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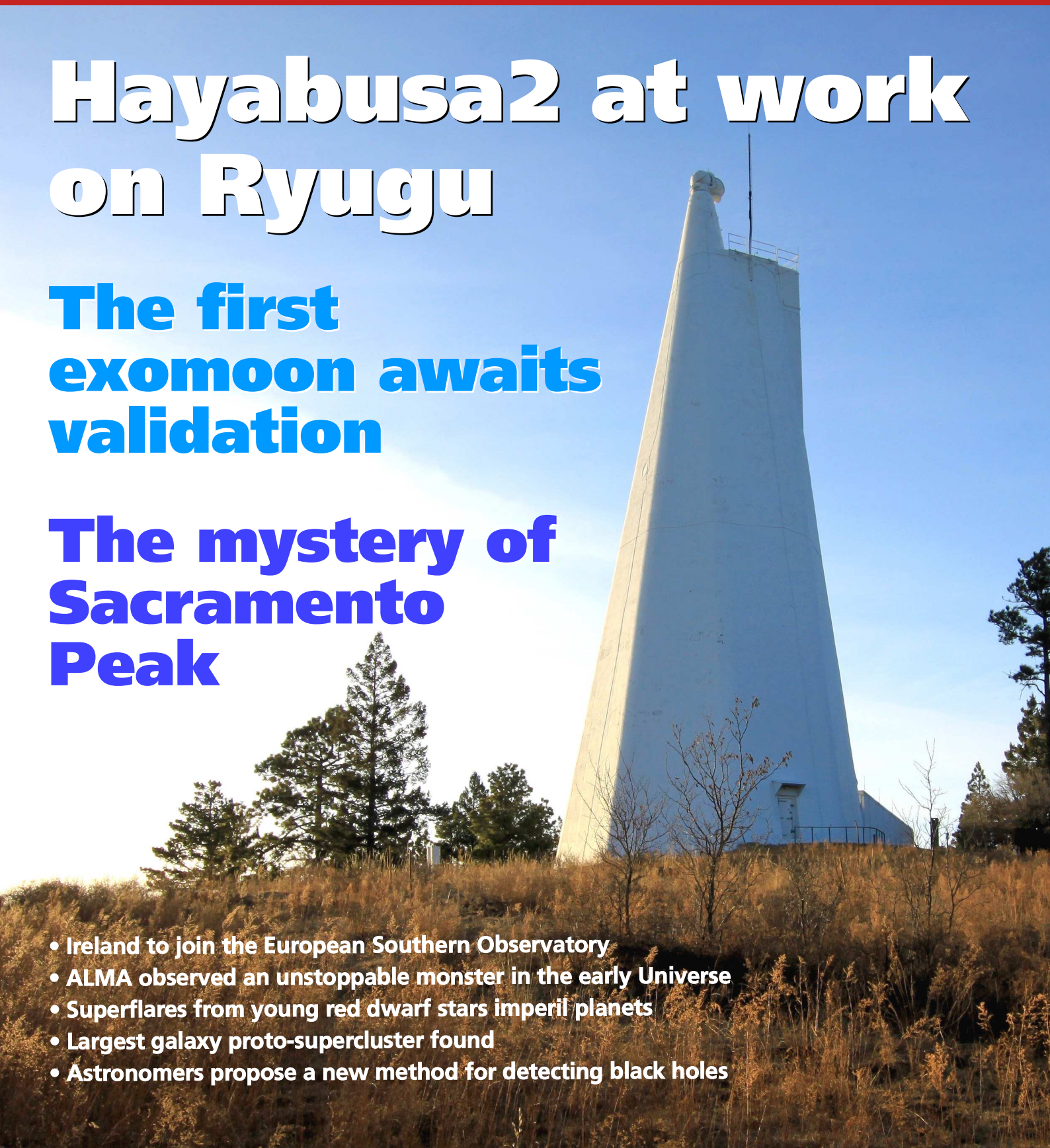

- Ireland to join the European Southern Observatory
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- Superflares from young red dwarf stars imperil planets
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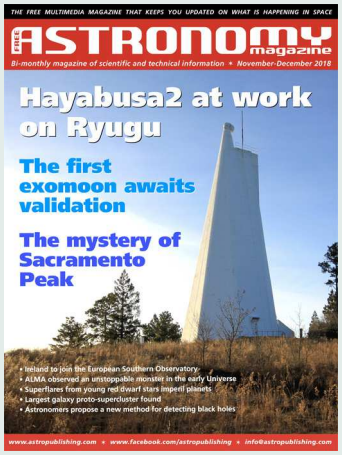

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SUMMARY

Hayabusa2 at work on Ryugu

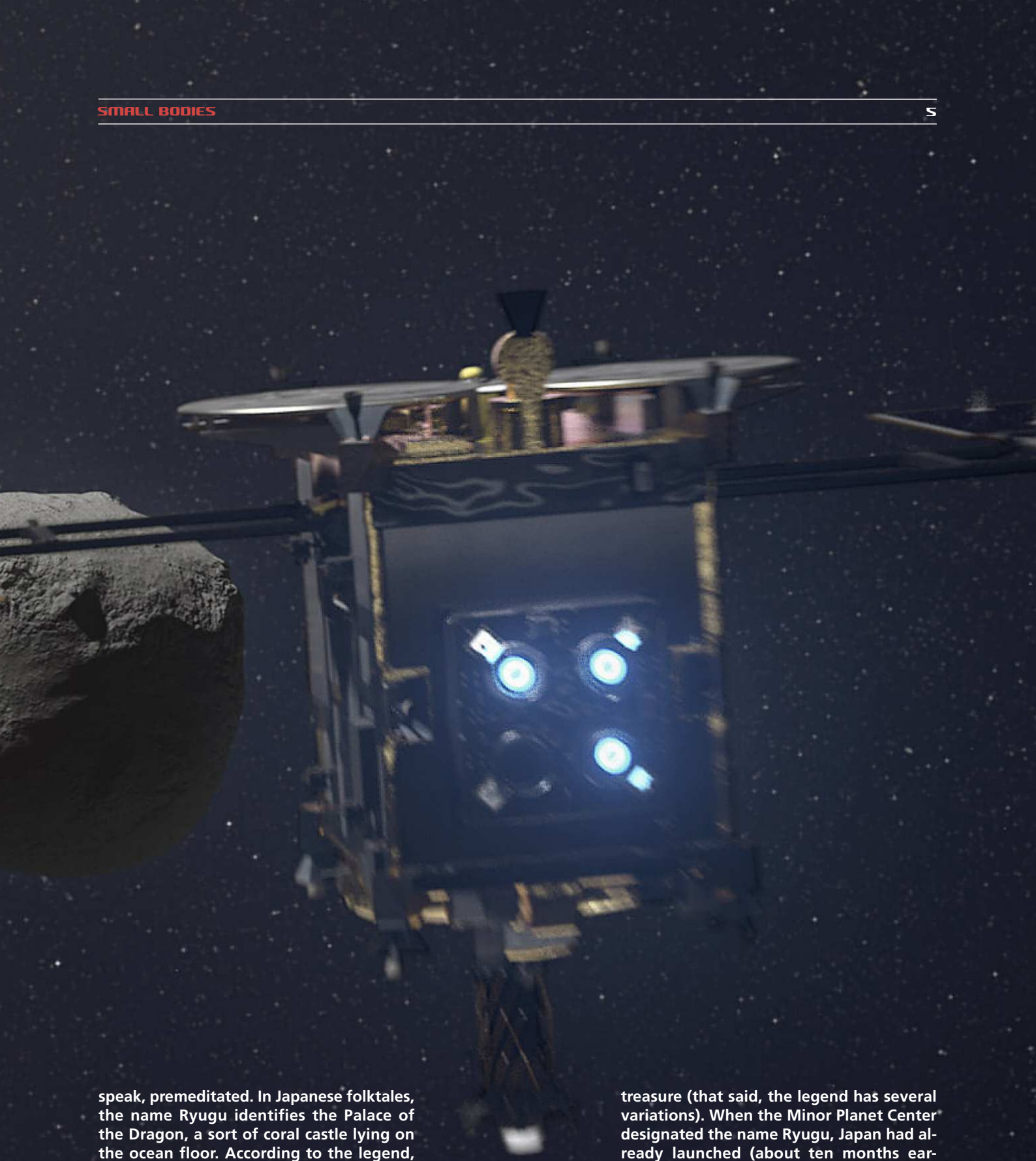
by Michele Ferrara

revised by Damian G. Allis
NASA Solar System Ambassador

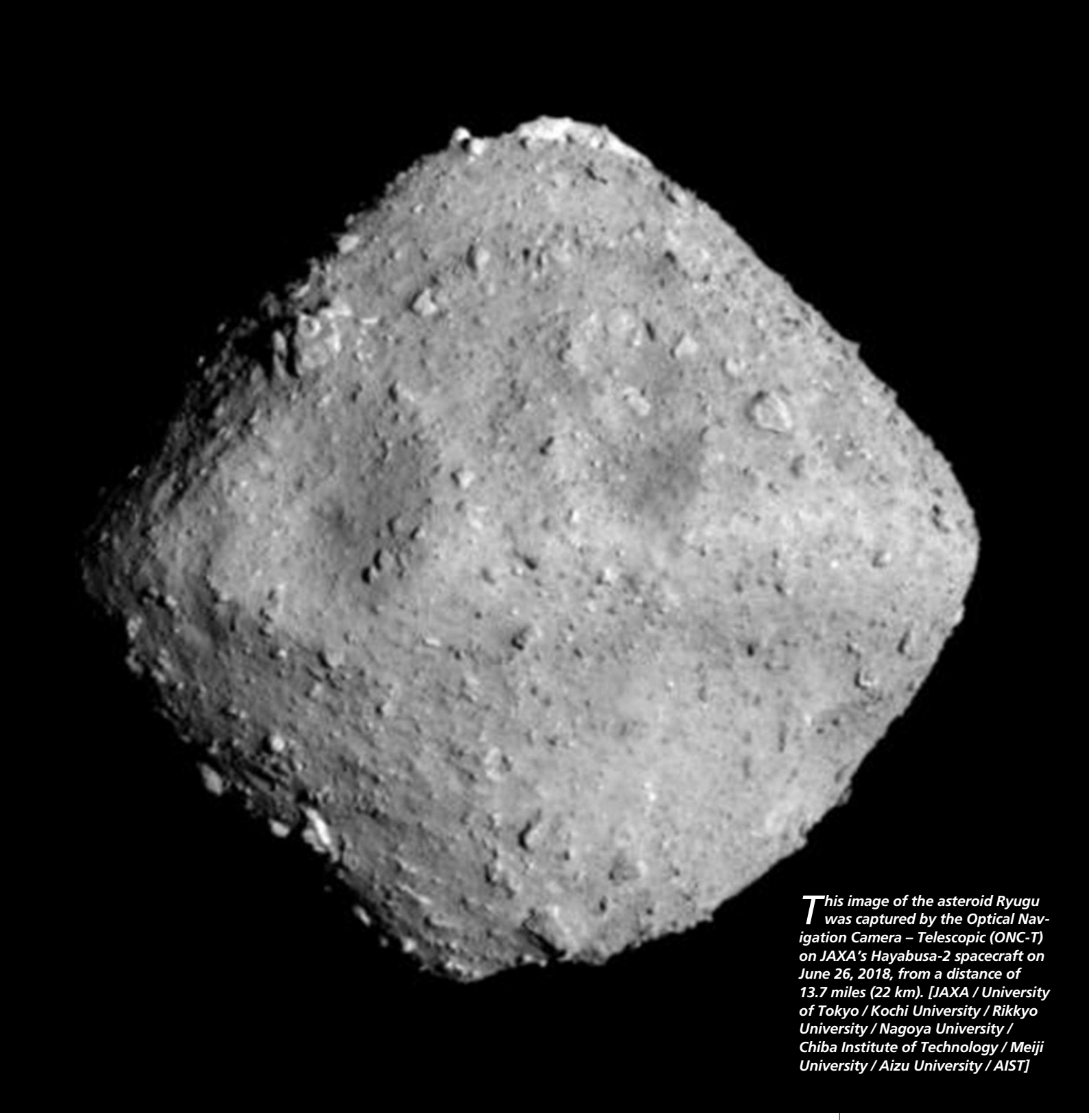
A space mission that sees a group of small probes exploring a primordial asteroid, largely made up of pristine material possibly unchanged for billions of years, is underway. One of the most important goals of the mission is to bring back to Earth samples of that material. Analyzed in the laboratory, the samples will provide key information on the origin of the planets and on the conditions that led to the appearance of life.

Another minor body joins the rather long list of those explored closely by robotic probes. It is the asteroid 162173 Ryugu, a rocky object almost 1 km in diameter that, as a member of the Apollo group, can be considered as potentially dangerous, since its orbit can cross that of the Earth. This small asteroid was discovered on May 10, 1999, by a 1-meter-diameter telescope belonging to the Lincoln Near-Earth Asteroid Research (LINEAR) project. After having received 1999 JU_3 as a provisional name, the object was definitively named (162173) Ryugu in September 2015 by a decision of the Minor Planet Center. The choice of that name was, so to

In the background, a graphic representation of the arrival of the Hayabusa2 probe near the asteroid Ryugu. [DLR]



speak, premeditated. In Japanese folktales, the name Ryugu identifies the Palace of the Dragon, a sort of coral castle lying on the ocean floor. According to the legend, one day a fisherman called Urashima Taro traveled to the castle astride a turtle. After a short stay, the fisherman returned home carrying a mysterious box containing a treasure (that said, the legend has several variations). When the Minor Planet Center designated the name Ryugu, Japan had already launched (about ten months earlier, on December 3, 2014, from the Tanegashima Space Center) the Hayabusa2 probe towards that asteroid. Not surprisingly, the mission of this probe retraces



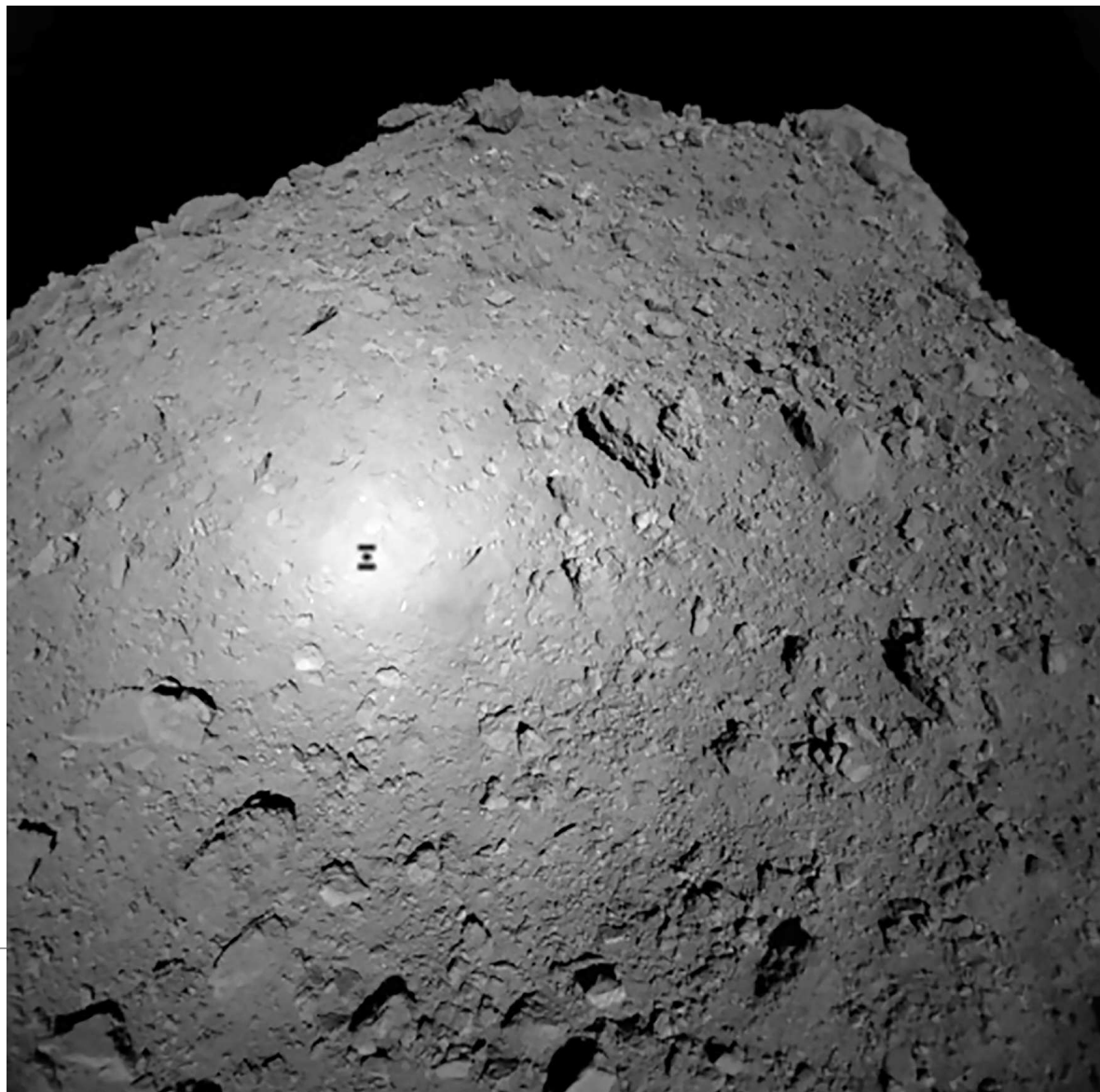
This image of the asteroid Ryugu was captured by the Optical Navigation Camera – Telescopic (ONC-T) on JAXA's Hayabusa-2 spacecraft on June 26, 2018, from a distance of 13.7 miles (22 km). [JAXA / University of Tokyo / Kochi University / Rikkyo University / Nagoya University / Chiba Institute of Technology / Meiji University / Aizu University / AIST]

that of the fisherman: reaching the target, knowing the environment, and coming back with something precious. Hayabusa2 is the improved version of a previous mission called Hayabusa ("falcon peregrine" in Japanese), which, between September and November 2005, studied the asteroid Itokawa, also a near-Earth asteroid (NEA), also discovered by LINEAR, and also named after the launch of the probe. Hayabusa landed on Itokawa and took samples of the surface that a special vehicle brought back to Earth in 2010, overcoming a series of obstacles. Hayabusa2 has the same basic final goal, but the operations to be performed on Ryugu are much more ambitious and complex.

