of its way.

Small satellites equipped with mirrors could concentrate solar light to vaporize a portion of the asteroid. Powerful lasers would achieve the same goal: ablating a small amount of material to change the asteroid's gravity center, and alter its path.

We can also use less intuitive anti-Doomsday devices; like a gravity tractor: a spaceship that would hover over the party crasher, its minuscule gravity field gently but steadily deflecting the cosmic voyager to a less spectacular journey. Or painting the rock black: increasing the anisotropic emission of pho-

These orbits identify known NEOs of more than 140 meters across, the most dangerous, should they collide with Earth. [American Association for the Advancement of Science]



Asteroid 2015 TB_{145} is depicted in eight individual radar images collected on 31 October. At the time the radar images were taken, the asteroid was between 710,000 km and 690,000 km distant. Asteroid 2015 TB_{145} safely flew past Earth at about 1.3 lunar distances. On the side, asteroid Toutatis, visited by the Chinese probe Chang'e 2 on December 2012.

tons would unbalance the trajectory, a phenomenon known as the Yarkosky effect.
But years of preparation are a luxury affordable only for the biggest impactors. In the Halloween warning from the Scout program, the forecast was five days in advance: a space mission in such a short term is not an option, but if the odds of impact had been confirmed, five days would have allowed the evacuation of the threatened zone. US FEMA (Federal Emergency Management Agency), for example, is routinely prepared to cope with such scenarios.
Beside the thrill, the hunting of asteroids is also a valuable scientific quest. Unlike planets, asteroids and comets did not suffer geological and thermic modification in their youth. Their composition can then give a good idea of the conditions in our early Solar System. But their faraway locations are not easily reachable. A one-way probe can study them, like the Chinese mission Chang'e 2 which managed to take astonishing photos, flying only 770 m from the

NEO Toutatis in 2012, or the European probe Rosetta, which orbited the comet Churyumov-Gerasimenko for more than two years. Round-trip missions are also possible: the first Habayusa mission, launched in 2003 by Japan, managed to scrape off the regolith from the surface of asteroid Itokawa in 2005. It returned a pod containing the particles back on Earth in 2010. A second Habayusa mission, launched in December 2014, should return another pod around 2020. And last September, NASA sent a new probe Osiris Rex, supposed to reach asteroid Bennu in 2018, study it, and shovel some ground samples back to Earth by 2023. NASA is also developing the Asteroid Redirect Mission (ARM), to bring a NEO into a stable orbit around the Moon. Four asteroids are potential candidates, and NASA plans to launch the ARM spacecraft at the end of this decade.

A manned mission on-board the Orion spacecraft could then land on the asteroid and explore it, in the mid-2020s. A full-scale training for a deflection technique that might be used for planetary defense one day…

This very detailed view shows the strange peanut-shaped asteroid Itokawa. This picture comes from the Japanese spacecraft Hayabusa during its close approach in 2005. [JAXA] The animation on the left shows asteroid 2004 BL_{86}, which safely flew past Earth on 26 January 2015. [NASA/JPL-Caltech]

http://www.jpl.nasa.gov/video/details.php?id=1357

Man-made weapons kill more on every single day than asteroids have in all recorded human history. But the myth of Sodome, and the number of people that would be killed in a single event, urge us to keep the risk under control. The technology exists to detect a cosmic voyager, and capture it for study, or shove it out of the way. The deflection techniques are easy as pie though, compared to the international coordination, cooperation, and funding they require… Plus the diplomatic skills, as the impact point would gradually shift from one country to the next over the months of light alteration of trajectory, until we are all safe. Eventually, in case of unavoidable impact, how will the international community welcome a few millions of "astronomical refugees"?

An impact threat may well be a good maturity test for humanity… ■

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Image: Saturn by NASA

Tsunami produces dazzling eye-shaped feature in galaxy

by ALMA Observatory

Astronomers using the Atacama Large Millimeter/submillimeter Array (ALMA) have discovered a tsunami of stars and gas that is crashing midway through the disk of a spiral galaxy known as IC 2163. This colossal wave of material – which was triggered when IC 2163 recently sideswiped another spiral galaxy dubbed NGC 2207 – produced dazzling arcs of intense star formation that resemble a pair of eyelids. *"Although galaxy collisions of this type are not uncommon, only a few galaxies with eye-like, or ocular, structures are known to exist,"* said Michele Kaufman, an astronomer formerly with The Ohio State University in Columbus and lead author on a paper published in *The Astrophysical Journal.*

Galaxies IC 2163 (left) and NGC 2207 (right) recently grazed past each other, triggering a tsunami of stars and gas in IC 2163 and producing the dazzling eyelid-like features there. ALMA image of carbon monoxide (orange), which revealed motion of the gas in these features, is shown on top of Hubble image (blue) of the galaxy pair. [M. Kaufman; B. Saxton (NRAO/AUI/NSF); ALMA (ESO/NAOJ/NRAO); NASA/ESA Hubble Space Telescope]

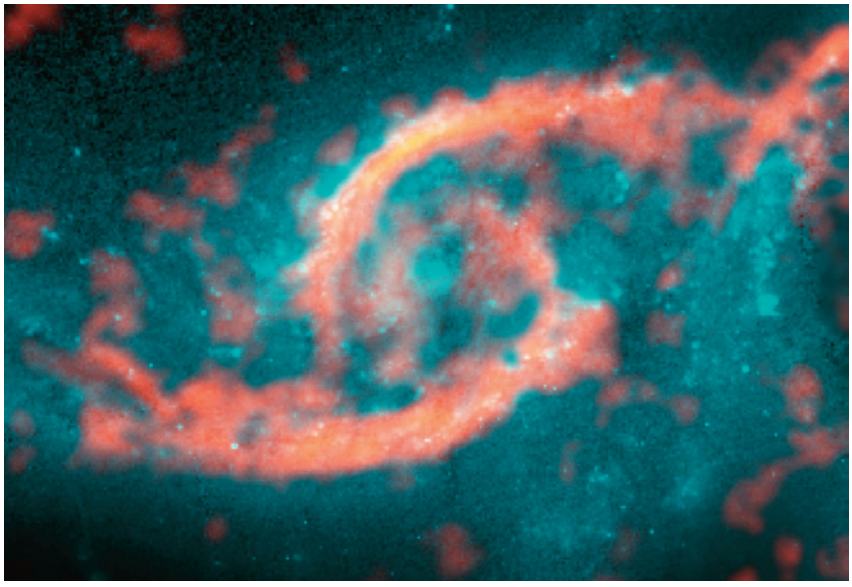
Kaufman and her colleagues note that the paucity of similar features in the observable universe is likely due to their ephemeral nature. *"Galactic eyelids last only a few tens of millions of years, which is incredibly brief in the lifespan of a galaxy. Finding one in such a newly formed state gives us an exceptional opportunity to study what happens when one galaxy grazes another,"* said Kaufman.

The interacting pair of galaxies resides approximately 114 million light-years from Earth in the direction of the constellation Canis Major. These galaxies brushed past each other – scraping the edges of their outer spiral arms -- in what is likely the first encounter of an eventual merger.

Using ALMA's remarkable sensitivity and resolution, the astronomers made the most detailed measurements ever of the motion of carbon monoxide gas in the galaxy's narrow eyelid features. Carbon monoxide is a tracer of molecular gas, which is the fuel for star formation. The data reveal that the gas in the outer portion of IC 2163's eyelids is racing inward at speeds in excess of 100 kilometers a second. This gas, however, quickly decelerates and its motion becomes more chaotic, eventually changing trajectory and aligning itself with the rotation of the galaxy rather than continuing its pell-mell rush toward the center.

"What we observe in this galaxy is very much like a massive ocean wave barreling toward shore until it interacts with the shallows, causing it to lose momentum and dump all of its water and sand on the beach," said Bruce Elmegreen, a scientist with IBM's T.J. Watson Research Center in Yorktown Heights, New York, and co-author on the paper.

"Not only do we find a rapid deceleration of the gas as it moves from the outer to the inner edge of the eyelids, but we also measure that the more rapidly it decelerates, the denser the molecular gas becomes," said Kaufman. *"This direct measurement of compression shows how the encounter between the two galaxies drives gas to pile up, spawn new star clusters and form these dazzling eyelid features."*



Dazzling eyelid-like features bursting with stars in galaxy IC 2163 formed from a tsunami of stars triggered by a glancing collision with galaxy NGC 2207 (a portion of its spiral arm is shown on right side of image). As for the previous one, also this ALMA image of carbon monoxide (orange) is shown on top of Hubble image (blue) of the galaxy. [M. Kaufman; B. Saxton (NRAO/AUI/NSF); ALMA (ESO/NAOJ/NRAO); NASA/ESA Hubble Space Telescope]

Computer models predict that such eyelid-like features could evolve if galaxies interacted in a very specific manner. *"This evidence for a strong shock in the eyelids is terrific. It's all very well to have a theory and simulations suggesting it should be true, but real observational evidence is great,"* said Curtis Struck, a professor of astrophysics at Iowa State University in Ames and co-author on the paper.

"ALMA showed us that the velocities of the molecular gas in the eyelids are on the right track with the predictions we get from computer models," said Kaufman. *"This critical test of encounter simulations was not possible before."*

Astronomers believe that such collisions between galaxies were common in the early universe when galaxies were closer together. At that time, however, galactic disks were generally clumpy and irregular, so other processes likely overwhelmed the formation of similar eyelid features.

