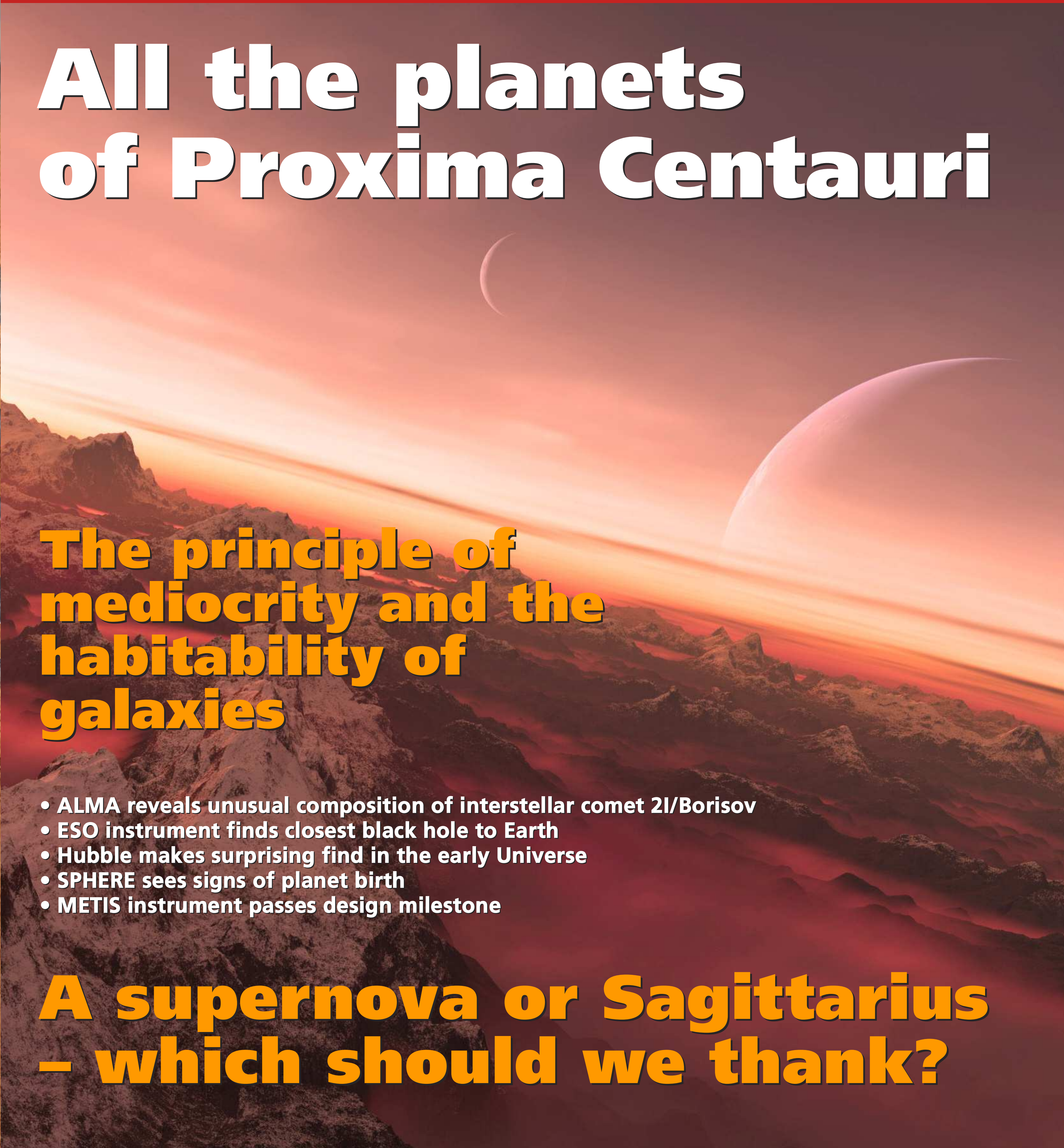
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS HAPPENING IN SPACE

FREE ASTRONOMY magazine

Bi-monthly magazine of scientific and technical information ✶ July-August 2020



All the planets of Proxima Centauri

The principle of mediocrity and the habitability of galaxies

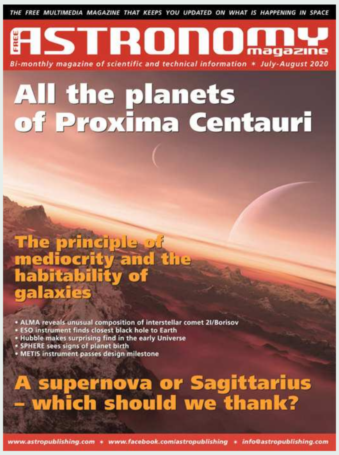
- ALMA reveals unusual composition of interstellar comet 2I/Borisov
- ESO instrument finds closest black hole to Earth
- Hubble makes surprising find in the early Universe
- SPHERE sees signs of planet birth
- METIS instrument passes design milestone

A supernova or Sagittarius – which should we thank?