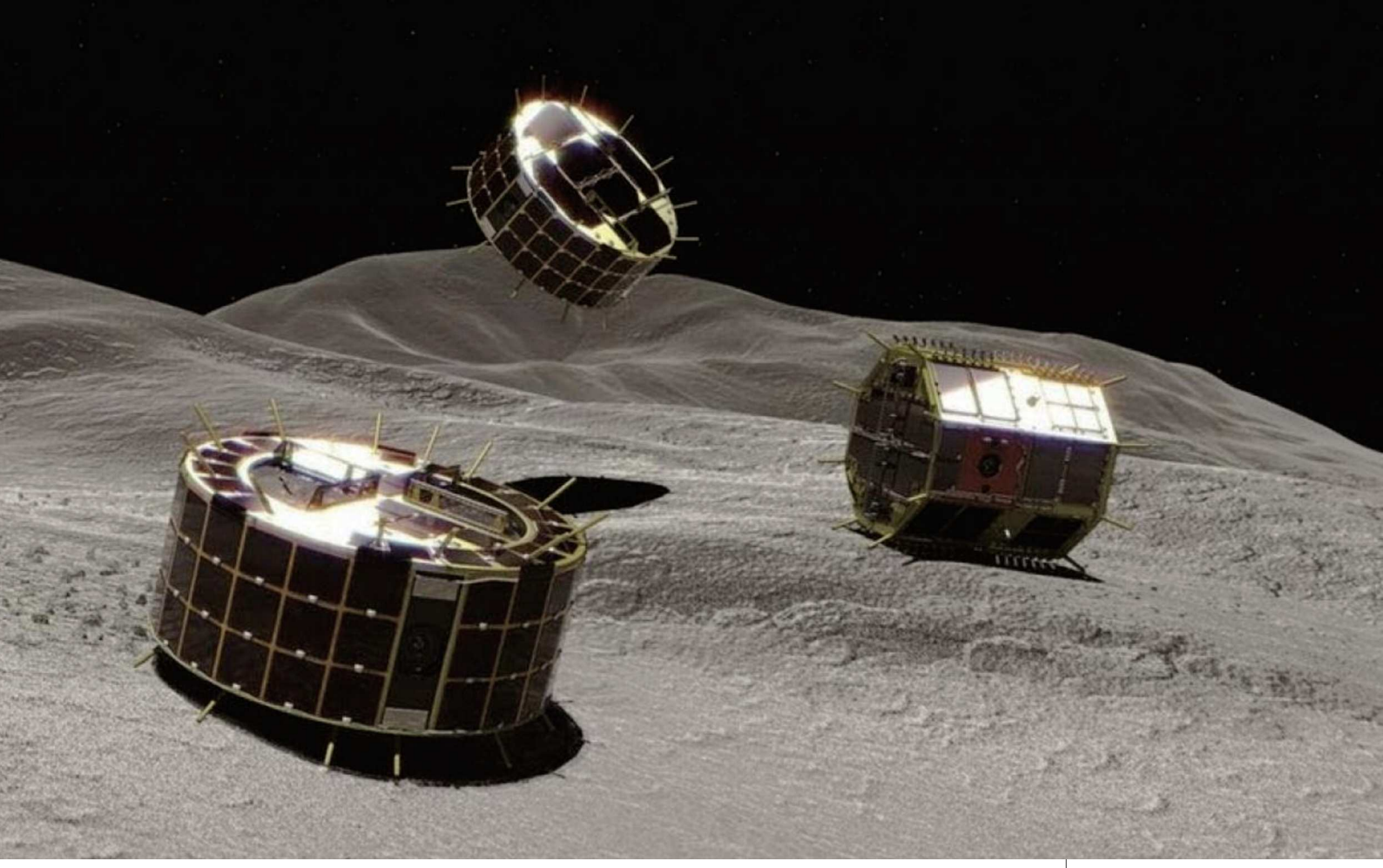
Let's take a brief look at how the probe is structured and what the expected tasks for

The people behind the Naval Operations. From the left in the front row, we see Tsuda, Onishi, Oki and Kikuchi, starting from the left in the middle row is Kato, Taniguchi, Matsuoka, and from the left in the back two is Takeuchi, Miyahara, Oi, and Takao (Family name only is given with titles omitted).

the scientific load charged with studying the asteroid are. Hayabusa2 is the size of a large fridge (1×1.6×1.25 m), weighs just over 600 kg, and is at the same time a probe with its own instruments and also itself a cargo vessel carrying some independent mini-probes. Among the scientific instruments on board Hayabusa2, there are some cameras (Optical Navigation Camera, Near-Infrared Camera, Thermal-Infrared Camera) and some devices for sampling the surface of Ryugu (Sampling device (SMP), Small Carry-on Impactor (SCI), Deployable Camera). During the whole forward journey, four rovers (Rover-1A, Rover-1B, MASCOT and Rover-2) have been holding onto Hayabusa2. Their task includes exploring the surface of the asteroid and gathering information on the environment. Rover-1A



On the side, the Japanese probe Hayabusa2 cast its shadow on asteroid Ryugu. [JAXA]



and Rover-1B, developed by JAXA (Japan Aerospace Exploration Agency) and University of Aizu, and housed in the Minerva-II1 container, have the shape of cookie boxes: two cylinders 18 cm wide, 7 cm high and 1.1 kg heavy. Each of them is equipped with a stereo camera, a wide-angle camera and a thermometer. Their service life could last the entire 15 months planned for the scientific mission in situ, since their energy autonomy is guaranteed by solar panels.

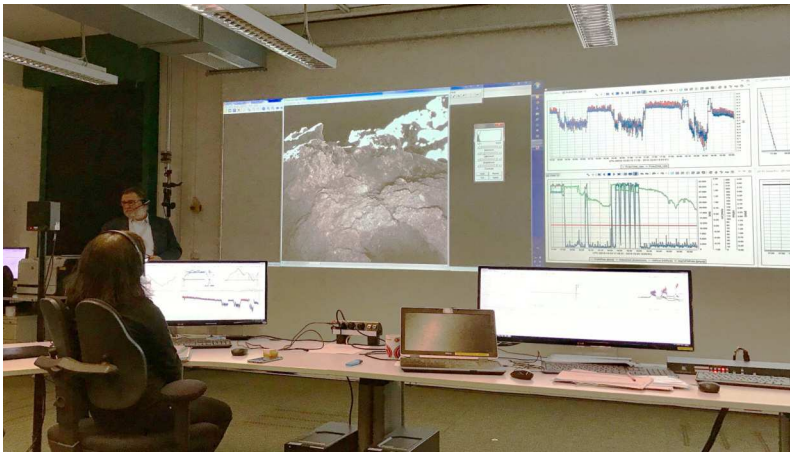
Rover-2 is housed inside MINERVA-II-2 and was developed by a university consortium led by Tohoku University. It has the shape of an octagonal prism 15 cm wide and 16 cm high, and weighs about 1 kg. It is equipped with two cameras, LEDs to illuminate dust in suspension, an accelerometer, and a thermometer.

Rover-2 is also powered by solar panels. Its landing on Ryugu is scheduled for July, 2019.

These three small rovers have in common the peculiarity of being able to move on the asteroidal surface not by wheels, but through leaps triggered by the acceleration and sudden braking of flywheels placed on more than one axis of their structure. It is the first time that this solution has been put into practice in a space mission, and this is by far the best way to move a rover on rough and irregular terrains like those typical of the small bodies of the solar system.

The fourth rover, the Mobile Asteroid Surface Scout (MASCOT) was developed by the Deutsches Zentrum für Luft- und Raumfahrt (DLR) and the Centre National d'Etudes Spatiales (CNES). It measures almost

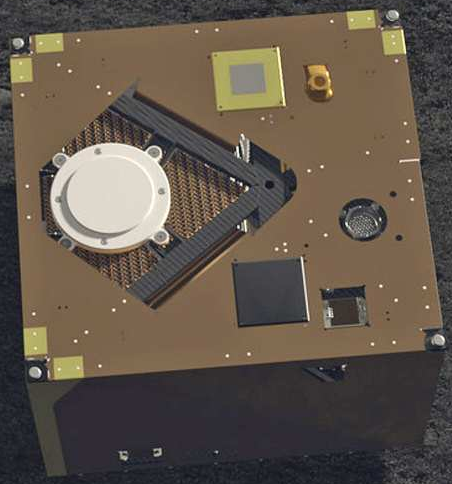
Graphic representation of the twin rovers 1A and 1B at work on the surface of Ryugu, together with Rover-2. The latter will fall on the asteroid next year. [JAXA]
In the video below, an overview of the Hayabusa2 mission and, in particular, of the MASCOT operations. [DLR]



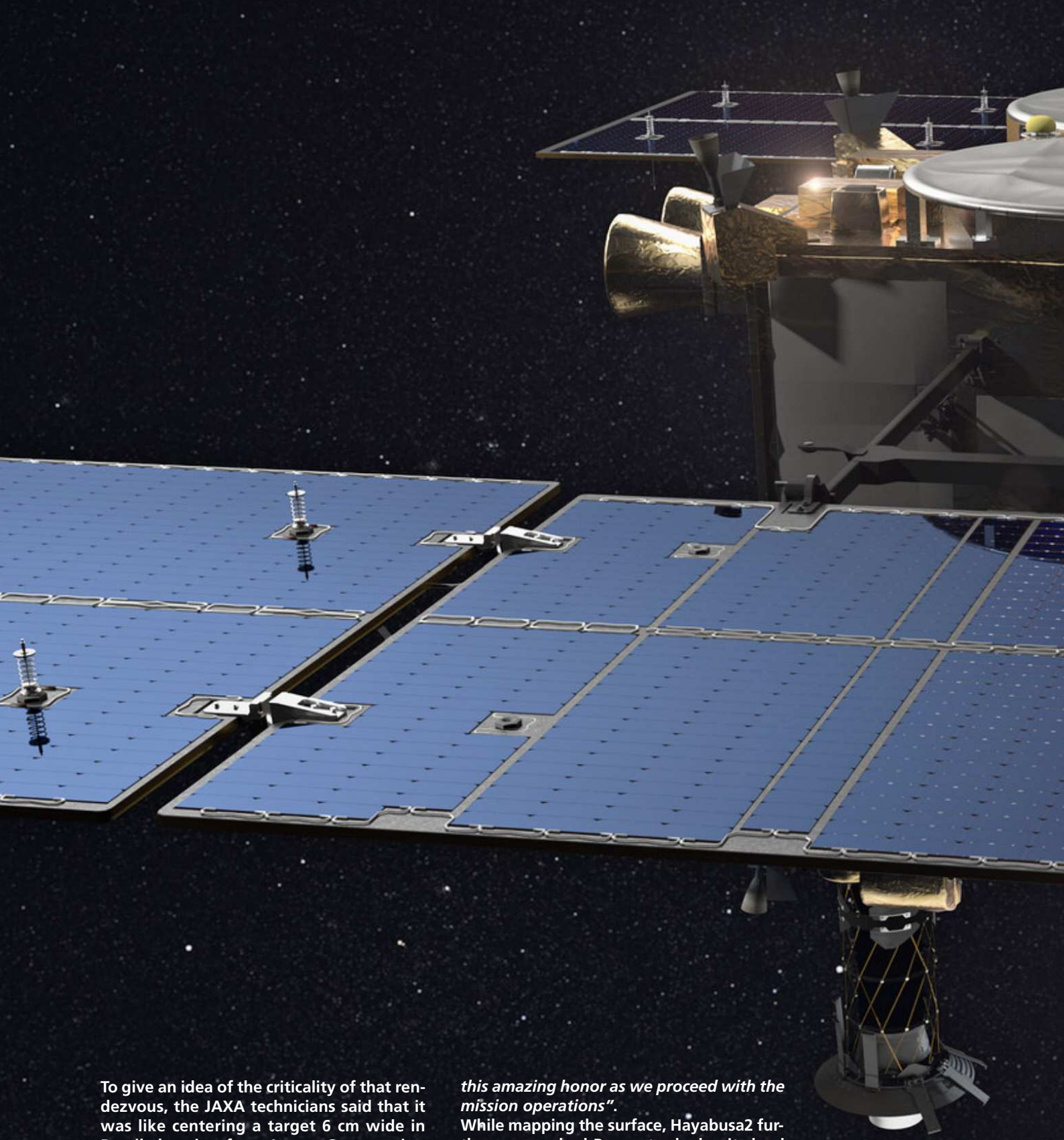
On the right, some researchers of the Deutsches Zentrum für Luft- und Raumfahrt evaluate the first images sent to Earth by Hayabusa2. [DLR]

30x30x20 cm, weighs nearly 10 kg, and carries four scientific instruments (the MASCAM camera, the MicrOmega infrared spectrometer, the MASMAG magnetometer and the MARA radiometer). MASCOT does not have solar panels, but a battery with an autonomy of about 15 hours. For this reason, unlike the three smaller rovers, it has already completed its mission, as we will detail later.

After 1302 days of flight and at a distance of almost 300 million km from the Earth, Hayabusa2 and its fleet of rovers reached their destination on June 27, 2018. With a total of ten trajectory correction maneuvers (TCM), the probe approached the asteroid up to a distance of about 20 km. The relative speed between the two objects does not exceed 1 cm/s. Beginning from that moment, and for the following months, the probe and the asteroid proceed side-by-side in their run around the Sun.

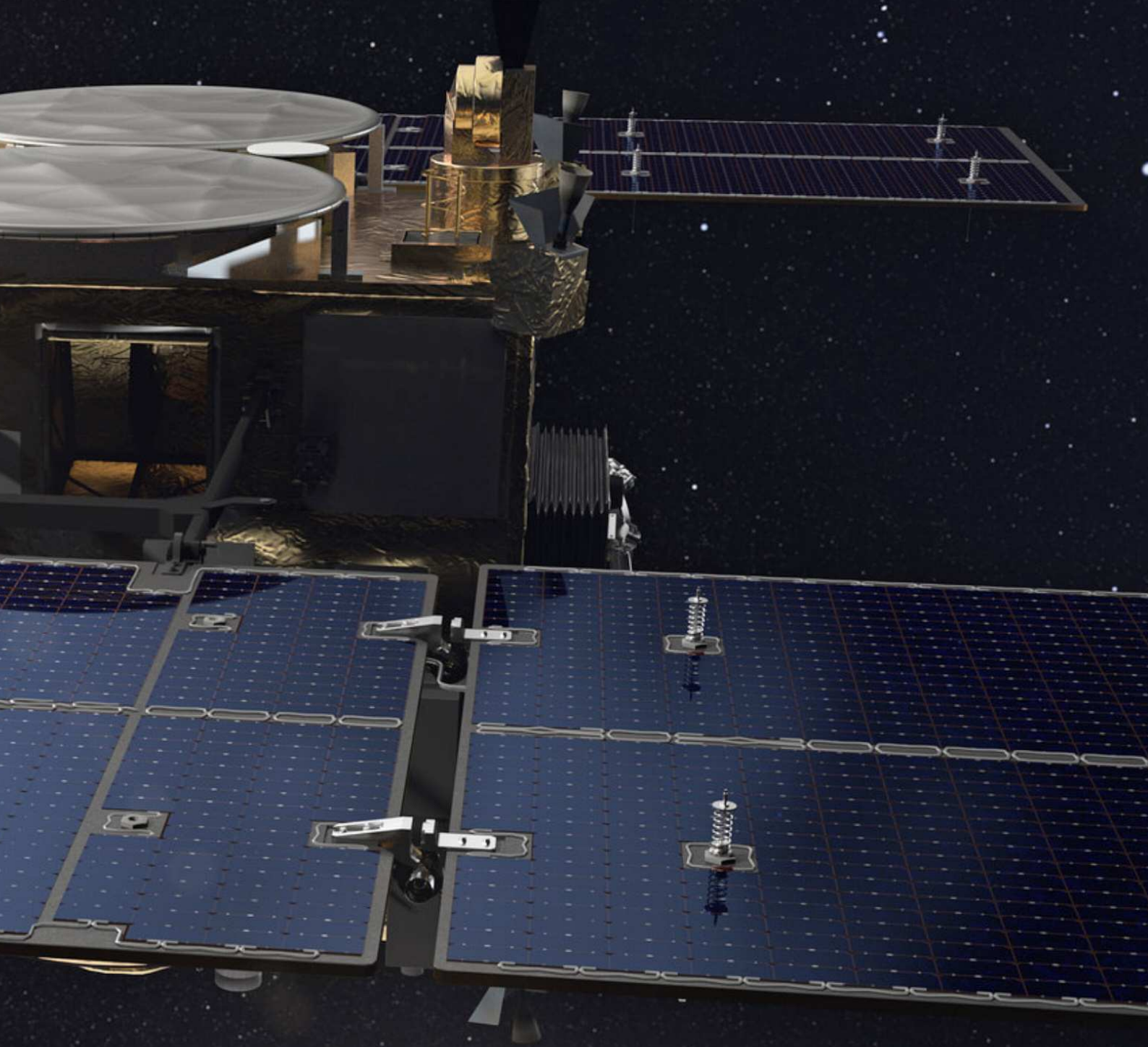


Above, MASCOT on the surface of Ryugu according to a graphic reconstruction. On the right, a sequence of images of the real landing of MASCOT on the surface of the asteroid acquired on 3 October 2018 with the wide-angle optical navigation camera. [DLR, JAXA, Tokyo University, Kochi Univ., Rikkyo Univ., Nagoya Univ., Chiba Institute of Technology, Meiji Univ., Aizu Univ., AIST]



To give an idea of the criticality of that rendezvous, the JAXA technicians said that it was like centering a target 6 cm wide in Brazil shooting from Japan. Commenting on the exploit, the project manager Yuichi Tsuda said: *"Today, we are at the beginning of a space science exploration that is unprecedented for humankind. Together with all of you, we have become the first eyewitnesses to see asteroid Ryugu. I feel this amazing honor as we proceed with the mission operations"*.

While mapping the surface, Hayabusa2 further approached Ryugu to deploy its load as scheduled, until it was, on September 21st, just 55 meters away. On that day, the probe released and pushed towards the asteroid the first two hopping rovers, Rover-1A and Rover-1B. Thanks to the weak gravity exerted by Ryugu on the robotic



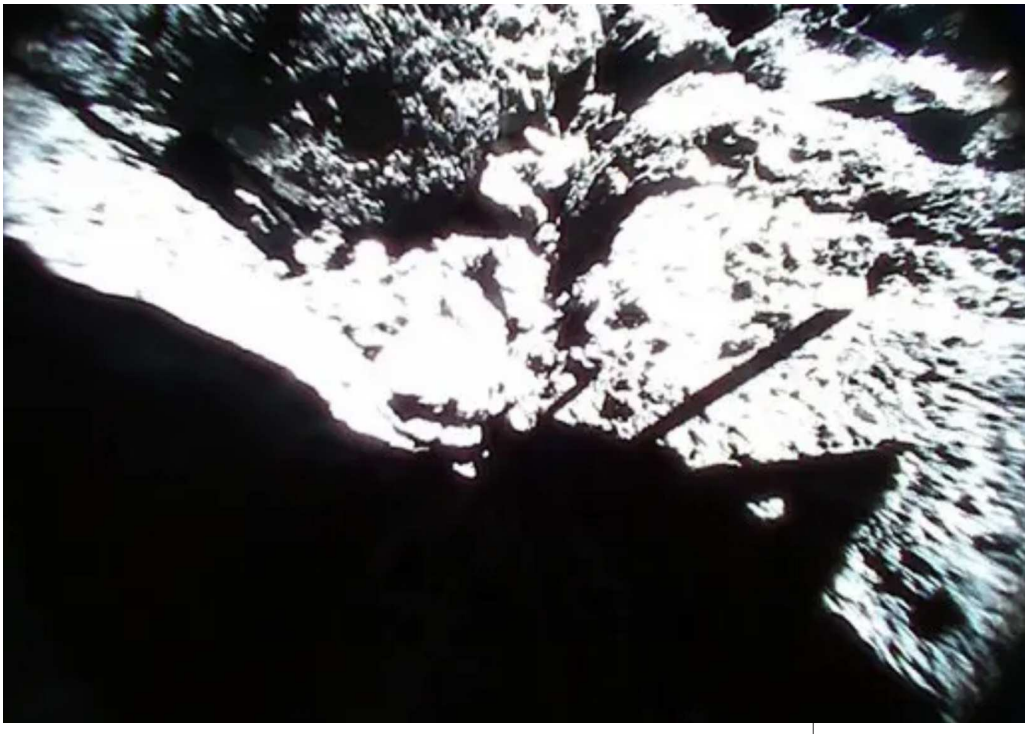
A remarkable illustration of the Hayabusa2 probe, with the solar panels in the foreground. [DLR]

visitors, the only precaution necessary for a soft landing was a slow approach speed. And indeed, to confirm the contact, it was necessary to wait until the following day. The two rovers then began to operate as planned, moving by jumping on the surface. Each jump can reach 15 meters in height and last up to a quarter of an hour, during which cameras and sensors onboard the small robots investigate the surface.

About ten days later, Hayabusa2 also released MASCOT. When it landed on Ryugu early in the morning of October 3rd, it ended up in an unfavorable position for the tasks it had to perform, so it was repositioned by a remote maneuver, thanks to a swing arm settled into its structure.