The authors continue to study this galaxy pair and currently are comparing the properties (e.g., locations, ages, and masses) of the star clusters previously observed with NASA's Hubble Space Telescope with the properties of the molecular clouds observed with ALMA. They hope to better understand the differences between molecular clouds and star clusters in the eyelids and those elsewhere in the galaxy pair. ■

Striking features in planet-forming discs around young stars

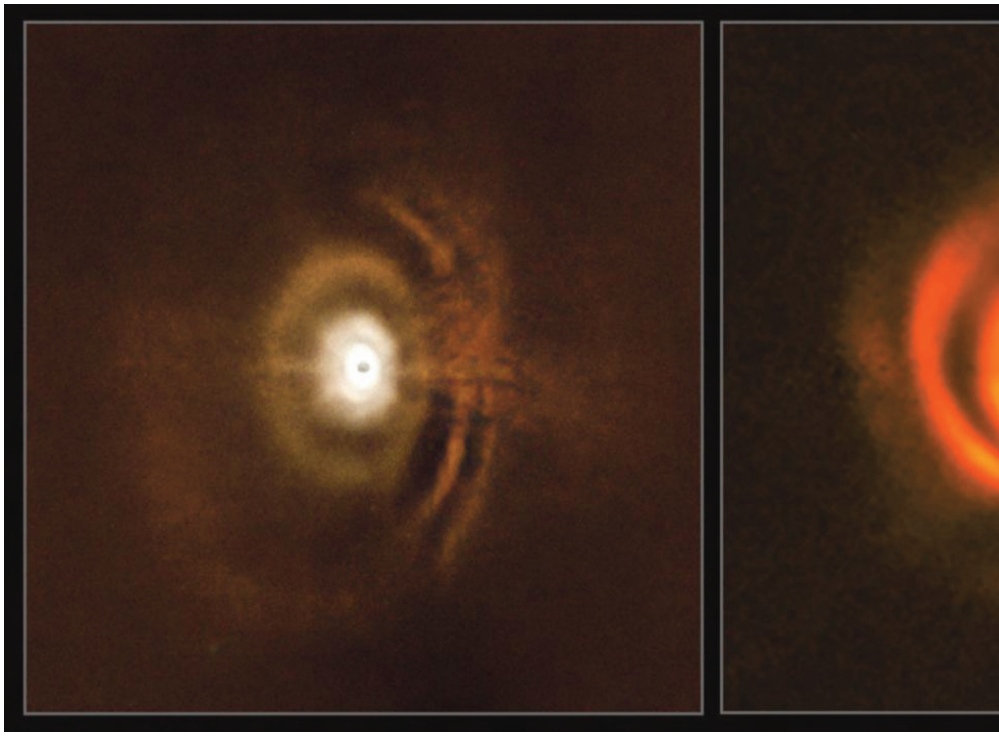
by ESO

Three teams of astronomers have made use of SPHERE, an advanced exoplanet-hunting instrument on the Very Large Telescope (VLT) at ESO's Paranal Observatory, in order to shed light on the enigmatic evolution of fledgling planetary systems. The explosion in the number of known exoplanets in recent years has made the study of them one of the most dynamic fields in modern astronomy.

Today it is known that planets form from vast discs of gas and dust encircling newborn stars, known as protoplanetary discs. These can extend for thousands of millions of kilometres. Over time, the particles in these protoplanetary discs collide, combine and eventually build up into planet-sized bodies. However, the finer details of the evolution of these planet-forming discs remain mysterious.

SPHERE is a recent addition to the VLT's array of instruments and with its combination of novel technologies, it provides a powerful method to directly image the fine details of protoplanetary discs.

The instrument uses advanced adaptive optics to remove atmospheric distortion, a coronagraph to block most of the light from the central star and a combination of differential imaging and polarimetry to isolate the light from features in the disc. The interaction between protoplanetary discs and growing planets can shape the discs into various forms: vast rings, spiral arms or shadowed voids. These are of special interest as an unambiguous link between these structures and the sculpting planets is yet to be found; a mystery astronomers are keen to solve.

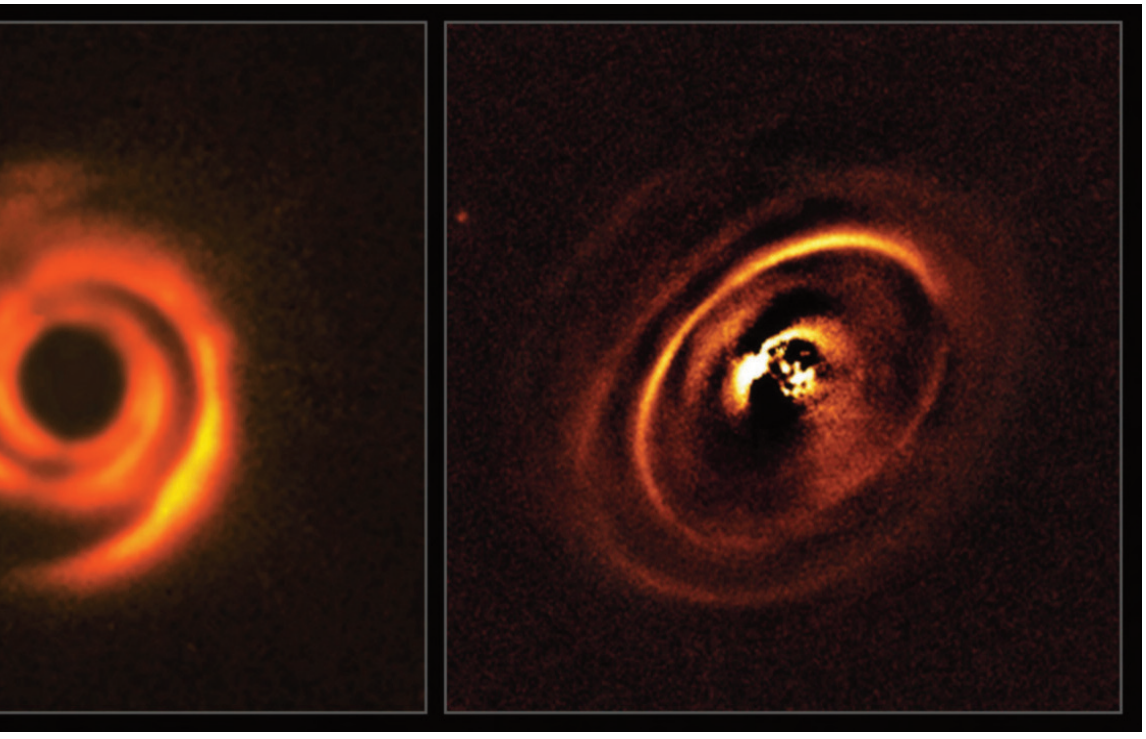


These three planetary discs have been observed with the SPHERE instrument, mounted on ESO's Very Large Telescope. The observations were made in order to shed light on the enigmatic evolution of fledgling planetary systems. The central parts of the images appear dark because SPHERE blocks out the light from the brilliant central stars to reveal the much fainter structures surrounding them. [ESO]

Fortunately, SPHERE's specialised capabilities make it possible for research teams to observe these striking features of protoplanetary discs directly.

For example, RX J1615 is a young star, which lies in the constellation of Scorpius, 600 light-years from Earth. A team led by Jos de Boer, of Leiden Observatory in the Netherlands, found a complex system of concentric rings surrounding the young star, forming a shape resembling a titanic version of the rings that encircle Saturn. Such an intricate sculpting of rings in a protoplanetary disc has only been imaged a handful of times before, and even more excitingly, the entire system seems to be only 1.8 million years old. The disc shows hints of being shaped by planets still in the process of formation.

The age of the newly detected protoplanetary disc makes RX J1615 an outstanding system, as most other examples of protoplanetary discs detected so far are relatively old or evolved. De Boer's unexpected result was quickly echoed by the findings of a team led by Christian Ginski, also of Leiden Observatory. They observed the young star HD 97048, located in the constellation of Chamaeleon, about 500 light-years from Earth. Through painstaking analysis, they found that the juvenile disc around this star has also formed into concentric rings. The symmetry of these two systems is a surprising result, as most protoplanetary systems contain a multitude of asymmetrical spiral arms, voids and vortexes. These discoveries significantly raise the number of known systems with multiple highly symmetrical rings.



A particularly spectacular example of the more common asymmetric disc was captured by a group of astronomers led by Tomas Stolker of the Anton Pannekoek Institute for Astronomy, the Netherlands. This disc surrounds the star HD 135344B, about 450 light-years away. Although this star has been well-studied in the past, SPHERE allowed the team to see the star's protoplanetary disc in more detail than ever before. The large central cavity and two prominent spiral arm-like structures are thought to have been created by one or multiple massive protoplanets, destined to become Jupiter-like worlds. In addition, four dark streaks, apparently shadows thrown by the movement of material within HD 135344B's disc, were observed. Remarkably, one of the streaks noticeably changed in the months between observing periods: a rare example of observing planetary evolution occur in real time, hinting at changes occurring in the inner disc regions that can not be directly detected by SPHERE. As well as producing beautiful images, these flickering shadows provide a unique way of probing the dynamics of innermost disc regions.

As with the concentric rings found by de Boer and Ginski, these observations by Stolker's team prove that the complex and changing environment of the discs surrounding young stars are still capable of producing surprising new discoveries. By building an impressive body of knowledge about these protoplanetary discs, these teams are stepping closer to understanding how planets shape the discs that form them — and therefore understanding planet formation itself. ■