ASTRONOMY magazine

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

July-August 2020



English edition of the magazine

ASTROFILO

Editor in chief
Michele Ferrara

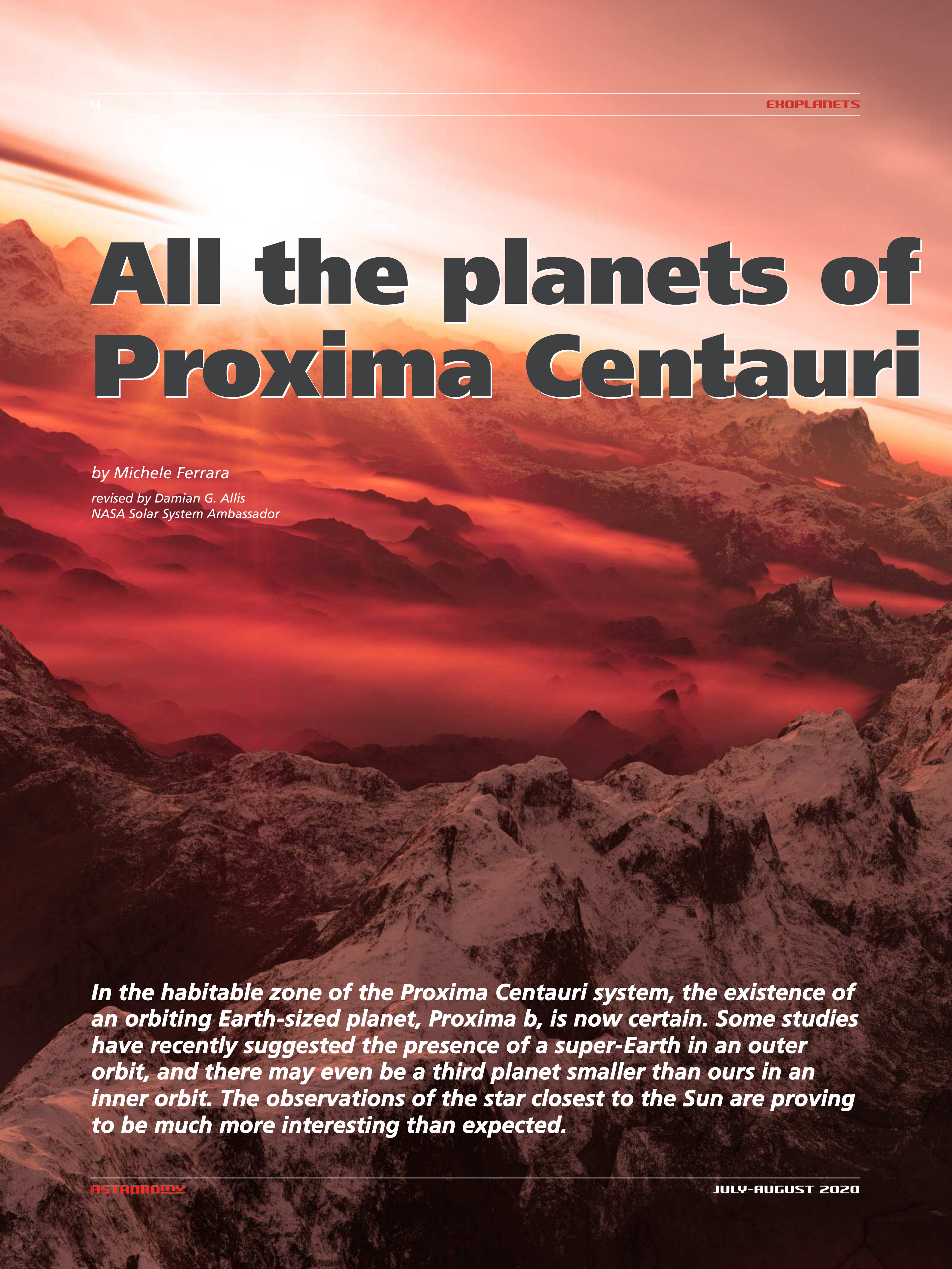
Scientific advisor
Prof. Enrico Maria Corsini

Publisher
Astro Publishing di Pirlo L.
Via Bonomelli, 106
25049 Iseo - BS - ITALY
email info@astropublishing.com

Internet Service Provider
Aruba S.p.A.
Via San Clemente, 53
24036 Ponte San Pietro - BG - ITALY

Advertising - Administration
Astro Publishing di Pirlo L.
Via Bonomelli, 106
25049 Iseo - BS - ITALY
email admin@astropublishing.com