At that point, the probe performed a complete sequence of measurements with all the instruments, lasted one day and

one night of Ryugu (about 7 hours and 36 minutes). Once this first sequence finished, the control center of DLR commanded MASCOT to make a small movement in place in order to record some images that could be used to generate stereo views of the surface.
From the landing to this last maneuver, the rover moved itself on the surface by a few meters. Seeing that the battery was still well-charged, the mission technicians decided to let the rover make a small leap, thus managing



On this page and the following one, a few of the first images of the surface of Ryugu, recorded at the beginning of the scientific phase of the Hayabusa2 mission. [DLR, JAXA]

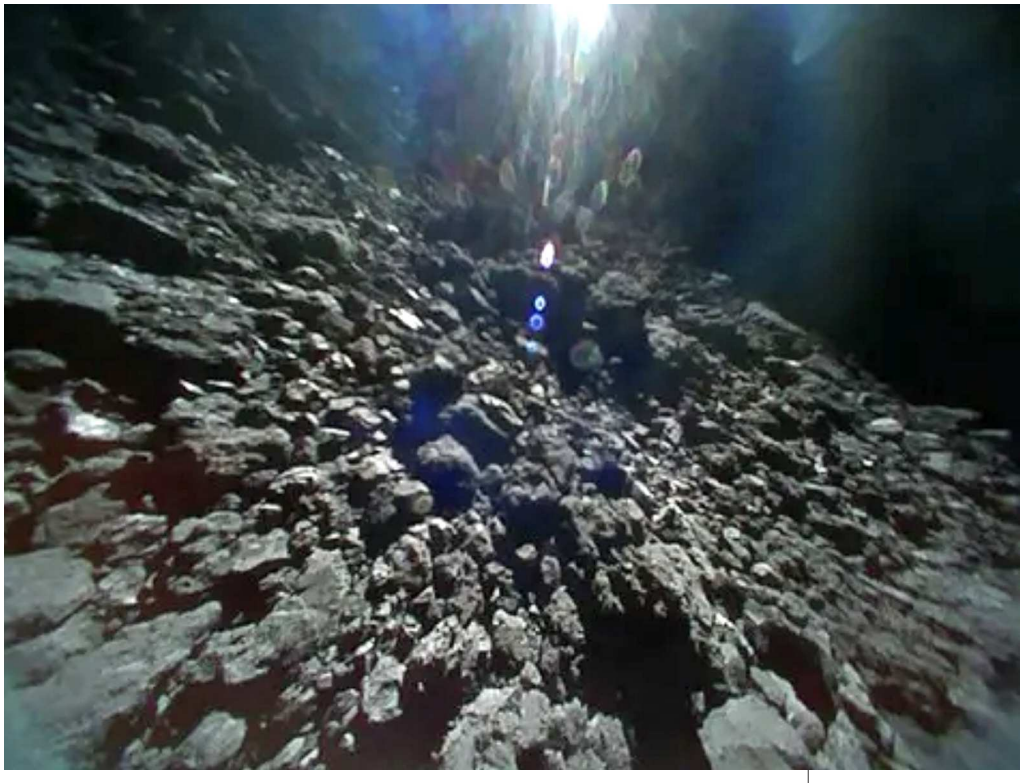
On the right, Rover-1B succeeded in shooting a movie on Ryugu's surface! The movie has 15 frames captured on September 23, 2018 from 10:34 - 11:48 JST (Japan Standard Time). [JAXA]

to study a new area of the surface. Before stopping its activity, MASCOT analyzed several sites during more than two asteroid rotations (over 17 hours in total), collecting images and data on the composition, structure, and the magnetic and thermal properties of Ryugu. Each recording was transferred to the Hayabusa2 computer before the MASCOT battery depletion and then retransmitted back to the Earth. It will take some time to analyze the vast amount of information collected.

On the evening of October 3rd, the MASCOT mission was successfully completed and Hayabusa2 returned to its parking position 20 km above the surface of the asteroid. By the end of October (when this issue of the magazine will be closed) a first contact between Hayabusa2 and Ryugu was scheduled, with the explicit goal of collecting precious samples of superficial material. The first specimens will be (were, for the reader) collected from a kind of horn that is in contact with the surface, expelling a small projectile consisting of 5 grams of tantalum at a speed of about 300 m/s. Part of the material ejected in the impact will be collected by a "funnel" placed on the top of the horn. In this case, the weak gravity of the asteroid also facilitates this operation. Subsequently, Hayabusa2 will collect samples of more in-depth material, which may have remained unaffected since the formation of the solar system, and certainly protected from the action of solar wind and cosmic radiation.

To reach that underground material, it will be necessary to remove the layer of overlying regolith and rock. For this purpose, Hayabusa2 will release the Small Carry-on Impactor, a sort of copper bullet weighing over 2 kg, with

a plastic explosive charge. About 40 minutes after the separation from the probe (with the latter in a safe position) and at the height of about 500 meters, the projectile will begin its run, followed by a camera that will have to accurately map the site of the impact (previously chosen based on observations from MASCOT). It is expected that the explosion can dig a crater up to 2 meters wide and that the ejecta will remain in suspension above the area affected by the event for at least two weeks. Consequently, to avoid any possible damage, Hayabusa2 will have to wait until the material has settled before going down into the crater to recover the most precious samples of the whole mission.



The researchers hope to see at least three different types of material coming back to Earth in December, 2020: regolith that ex-

On this page and the following one, other images of the surface of Ryugu, gathered at the beginning of the scientific phase of the Hayabusa2 mission. [DLR, JAXA]

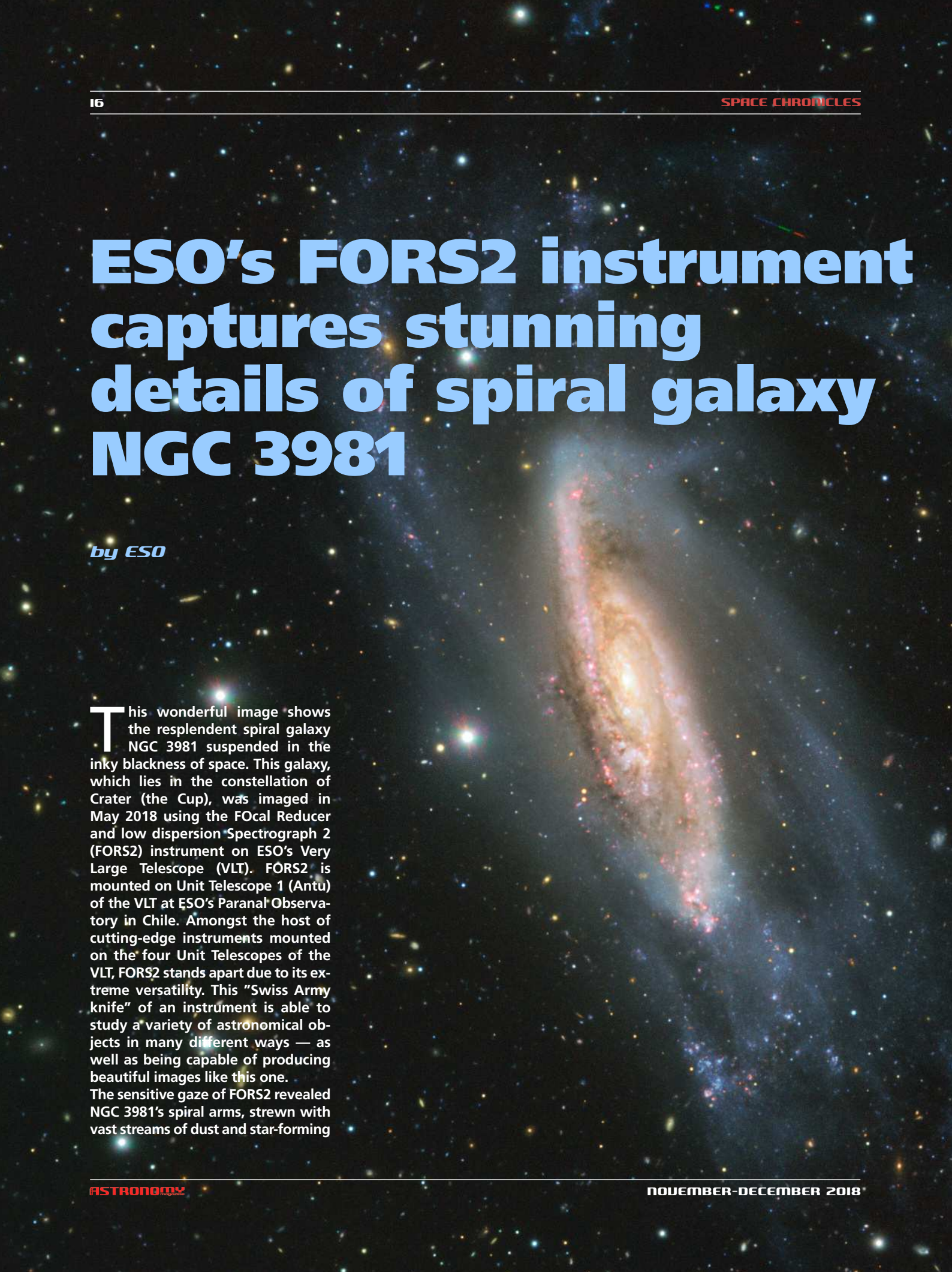
hibits traits of hydrous minerals; regolith with weak or undetectable alterations due to water; primordial sub-surface rock. The expected amount for each sample is between 0.1 and 10 grams.

The choice of a carbonaceous asteroid like Ryugu is necessary if the goal is to collect and study pristine material from the solar system. Unlike the metallic and siliceous asteroids (which are probably fragments of larger bodies, with differentiated internal structure destroyed by collisional events), the carbonaceous ones are instead the survivors of the planetesimal population from whose aggregation planets and moons of our solar system were born. For this reason, the study of the primordial material (non-differentiated and therefore not transformed by external or internal forces) that constitutes the carbonaceous asteroids like Ryugu is fundamental to understanding the origin and evolution of the inner planets, in particular. That primeval material can also tell us where organic compounds and water on Earth might have come from. Moreover, more precise knowledge of the mineralogical composition and the physical and structural characteristics of Near-Earth Asteroids as a whole could be of vital importance if, in a distant day, one of them should point straight towards our planet.

We will undoubtedly have the opportunity to update the important mission of Hayabusa2 during 2019 – stay tuned! ■

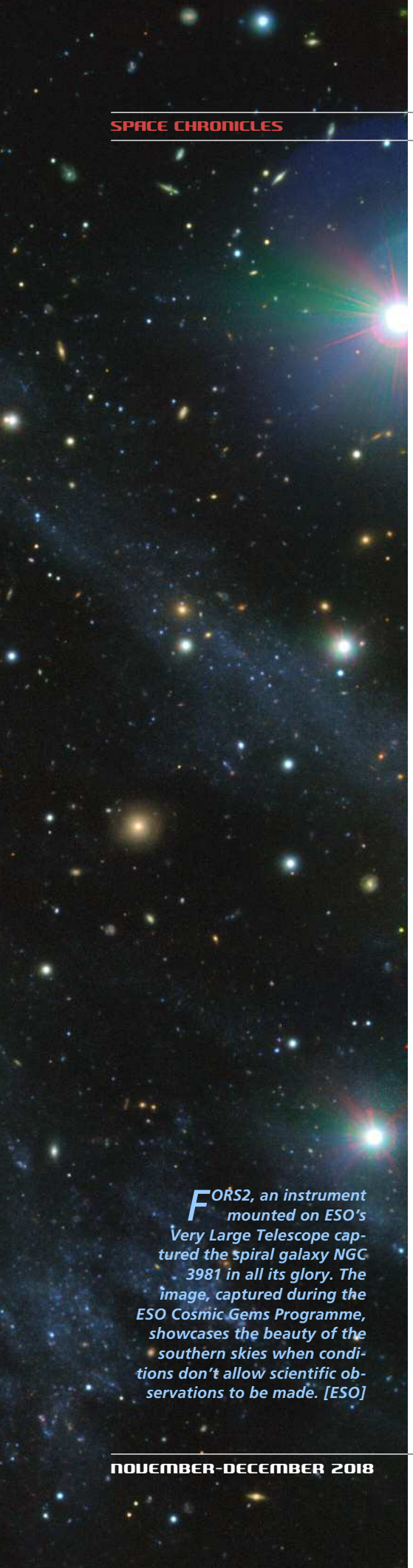
ESO's FORS2 instrument captures stunning details of spiral galaxy NGC 3981

by ESO



This wonderful image shows the resplendent spiral galaxy NGC 3981 suspended in the inky blackness of space. This galaxy, which lies in the constellation of Crater (the Cup), was imaged in May 2018 using the FOcal Reducer and low dispersion Spectrograph 2 (FORS2) instrument on ESO's Very Large Telescope (VLT). FORS2 is mounted on Unit Telescope 1 (Antu) of the VLT at ESO's Paranal Observatory in Chile. Amongst the host of cutting-edge instruments mounted on the four Unit Telescopes of the VLT, FORS2 stands apart due to its extreme versatility. This "Swiss Army knife" of an instrument is able to study a variety of astronomical objects in many different ways — as well as being capable of producing beautiful images like this one.

The sensitive gaze of FORS2 revealed NGC 3981's spiral arms, strewn with vast streams of dust and star-forming



FORS2, an instrument mounted on ESO's Very Large Telescope captured the spiral galaxy NGC 3981 in all its glory. The image, captured during the ESO Cosmic Gems Programme, showcases the beauty of the southern skies when conditions don't allow scientific observations to be made. [ESO]

This zoom video starts with a wide view of the Milky Way and ends with a close-up look at the spiral galaxy NGC 3981 in the constellation of Crater (The Cup). The final view of this region was captured by FORS2, an instrument mounted on ESO's Very Large Telescope, as part of the ESO Cosmic Gems Programme. This programme showcases the beauty of the southern skies when conditions don't allow scientific observations to be made. [ESO/Digitized Sky Survey 2/N. Risinger (skysurvey.org). Music: Astral Electronic.]

regions, and a prominent disc of hot young stars. The galaxy is inclined towards Earth, allowing astronomers to peer right into the heart of this galaxy and observe its bright centre, a highly energetic region containing a supermassive black hole. Also shown is NGC 3981's outlying spiral structure, some of which appears to have been stretched outwards from the galaxy, presumably due to the gravitational influence of a past galactic encounter.

NGC 3981 certainly has many galactic neighbours. Lying approximately 65 million light years from Earth, the galaxy is part of the NGC 4038 group, which also contains the well-known interacting Antennae Galaxies. This group is part of the larger Crater Cloud, which is itself a smaller component of the Virgo Supercluster, the titanic collection of galaxies that hosts our own Milky Way galaxy.

NGC 3981 is not the only interesting feature captured in this image. As well as several foreground stars from our own galaxy, the Milky Way, FORS2 also captured a rogue asteroid streaking across the sky, visible as the faint line towards the top of the image. This particular asteroid has unwittingly illustrated the process used to create astronomical images, with the three different exposures making up this image displayed in the blue, green and red sections of the asteroid's path.

This image was taken as part of ESO's Cosmic Gems programme, an outreach initiative to produce images of interesting, intriguing or visually attractive objects using ESO telescopes, for the purposes of education and public outreach. The programme makes use of telescope time that cannot be used for science observations. In case the data collected could be useful for future scientific purposes, these observations are saved and made available to astronomers through ESO's science archive. ■

Ireland to join the European Southern Observatory

by ESO

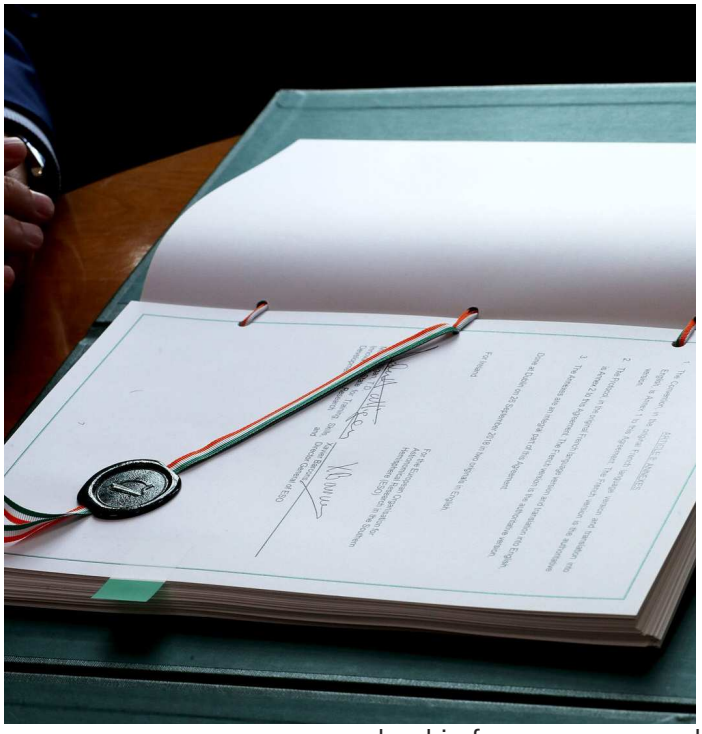
The Irish flag is hoisted for the first time at ESO's Headquarters in Garching bei München, Germany, signifying Ireland becoming a Member State of ESO once the ratification process is complete. The flag joins those of the other Member States, taking the total number up to 16. [ESO]

Irish astronomers are set to gain access to the world's most advanced ground-based astronomical telescopes following the signature of Ireland's Accession Agreement in Dublin today, 26 September 2018.

The signing of the Agreement follows the unanimous approval of Irish membership by the ESO Council at a meeting on 6 June 2018.

The formal ratification process for Irish membership of ESO has already almost been completed, following the approval of Dáil Éireann and Seanad Éireann — the Irish National Assembly and Senate. This process will be fully completed once the instrument of ratification — an official document — is deposited at the French Ministry of Foreign Affairs, which is expected to happen within a matter of days. The day of the deposit will be the official date of the Irish accession to ESO.

"We are delighted to welcome Ireland as the newest member of our organisation" stated ESO's Director General, Xavier Barcons. *"Ireland's mature and thriving astronomical community will add to the broad variety of expertise in the ESO Member States, strengthening ESO's position at the forefront of global astronomy. Irish astronomers will gain access to a suite of the world's most advanced ground-based astronomical telescopes and will have the opportunity to be part of the construction of the next generation of ESO instruments in partnership with other ESO Member States. We are also very much looking forward to working with Irish industrial partners to build and operate ESO's state-of-the-art telescopes."*



ESO's Director General, Xavier Barcons, and John Halligan T.D., Irish Minister of State for Training, Skills, Innovation, Research and Development, today signed the Accession Agreement that will lead to Ireland joining the European Southern Observatory. [ESO]

The accession cements the position of Ireland's astronomical research community as an asset to worldwide astronomy. With the ESO Membership, Ireland gets access to ESO's world-class suite of telescopes and instruments, including the Very Large Telescope (VLT) on Paranal and the Atacama Large Millimeter/submillimeter Array (ALMA) at Chajnantor, as well as the opportunity to contribute to the construction of the Extremely Large Telescope (ELT) in coming years.

By joining ESO, Ireland adds to their already rich astronomical history, stretching back centuries. For several decades in the 19th century, Ireland hosted the world's largest telescope — the Leviathan of Parsonstown — a 1.8-metre reflecting telescope at Birr Castle (whose grounds are now home to I-LOFAR, port of a Europe-wide low-frequency radio telescope). Ireland's vibrant research community and high-tech industrial sector have supported ESO membership for many years, and will now gain access to a range of instrumentation and industrial opportunities as a result of ESO membership.

ESO's Director General, Xavier Barcons (front right), and John Halligan T.D., Irish Minister of State for Training, Skills, Innovation, Research and Development (front left), sign the Accession Agreement that will lead to Ireland joining the European Southern Observatory. [ESO]

Speaking at the signing, Minister Halligan welcomed this important step in Ireland's membership process: *"I am delighted to have signed this membership agreement with the European Southern Observatory. This represents the culmination of significant work by the Government and ESO as well as the Irish astrophysics community. As a member of the leading astronomical research organisation in the world, Ireland has an opportunity to gain access to excellent research, innovation, collaboration and industry contracts. This significant investment in our scientific community demonstrates the Irish Government's continued commitment to research and development in both our academic and industrial sectors."* ■

ALMA observed an unstoppable monster in the early Universe

by ALMA Observatory

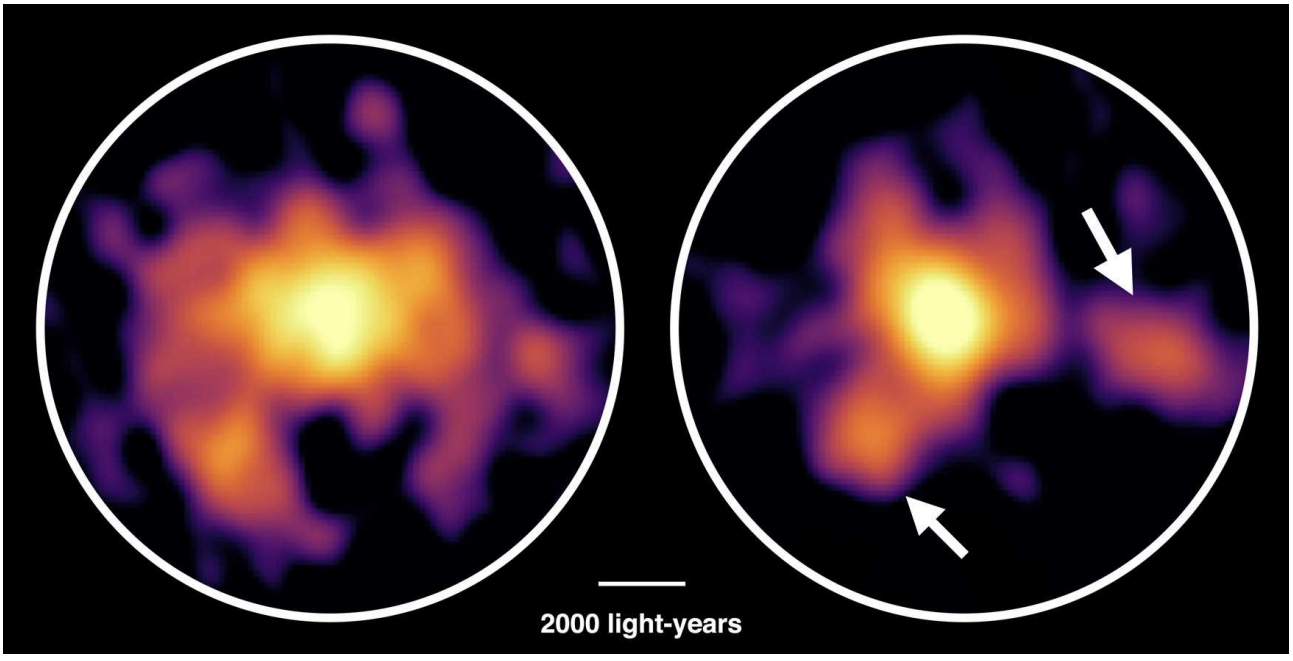
Astronomers obtained the most detailed anatomy chart of a monster galaxy located 12.4 billion light-years away. Using the Atacama Large Millimeter/submillimeter Array (ALMA), the team revealed that the molecular clouds in the galaxy are highly unstable, which leads to runaway star formation. Monster galaxies are thought to be the ancestors of the huge elliptical galaxies in today's Universe; therefore, these findings pave the way to understand the formation and evolution of such galaxies.