ALMA measures size of planets' seeds

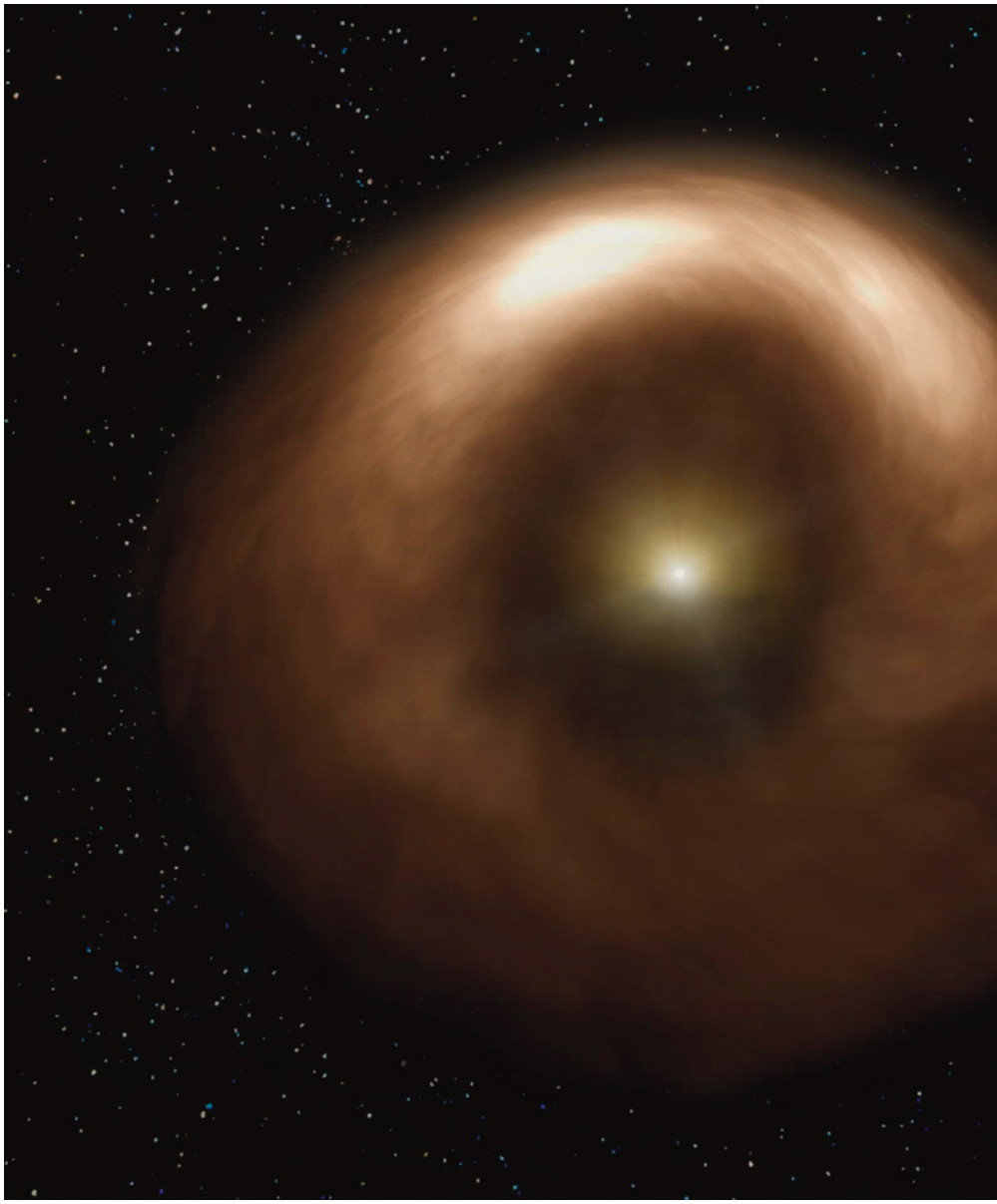
by ALMA Observatory

Researchers using the Atacama Large Millimeter/submillimeter Array (ALMA), have for the first time, achieved a precise size measurement of small dust particles around a young star through radio-wave polarization. ALMA's high sensitivity for detecting polarized radio waves made possible this important step in tracing the formation of planets around young stars.

Astronomers have believed that planets are formed from gas and dust particles, although the details of the process have been veiled. One of the major enigmas is how dust particles as small as 1 micrometer aggregate to form a rocky planet with a diameter of 10 thousand kilometers. Difficulty in measuring the size of dust particles has prevented astronomers from tracing the process of dust growth.

Akimasa Kataoka, a Humboldt Research Fellow stationed at Heidelberg University and the National Astronomical Observatory of Japan (NAOJ), tackled this problem.

He and his collaborators have theoretically predicted that, around a young star, radio waves scattered by the dust particles should carry unique polarization features.



Artist's impression of a dust ring around the young star HD 142527. Dust around the star has an asymmetric distribution. [NAOJ]

He also noticed that the intensity of polarized emissions allows us to estimate the size of dust particles far better than other methods.

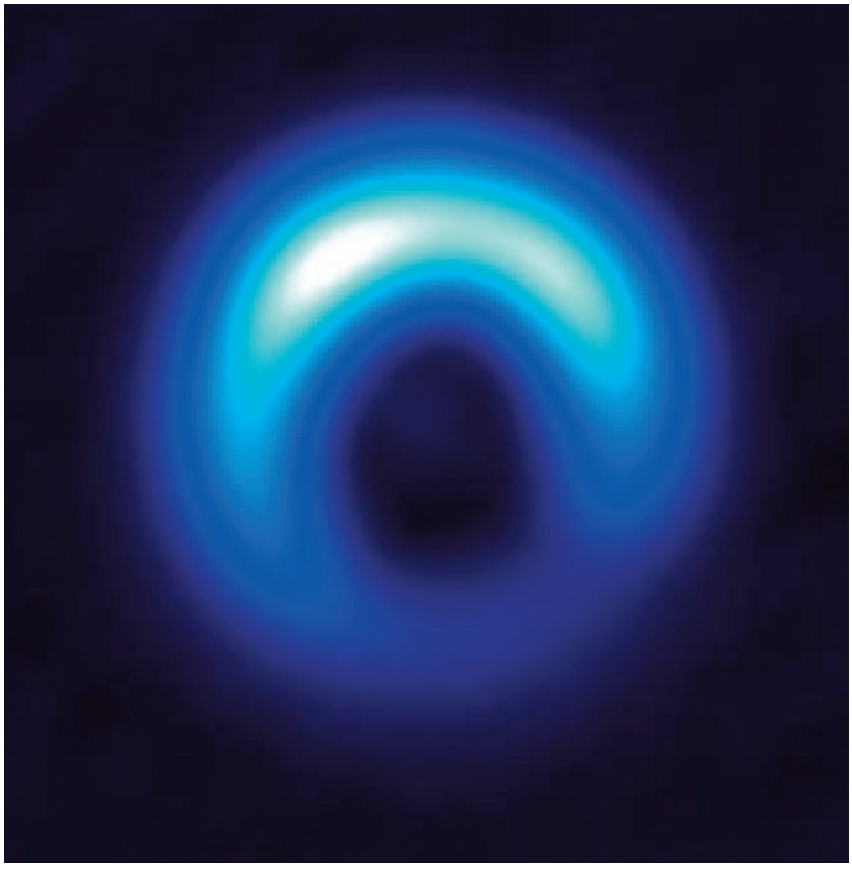
To test their prediction, the team led by Kataoka observed the young star HD 142527 with ALMA, located 500 light-years away from the Earth, in the direction of the constellation Lupus, and discovered, for the first time, the unique polarization pattern in the dust disk around the star. As predicted, the polarization has a radial direction in most parts of the disk, but at the edge of the disk, the direction is flipped perpendicular to the radial direction.

Comparing the observed intensity of the polarized emissions with the theoretical prediction, they determined that the size of the dust particles is at most 150 micrometers. This is the first estimation of the dust size based on polarization. Surprisingly, this estimated size is more than 10 times smaller than previously thought.

"In the previous studies, astronomers have estimated the size based on radio emissions assuming hypothetical spherical dust particles," explains Kataoka.

"In our study, we observed the scattered radio waves through polarization, which carries independent information from the thermal dust emission. Such a big difference in the estimated size of dust particles implies that the previous assumption might be wrong."

The team's idea to solve this inconsistency is to consider fluffy, complex-shaped dust particles, not simple spherical dust . In the macroscopic view, such particles are indeed large, but in the microscopic view, each small part of a large dust particle scatters radio waves and produces unique polarization features. Per the present study, astronomers obtain these "microscopic" features through polarization observations. This idea might prompt astronomers to reconsider the previous interpretation of observational data. *"The polarization fraction of radio waves from the dust disk around HD 142527 is only a few percent. Thanks to ALMA's high sensitivity, we have detected such a tiny signal to derive information about the size and shape of the dust particles,"* said Kataoka. *"This is the very first step in the research on dust evolution with polarimetry, and I believe the future progress will be full of excitement."* ■



The true dust disk around the young star HD 142527 observed with ALMA. [ALMA (ESO/NAOJ/NRAO), Kataoka et al.]

LR experimen biological hyp strengthens

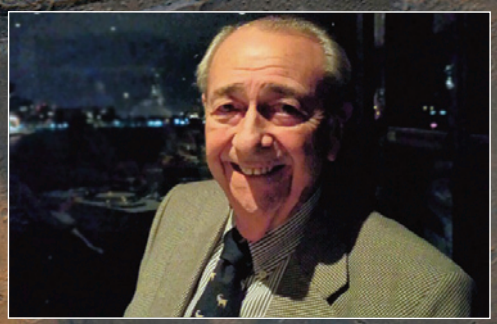
by Michele Ferrara

40 years before the crash of the Italian and European probe Schiaparelli on Mars (a success to someone's eyes), two equally heavy NASA probes softly landed on the red planet's surface and performed the historical experiments that still stimulate scientists' interest, since they may have demonstrated the existence of life outside the Earth.