S U M M A R Y



All the planets of Proxima Centauri

by Michele Ferrara

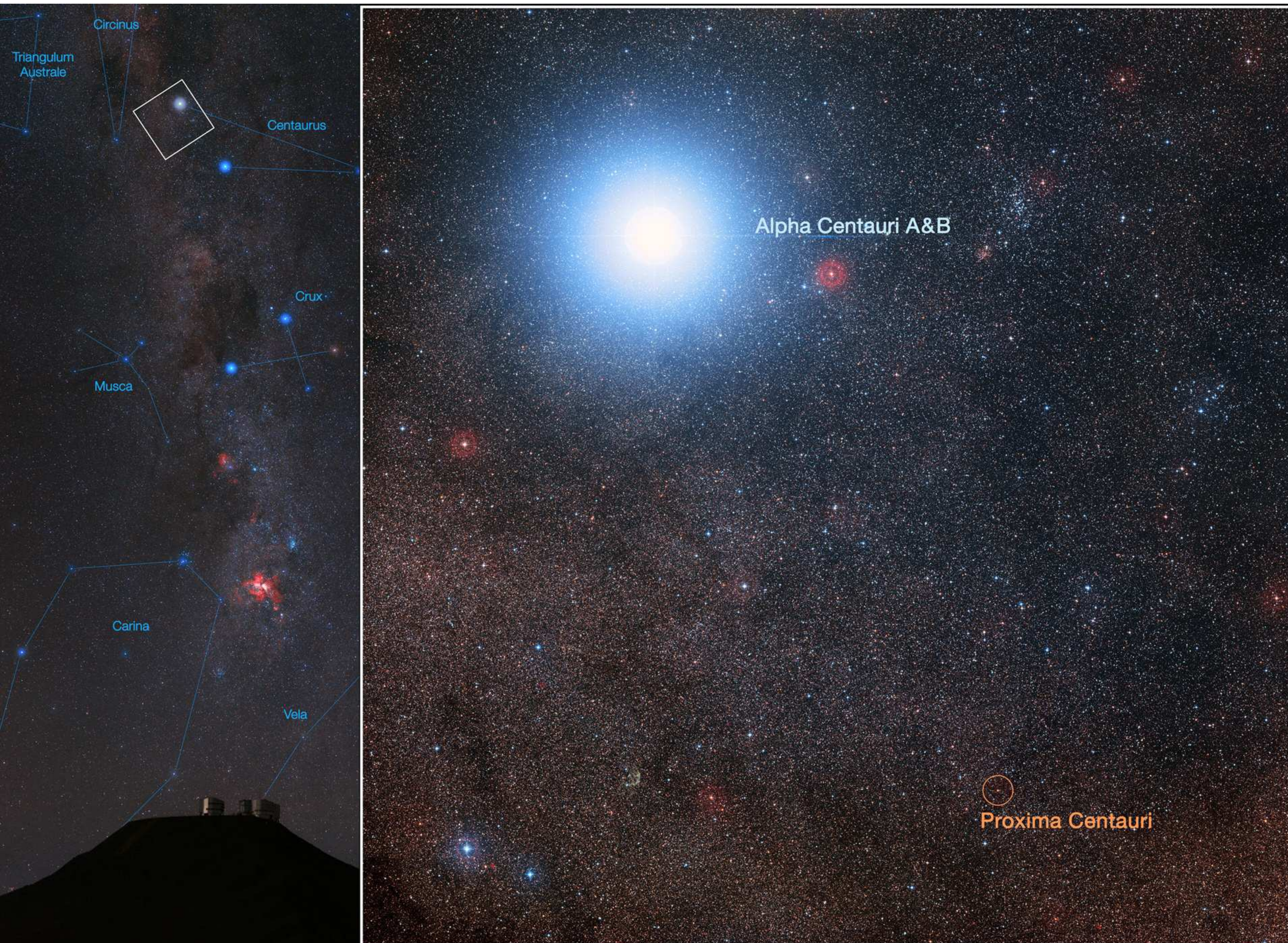
*revised by Damian G. Allis
NASA Solar System Ambassador*

In the habitable zone of the Proxima Centauri system, the existence of an orbiting Earth-sized planet, Proxima b, is now certain. Some studies have recently suggested the presence of a super-Earth in an outer orbit, and there may even be a third planet smaller than ours in an inner orbit. The observations of the star closest to the Sun are proving to be much more interesting than expected.

A hypothetical view of the Proxima Centauri system, as it might appear from one of its planets. [IAU/L. Calçada]

In 2016, the announcement of the discovery of an Earth-sized planet around the star closest to the Sun, Proxima Centauri, was a great surprise. The suspicion that this red dwarf was orbited by a planet dates back to at least a decade ago, but there was no physical evidence to prove it.

The Catalan astronomer Guillem Anglada-Escudé (Queen Mary University of London) organized a team of thirty researchers in 2013 to find evidence that established the existence of the planet. The observation campaign conducted by the team was called "Pale Red Dot" and involved the use of advanced instrumentation to follow Proxima Centauri photometrically and spectroscopically. A few years passed before the initiative became fully operational. During the