"One of the best parts of ALMA observations is to see the far-away galaxies with unprecedented resolution," says Ken-ichi Tadaki, a postdoctoral researcher at the Japan Society for the Promotion of Science and the National Astronomical Observatory of Japan, lead author of the research paper published in the journal *Nature*.

Monster galaxies, or starburst galaxies, form stars at a startling pace: 1000 times higher than the star formation rate in our Galaxy. However, why are they so active? To tackle this problem, researchers need to know the environment around the stellar nurseries. Drawing detailed maps of molecular clouds is one crucial step to scout these cosmic monsters.

Tadaki and the team targeted a chimerical galaxy COSMOS-AzTEC-1. This galaxy was first discovered with

Artist's impression of the monster galaxy COSMOS-AzTEC-1. This galaxy is located 12.4 billion light-years away and is forming stars 1000 times more rapidly than our Milky Way Galaxy. ALMA observations revealed dense gas concentrations in the disk and intense stars formation in those concentrations. [National Astronomical Observatory of Japan]



The monstrous galaxy COSMOS-AzTEC-1 observed with ALMA, which revealed the distribution of molecular gas (left) and dust particles (right). In addition to the dense cloud in the center, the research team detected two thick clouds several thousand light years from the center. They are dynamically unstable clouds, and are thought to harbor intense star formation activity. [ALMA (ESO/NAOJ/NRAO), Tadaki et al.]

the James Clerk Maxwell Telescope in Hawai`i, and later the Large Millimeter Telescope (LMT) in Mexico found an enormous amount of carbon monoxide gas in the galaxy and revealed its hidden starburst. The LMT observations also measured the distance to the galaxy, and found that it is 12.4 billion light-years.

Researchers have found that COSMOS-AzTEC-1 is rich with the ingredients of stars, but it was still difficult to figure out the nature of the cosmic gas in the galaxy. The team utilized the high resolution and high sensitivity of ALMA to observe this monster galaxy and obtain a detailed map of the distribution and the motion of the gas. Thanks to the most extended ALMA antenna configuration of 16 km, this is it the highest resolution molecular gas map of a distant monster galaxy. *"We found that there are two distinct large clouds several thousand light years away from the center,"* explains Tadaki. *"In most distant starburst galaxies, stars are actively formed in the center. So, it is surprising to find off-center clouds."*

The astronomers further investigated the nature of the gas in COSMOS-AzTEC-1 and found that the clouds throughout the galaxy are very unstable, which is unusual. In a typical situation, the inward gravity and outward pressure are balanced in the clouds. Once gravity overcomes pressure, the gas cloud collapses and forms stars at a rapid pace. Then, stars and supernova explosions at the end of the stellar life cycle blast out gases, which increases the outward pressure. As a result, gravity and pressure reach a balanced state and star formation continues at a moderate pace. In this way star formation in galaxies is self-regulating. However, in COSMOS-AzTEC-1, the pressure is far weaker than the gravity and hard to balance. Therefore, this galaxy shows runaway star formation and morphed into an unstoppable monster galaxy. The team estimated that the gas in COSMOS-AzTEC-1 will be completely consumed in 100 million years, which is ten times faster than in other star-forming galaxies.

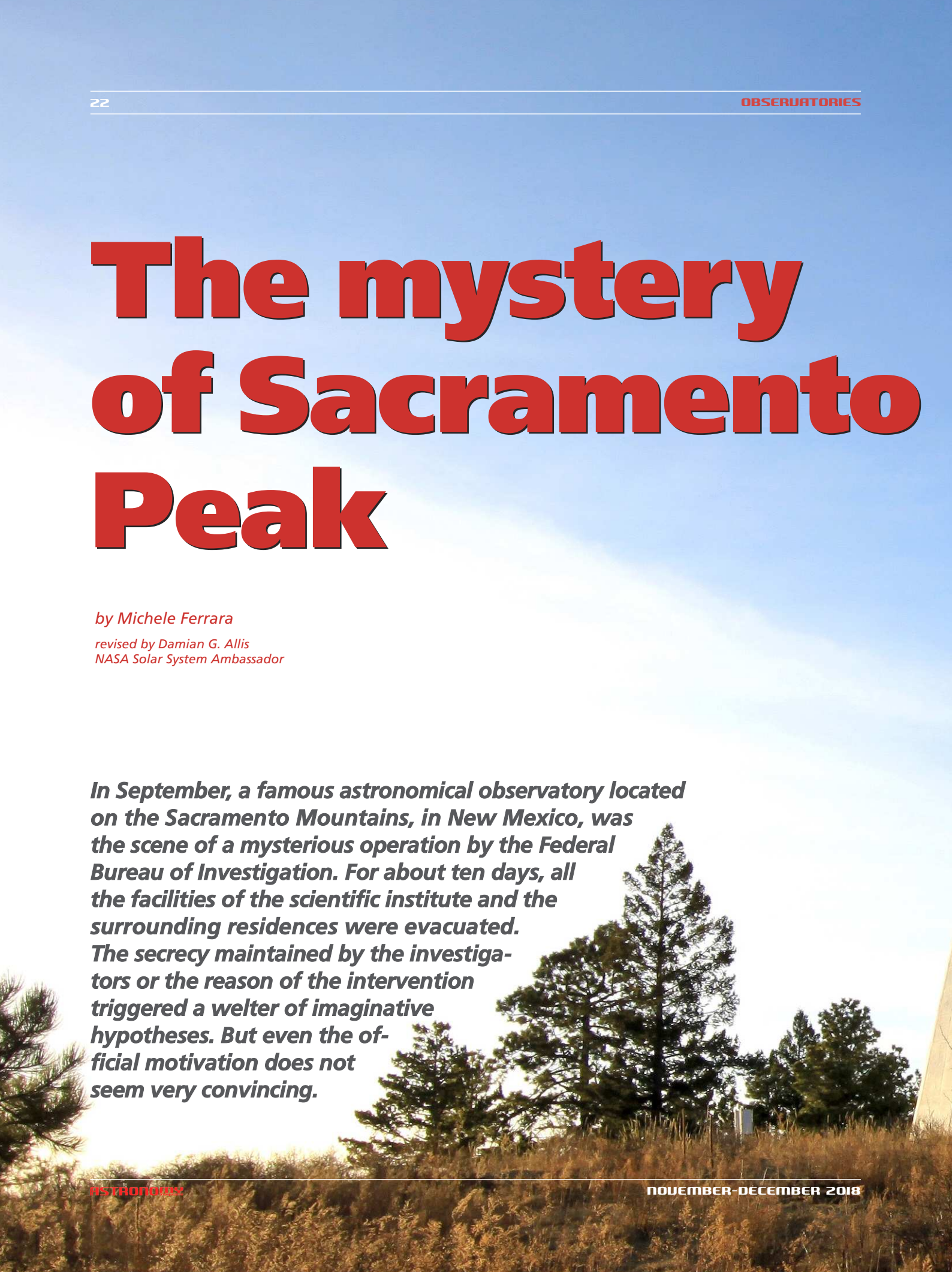
However, why is the gas in COSMOS-AzTEC-1 so unstable? Researchers do not have a definitive answer yet, but galaxy merger is a possible cause. Galaxy collision may have efficiently transported the gas into a small area and ignited intense star formation. *"At this moment, we have no evidence of merger in this galaxy. By observing other similar galaxies with ALMA, we want to unveil the relation between galaxy mergers and monster galaxies,"* summarizes Tadaki. ■

The mystery of Sacramento Peak

by Michele Ferrara

revised by Damian G. Allis
NASA Solar System Ambassador

In September, a famous astronomical observatory located on the Sacramento Mountains, in New Mexico, was the scene of a mysterious operation by the Federal Bureau of Investigation. For about ten days, all the facilities of the scientific institute and the surrounding residences were evacuated. The secrecy maintained by the investigators or the reason of the intervention triggered a welter of imaginative hypotheses. But even the official motivation does not seem very convincing.

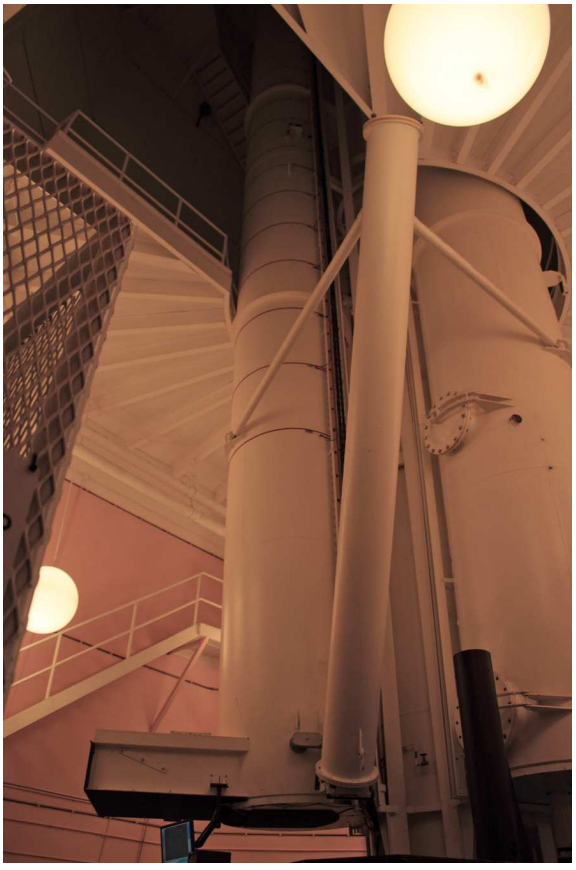


The unmistakable tower of the Richard B. Dunn Solar Telescope. The visible part of the structure is 41 meters high. The instrument then develops vertically in the subsoil for another 59 meters. [Samat Jain]

Let's try to imagine the plot of a spy story set in an astronomical observatory. On any given day, researchers and staff of the adjoining facilities, as well as the inhabitants of a nearby village, are evacuated by the FBI, whose men occupy the entire area. The official motivation told by the well-known federal investigative service is a generic "security reasons".

The FBI throws out from the investigation the sheriff of the county in which the spy story takes place, keeping him and his deputy in the dark about everything. Instead, a private security service is recruited to monitor the perimeter of the observatory area, so that no one can enter illegally or take photos or video with drones.

During the occupation of the complex of buildings belonging to the observatory, FBI agents root around a system of telecommunications antennas, within whose radius there are two high-profile military



bases, the place where the first atomic explosion test was carried out, and the area where, according to some, an alien spaceship fell.

There is enough to develop a long and compelling story, in which to unleash fantasies and speculations on the real motivation that led the FBI to evacuate the observatory.

Those who think that this plot is pure invention should not stop reading this article, because what has been written so far has really happened last September.

The location of the real version of what looks like a spy story is the Sunspot Solar Observatory on Sacramento Peak, New Mexico. Built in the early 50s, this research center has been the spearhead of solar physics for decades, thanks to the Vacuum Tower Telescope (70 cm in diameter), also known as the Richard B. Dunn Solar Telescope (DST), named after its designer. After a long and glorious activity, repeated funding cuts

Left, inside the Richard B. Dunn Solar Telescope, in Sunspot, NM. Below, the entrance to the National Solar Observatory is blocked by yellow crime scene tape and two security guards, who said even they had been kept in the dark. [Dylan Taylor-Lehman/Almagordo Daily News]

Satellite map of the territories surrounding the village of Sunspot. The places that have contributed to making the observatory evacuation more mysterious are highlighted with red circles: the military bases of White Sands and Holloman; the area of the first atomic test, near Socorro; the town of Roswell, so loved by ufologists. [Google Maps]

have led the observatory to a progressive decline, which perhaps will culminate with its closure when the Daniel K. Inouye Solar Telescope (DKIST), 4 meters in diameter, the successor to DST, will be completed. Today, most of the facilities that make up the Sunspot Solar Observatory are no longer managed and the whole area is animated only by a few researchers working with DST and guiding groups of visitors, by a handful of employees and workers, by the residents of the small town of Sunspot, and by the staff assigned to the local office.

Altogether, about twenty people, protagonists in spite of themselves, were involved in the mysterious evacuation that kept them away from their residences for more than ten days between September 6th and 17th. Immediately, the affair was cloaked in secrecy, which triggered a turmoil of hypothesis about why the population was moved

A video recorded through a drone by a stranger during the first days of the evacuation of the observatory. Also to avoid these intrusions, a security service was quickly activated.

away, included a possible terrorist attack and a contact with an alien civilization.

To feed the allegations, vague declarations were also contributed by the Association of Universities for Research in Astronomy (AURA), the consortium that manages the observatory. From the beginning, AURA explained away the evacuation with a generic "security reasons," a choice that left open any interpretation.

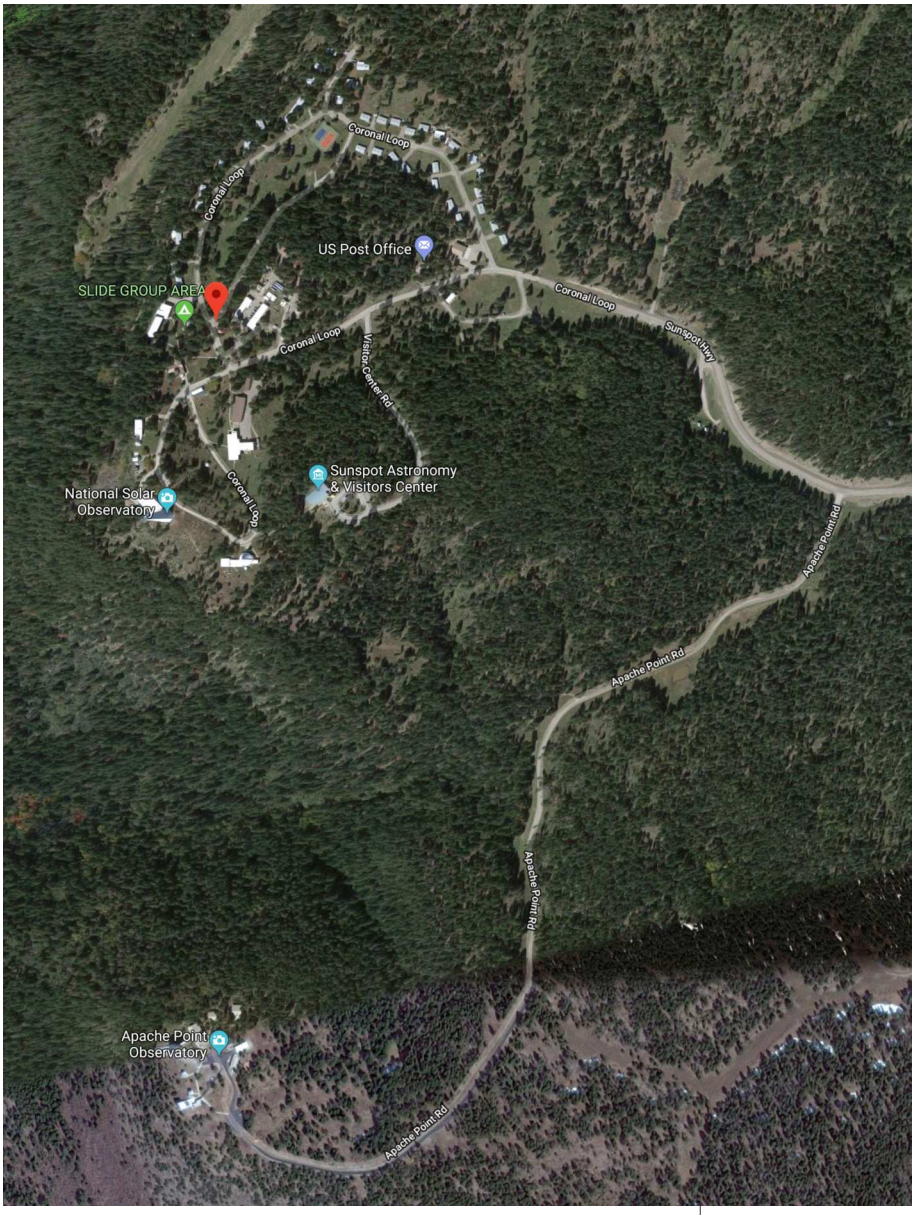
In the absence of satisfactory official clarifications, we try to create our own opinion of what happened by reading what was written during and after the event by the most authoritative local newspaper, the Daily News of the town of Alamogordo, Otero County, located between the Sacramento Mountains (to the east) and the Holloman Air Force Base (to the west).

Here is an extract of what has been published by that newspaper in various articles devoted to the mystery of the Sunspot Solar Observatory.

Sep 14, 2018 – Sunspot Observatory was closed and evacuated Sept. 6 due to an un- disclosed security risk. Federal officials aren't saying why it was closed, and the silence has led to international media coverage and plenty of speculation. Authorities remain tight- lipped. The FBI referred all questions to the group that manages the site, the Association of Universities for Research in Astronomy. Officials there say they're working with authorities.

AURA released a statement, stating it has "decided that the observatory will remain closed until further notice due to an ongoing security concern. Nothing's changed from last week," AURA spokeswoman Shari Lifson said by phone Thursday afternoon. Lifson offered no further information. Security guards from Alamogordo private security firm Red Rock Security were posted at the observatory's gate on Thursday due to the amount of curious visitors who have come to the site since the closure.

[...] Everyone in the facility and the Sunspot community was evacuated, said Sunspot Solar Observatory Director and New Mexico State University astronomy professor R.T. James McAteer. NMSU's four em-



A detailed map of the Sunspot area and the nearby Apache Point Observatory, which has not been affected by the September FBI operations. [Google Maps]

The main scientific structures of Sacramento Peak: the John W. Evans Solar Facility (below), the Richard B. Dunn Solar Telescope (top center), and the Patrol and Hilltop Domes (on the right). [National Solar Observatory]

ployees at Sunspot were evacuated, as were employees of AURA, McAteer said. The U.S. Postal Service, which operates the Sunspot Post Office, evacuated its employees as well. There were also about 12 to 15 residents who were evacuated, he said. "Last Thursday (Sept. 13), we got a phone call in the morning from AURA who told us to say that they were temporarily evacuating the site and asked us to evacuate our people," McAteer said. "So, I called our people up and asked them to leave in a very sensible and calm manner and locked everything up. We've been out of there since Thursday morning."

McAteer said in an email to the Associated Press that it will be up to the astronomy research association to decide when Sunspot reopens. "We have paused observations, and are taking this opportunity to catch up with the back log of data from previous months," he said.