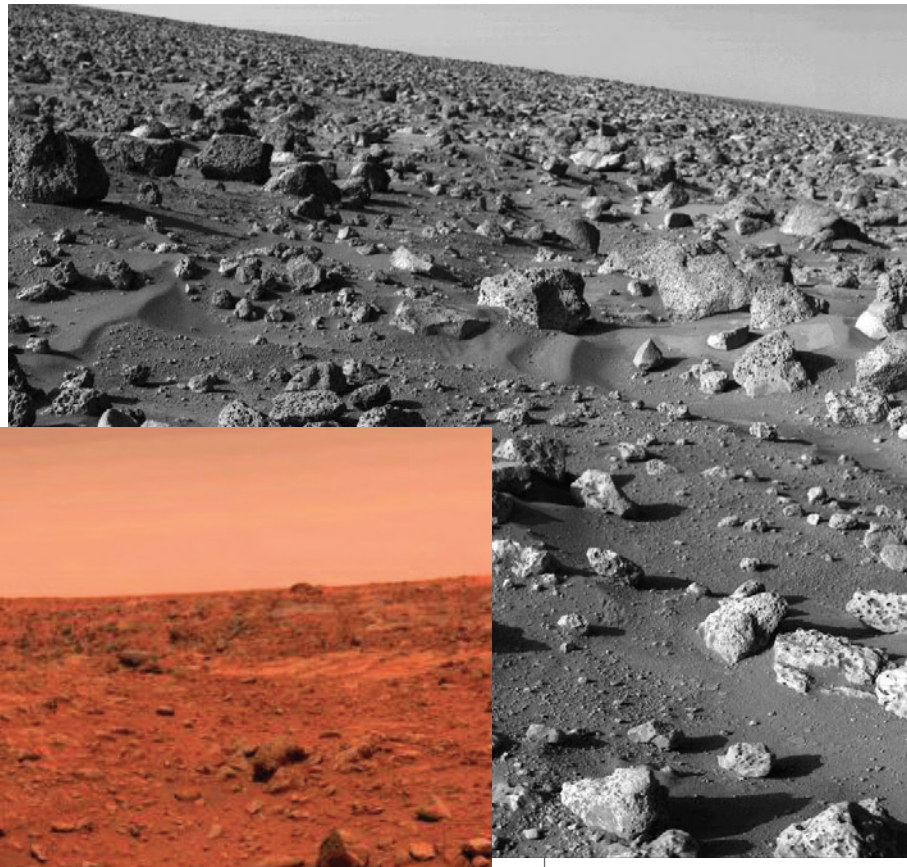
t, the othesis

In the background, mosaic of Mars made by about hundred images taken by Viking Orbiter 1 in 1980. [NASA/JPL/USGS] Right, Gilbert V. Levin, creator of the discussed LR experiment.

There's a question of relevant importance which has been carried on for forty years and which refers to the possible discovery of life on Mars made by landers Viking 1 and 2 between 1976 and 1977. It's a question which resurfaces from time to time and is updated by supporters and opponents of the biological hypothesis based on the progress of the discoveries accomplished by the automatic missions which studied, one after the other, the Red Planet's

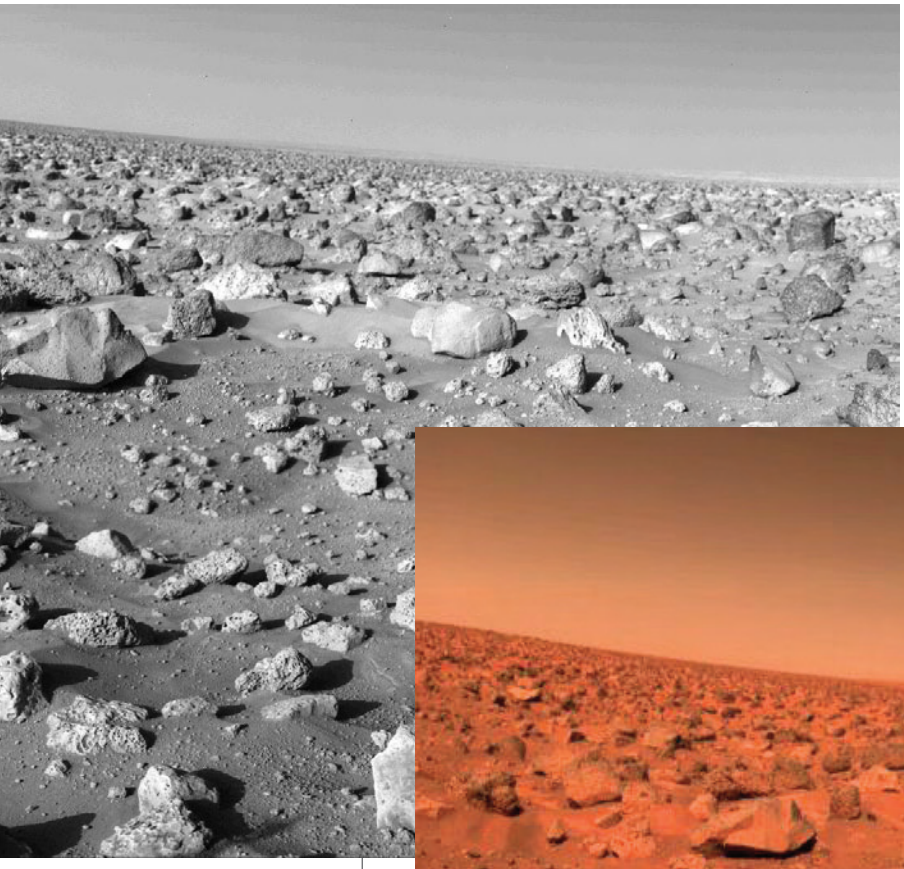


surface and atmosphere. Recently, last November, another chapter was added to the question, with the publishing on *Astrobiology* of a long paper that explains the state of art. The paper has the signatures of the two most important supporters of the biological hypothesis, Gilbert V. Levin and Patricia Ann Straat, instrumental in the development and implementation of the so called Labeled Release experiment (LR), one of the three biological experiments onboard the Viking landers and designed to identify potential traces of bacterial life on Mars. When, on several occasions, LR gave a positive result, a dispute began concerning the reliability of the experiment itself and its results, which were never confirmed by the other two experiments.



Left, the first photo in colors of the martian landscape, taken by Viking 1 on 21 July 1976, the day after the landing. Above, a high-resolution mosaic made with images taken by Viking 2. The rock closest to the center of the scene is about 60 cm in length and half in height. [NASA/JPL]

To fully understand how things happened and the actual value of those results, we have to dive into detail. LR was a radiorespirometry experiment in which organic compounds "labeled" with carbon-14 atoms (^{14}C) were injected in a liquid solu-



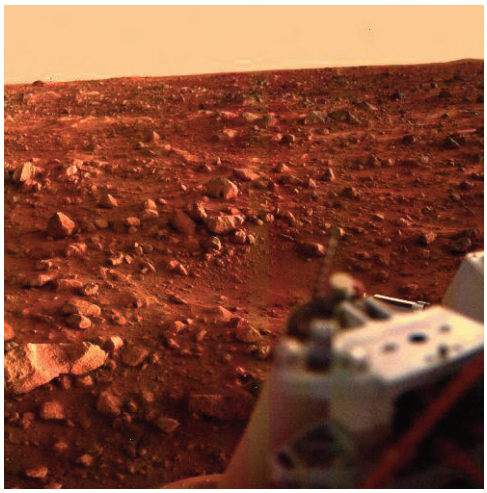
Right, the first landscape in colors photographed by Viking 2 lander. [NASA/JPL]

ed, having been completely developed in 1956 by Levin and having been proven to be always reliable on terrestrial sample testing. NASA had decided to include it in the Viking landers based on the assumption (at that time by no means certain, but today proved) that Mars and the Earth had similar primordial environments, able to produce that mixture of organic compounds (called Miller-Urey and mainly composed by sodium formate, glycine, sodium lactate, alanine and calcium glycolate) which would have made possible the emergence and evolution of life.

tion above martian soil samples, in the hope that any bacteria contained in the samples could manifest themselves through gases of radioactive waste, a by-product of metabolic processes. LR was thoroughly test-

Being also possibly the best nutrients for eventual martian bacteria, those compounds were selected as substrate to be injected on the excavated soil samples, with the difference that in those molecules the

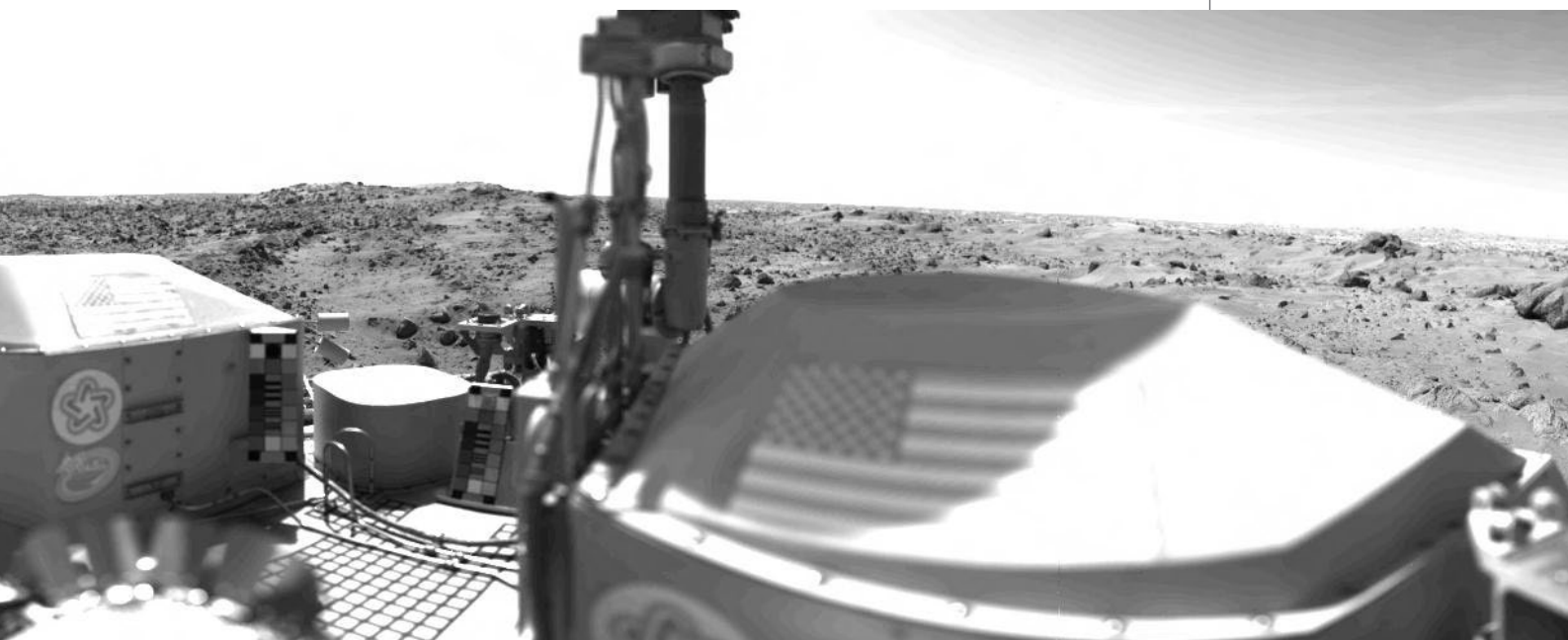
^{14}C had taken the place of the much more common ^{12}C. The experimental procedure consisted in the addition of 0.115 ml of nutrient solution (with a low concentration of organic compounds, to reduce the toxicity) to 0.5 cc of martian regolith, inside a cylindrical camera of 3.5 cc and 2 cm in diameter. Each Viking had some sort of revolving loader (similar to the one on a Colt revolver), with four of these cameras, inside which a robotic arm would put a sample of soil extracted from a depth of a few cm. After receiving the sample, the loader rotated, the camera closed itself and in an internal atmosphere of martian type the experiment and the monitoring of its result would begin.