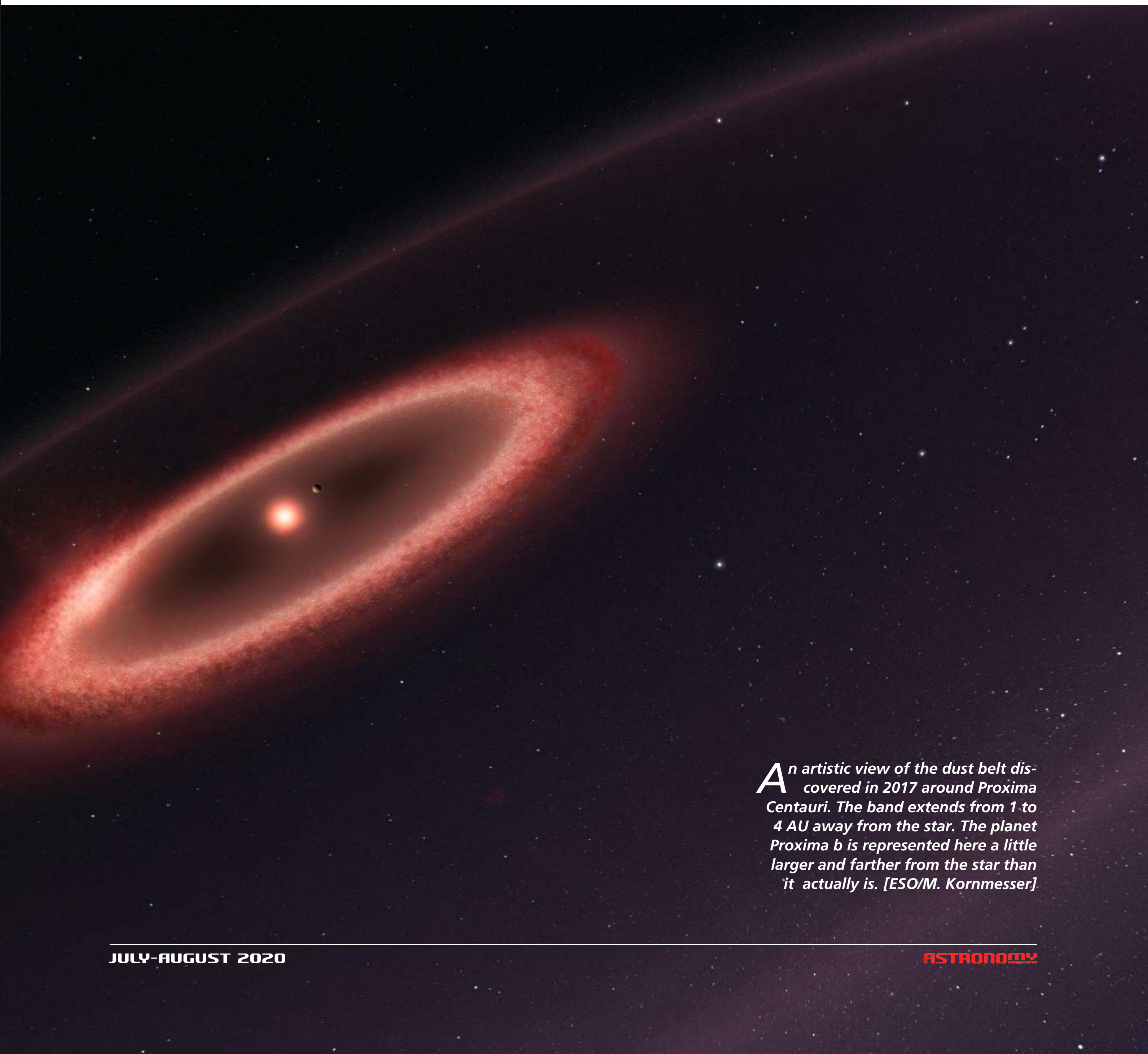


first half of 2016, the HARPS spectrograph, installed on the ESO's 3.6-meter telescope (La Silla Observatory, Chile), was used for a total of 60 nights to show the researchers more clearly than before that Proxima Centauri cyclically approaches and moves away from the Earth at a speed of about 1.4 m/s over a period of 11.2 days. The possibility that this behavior was attributable to the magnetic activity of the star (the expansion and contraction movements of the photosphere) was ruled out. The most convincing interpretation of the phenomenon was the presence of a planet that, traveling in its orbit, attracted the star towards itself. The 11.2-day period would then be the time it takes for the planet to orbit the star, from which a planet-star distance of just 0.05 AU was calculated, equal to one-twentieth that of the Earth-Sun distance.

If the orbital planes of our Solar System and Proxima Centauri were aligned just right, we would be able to observe the transits of a planet from Earth, when the planet passed directly in front of Proxima Centauri's stellar

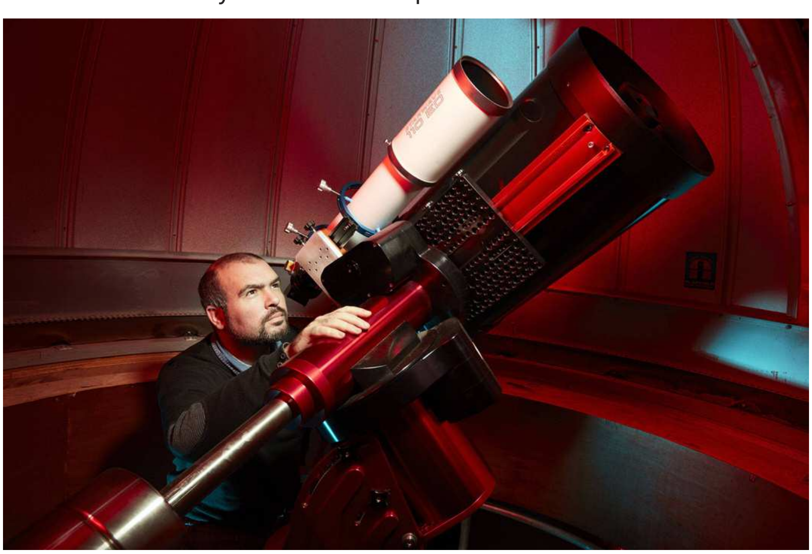
Opposite page, the position in the sky of Alpha Centauri's triple star system. [ESO/B. Tafreshi (twanight.org)/ DSS 2. Ack: Davide De Martin/ Mahdi Zamani]

disk. In this case, the calculation of the mass of the transiting planet is straightforward and we can obtain a "true mass" for the planet. When the planes are not aligned and we do not observe passage of the planet across the stellar disk, we are left to predict a range of possible masses for a planet based on how that planet causes its host star to oscillate towards and away from us. From this range of possible masses, we are able to determine a planet's "minimum mass" for the case when that planet's orbital plane places it just above or below the stellar disk when it passes between its star and Earth (the largest gravitational influence it can have on the star with respect to our observing position without being able to observe a transit). For the observed Prox-



An artistic view of the dust belt discovered in 2017 around Proxima Centauri. The band extends from 1 to 4 AU away from the star. The planet Proxima b is represented here a little larger and farther from the star than it actually is. [ESO/M. Kornmesser]

ima Centauri oscillation, this minimum mass for the planet turned out to be approximately 30% greater than that of the Earth. If the orbital plane of the Proxima Centauri system deviates even more from our own, it becomes necessary to consider proportionally more relevant masses to explain the forward-backward oscillation of Proxima Centauri.
Theoretical considerations of the size of the planet led its discoverers to estimate its diameter to be in the range of 0.9-1.4 Earth diameters, a size comparatively similar to Earth's.
A part of the surprise of the discovery of Proxima b was due precisely to its size, while the rest of the surprise was attributable to the fact that it orbits within the habitable zone of Proxima Centauri and receives a total amount of energy comparable to what the Earth receives from the Sun. The observed similarities end there, and we now wait for the direct observation and study of that elusive planet that is, for now, only perceivable through the very small oscillation of the spectral lines of the red dwarf. This discovery was enough to push many other researchers to further intensify their observations of the Proxima Centauri system. Among those researchers were Mario Damasso (National Institute for Astrophysics – INAF, Pino Torinese Observatory, Italy) and Fabio Del Sordo (University of Crete).
On the occasion of the Breakthrough Discuss in April 2019 (a part of the Breakthrough Initiatives program), these two astronomers announced that they had discovered evidence of