The Sunspot and Astronomy Visitor's Center is where visitors begin their tour of the facility. [Alamogordo Daily New]

Sep 16, 2018 – The National Solar Observatory in Sunspot will reopen Monday, according to a statement released Sunday afternoon by Association of Universities for Research in Astronomy, the organization that oversees operations at the facility. According to AURA, the observatory was closed due to investigation into possible criminal activity at the site. The residents that vacated their homes will be returning to the site, and all employees will return to work this week, the release stated. "In light of recent developments in the investigation, we have determined there is no risk to staff, and Sunspot Solar Observatory is transitioning back to regular operations as of September 17th," the news release stated. AURA did not specify the nature of the criminal activity.

The post office of the small village of Sunspot, also evacuated by the FBI. [National Science Foundation] Left, NMSU astronomy professor and Sunspot Solar Observatory Director James McAteer. [Darren Phillips]

Despite the good will of Alamogordo Daily News reporters, we do not find the slightest mention of a possible concrete reason that could justify the evacuation of the entire area centered on the observatory. To get less generic information, in those days we, therefore, went looking in the section "The war zone" of Thedrive.com, and here we add some, perhaps, revealing details.

Otero County Sheriff Benny House said the FBI asked him to support the initial evacuations at the observatory itself, but gave him no other information and that he and his deputies left after there was no evidence of an ongoing or imminent threat. "There was a Black Hawk helicopter, a bunch of people around antennas and work crews on towers but nobody would tell us anything," Sheriff House explained. "We went up there and everything was good. There was no threat. Nobody would identify any specific threat. We hung out for a little while then we left. No reason for us to be there. Nobody would tell us what we're supposed to be watching out for." [...] Otero County Sheriff Benny House stated to local media: "The FBI is refusing to tell us what's going on," House said. "We've got people up there (at Sunspot)

The presence of White Sands and Holloman military bases was the element that more than others contributed to turning the evacuation of Sunspot into a spy story. Electronic devices conveniently placed between the antennas of the observatory could have captured messages coming out of the bases.

that requested us to standby while they evacuate it. Nobody would really elaborate on any of the circumstances as to why. The FBI were up there. What their purpose was nobody will say... But for the FBI to get involved that quick and be so secretive about it, there was a lot of stuff going on up there."

[...] It's important to note that AURA has consistently described the situation was a "security issue" rather than a "risk" or a "threat," which strongly suggests the reason for the evacuations was not tied to something such as a bomb threat. Had there been a danger of some sort chemical or biological hazard, the responding officials would have been wearing suitable protective gear.

[...] But given AURA's statements and what else we know about the situation, there is a distinct possibility that "security issue" is actually related to espionage or a similar operational security concern. The National Solar Observatory's site is very low security — as in not really any at all — yet sits in a highly strategic location overlooking one of America's preeminent weapons test complexes, White Sands Missile Range, and Holloman AFB. Sunspot Solar Observatory has multiple places where sensors, such as antenna aerials, could potentially be planted

without drawing outright attention. These could be used to record and intercept electronic emissions related to military activities in, above, and around the valley below.

At this point, the scenario seems a bit more concrete and credible, and the absence of official explanations, as well as attempts to ridicule the "spy story", reinforce what appeared to be the most reasonable interpretation from the very beginning. Here are the conclusions of Thedrive.com.

It seems more plausible that a foreign operative or an operative working on a foreign government's behalf might have been able to install an antenna/sensor apparatus onto the top of a structure that is part of the facility and within line-of-sight of the valley below without anyone noticing. This could allow them to persistently gather electronic intelligence on whatever might be happening on, around, and over White Sands and at Holloman. With the capabilities of modern electronics and batteries, it's possible that such a system wouldn't even need to be hard wired.

On 20 September, a few days after the residents went back home and after everything returned to normality in Sacramento Peak, an astonishing article in the Alamogordo Daily News proposes the official motivation of the evacuation.

The mysterious closure of a solar observatory in New Mexico earlier this month happened after the FBI opened a child pornography investigation involving a janitor's computer found at the observatory, and agents tracked wireless signals used to access child porn, according to an FBI search warrant affidavit. The mountaintop

The "Trinity Site", near Socorro, is the place where the first atomic bomb was tested, on July 16, 1945. Both this site and the town of Roswell (which houses a bizarre UFO museum) are relatively close to Sunspot, and this has triggered the most imaginative theories about the evacuation of the solar observatory.

Several witnesses claimed to have seen a Black Hawk military helicopter (like the one pictured) flying over the Sunspot area at the beginning of the FBI operations on the Sacramento Peak. If, as stated by the official version given by the authorities, the action had as its objective the seizure (already happened!) of a laptop computer of a depraved janitor, is an intervention of that extent justified?

Sunspot Solar Observatory closed from Sept. 6 to Sept. 17, but the research association that manages it has said only that an unspecified security issue was the reason for the closure.

The search warrant filed last week in federal court in Las Cruces said the facility's chief observer, who was not identified, told FBI agents in August he found a laptop computer with child pornography several months earlier but did not immediately report the discovery to authorities because he was "distracted" by an unspecified urgent issue at the observatory.

The search warrant provided to a judge the justifications for agents to search computers, cellphones or tablets owned by the janitor, Joshua Lee Cope, and the house trailer where he lives. An FBI agent seized the laptop at the observatory on Aug. 21, 2018, and took it to the FBI office in Las Cruces, court documents said. FBI spokesman Frank Fisher said Thursday that no one has been charged and the investigation is ongoing. Cope, 30, lives on property owned by his parents in La Luz, the search warrant said. A phone message left for Cope at a telephone number listed for his parents seeking comment was not immediately returned. After Cope could not find his laptop, the court documents said, he began to act frantically and told the chief observer that there was a "serial killer in the area, and that he was fearful that the killer might enter the facility and execute someone." The observatory closed, without consulting FBI agents, after Cope's comments about the serial killer and his erratic behavior, the warrant said.

The motivation reported by the Alamogordo Daily News (certainly in good faith) is really at the limits of credibility. The article even goes so far as to affirm that the evacuation was an initiative of the observatory and not the FBI. Quite incredible is the fact that it was necessary to remove twenty people from their residences for over ten days and inspect the complex of antennas, because the alleged depraved janitor, no longer finding his computer, began to rant about a serial killer in the area.

The impression we have is that the suspected employee is the ideal scapegoat with which to cover the real motivations of the investigative operations that have affected Sacramento Peak. Probably, we will never know the truth, but no doubt there is already enough material to write a thriller and to turn the Sunspot Solar Observatory into a movie set one day, to rebuild what happened last September. The screenplay, after all, is already written. ■

Superflares from young red dwarf stars imperil planets

by NASA/ESA

The word "HAZMAT" describes substances that pose a risk to the environment, or even to life itself. Imagine the term being applied to entire planets, where violent flares from the host star may make worlds uninhabitable by affecting their atmospheres.

NASA's Hubble Space Telescope is observing such stars through a large program called HAZMAT — HAbitable Zones and M dwarf Activity across Time. "M dwarf" is the astronomical term for a red dwarf star — the smallest, most abundant, and longest-lived type of star in our galaxy. The HAZMAT program is an ultraviolet survey of red dwarfs at three different ages: young, intermediate, and old. Stellar flares from red dwarfs are particularly bright in ultraviolet wavelengths, compared with Sun-like stars. Hubble's ultraviolet sensitivity makes the telescope very valuable for observing these flares.

The flares are believed to be powered by intense magnetic fields that get tangled by the roiling motions of the stellar atmosphere. When the tangling gets too intense, the fields break and reconnect, unleashing tremendous amounts of energy.

The team has found that the flares from the youngest red dwarfs they surveyed — just about 40 million years old — are 100 to 1,000 times more energetic than when the stars are older. This younger age is when terrestrial planets are forming around their stars.

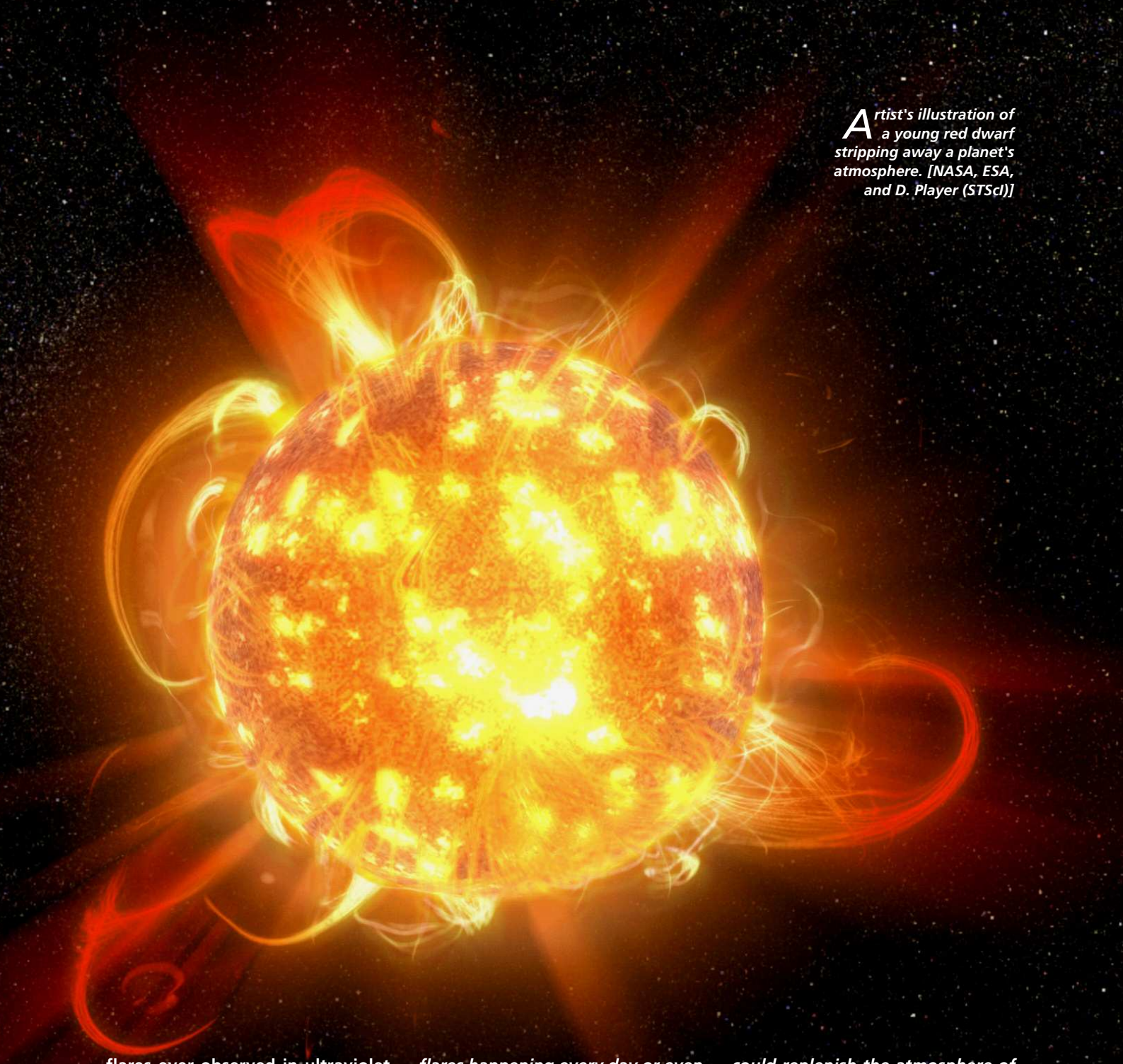
Approximately three-quarters of the stars in our galaxy are red dwarfs. Most of the galaxy's "habitable-zone" planets — planets orbiting their stars at a distance where temperatures are moderate enough for liquid water to exist on their surface — likely orbit red dwarfs. In fact, the nearest star to our Sun, a red dwarf named Proxima Centauri, has an Earth-size planet in its habitable zone. However, young red dwarfs are active stars, producing ultraviolet flares that blast out so much energy that they could influence atmospheric chemistry and possibly strip off the atmospheres of these fledgling planets.

"The goal of the HAZMAT program is to help understand the habitability of planets around low-mass stars," explained Arizona State University's Evgenya Shkolnik, the program's principal investigator. *"These low-mass stars are critically important in understanding planetary atmospheres."*

The results of the first part of this Hubble program are being published in *The Astrophysical Journal*. This study examines the flare frequency of 12 young red dwarfs.

"Getting these data on the young stars has been especially important, because the difference in their flare activity is quite large as compared to older stars," said Arizona State University's Parke Loyd, the first author on this paper.

The observing program detected one of the most intense stellar



Artist's illustration of a young red dwarf stripping away a planet's atmosphere. [NASA, ESA, and D. Player (STScI)]

flares ever observed in ultraviolet light. Dubbed the "Hazflare," this event was more energetic than the most powerful flare from our Sun ever recorded. *"With the Sun, we have a hundred years of good observations," Loyd said. "And in that time, we've seen one, maybe two, flares that have an energy approaching that of the Hazflare. In a little less than a day's worth of Hubble observations of these young stars, we caught the Hazflare, which means that we're looking at super-flares happening every day or even a few times a day."*

Could super-flares of such frequency and intensity bathe young planets in so much ultraviolet radiation that they forever doom chances of habitability? According to Loyd, *"Flares like we observed have the capacity to strip away the atmosphere from a planet. But that doesn't necessarily mean doom and gloom for life on the planet. It just might be different life than we imagine. Or there might be other processes that could replenish the atmosphere of the planet. It's certainly a harsh environment, but I would hesitate to say that it is a sterile environment."*

The next part of the HAZMAT program will be to study intermediate aged red dwarfs that are 650 million years old. Then the oldest red dwarfs will be analyzed and compared with the young and intermediate stars to understand the evolution of the ultraviolet radiation environment of low-mass planets around these low-mass stars. ■

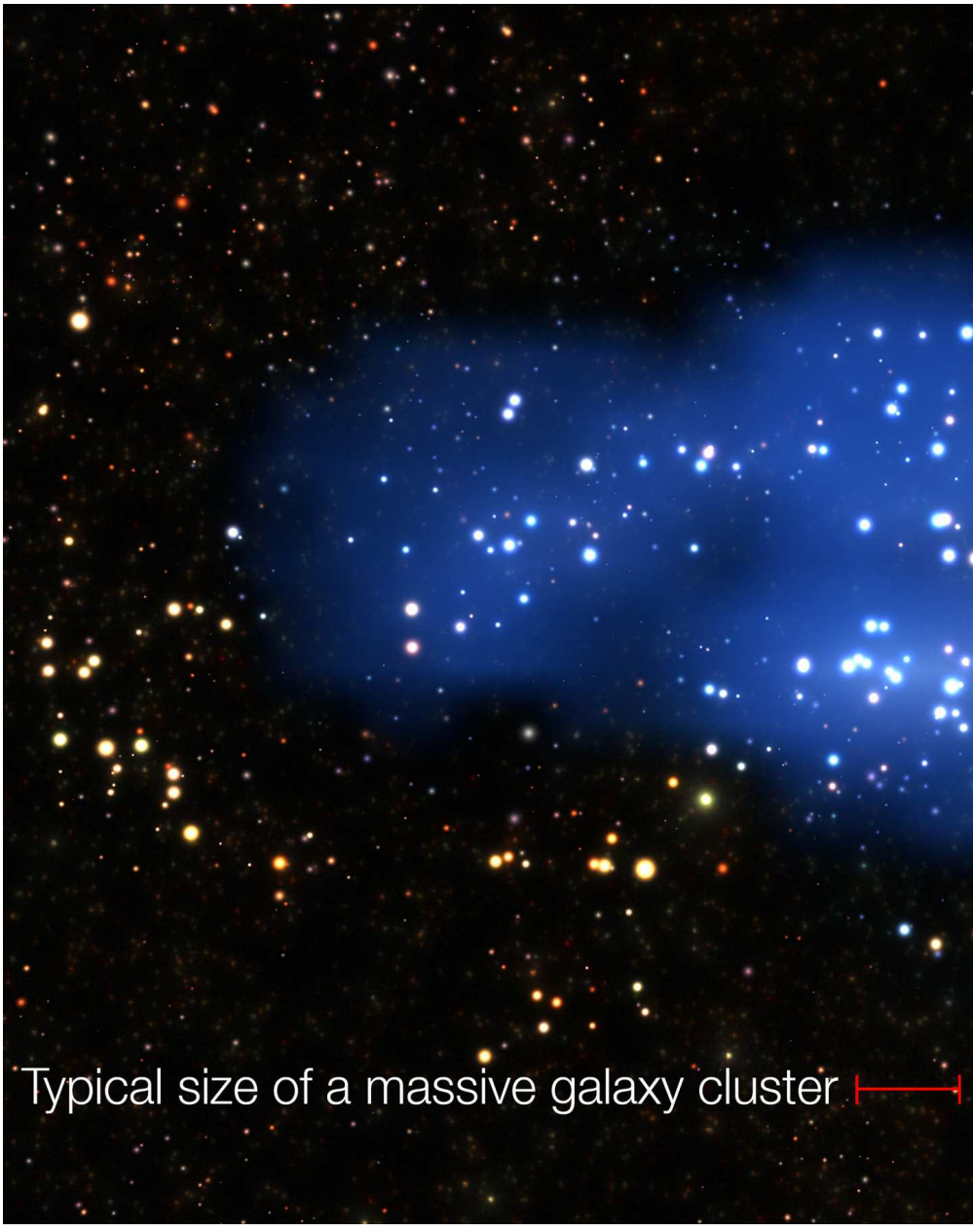
Largest galaxy proto-supercluster found

by ESO

A team of astronomers, led by Olga Cucciati of Istituto Nazionale di Astrofisica (INAF) Bologna, have used the VIMOS instrument on ESO's Very Large Telescope (VLT) to identify a gigantic proto-supercluster of galaxies forming in the early Universe, just 2.3 billion years after the Big Bang. This structure, which the researchers nicknamed Hyperion, is the largest and most massive structure to be found so early in the formation of the Universe.

The enormous mass of the proto-supercluster is calculated to be more than one million billion times that of the Sun. This titanic mass is similar to that of the largest structures observed in the Universe today, but finding such a massive object in the early Universe surprised astronomers.

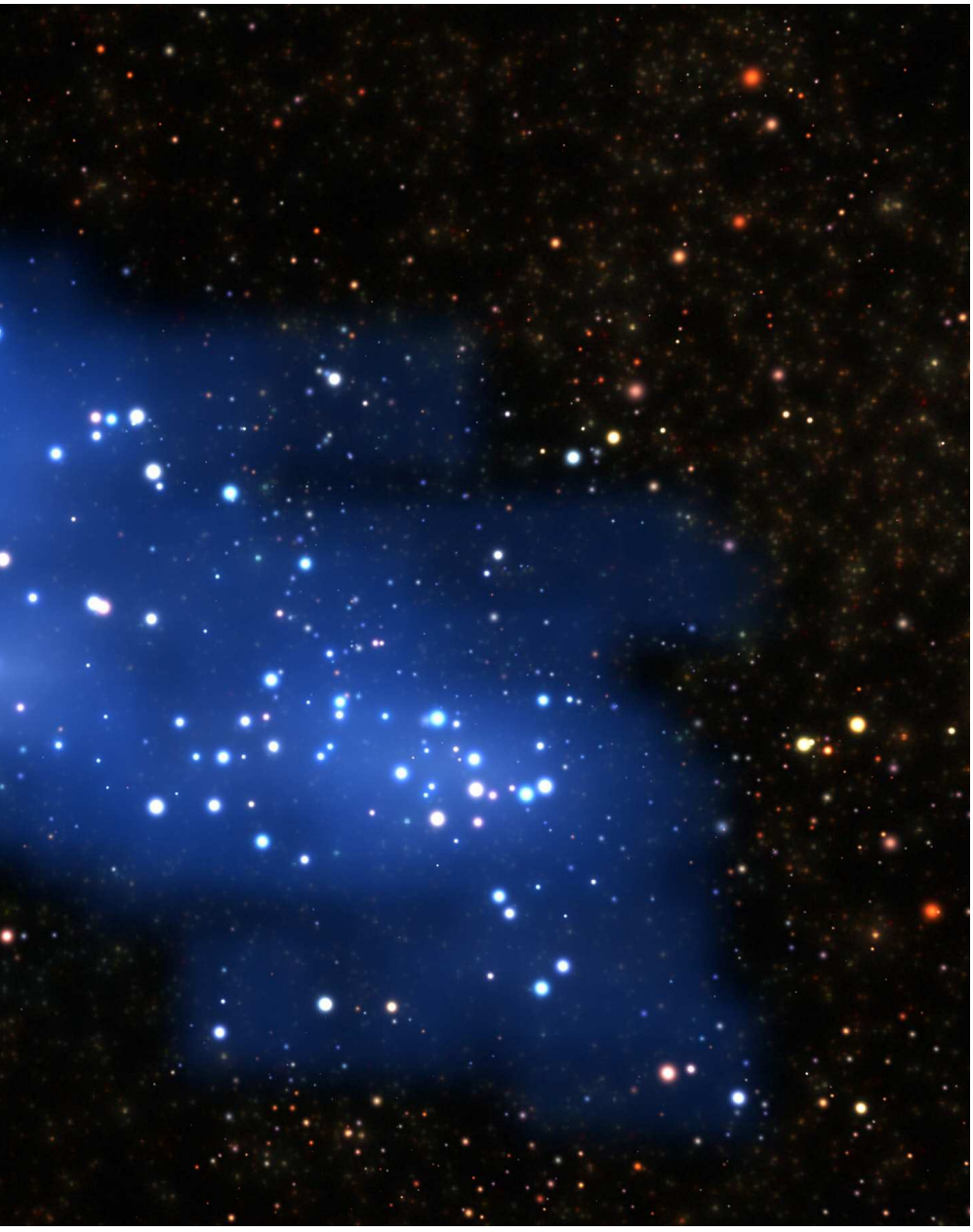
"This is the first time that such a large structure has been identified at such a high redshift, just over 2



This visualisation shows the extent of Hyperion compared to the size of a typical massive galaxy cluster in the local universe. [ESO/L. Calçada & Olga Cucciati et al.]

billion years after the Big Bang," explained the first author of the discovery paper, Olga Cucciati. *"Normally these kinds of structures are known at lower redshifts, which means when the Universe has had much more time to evolve and construct such huge things. It was a surprise to see something this evolved when the Universe was relatively young!"*

Located in the COSMOS field in the constellation of Sextans (The Sextant), Hyperion was identified by analysing the vast amount of data obtained from the VIMOS Ultra-deep Survey led by Olivier Le Fèvre (Aix-Marseille Université, CNRS, CNES). The VIMOS Ultra-Deep Survey provides an unprecedented 3D map of the distribution of over 10000 galaxies in the distant Universe.