The experiment would be conducted on a temperature of around 10°C in order to ensure the liquid state of the organic solution, while the internal atmospheric pressure in each camera would be increased by 85 mbar with the addition of helium (with respect to the external one of 6 mbar), to be sure not to drop below the so-called triple point, a thermodynamic state determined by temperature and pressure values in which water can exist as solid, liquid and vapor. Except in very high places, today we know that the atmospheric pressure of Mars doesn't go below the triple point, and consequently in favorable conditions water can drain through a large part of the martian surface, although for brief periods of time.

On 30 July 1976, ten martian days (sols) after landing in Chryse Planitia, Viking 1 started the first LR experiment, called VL1-1, on a sample of martian soil dug out two sols earlier by the robotic arm. The outcome of that first attempt was immediate and positive: something had transformed a large part of the nutrients and expelled gas molecules where ^{14}C was present (essentially radioactive carbon dioxide, or $^{14}CO_2$). The type of

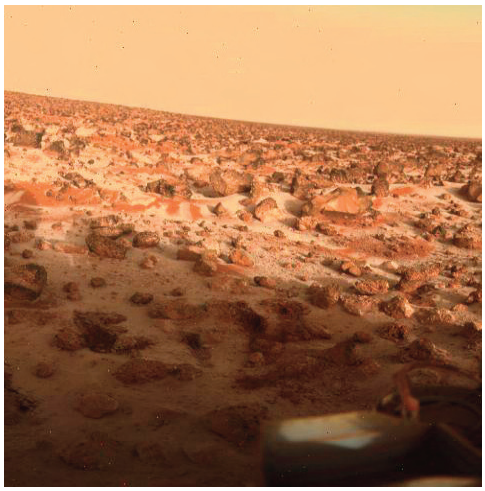
Above, the first image ever of the martian surface, registered by Viking 1 just 1 minute after the landing on 20 July 1976. The camera was about 1.4 meters away from the center of the framed field. The rock closest to the center of the scene measures about ten centimeters. Left, a sunset in Chryse Planitia photographed by Viking 1 on 21 August 1976. Below, panoramic representation of Viking 1 made three days after its landing. The horizon is approximately 3 km away. [NASA/JPL]



Above, the first photograph of the surface of Mars taken by Viking 2 on 03 September 1976, a few minutes after the landing in Utopia Planitia. In the colored image on the side, taken on 18 May 1979, a Viking 2 camera has highlighted a very thin layer of water ice deposited on the ground. [NASA/JPL]

result was comparable to the lower limit of the ones obtained on tests with terrestrial samples rich in bacteria.

As required by the procedures, to rule out that the positive response could be the result of simple chemical reactions, the experiment was repeated on a duplicate sample of the same soil, collected in the same excavation, but this time subjected to a sterilization process consisting in a heating process at 160°C temperature for 3 hours, before injecting the nutrients. This treatment would not have stopped eventual chemical reactions to repeat on VL1-2, but it would certainly have eliminated the martian bacteria. The verification result left no doubt: no gas release, the second sample was completely sterile. Taken together, the results from VL1-1 and VL1-2 were consistent with bacterial activity.



It's interesting to remark that in VL1-1 experiment the gas evolution (and then the hypothetical metabolic process) remained measurable for a couple of sols, then it gradually fell, and disappeared after 7 sols. Not detecting any more activity could mean essentially two things: either the nutrients had been entirely consumed, or the present bacteria had died. The latter hypothesis looked more likely after a new injection of organic compounds, made the seventh sol, did not give a positive result: the active agents were not active anymore. According to scientific protocol, a third experiment was then carried out, VL1-3, whose task was to verify the positive result of VL1-1. A new soil sample was extracted from the same area and also in this case the response to the supply of nutrients was positive.

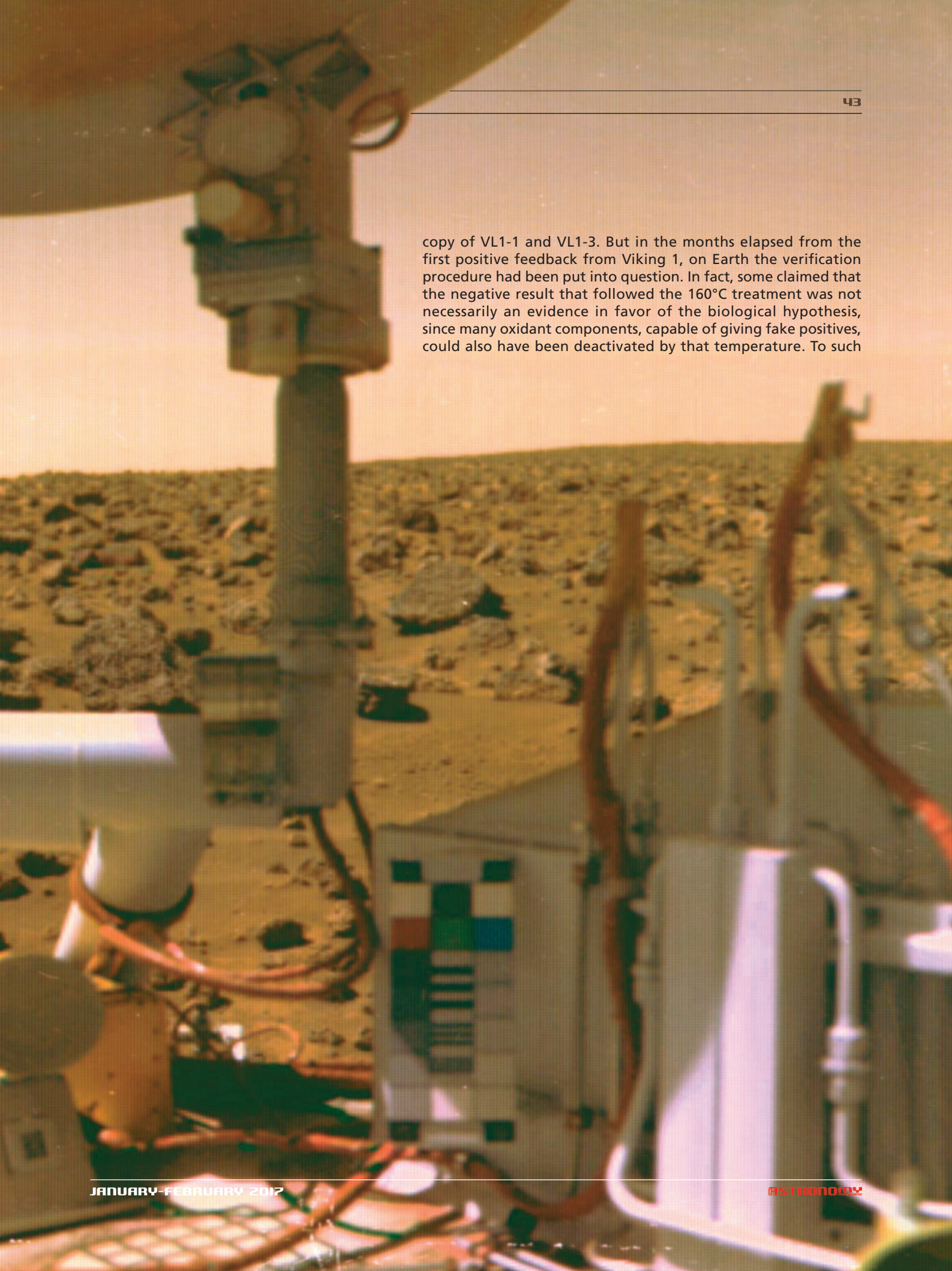
The last experiment at Viking 1's disposal, VL1-4, was performed on a sample of soil taken together with that of VL1-1, i.e. 141 sols before actual use. The "new" sample had remained stored during all that time

in the so called distribution box, in a martian atmosphere and at a temperature of 10°C to 26°C. Despite two injections of nutrients spaced 3 hours apart (a break long enough to record the outcome of the first one), the reaction was negative, no presence of agents.