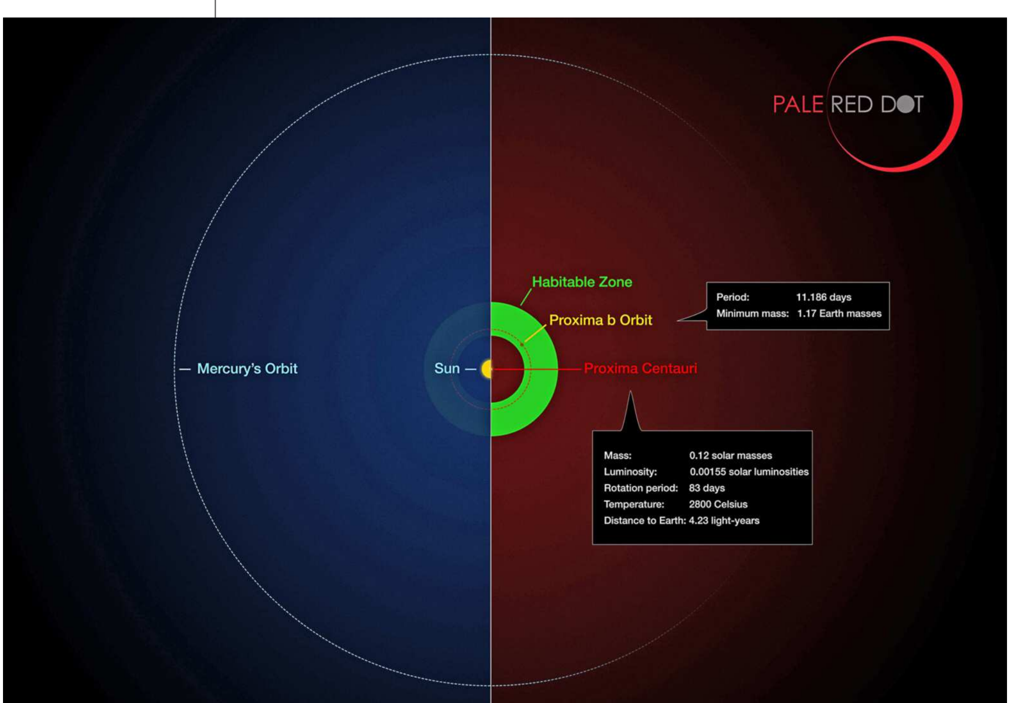
Here's what Proxima b could look like, the only confirmed planet in orbit around Proxima Centauri. [Ricardo Ramirez and James Jenkins, University of Chile]
Left, Guillem Anglada-Escudé, the team leader who discovered Proxima b. [Jay Brooks]

Mario Damasso and Fabio Del Sordo, at the end of their Breakthrough Discuss session, during which they reported the possible existence of the planet Proxima c. [Breakthrough Initiatives]

The infographic below compares regions of the same size in the Proxima Centauri system and in our Solar System. Proxima b is located inside the habitable zone, the one where liquid water could exist on its rocky surface. [ESO/ M. Kornmesser/ G. Coleman]

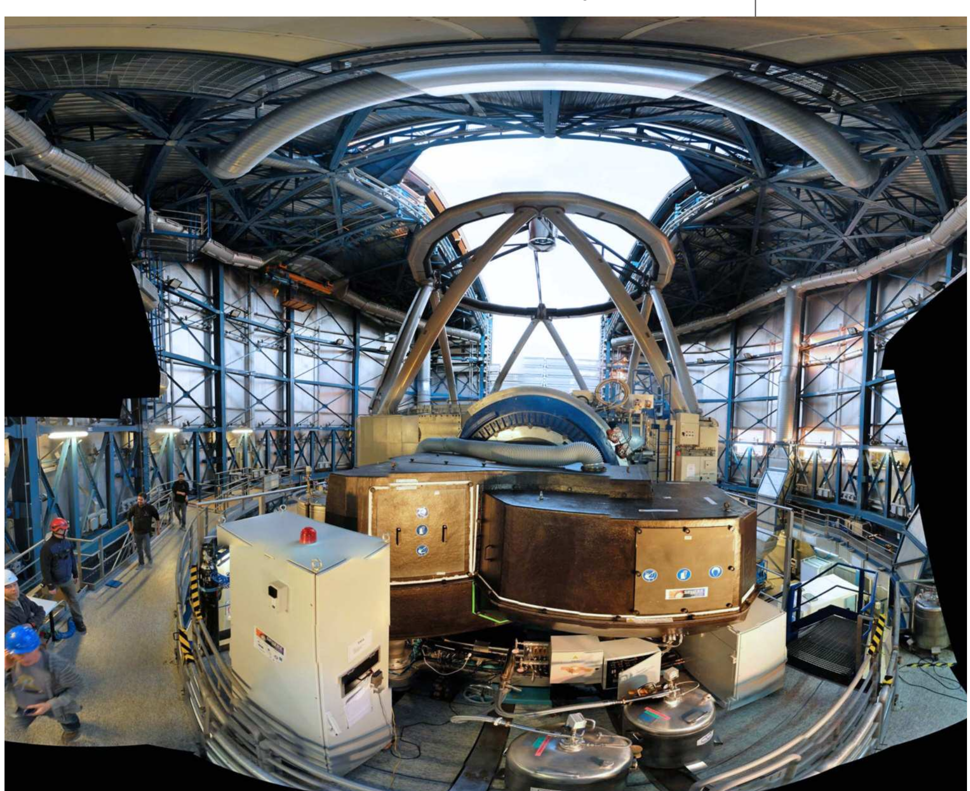
a second planet in the Proxima Centauri system. The presence of the new candidate emerged from the processing of data collected by HARPS over 17 years of activity. In these data were discovered a "swing effect" of the star, with a decidedly longer period than that attributable to Proxima b: around 1900 days. From the periodicity of the signal and the deviation of the star, Damasso and Del Sordo calculated both the distance of the (possible) second planet from its star, about 1.5 UA, and its minimum mass, close to six Earth masses. It would therefore be a "super-Earth" traveling in an orbit far enough from Proxima Centauri to translate into surface temperatures lower than -200 °C.