The team found that Hyperion has a very complex structure, containing at least 7 high-density regions connected by filaments of galaxies, and its size is comparable to nearby superclusters, though it has a very different structure.

"Superclusters closer to Earth tend to a much more concentrated distribution of mass with clear structural features," explains Brian Lemaux, an astronomer from University of California, Davis and LAM, and a co-leader of the team behind this result. *"But in Hyperion, the mass is distributed much more uniformly in a series of connected blobs, populated by loose associations of galaxies."*

This contrast is most likely due to the fact that nearby superclusters have had billions of years for gravity to gather matter together into denser regions — a process that has been acting for far less time in the much younger Hyperion.

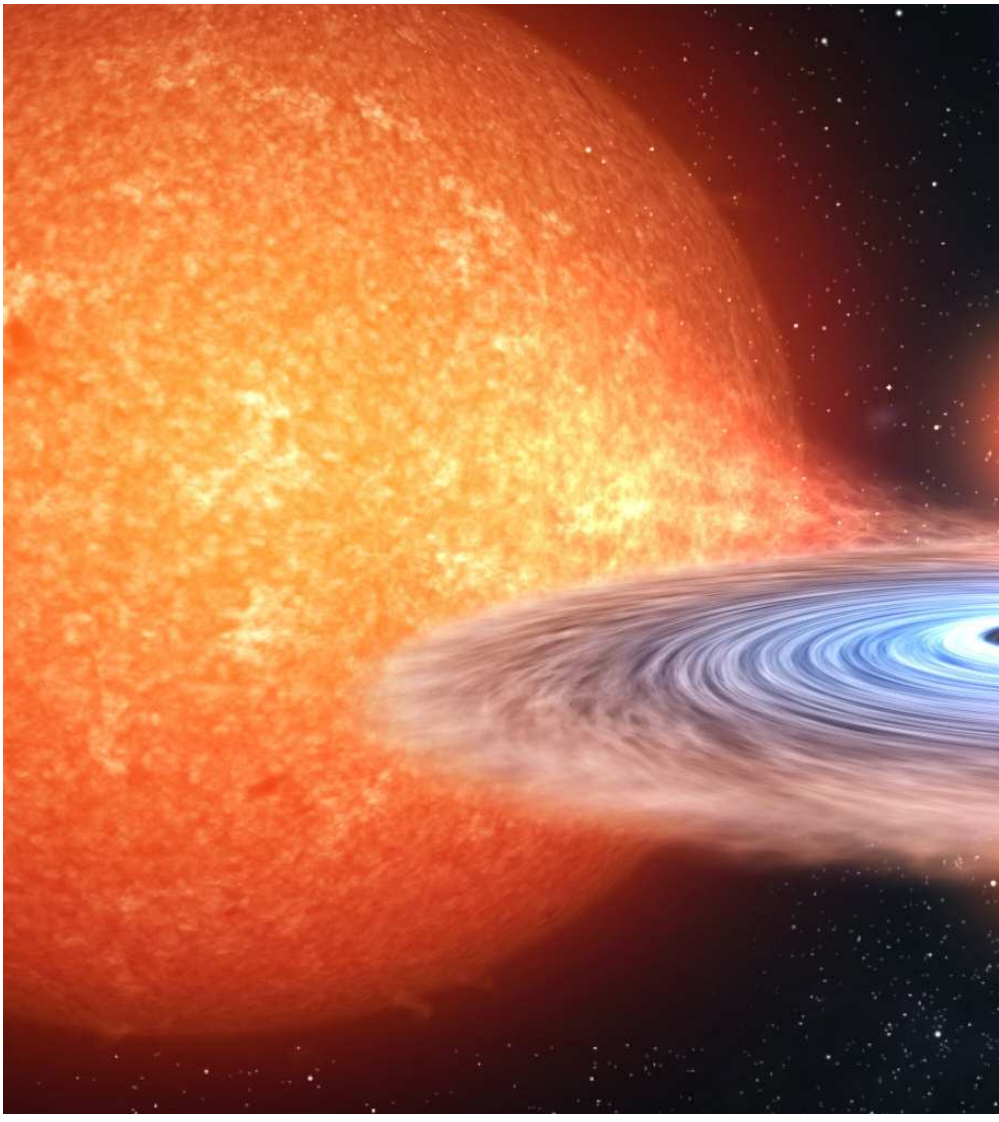
Given its size so early in the history of the Universe, Hyperion is expected to evolve into something similar to the immense structures in the local Universe such as the superclusters making up the Sloan Great Wall or the Virgo Supercluster that contains our own galaxy, the Milky Way. *"Understanding Hyperion and how it compares to similar recent structures can give insights into how the Universe developed in the past and will evolve into the future, and allows us the opportunity to challenge some models of supercluster formation,"* concluded Cucciati. *"Unearthing this cosmic titan helps uncover the history of these large-scale structures."* ■

Astronomers propose a new method for detecting black holes

by IAC

A stellar-mass black hole is a compact object with a mass greater than 3 solar masses. It is so dense and has such a powerful force of attraction that not even light can escape from it. That is why it cannot be observed directly, but only via the effects it produces, in the present case on its companion star, from which it "feeds". In general when matter falls onto a black hole is does so "quietly" by way of an accretion disc. However, there are periods when this in fall is violent, and "bursty", producing a strong outburst of X-ray brightness.

Binary systems composed of a star donating mass to a black hole are essential laboratories for the understanding of the most extreme physical phenomena in the universe, such as those which, towards the end of the life of a massive star lead to the formation of the black hole itself, or to a neutron star. Until now some 60 candidates for this type of black holes have been found in our Galaxy, thanks to the detection of



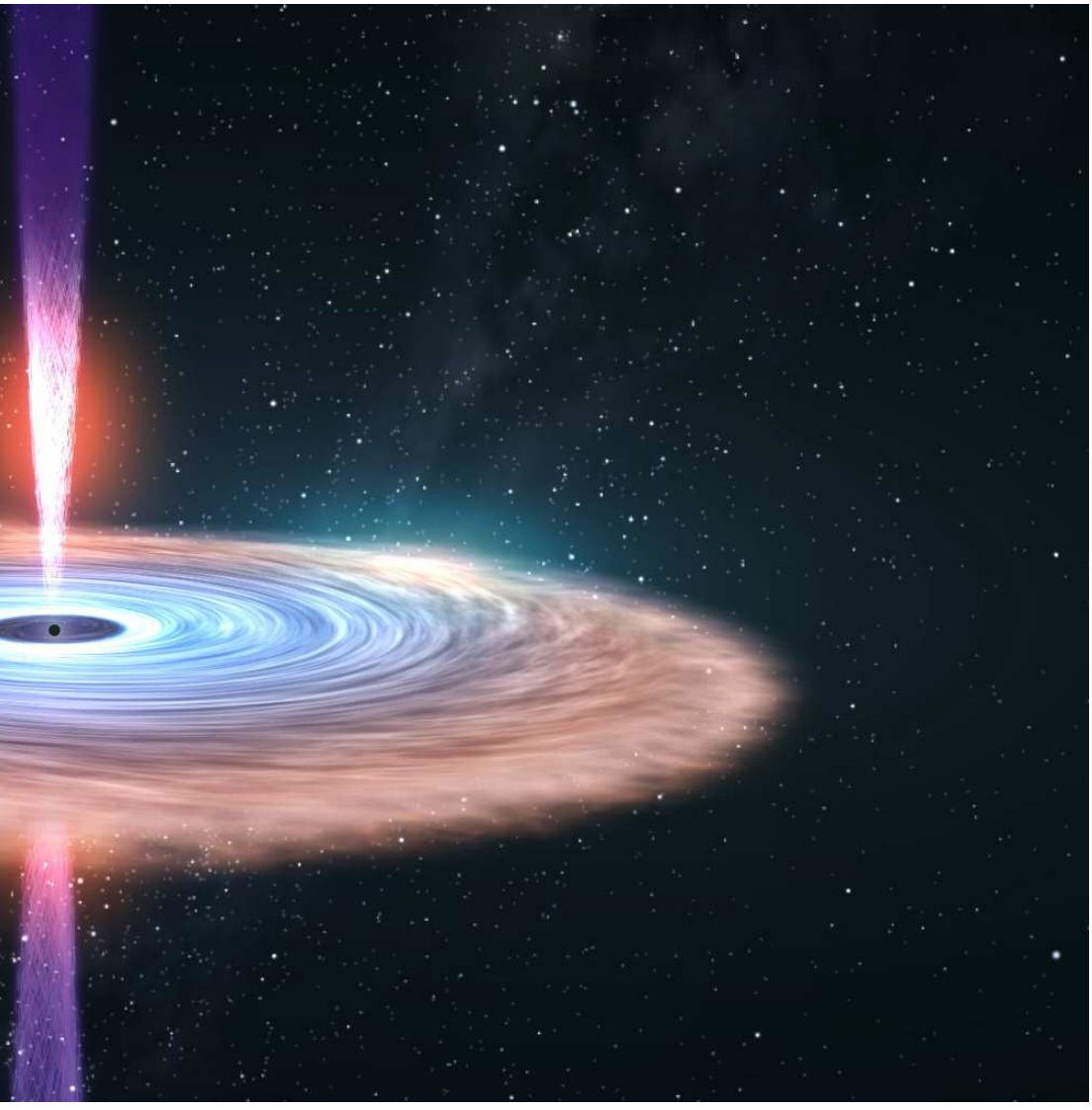
Artist's impression of astrophysical jets emitting from the binary system V404 Cygni. [Gabriel Pérez Díaz, Multimedia systems (IAC)]

transient eruptions of X-rays, but only 17 of these have been confirmed. This is because of the difficulties in the way of studying the motion of the companion star around the black hole, which would allow us to infer its mass, and confirm the type of object.

Researchers have only a limited knowledge of the formation and the evolution of this type of objects, because of the small number of known binaries containing a black hole. That is why it is important to develop new strategies which will let us discover the "hidden" population of the Galaxy, that is those objects which are "hibernating", not in an active phase, and so are not emitting X-rays.

The IAC researchers Jorge Casares, and Miguel A. Pérez Torres have tested a novel technique measuring the brightness of these binary pairs with a combination of filters centred on the line of hydrogen H-alpha. The measurements give information about the intensity and the width of this line, which forms in the accretion disc around the black hole.

In particular, the width of H-alpha can be used as an indicator of the strength of the gravitational field, and so can be used as a diagnostic of the presence of a black hole. This technique could reveal, very efficiently, new black hole binaries in an inactive phase. To show this they observed 4 systems with confirmed black holes using a set of special filters on ACAM, an instrument on the 4.2m William Herschel Telescope (WHT) of the Isaac Newton Group of Telescopes at the Roque de los Muchachos Observatory (Garafía, La Palma). The results were then compared with direct measurements of the width of the H-alpha line obtained with the ISIS spectrograph on the Gran Telescopio de Canarias (GTC). The result showed that it is practical to measure the width of the H-alpha line using photometric techniques, which opens the door to a more efficient detection of inactive black holes in binary systems.



They estimate that an analysis of some 1000 square degrees (10%) of the zone of the Galactic plane with this strategy should detect at least 50 new objects of this type, which is three times the currently known population. This search could also yield a detailed census of other Galactic populations, such as short period cataclysmic variables, X-ray binaries containing neutron stars, and ultra-compact binaries with a period shorter than one hour. ■

The first exom validation

by Michele Ferrara

revised by Damian G. Allis
NASA Solar System Ambassador

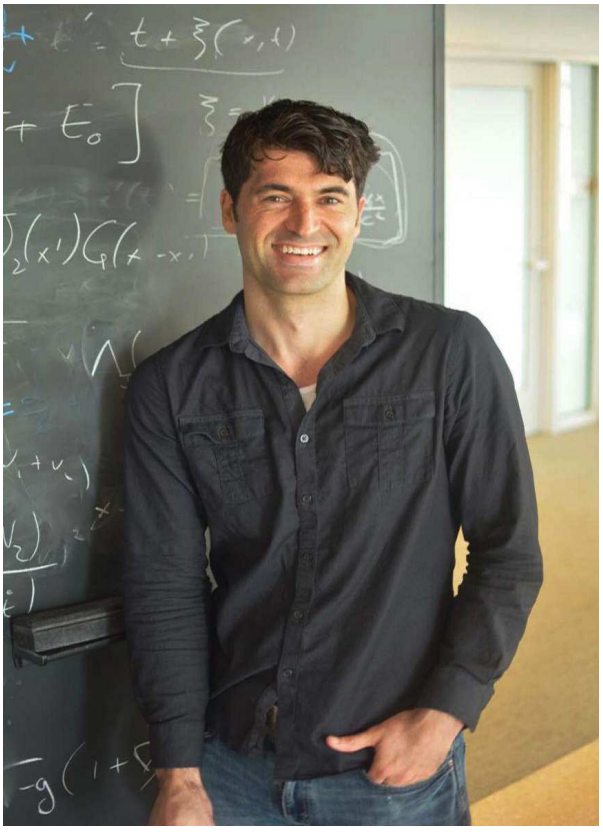
One of the new frontiers of astrobiology is the search for habitable moons beyond the Solar System. For some years now, a few projects have been carried out to identify natural satellites in orbit around giant planets, which in turn orbit in the habitable zone of stars not very dissimilar to the Sun. So far, we have had only a vague perception of those moons, but finally, there is now an up-and-coming candidate that could officially become our first identified exomoon.

oon awaits

The planetary system depicted in the background is an artwork, but it effectively illustrates how an Earth-sized moon could orbit around a giant planet.

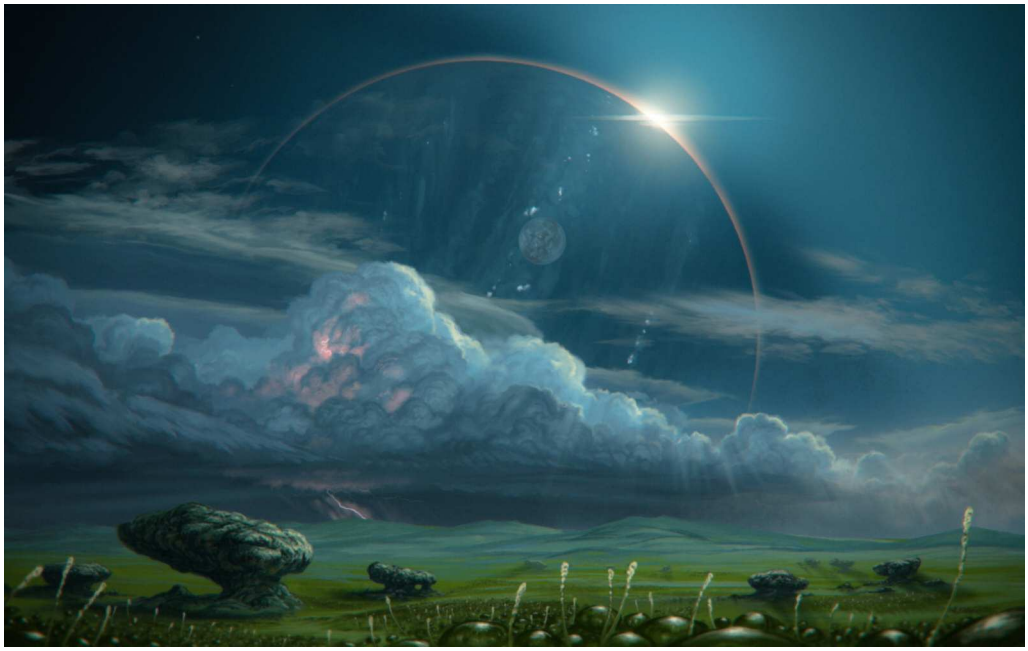
About 200 moons are orbiting the planets of our Solar System. Among them, Ganymede, Titan and Callisto have dimensions comparable to those of Mercury, and if they or their associated planets had formed within the habitable zone of our Sun, these moons might have formed environments hospitable to life. It is likely that the other planetary systems of our galaxy (and perhaps of the whole universe) also contain a large number of moons, some of which are of planetary in size. But as we are limited to the moons of our Solar system for knowledge, we can only assume that the oldest possible extrasolar moons around a given star were born from to the accretion of material left behind by the formation of the planet around which they orbit or, similarly, material resulting from planetary impacts between protoplanets occurring in primordial epochs (as happened for the Moon and Charon).