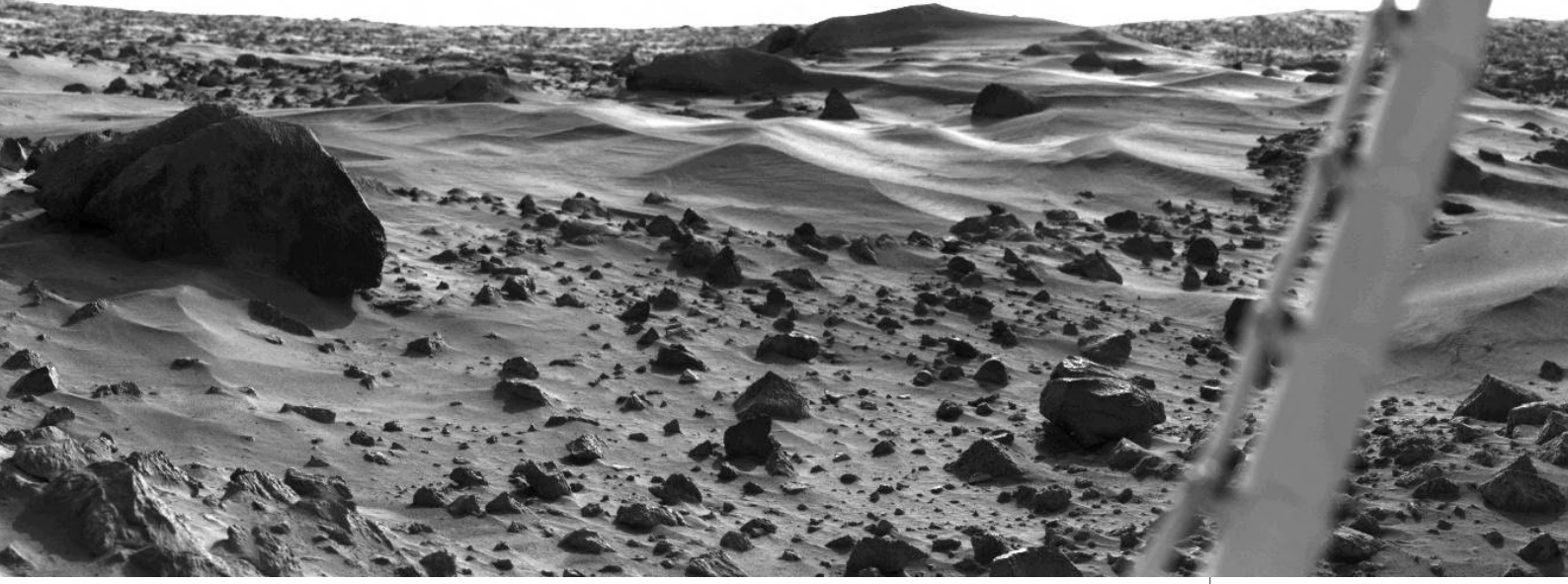
Apparently, the conditions in which the soil samples had been conserved had eliminated possible bacteria; it is in fact less likely that a chemical agent can be deactivated through that treatment. Certainly, the terrestrial bacteria would not die for so little, but the martians ones, if they exist, live at temperatures warmer than 0°C just for brief periods, therefore spending 5 months in the heat would be surely fatal for them.

Meanwhile, about 6400 km away, in Utopia Planitia, Viking 2 was performing the same experiments, getting almost identical results. Particularly, VL2-1 was the photo-

A "selfie" from Viking 2, partially pictured in the desolated landscape of Utopia Planitia. The circular structure here above is the high-gain antenna for telecommunication with Earth. [NASA/JPL]



copy of VL1-1 and VL1-3. But in the months elapsed from the first positive feedback from Viking 1, on Earth the verification procedure had been put into question. In fact, some claimed that the negative result that followed the 160°C treatment was not necessarily an evidence in favor of the biological hypothesis, since many oxidant components, capable of giving fake positives, could also have been deactivated by that temperature. To such

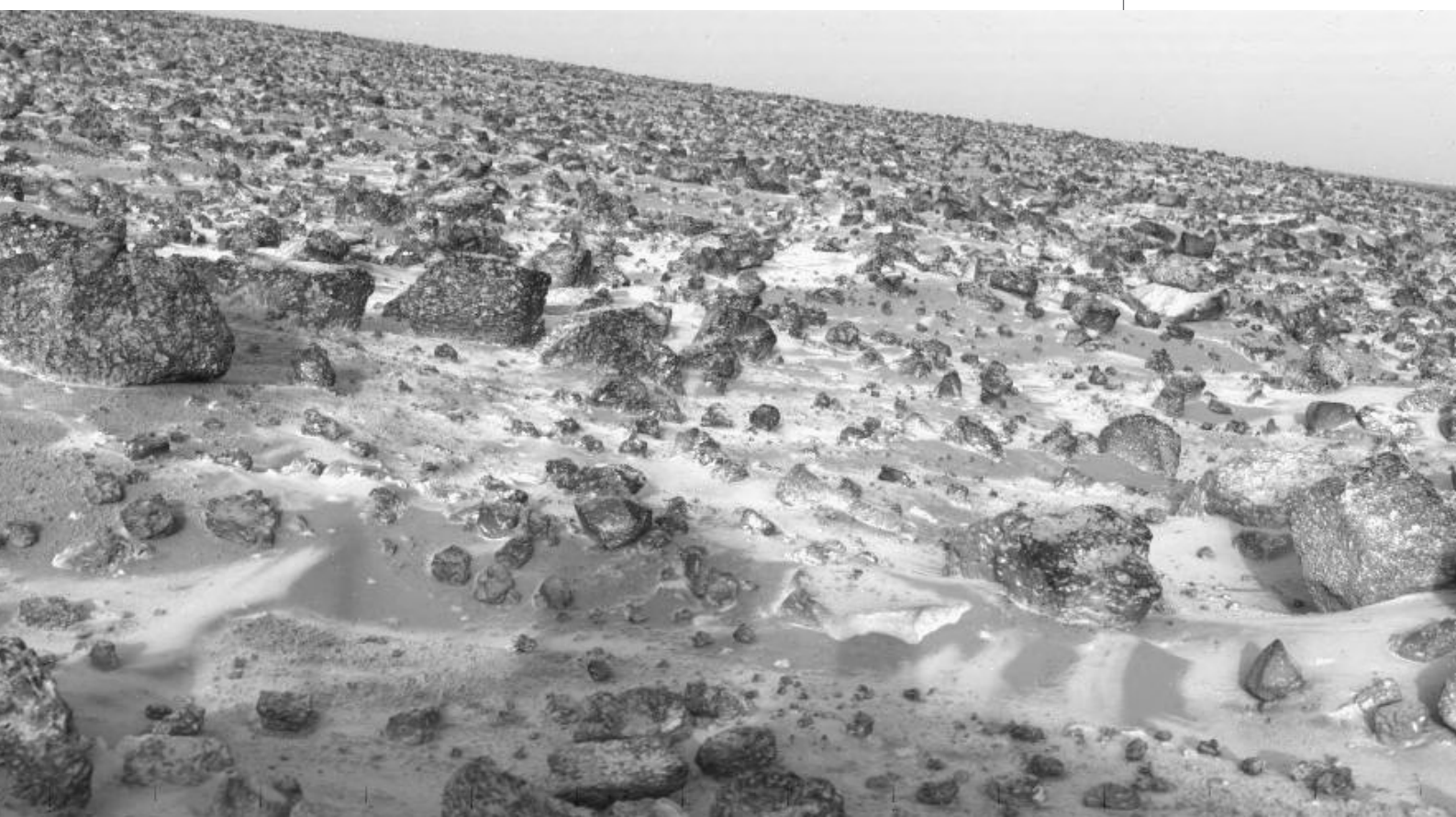


objections, Viking Biology Team answered by proposing to eliminate the post-treatment at 160°C and conversely preheat the subsequent samples at a temperature of only 50°C for 3 hours, which would not inactivate almost any existing oxydant, but would almost certainly compromise the existence of potential bacteria.

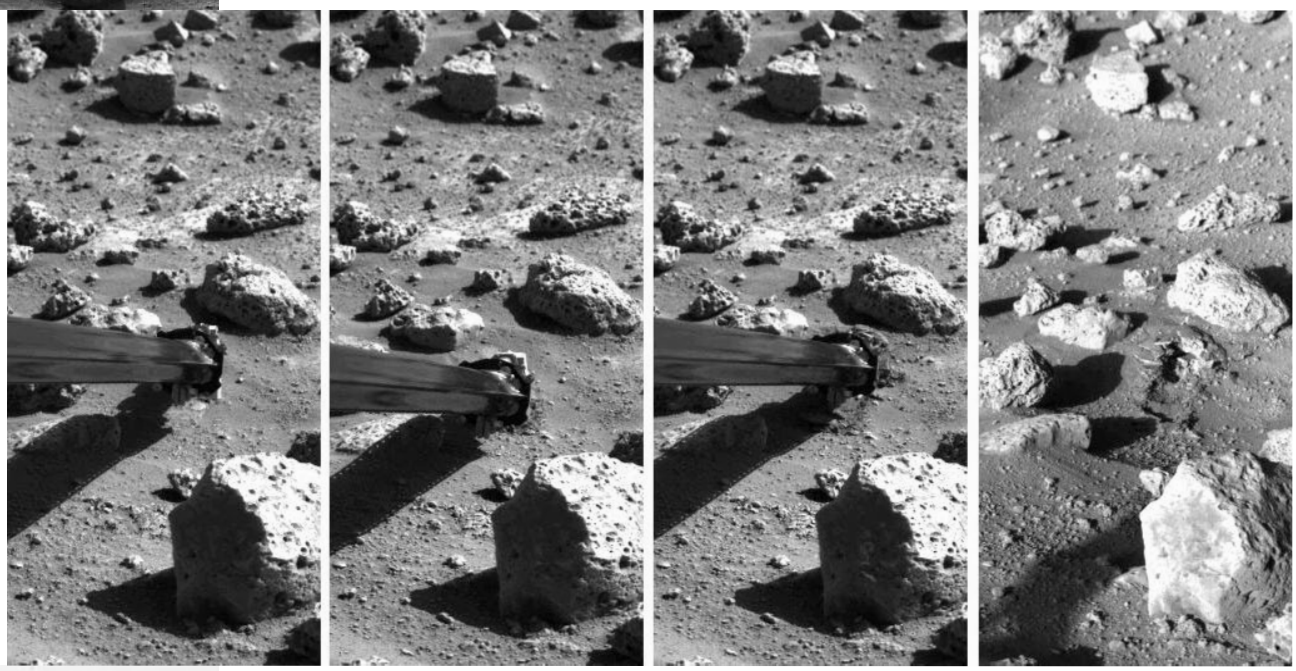
The team then began the VL2-2 experiment, collecting a new sample of regolith in the same point of the VL2-1 sampling and preheating it for the established time at an estimated temperature of 51°C. Once it cooled down, the sample was fed with the mixture and the obtained answer was completely compatible with the biological hypothesis: positive result, but widely reduced due to the new procedure.