The first announcement in April 2019 was followed in January of this year by the publication in *Science Advances* of a paper detailing the discovery. In addition to Damasso and Del Sordo, the authorship of this 2020 paper includes the aforementioned Anglada-Escudé and many other researchers. The authors are justifiably cautious about the existence of the new planet, called Proxima c, and say that more detailed observations will be needed to confirm it. In fact, there is a remote possibility that the signal attributed to the second planet is actually produced by the magnetic activity of the red dwarf.

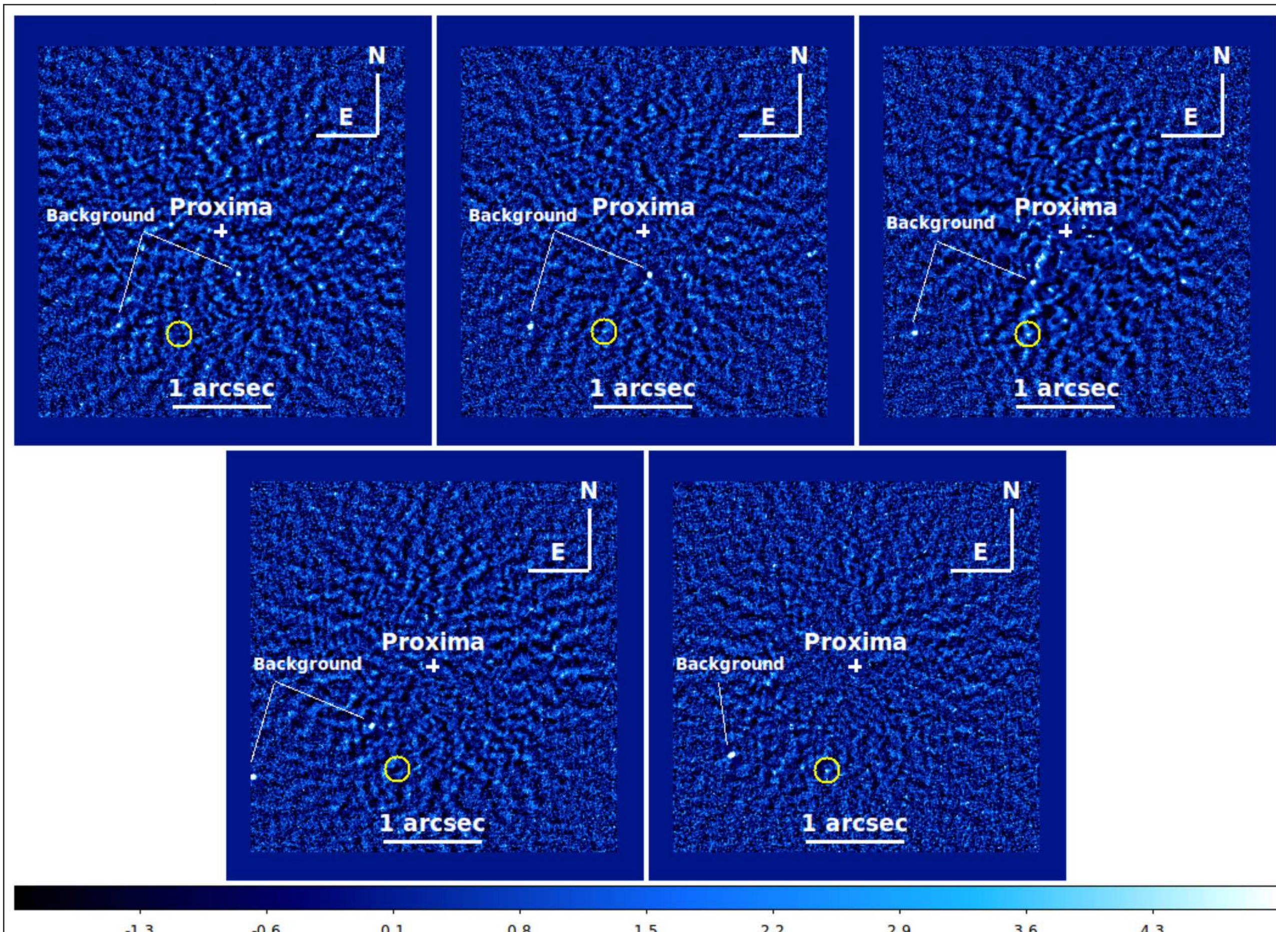


One way to confirm the existence of Proxima c with certainty would be to photograph it directly, a task certainly within the reach of the next generation of telescopes. Nonetheless, the results of the first attempt to recognize that planet on archive images produced by the SPHERE instrument, installed on the ESO's Very Large Telescope (Cerro Paranal, Chile), were already published