Existing moons in extrasolar systems may have born through different processes, and those moons could have sizes far larger than those of the terrestrial planets we know and could orbit around gaseous giants even bigger than Jupiter.
For some years, this possibility intrigued astronomers, who have started specific programs aimed at discovering the so-called "exomoons" (hereafter simply moons, and the "exoplanets" simply planets). One of those programs is the Hunt for Exomoons with Kepler (HEK) that sifts through data produced by the Kepler Space Telescope during its monitoring of over 150 thousand stars not very different from the Sun. In the first four years of the mission, Kepler has gathered many photometric measurements of planetary transits. By further scrutinizing this material, it is possible to highlight anomalies in the light curves of transits that could be due to the presence of moons. This is what two researchers at Columbia University did – the astronomer David Kipping (founder of HEK) and graduate student Alex Teachey – by analyzing data of 284 planets discovered by Kepler by their planetary transits across the discs of their stars.
The sample to be analyzed was obviously chosen on the basis of some requirements necessary to exclude a priori all those planets that for various reasons should not host moons. For example, the two researchers preferred to consider only worlds in orbits with a period longer than 30 days, since previous research had established that the existence of large moons in planet-moon systems to close to the star (between 0.1 and 1



The two authors of the study that highlighted evidence of a possible exomoon in orbit around Kepler-1625b, Alex Teachey (above), and David Kipping. [Columbia University]

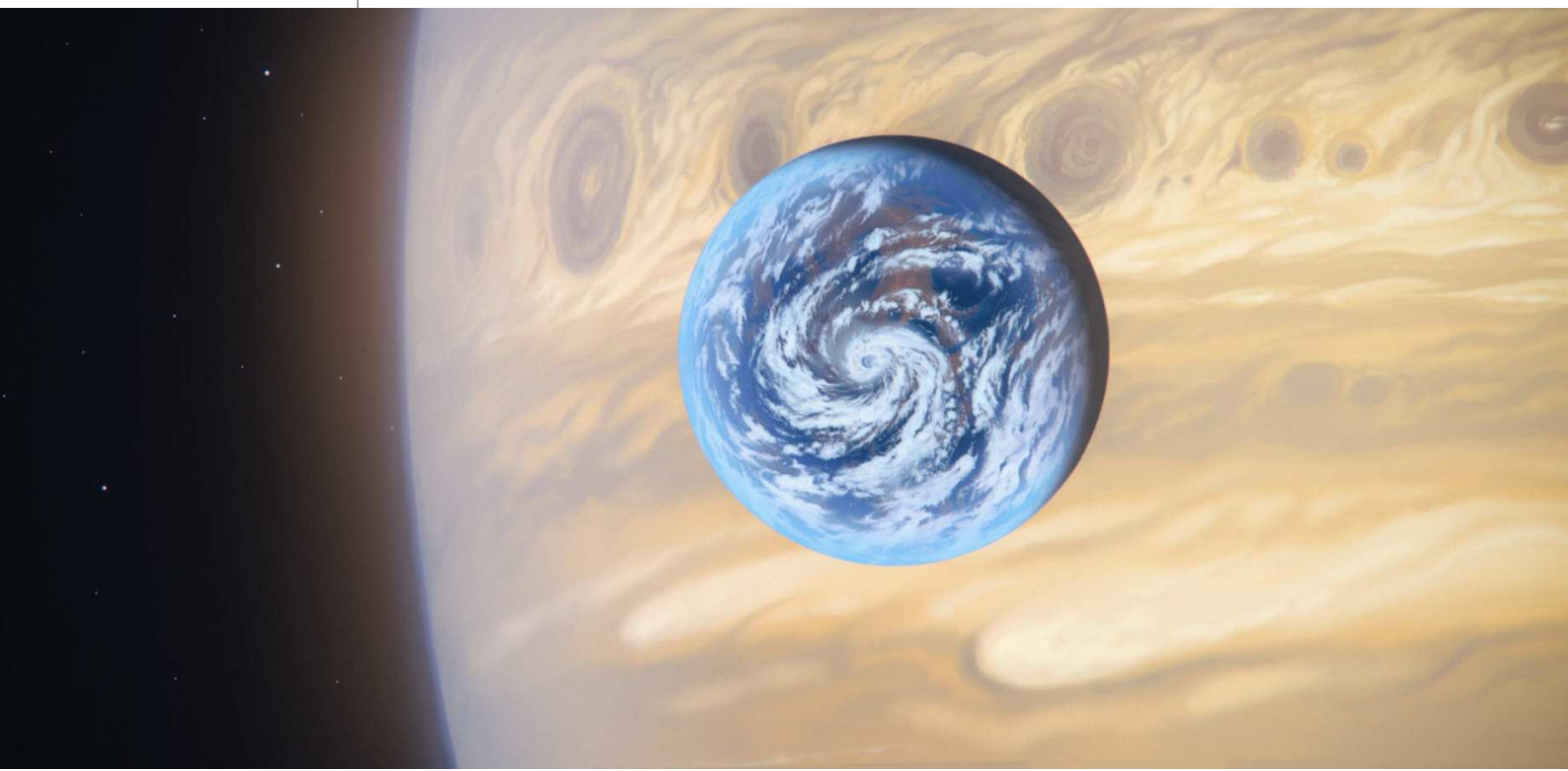
On the side and below, two artworks by the illustrator Justinas Vitkus (Kaunas, Lithuania) that could describe the appearance, on the ground and in space, of two habitable moons.

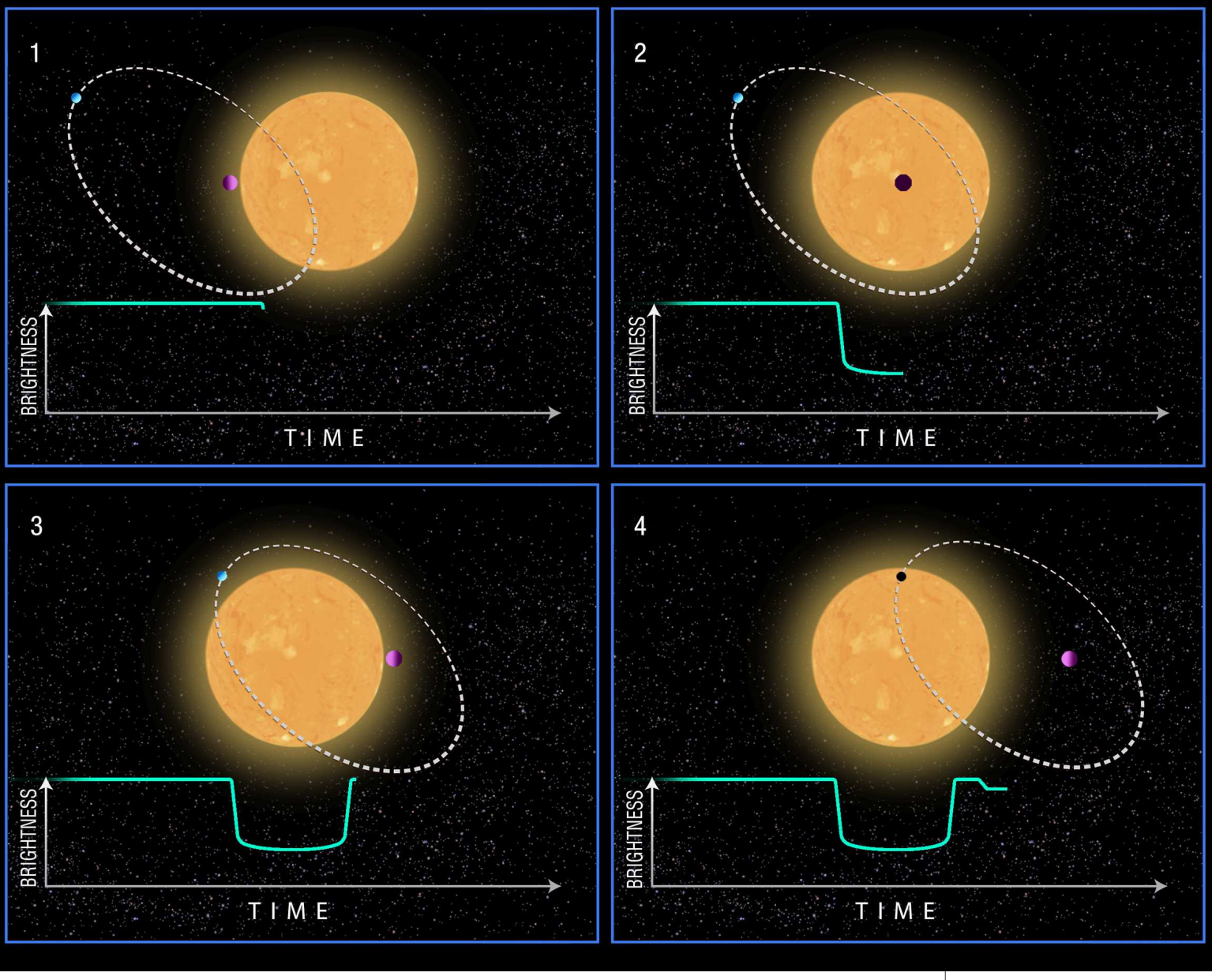


AU) is very improbable. In that range of distances, in fact, young moons have more chances to be removed from their orbits because of the gravitational influence of the star, which in specific scenarios may exceed that of the planet, for example as a result of an inward planetary migration.

In the light curves of the 284 selected planets, Kipping and Teachey hoped to find essentially two different "fingerprints", both of which could be associated with the revolution of possible moons around the planets. A fingerprint is of a timing type and concerns the punctuality with which the planet begins the transit.

By having Kepler (necessarily) observe multiple transits for each planet, their revolution periods around their stars are known, and it is, therefore, possible to foresee with great precision the beginning moments of





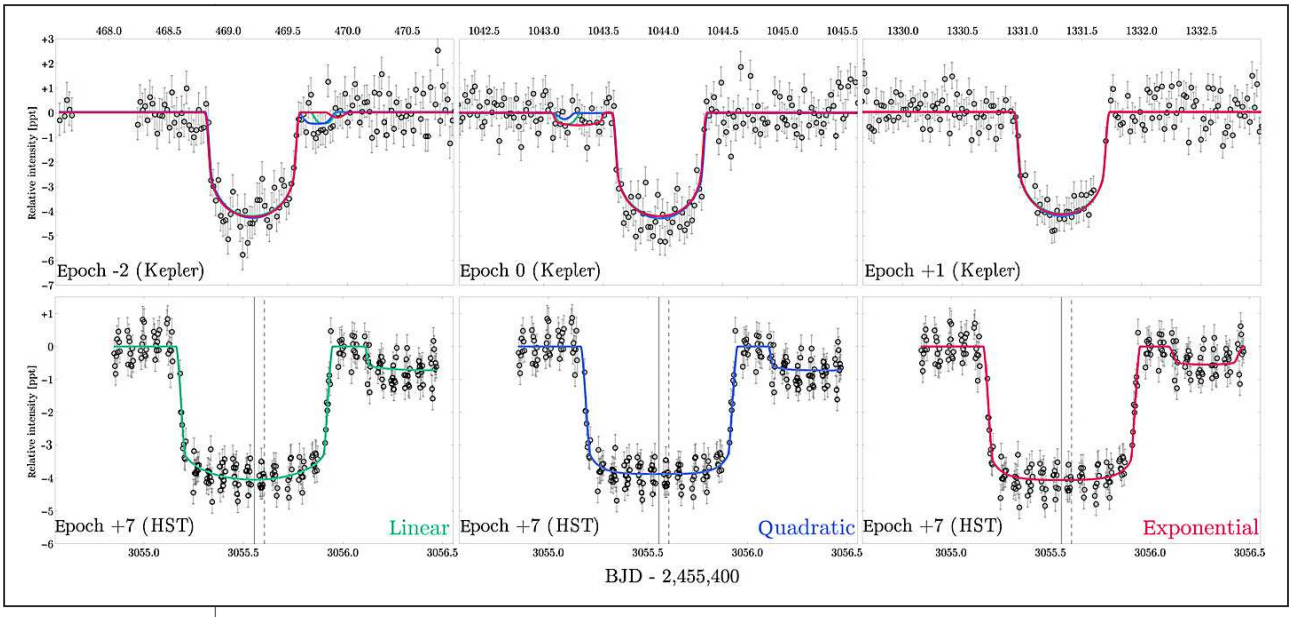
future transits. If these occur in noticeable advance or delay of prediction, it means that there is a non-negligible mass that alters the planet's orbital velocity. That mass can be either another planet, probably placed on a more external orbit, or a moon orbiting the planet in transit.

The first scenario is not easily verifiable if the perturbing planet does not appear to transit the stellar disk. The second scenario can instead be verified by highlighting the other type of fingerprint, that is, a very slight secondary drop in starlight, which manifests itself during the transit or in its proximity, but that is not due to the planet.

Depending on where the moon is with respect to the observer, it can enter the disk before the planet, it can follow it, or it can be overlapped with it. This means that the light curve can be quite complex for a planet-moon combination, but it is clear that the larger the moon, the easier it is to discover.

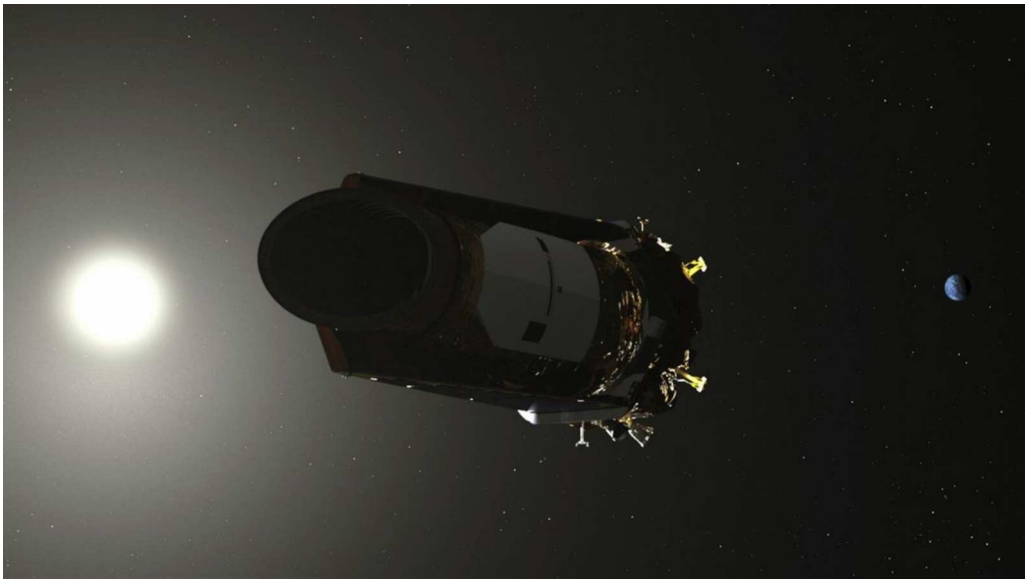
Current instruments enable the discovery of much larger moons than those familiar to us. It follows that we must look for them around gigantic planets. Among the 284 worlds investigated by Kipping and Teachey, only one showed during the transits a double fingerprint attributable to the presence of a moon. That planet is called Kepler-1625b and is the only known one in orbit around Kepler-1625, a star of mass comparable to that of the Sun but with a diameter 80% larger. These physical features suggest that Kepler-1625 is an old star, aged between 7 and 11 billion years. Its planet runs through an orbit that looks like the Earth's and Kepler-1625b was determined by analysis to be within the star's habitable zone in the first 5.4 billion years. Despite its favorable position, we can conclude that Kepler-1625b is likely not a hospitable world, since it is a gas giant. Nevertheless, a possible moon, more or less the

This diagram represents Hubble Space Telescope photometric observations of the transit of Kepler-1625b. After the planet's 19-hour-long transit was completed, astronomers noted a second, smaller dip in the light curve about three and a half hours later (panel 4). The second dip is interpreted as the signature of a moon trailing the planet. [NASA, ESA, D. Kipping (Columbia University), and A. Feild (STScI)]



The three transits from Kepler (top) and the October 2017 transit observed with the HST (bottom) for the three trend model solutions. The three colored lines show the corresponding trend model solutions for model M, the authors' favored transit model. The shape of the HST transit differs from that of the Kepler transits due to limb darkening differences between the bandpasses. [Advances Science] Right, a render of the Kepler Space Telescope. This instrument has spotted many exoplanets, and now maybe an exomoon. [NASA]

size of the Earth, could be habitable. When Kipping and Teachey analyzed the light curves of the three previously recorded Kepler-1625b transits, they noticed the existence of some anomalies, small photometric deviations and oscillations that could not be generated by the transit above the star disc of a lonely planet. The resolution of Kepler's observations were, however, insufficient to understand if these anomalies were real (astrophysical) and, if so, what produced them. The researchers then requested telescope time on Hubble (obtaining 40 hours) to observe the expected Kepler-1625b transit on 28-29 October 2017 with a resolution four times greater than with Kepler. Knowing that the phenomenon would last about 19 hours, Kipping and Teachey began to monitor the star many hours in advance in order to not risk losing



the first contact. This was a wise choice, as the planet started to transit across the disc 77.8 minutes earlier than expected. This conspicuous advance was already indicative of the fact that Kepler-1625b is not the only body in orbit around its star. The most exciting part of the transit monitoring of October 2017 was at the end, 3.5 hours after the planet came out of the disk, when Hubble recorded a secondary and very weak dimming of the starlight, consistent with the existence of a moon orbiting the planet. Unfortunately, the telescope time at the disposal of the two researchers exhausted before the candidate moon ended its transit, and it was therefore not possible to complete a series of measurements perhaps decisive for the identification of the object. This is how the two authors of the study comment on these observations in their article published on 3 October 2018 in *Science Advances*: *"The most compelling piece of evidence for an exomoon would be an exomoon transit, in addition to the observed TTV [transit timing variation]. If Kepler-1625b's early transit were indeed due to an exomoon, then we should expect the moon to transit late on the opposite side of the barycenter. The previously mentioned existence of an apparent flux decrease toward the end of our observations is therefore where we would expect it to be under this hypothesis. Although we have established that this dip is most likely astrophysical, we have yet to discuss its significance or its compatibility with a self-consistent moon model".*

If, at the moment, it is not yet possible to confirm that the "mysterious" object temporarily named Kepler-1625b-I is a moon, the data collected during the transit still tell us that, if it were, it should have a mass of about 1.5% that of the planet, and it could, therefore, have a size comparable to that of Neptune. Such a big moon, not having been formed through the typical processes of our known satellite systems, would require the review of the current theories

A graphic representation of the gas giant Kepler-1625b with its Neptune-sized moon. In the box, the planet seen from the surface of a hypothetical smaller, farther and colder moon.

that govern moon formation processes and their extension to unknown scenarios.

Kipping and Teachey are planning to observe a new transit in 2019 and, on that occasion, a definitive answer may come about the existence of the candidate moon. If it is confirmed, we will take another step forward in the discovery of new habitable worlds, even if, in the specific case of Kepler-1625b-I, we likely cannot talk about habitability. It is precisely the oversized moons that researchers expect to discover first inside other stars' habitable zones. The largest telescopes that will become operational from 2019 onward, starting from the James Webb Space Telescope, will be able to confirm the existence of potentially habitable moons, more or less the size of Earth. It is estimated that millions of moons suitable for the development of life can exist in the galaxy. Orbiting around a giant planet is not necessarily harmful. The tidal warming resulting from the gravitational interaction with the giant planet could, for example, extend the lifetime of the moon's geological activities to the benefit of maintaining a potentially livable environment. It would be curious to discover the first twin of the Earth in orbit around another planet, rather than around another sun! ■

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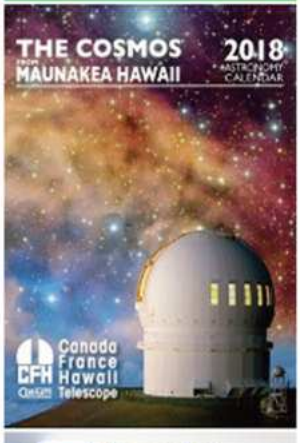

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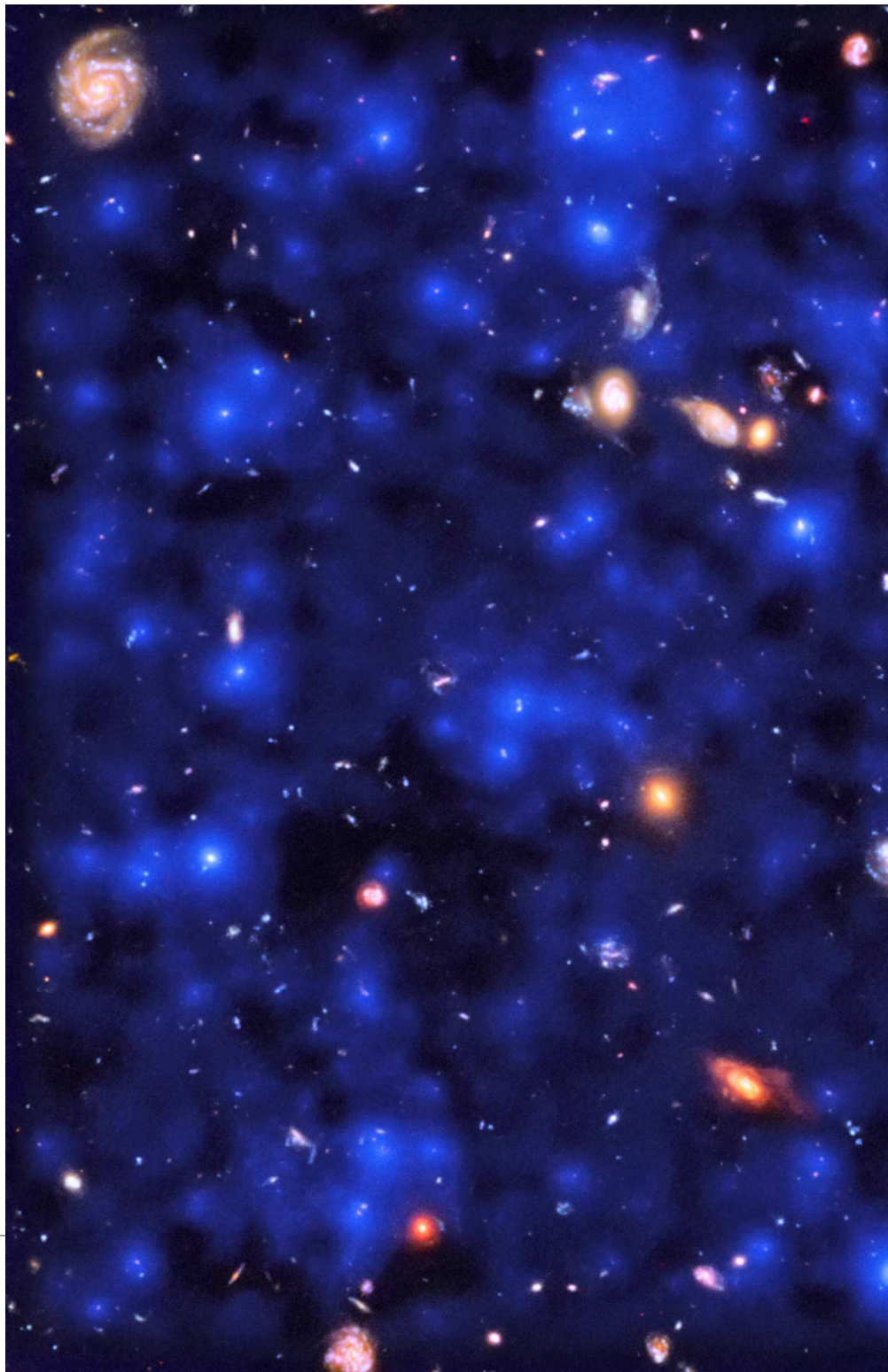
A Universe aglow

by ESO

An unexpected abundance of Lyman-alpha emission in the Hubble Ultra Deep Field (HUDF) region was discovered by an international team of astronomers using the MUSE instrument on ESO's Very Large Telescope (VLT). The discovered emission covers nearly the entire field of view — leading the team to extrapolate that almost all of the sky is invisibly glowing with Lyman-alpha emission from the early Universe.