The more confirmations reached by the two Vikings, the more the skeptical would try to arrange alternative readings, even coming to claim that the intense flux of UV light impacting the martian surface would have activated not better specified soil components, which produced the fake positives. The Viking Biology Team faced this hypothesis with the VL2-3 experiment, in which the removal of soil was made at dawn and at the bottom of a rock that had shielded that specific sample of soil for countless millions of years. Once fed, also the VL2-3 sample gave a clear positive response. There was still room for one last experiment, VL2-4, which was used to reproduce the result of VL2-2. This time, the sample, retrieved from the same point as the previous one, was preheated at an estimated temperature of 46°C, and as one might be expecting in the case of biological agents, it got a better response than the one from VL2-2 (about the double), but always lower (about 1/3) when com-

Morning of 03 August 1976 in Chryse Planitia. The stone on the left is about 8 meters far from Viking 1 and measures 3x1 meters. The image below shows in more detail the ice deposit in Utopia Planitia. Next page, a series of images showing the robotic arm of Viking 2 while it grabs a soil sample for analysis. [NASA/JPL]



pared to that of the not preheated samples. The 5°C below had then provided indications in favor of the biological hypothesis. VL2-4 had to be the last LR experiment, but since there was still nutrient solution available, the Viking Biology Team decided to add on the top of the sample of soil of that experiment another sample identical, but stored inside the distribution box for 84 sols at 10°C. As it happened with VL1-4, the experiment did not reveal the presence of any active agents.



Despite all these impressive results of LR experiments, the skepticism prevailed inside the scientific community. The fact that the other two biological experiments (the Gas Exchange and the Pyrolitic Release) had not found found anything that could be attributed to biological processes, and that not even the Gas Chromatograph Mass Spectrometer had discovered organic compounds on the surface (necessary for feeding bacteria, with the exception of the autotrophic ones), cast a shadow on the LR experiment results.

The more recent discoveries by NASA's rover are, however, changing our vision of Mars, before reputed to be extremely arid and sterile, but now considered relatively rich in water and, between certain limits, hospitable as well for certain particularly resistant life forms (many terrestrial bacteria species would proliferate a little bit below the martian surface).

As it should be, scientists continue to propose even interpretations other than the biological one, many of which based on the presence of oxidant elements.

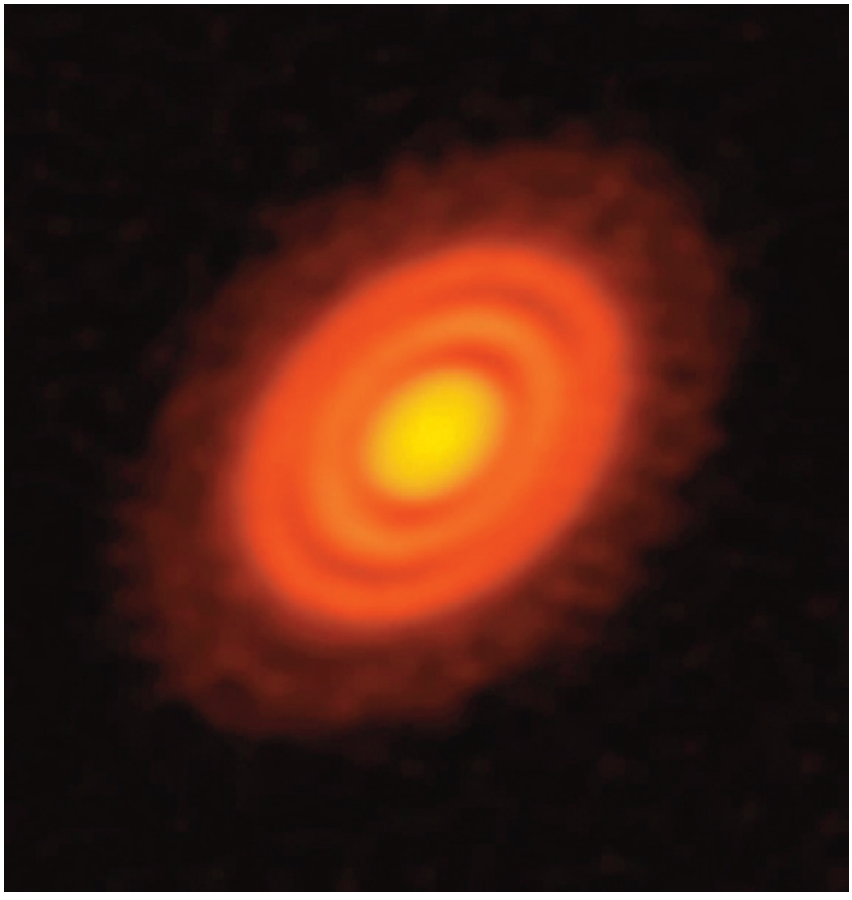
Skeptics' last weapon are the perchlorates, widespread on the martian surface. Actually, these chlorine-based molecules remain substantially stable at 160°C, therefore it cannot hurt the biological hypothesis. Nevertheless, through complex (not to say fortuitous) processes, perchlorates could produce hypochlorite on Mars, which in turn would not resist a forceful heat treatment as the 160°C one. At this point, two questions spontaneously arise: can martian hypochlorite explain the results obtained with the 50°C preheating? Why should these molecules, or other oxidants, be made completely inactive by a simple soil sample storage, as it happened with VL1-4 and VL2-5 experiments? Inevitably, sooner or later we will know the truth. ■

Pair of infant planets around young star HD 163296

by ALMA Observatory

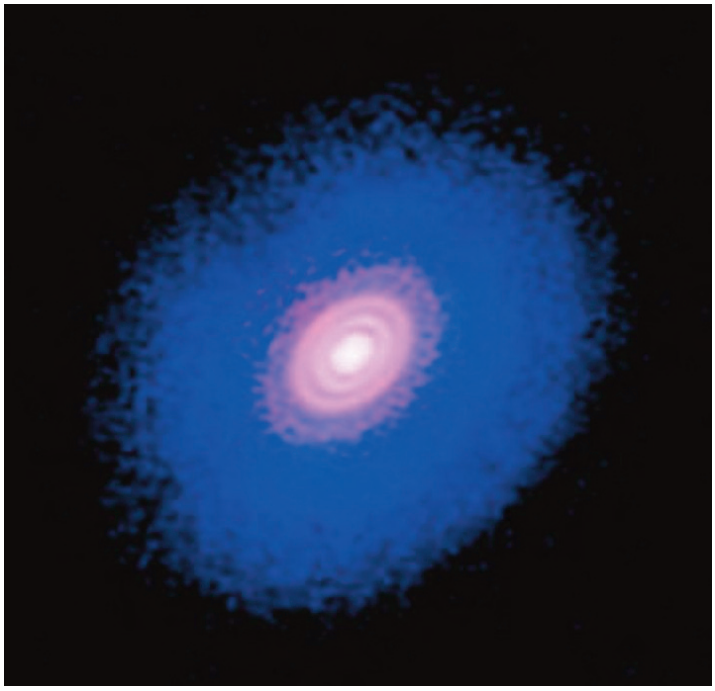
Astronomers now know that our galaxy is teeming with planets, from rocky worlds roughly the size of Earth to gas giants bigger than Jupiter. Nearly every one of these exoplanets has been discovered in orbit around a mature star with a fully evolved planetary system. New observations with the Atacama Large Millimeter/submillimeter Array (ALMA) contain compelling evidence that two newborn planets, each about the size of Saturn, are in orbit around a young star known as HD 163296.

These planets, which are not yet fully formed, revealed themselves by the dual imprint they left in both the dust and the gas portions of the star's protoplanetary disk. Previous observations of other young star sys-tems have helped to reshape our understanding of planet formation. For example, ALMA's images of HL Tauri and TW Hydrae revealed striking gaps and prominent ring structures in the stars' dusty disks. These features may be the tantalizing first signs that planets are being born. Remarkably, these signs appeared around much younger stars than astronomers thought possible, suggesting that planet formation can begin soon after the formation of a protoplanetary disk.



ALMA image of the protoplanetary disk surrounding the young star HD 163296 as seen in dust. New observations suggested that two planets, each about the size of Saturn, are in orbit around the star. These planets, which are not yet fully formed, revealed themselves by the dual imprint they left in both the dust and the gas portions of the star's protoplanetary disk. [ALMA (ESO/NAOJ/NRAO); A. Isella; B. Saxton (NRAO/AUI/NSF)]

"ALMA has shown us amazing images and never-before-seen views of the rings and gaps around young stars that could be the hallmarks of planet formation. However, since we were only looking at the dust in the disks with sufficient detail, we could not be sure what created these features," said Andrea Isella, an astronomer at Rice University in Houston, Texas, and lead author on a paper published in Physical Review Letters. In studying HD 163296, the research team used ALMA to trace, for the first time, the distribution of both the dust and the carbon monoxide (CO) gas components of the disk at roughly the same level of detail. These observations revealed three distinct gaps in HD 163296's dust-filled protoplanetary disk. The first gap is located approximately 60 astronomical units from the central star, which is about twice the distance from our Sun to Neptune (an astronomical unit – AU – is the average distance from the Earth to the Sun). The other two gaps are 100 AU and 160 AU from the central star, well beyond the extent of our solar system's Kuiper Belt, the region of icy bodies beyond the orbit of Neptune. Using ALMA's ability to detect the faint millimeter-wavelength "glow" emitted by gas molecules, Isella and his team discovered that there was also an appreciable dip in the amount of CO in the outer two dust gaps.



Composite image of the protoplanetary disk surrounding the young star HD 163296. The inner red area shows the dust of the protoplanetary disk. The broader blue disk is the carbon monoxide gas in the system. ALMA observed that in the outer two gaps in the dust, there was a significant dip in the concentration of carbon monoxide, suggesting two planets are forming there. [ALMA (ESO/NAOJ/NRAO); A. Isella; B. Saxton (NRAO/AUI/NSF)]

https://vimeo.com/195018782#at=0

Video of ALMA's recent observations of the young star HD 163296 and how the dust and gas profiles of its protoplanetary disk may herald the presence of two infant planets. [NRAO/AUI/NSF]

By seeing the same features in both the gas and the dust components of the disk, the astronomers believe they have found compelling evidence that there are two planets coalescing remarkably far from the central star. The width and depth of the two CO gaps suggest that each potential planet is roughly the same mass as Saturn, the astronomers said.