in *Astronomy & Astrophysics* in April of this year. A crowded team of researchers led by Raffaele Gratton (National Institute for Astrophysics – INAF, Padua Observatory, Italy) attempted this feat.
SPHERE is equipped with a coronograph and a sophisticated adaptive optics system, also designed to characterize extrasolar planets at visible and near-infrared wavelengths. Starting in 2014, this instrument has revealed the existence of several protoplanetary disks around distant stars and, for a period of four years, it was the fulcrum of the SHINE survey, during which it photographed about 600 nearby stars. One of these stars was Proxima Centauri, around which the existence of Proxima c was not yet suspected.
Gratton's team searched for traces of this potential planet in the SHINE survey images, trusting that if it had emitted a fairly intense infrared signal, SPHERE might have detected it. It had been calculated that the maximum projected separation between planet and star, or the angular distance to the orbital quadratures, could exceed 1 arcsecond, an encouraging value considering the resolving power of the photographic instrument.
In order to account for the expected large orbital motion of the planet, the researchers used a method that assumes a circular orbit obtained from radial velocities and exploits the sequence of observations acquired close to quadrature in the orbit. Unfortunately, the images acquired by SPHERE did not detect any clear trace of Proxima c. The best candidate was a small and faint patch of light with a signal-to-noise ratio of 6-to-1. Statistically, the probability that this detection is due to a random fluctuation is less than 1%, a value that would be encouraging if the noise distribution in the images was uniform, which is not the case. However, Gratton and colleagues point out that the position and orientation of the candidate planet's possible orbital plane is well-suited to the arrangement of an external belt of residual material imaged by ALMA. On the other hand, the position and the orbital motion of the detected signal are not consistent with what was observed by the Gaia



Raffaele Gratton, the team leader who attempted to confirm the existence of Proxima c through the images acquired by the SHINE survey. Below, the SPHERE spectropolarimeter, with which the SHINE survey was conducted. Here we see it installed on the UT3 unit of ESO's Very Large Telescope. [SPHERE/ ONERA/ JF Sauvage]



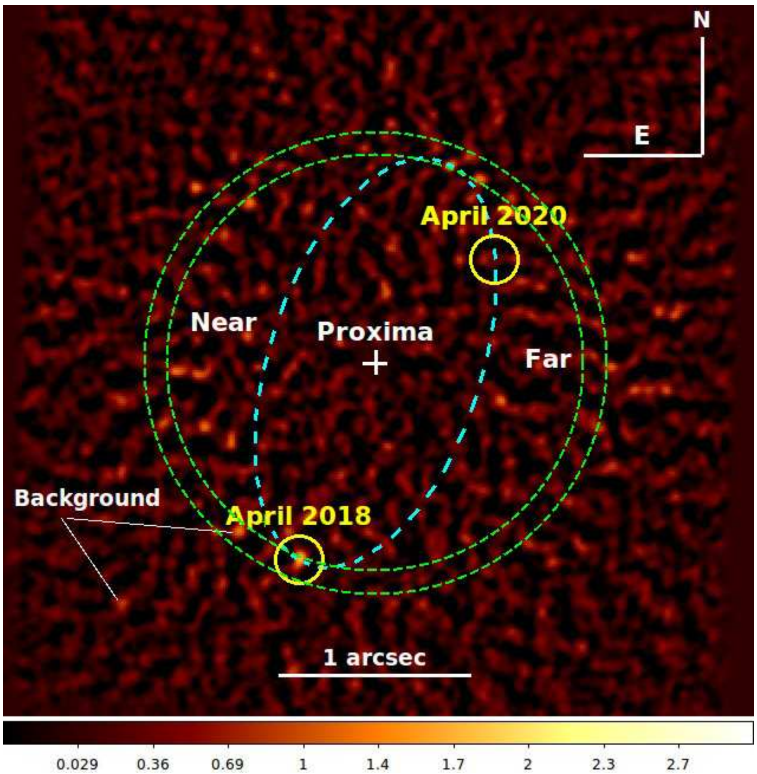
Signal-to-noise maps of the Proxima Centauri system, acquired in 2018 by SPHERE and in which Gratton's team sought evidence for Proxima c. The candidate planet is the signal enclosed in small circles, but the uneven distribution of the noise in the images makes identification uncertain. [R. Gratton et al.]

mission, with reference to the motion in the space of the Proxima Centauri system.

Another factor that makes the identification of the candidate planet uncertain in the SPHERE images is the excessive brightness of the signal. Previous theoretical studies have fixed specific constraints on the mass, brightness and distance from the star for different planetary sizes, but the flux highlighted by Gratton's team does not correspond to what the theoreticians forecasted. According to some commentators, the latter inconsistency might be resolvable by assuming that the candidate planet is surrounded by a system of rings similar to those of Saturn. An alternative explanation could be a scenario like that of Fomalhaut b, where the excess in brightness is attributable to the destruction (partial or total) of a planet and the scattering of its fragments in an increasing volume of space.

While the specialists were still arguing over the controversial existence of Proxima c, an article published last May 26 in *Astronomy & Astrophysics* brought Proxima b back again to the center of attention. In essence, the new work, carried out by a very crowded team of researchers led by Alejandro Suarez Mascareño (Instituto de Astrofísica de Canarias), has confirmed the existence of the first planet of Proxima Centauri, using the new and very powerful ESPRESSO spectrograph installed on the ESO's VLT.