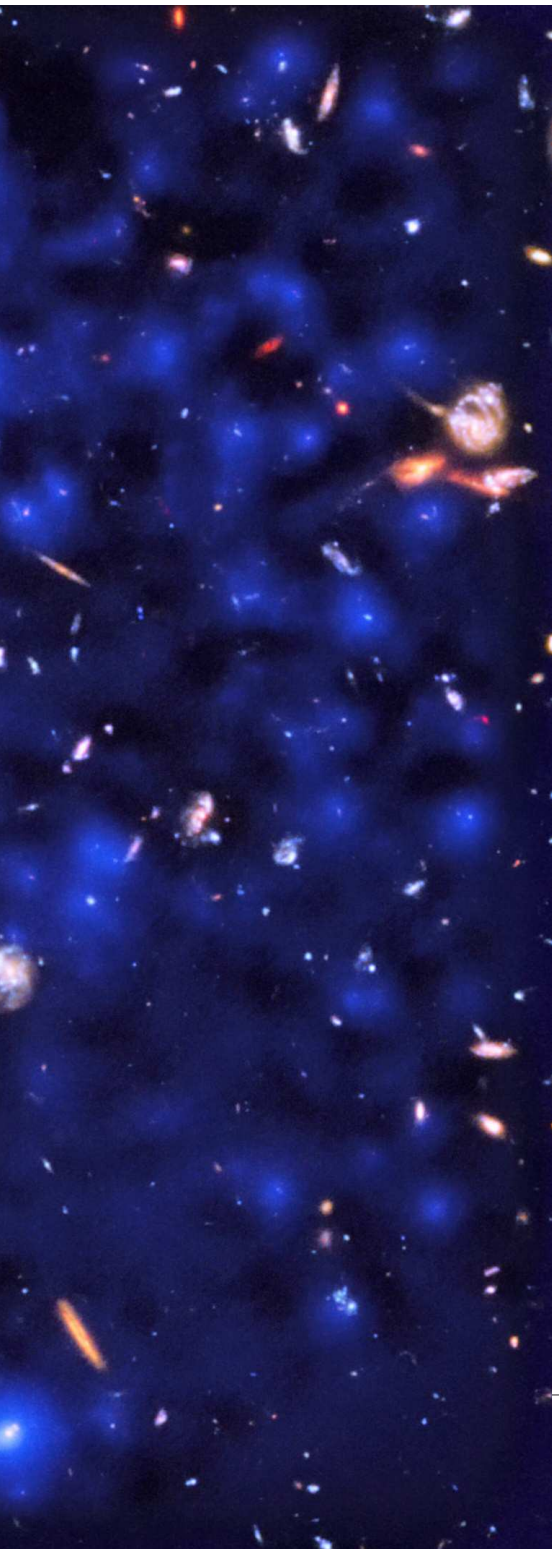
Astronomers have long been accustomed to the sky looking wildly different at different wavelengths, but the extent of the observed Lyman-alpha emission was still surprising. *"Realising that the whole sky glows in optical when observing the Lyman-alpha emission from distant clouds of hydrogen was a literally eye-opening surprise,"* explained Kasper Borello Schmidt, a member of the team of astronomers behind this result. *"This is a great discovery!"* added team member Themiya Nanayakkara. *"Next time you look*



Deep observations made with the MUSE spectrograph on ESO's Very Large Telescope have uncovered vast cosmic reservoirs of atomic hydrogen surrounding distant galaxies. The exquisite sensitivity of MUSE allowed for direct observations of dim clouds of hydrogen glowing with Lyman-alpha emission in the early Universe—revealing that almost the whole night sky is invisibly aglow. [ESA/Hubble & NASA, ESO/ Lutz Wisotzki et al.]

at the moonless night sky and see the stars, imagine the unseen glow of hydrogen: the first building block of the universe, illuminating the whole night sky."

The HUDF region the team observed is an otherwise unremarkable area in the constellation of Fornax (the Furnace), which was famously mapped by the NASA/ESA Hubble Space Telescope in 2004, when Hubble spent more than 270 hours of precious observing time looking deeper than ever before into this region of space.



This video from the ESOcast series summarizes the discovery by the team of astronomers led by Lutz Wisotzki in the Hubble Ultra Deep Field. [ESO]

The HUDF observations revealed thousands of galaxies scattered across what appeared to be a dark patch of sky, giving us a humbling view of the scale of the Universe. Now, the outstanding capabilities of MUSE have allowed us to peer even deeper. The detection of Lyman-alpha emission in the HUDF is the first time astronomers have been able to see this faint emission from the gaseous envelopes of the earliest galaxies. This composite image shows the Lyman-alpha radiation in blue superimposed on the iconic HUDF image.

MUSE, the instrument behind these latest observations, is a state-of-the-art integral field spectrograph installed on Unit Telescope 4 of the VLT at ESO's Paranal Observatory. When MUSE observes the sky, it sees the distribution of wavelengths in the light striking every pixel in its detector. Looking at the full spectrum of light from astronomical objects provides us with deep insights into the astrophysical processes occurring in the Universe.

"With these MUSE observations, we get a completely new view on the diffuse gas 'cocoons' that surround galaxies in the early Universe," commented Philipp Richter, another member of the team.

The international team of astronomers who made these observations have tentatively identified what is causing these distant clouds of hydrogen to emit Lyman-alpha, but the precise cause remains a mystery. However, as this faint omnipresent glow is thought to be ubiquitous in the night sky, future research is expected to shed light on its origin.

"In the future, we plan to make even more sensitive measurements," concluded Lutz Wisotzki, leader of the team. *"We want to find out the details of how these vast cosmic reservoirs of atomic hydrogen are distributed in space."* ■

First science with ALMA's highest frequency capabilities

by ALMA Observatory

A team of scientists using the highest-frequency capabilities of the Atacama Large Millimeter/submillimeter Array (ALMA) has uncovered jets of warm water vapor streaming away from a newly forming star. The researchers also detected the "fingerprints" of an astonishing assortment of molecules near this stellar nursery.

The ALMA telescope in Chile has transformed how we see the universe, showing us otherwise invisible parts of the cosmos. This array of incredibly precise antennas studies a comparatively high-frequency sliver of radio light: waves that range from a few tenths of a millimeter to several millimeters in length. Recently, scientists pushed ALMA to its limits, harnessing the array's highest-frequency (shortest wavelength) capabilities, which peer into a part of the electromagnetic spectrum that straddles the line between infrared light and radio waves.

"High-frequency radio observations like these are normally not possible from the ground," said Brett McGuire, a chemist at the National Radio Astronomy Observatory in Charlottesville, Virginia, and lead author on a paper appearing in *The Astrophysical Journal Letters*.

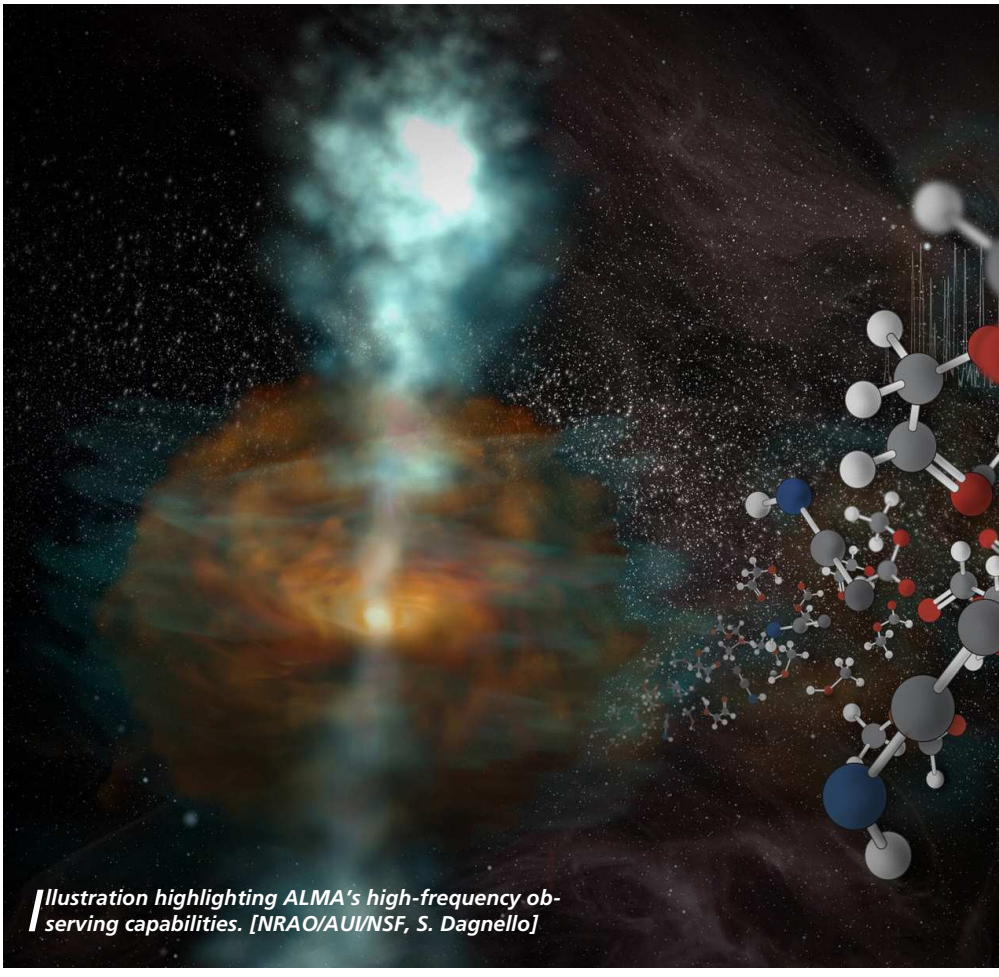


Illustration highlighting ALMA's high-frequency observing capabilities. [NRAO/AUI/NSF, S. Dagnello]

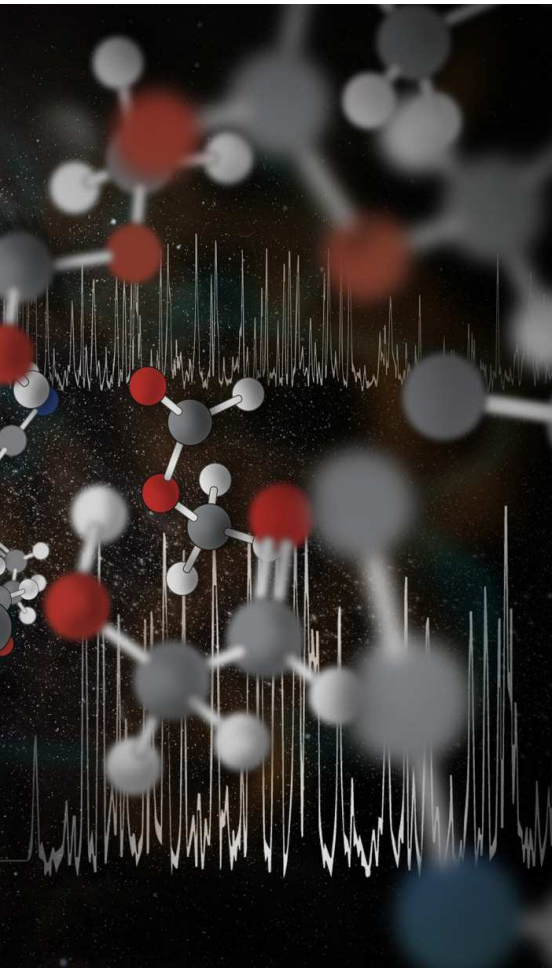
"They require the extreme precision and sensitivity of ALMA, along with some of the driest and most stable atmospheric conditions that can be found on Earth."

Under ideal atmospheric conditions, which occurred on the evening of 5 April 2018, astronomers trained ALMA's highest-frequency, submillimeter vision on a curious region of

the Cat's Paw Nebula (also known as NGC 6334I), a star-forming complex located about 4,300 light-years from Earth in the direction of the southern constellation Scorpius.

Previous ALMA observations of this region at lower frequencies uncovered turbulent star formation, a highly dynamic environment, and a wealth of molecules inside the nebula.

To observe at higher frequencies, the ALMA antennas are designed to



accommodate a series of "bands" — numbered 1 to 10 — that each study a particular sliver of the spectrum. The Band 10 receivers observe at the highest frequency (shortest wavelengths) of any of the ALMA instruments, covering wavelengths from 0.3 to 0.4 millimeters (787 to 950 gigahertz), which is also considered to be long-wavelength infrared light. These first-of-their-kind ALMA observations with Band 10 produced two exciting results.

One of ALMA's first Band 10 results was also one of the most challenging, the direct observation of jets of water vapor streaming away from one of the massive protostars in the region. ALMA was able to detect the submillimeter-wavelength light naturally emitted by heavy water (water molecules made up of oxygen, hydrogen and deuterium atoms, which are hydrogen atoms with a proton and a neutron in their nucleus). *"Normally, we wouldn't be able to directly see this particular signal at all from the ground,"* said Crystal Brogan, an astronomer at the NRAO and co-author on the paper. *"Earth's atmosphere, even at remarkably arid places, still contains enough of water vapor to completely overwhelm this signal from any cosmic source. During exceptionally pristine conditions in the high Atacama Desert, however, ALMA can in fact detect that signal. This is something no other telescope on Earth can achieve."*

Pictured here is one of the cold cartridge assemblies of the Band 10 receiver, which gives ALMA its highest-frequency capabilities. [ALMA (ESO/NAOJ/NRAO)]

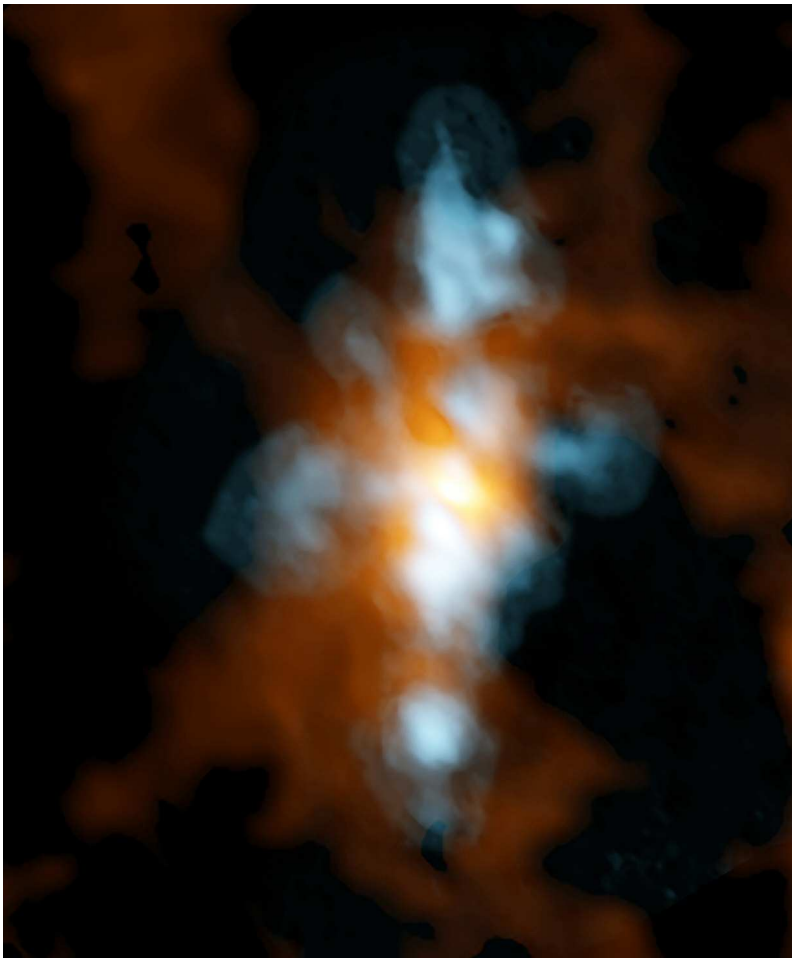
As stars begin to form out of massive clouds of dust and gas, the material surrounding the star falls onto the mass at the center. A portion of this material, however, is propelled away from the growing protostar as a pair of jets, which carry away gas and molecules, including water.

The heavy water the researchers observed is flowing away from either a single protostar or a small cluster of protostars. These jets are oriented differently from what appear to be much larger and potentially more-mature jets emanating from the same region. The astronomers speculate that the heavy-water jets seen by ALMA are relatively recent features just beginning to move out

into the surrounding nebula.

These observations also show that in the regions where this water is slamming into the surrounding gas, low-frequency water masers — naturally occurring microwave versions of lasers — flare up. The masers were detected in complementary observations by the National Science Foundation's Very Large Array. In addition to making striking images of objects in space, ALMA is also a supremely sensitive cosmic chemical sensor. As molecules tumble and vibrate in space, they naturally emit light at specific wavelengths, which appear as spikes and dips on a spectrum.

All of ALMA's receiver bands can detect these unique spectral fingerprints, but those lines at the highest frequencies offer unique insight into lighter, important chemicals, like heavy water. They also provide the ability to see signals from complex, warm molecules, which have weaker spectral lines at lower frequencies. Using Band 10, the researchers were able to observe a region of the spectrum that is extraordinarily rich in molecular fingerprints, including glycoaldehyde, the simplest sugar-related molecule. When compared to previous best-in-the-world observations of the same source with the European Space Agency's Herschel Space Observatory, the ALMA observations detected more than ten times as many spectral lines.



Composite ALMA image of NGC 6334I, a star-forming region in the Cat's Paw Nebula, taken with the Band 10 receivers, ALMA's highest-frequency vision. The blue component is heavy water (HDO) streaming away from either a single protostar or a small cluster of protostars. The orange region is the "continuum emission" in the same region, which scientists found is extraordinarily rich in molecular fingerprints, including glycoaldehyde, the simplest sugar-related molecule. [ALMA (ESO/NAOJ/NRAO): NRAO/AUI/NSF, B. Saxton]

"We detected a wealth of complex organic molecules surrounding this massive star-forming region," said McGuire. *"These results have been received with excitement by the astronomical community and show once again how ALMA will reshape our understanding of the universe."*

ALMA is able to take advantage of these rare windows of opportunity when the atmospheric conditions are "just right" by using dynamic scheduling.

That means, the telescope operators and astronomers carefully monitor the weather and conduct those planned observations that best fit the prevailing conditions. *"There certainly are quite a few conditions that have to be met to conduct a successful observation using Band 10,"* concluded Brogan. *"But these new ALMA results demonstrate just how important these observations can be."*

"To remain at the forefront of discovery, observatories must continuously innovate to drive the leading edge of what astronomy can accomplish," said Joe Pesce, the program director for the National Radio Astronomy Observatory at NSF. *"That is a core element of NSF's NRAO, and its ALMA telescope, and this discovery pushes the limit of what is possible through ground-based astronomy."* ■

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