In the gap nearest to the star, the team found little to no difference in the concentration of CO gas compared to the surrounding dusty disk. This means that the innermost gap could have been produced by something other than an emerging planet. *"Dust and gas behave very differently around young stars,"* said Isella. *"We know, for example, that there are certain chemical and physical process that can produce ringed structures in the dust like the ones we have seen previously. We certainly believe these structures could be the work of a nascent planet plowing through the dust, but we simply can't rule out other possible explanations. Our new observations provide intriguing evidence that planets are indeed forming around this one young star."* HD 163296 is roughly 5 million years old and about twice the mass of the Sun. It is located approximately 400 light-years from Earth in the direction of the constellation Sagittarius. ■

ESO telescopes help reinterpret brilliant explosion

by ESO

In 2015, the All Sky Automated Survey for SuperNovae (ASAS-SN) detected an event, named ASASSN-15lh, that was recorded as the brightest supernova ever — and categorised as a superluminous supernova, the explosion of an extremely massive star at the end of its life. It was twice as bright as the previous record holder, and at its peak was 20 times brighter than the total light output of the entire Milky Way.

An international team, led by Giorgos Leloudas at the Weizmann Institute of Science, Israel, and the Dark Cosmology Centre, Denmark, has now made additional observations of the distant galaxy, about 4 billion light-years from Earth, where the explosion took place and they have proposed a new explanation for this extraordinary event.

"We observed the source for 10 months following the event and have concluded that the explanation is unlikely to lie with an extraordinarily bright supernova. Our results indicate that the event was probably caused by a rapidly spinning supermassive black hole as it destroyed a low-mass star," explains Leloudas.

In this scenario, the extreme gravitational forces of a supermassive black hole, located in the centre of the host galaxy, ripped apart a Sun-like star that wandered too close — a so-called tidal disruption event, something so far only observed about 10 times. In the process, the star was "spaghettified" and shocks in the colliding debris as well as heat generated in accretion led to a burst of light. This gave the event the appearance of a very bright supernova explosion, even though the star would not have become a supernova on its own as it did not have enough mass.

The team based their new conclusions on observations from a selection of telescopes, both on the ground and in space. Among them was the Very Large Telescope at ESO's Paranal Observatory, the New Technology Telescope at ESO's La Silla Observatory and the NASA/ESA Hubble Space Telescope.

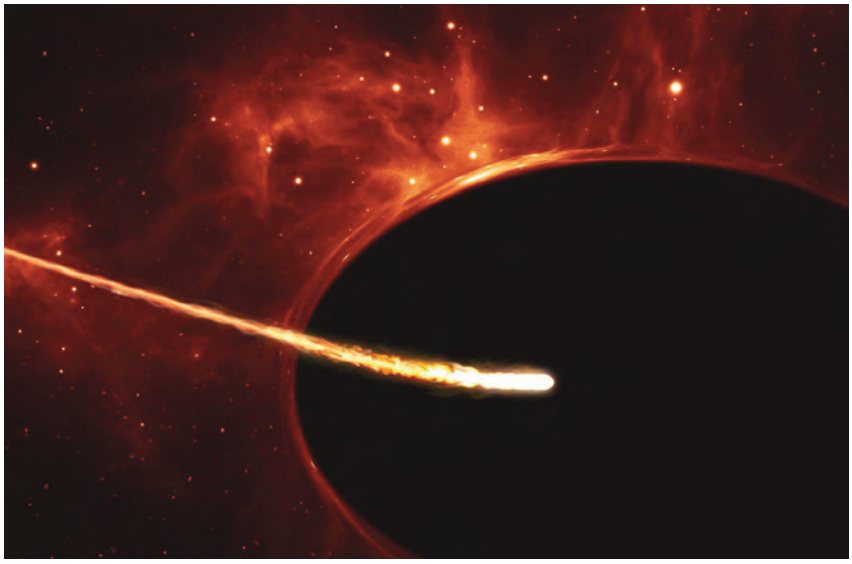
The observations with the NTT were made as part of the Public ESO Spectroscopic Survey of Transient Objects (PESSTO). As well as the data from the above mentioned telescope, the team used observations from NASA's Swift telescope, the

This artist's impression depicts a rapidly spinning supermassive black hole surrounded by an accretion disc. This thin disc of rotating material consists of the leftovers of a Sun-like star which was ripped apart by the tidal forces of the black hole. Shocks in the colliding debris as well as heat generated in accretion led to a burst of light, resembling a supernova explosion. [ESO, ESA/Hubble, N. Stone, K. Hayasaki]

http://www.eso.org/public/usa/videos/eso1644b/

This simulation shows a star getting torn apart by the gravitational tides of a supermassive black hole. The star gets "spaghettified" and after several orbits creates an accretion disc. Scientists believe that the superluminous ASASSN-15lh event originated in this way. The view on the right is from the side and that at the left face on. [ESO, ESA/Hubble, N. Stone, K. Hayasaki]

Las Cumbres Observatory Global Telescope (LCOGT), the Australia Telescope Compact Array, ESA's XMM-Newton, the Wide-Field Spectrograph (WiFeS) and the Magellan Telescope. *"There are several independent aspects to the observations that suggest that this event was indeed a tidal disruption and not a superluminous supernova,"* explains coauthor Morgan Fraser from the University of Cambridge, UK (now at University College Dublin, Ireland). In particular, the data revealed that the event went through three distinct phases over the 10 months of follow-up observations. These data overall more closely resemble what is expected for a tidal disruption than a superluminous supernova. An observed re-brightening in ultraviolet light as well as a temperature increase further reduce the likelihood of a supernova event. Furthermore, the location of the event — a red, massive and passive galaxy — is not the usual home for a superluminous supernova explosion, which normally occur in blue, star-forming dwarf galaxies. Although the team say a supernova source is therefore very unlikely, they accept that a classical tidal disruption event would not be an adequate explanation for the event either. Team member Nicholas Stone from Columbia University, USA, elaborates: *"The tidal disruption event we propose cannot be explained with a non-spinning supermassive black hole. We argue that ASASSN-15lh was a tidal disruption event arising from a very particular kind of black hole."*



This artist's impression depicts a Sun-like star close to a rapidly spinning supermassive black hole, with a mass of about 100 million times the mass of the Sun, in the centre of a distant galaxy. Its large mass bends the light from stars and gas behind it. Despite being way more massive than the star, the supermassive black hole has an event horizon which is only 200 times larger than the size of the star. Its fast rotation has changed its shape into an oblate sphere. The gravitational pull of the supermassive black hole rips the the star apart in a tidal disruption event. In the process, the star was "spaghettified" and shocks in the colliding debris as well as heat generated in accretion led to a burst of light. [ESO, ESA/Hubble, M. Kornmesser]

The mass of the host galaxy implies that the supermassive black hole at its centre has a mass of at least 100 million times that of the Sun. A black hole of this mass would normally be unable to disrupt stars outside of its event horizon — the boundary within which nothing is able to escape its gravitational pull. However, if the black hole is a particular kind that happens to be rapidly spinning — a so-called Kerr black hole — the situation changes and this limit no longer applies.

"Even with all the collected data we cannot say with 100% certainty that the ASASSN-15lh event was a tidal disruption event," concludes Leloudas. *"But it is by far the most likely explanation."* ■

http://www.eso.org/public/usa/videos/eso1644a/

This animation shows how the ASASSN-15lh most likely happened. A Sun-like star gets into the area of influence of a rapidly spinning supermassive black hole in the centre of a distant galaxy. While its orbit gets constantly closer to the black hole the star gets "spaghettified", creating an accretion disc around the supermassive black hole. When it finally gets ripped apart close to the event horizon it creates a bright flash, that could resemble a superluminous supernova. [ESO, ESA/Hubble, M. Kornmesser]

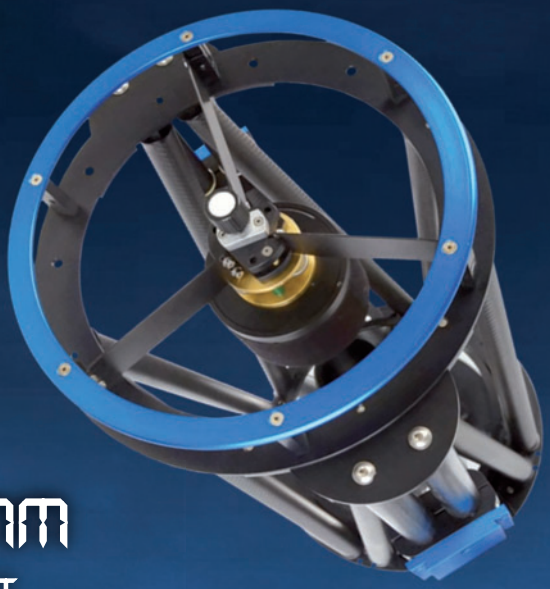
One of our most popular products, the ESO Calendar, is available in its 2017 incarnation, and can be ordered from the ESO online shop: www.eso.org/public/unitedkingdom/shop/product/calendar_2017
The calendar's cover features a pink-tinged picture of ALMA's majestic high-precision antennas, spread over the Chajnantor plateau at an altitude of 5000 metres in the Chilean Andes.
Inside, the calendar is packed with spectacular images of the cosmos as well as photographs of ESO's telescopes against the striking Chilean landscapes.
For the month of May, an artist's impression shows the forthcoming European Extremely Large Telescope that will be the world's largest optical and infrared telescope, set to tackle the biggest scientific questions in cosmology. The mysterious cometary globule CG4 glows menacingly in March, and one of the sharpest images ever taken of the entire star formation region of Messier 17 has been chosen for October.

In September, our home galaxy, the Milky Way, stretches across the sky above the La Silla Observatory, rich with state-of-the-art astronomical telescopes. Also marked for each month are the dates of the lunar phases.
The calendar measures 43 x 43 centimetres and has 14 pages, with a cardboard back. It is on sale for 9.99 euros in the ESOshop, but stock is limited, so don't delay!
View the individual pages of the ESO Calendar 2017 here: www.eso.org/public/unitedkingdom/products/calendars/?search=cal2017

Credit: ESO/P. Horálek

NortheK

Instruments - Composites - Optics



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