ESPRESSO was mostly designed and manufactured in Switzerland by scientists and technicians from the University of Geneva, just like its predecessor HARPS. While the latter manages to measure oscillations of

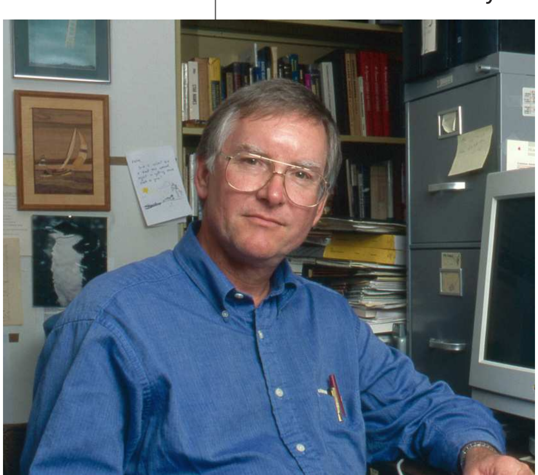


Composite image of the region around Proxima Centauri, taken by the SPHERE instrument in five periods between April 2018 and April 2020. The yellow circles indicate the best candidates of the planet Proxima c at the respective observation periods. In this case, the identification of the planet also remains uncertain. [R. Gratton et al.]

a star with an accuracy of about 1 m/s, ESPRESSO reaches an accuracy of 30 cm/s and it is expected that the next upgrades will push it up to the astonishing accuracy of 10 cm/s. What HARPS showed barely before is now clearly observed with ESPRESSO.
The Suarez Mascareño's team was able to quickly confirm the period of revolution and the mass of Proxima b, but the researchers went even further. Combining all the observations available to them (63 by ESPRESSO + 274 by HARPS and UVES) that were registered in a span of 15 years, the team was able to get a more precise value for the minimum mass of Proxima b: 1.173 ± 0.086 Earth masses.
Having entered full operation just over two years ago, ESPRESSO has not yet been able to provide useful indications of the existence of Proxima c, as the two-year observation period is too short compared to the calculated revolution of the hypothetical planet. ESPRESSO will have to observe the Proxima Centauri system for at least another three years before being able to confirm the presence of that candidate.
Meanwhile, the few observations carried out thus far with the new spectrograph have made it possible to exclude the presence of additional planets with masses greater than 0.6 Earth masses and periods of revolution fewer than 50 days. If other planets exist in very narrow orbits, they are small enough to represent a challenge for ESPRESSO as well. This challenge seems to have already been taken up by this excellent instrument, as the Suarez Mascareño's team has found faint traces of a second signal in the variations of the radial velocity of the red dwarf with a period of 5.15 days that could be produced by a planet with a minimum mass equal to 30% that of Earth's. If this third potential planet is confirmed, we will have identified the smallest planet ever measured by the radial velocity method.

Alejandro Suarez Mascareño, the team leader who, using the ESPRESSO spectrograph, has definitively confirmed the existence of Proxima b and detected traces of another candidate planet, smaller and in a closer orbit than Proxima c.

A part of the ESPRESSO facility which, through a fiber optic system, collects the light beams from the four VLT's 8.2-meter telescopes and sends them to the spectrograph located in another room. [ESO/P. Horálek] Below, Fritz Benedict, the astronomer whose independent work might have confirmed the existence of Proxima c using archive data from the Hubble Space Telescope. [University of Texas, McDonald Observatory]



Just a week after these latest remarkable revelations, news began to circulate about a new search in the archive data conducted by Fritz Benedict (retired astronomer of the McDonald Observatory) that would have confirmed the existence of the outer planet, Proxima c. The results of this latest work on the topic in question were presented in early June at the 236th meeting of the American Astronomical Society and are based on the reanalysis of astrometric measurements obtained in the last quarter of a century by the Fine Guidance Sensors of the Hubble Space Telescope. Although the primary task of these sensors is to ensure accurate pointing of the telescope, it is also possible to use them to make precise measurements of the positions and motions of stars. In the 1990s, Benedict had already attempted to highlight anomalies in Proxima Centauri's motion in the sky by searching for periods of less than 1000 days, but had been unable to find anything.

After learning about the work of Damasso's team, Benedict reviewed all of the available data, looking for a swing in the stellar motion with a longer period. This time, it seems that he has found a variation (acceleration and deceleration with respect to the straight motion) with a period of 1907 days, practically identical to that found by Damasso and colleagues. But Benedict went further, combining his results with those of previous measurements and producing a calculated mass of seven Earth masses for Proxima c.

Until Benedict's results are validated by other researchers, the presence of extra planets in addition to Proxima b remains unconfirmed. Discovering others would not be a surprise, however, because small-mass stars tend to host several rocky planets, not infrequently in very narrow orbits. We, therefore, expect further and compelling discoveries in the Proxima Centauri system. ■

NORT

RAPIDO 450

ALTAZIMUTH NEWTONIAN TELESCOPE

- ➢ **SCHOTT Supremax 33 optics**
- ➢ **optical diameter: 460 mm**
- ➢ **useful diameter: 450 mm**
- ➢ **focal ratio: f/4**
- ➢ **primary mirror thickness: 35 mm**
- ➢ **minor axis secondary mirror: 100 mm**
- ➢ **axial cell cooling system**
- ➢ **multi-fan removal of the mirror surface boundary layer**
- ➢ **carbon truss with self-centering conical couplings**
- ➢ **lateral supports (six) designed for altazimuth instruments**
- ➢ **zero deformations**

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

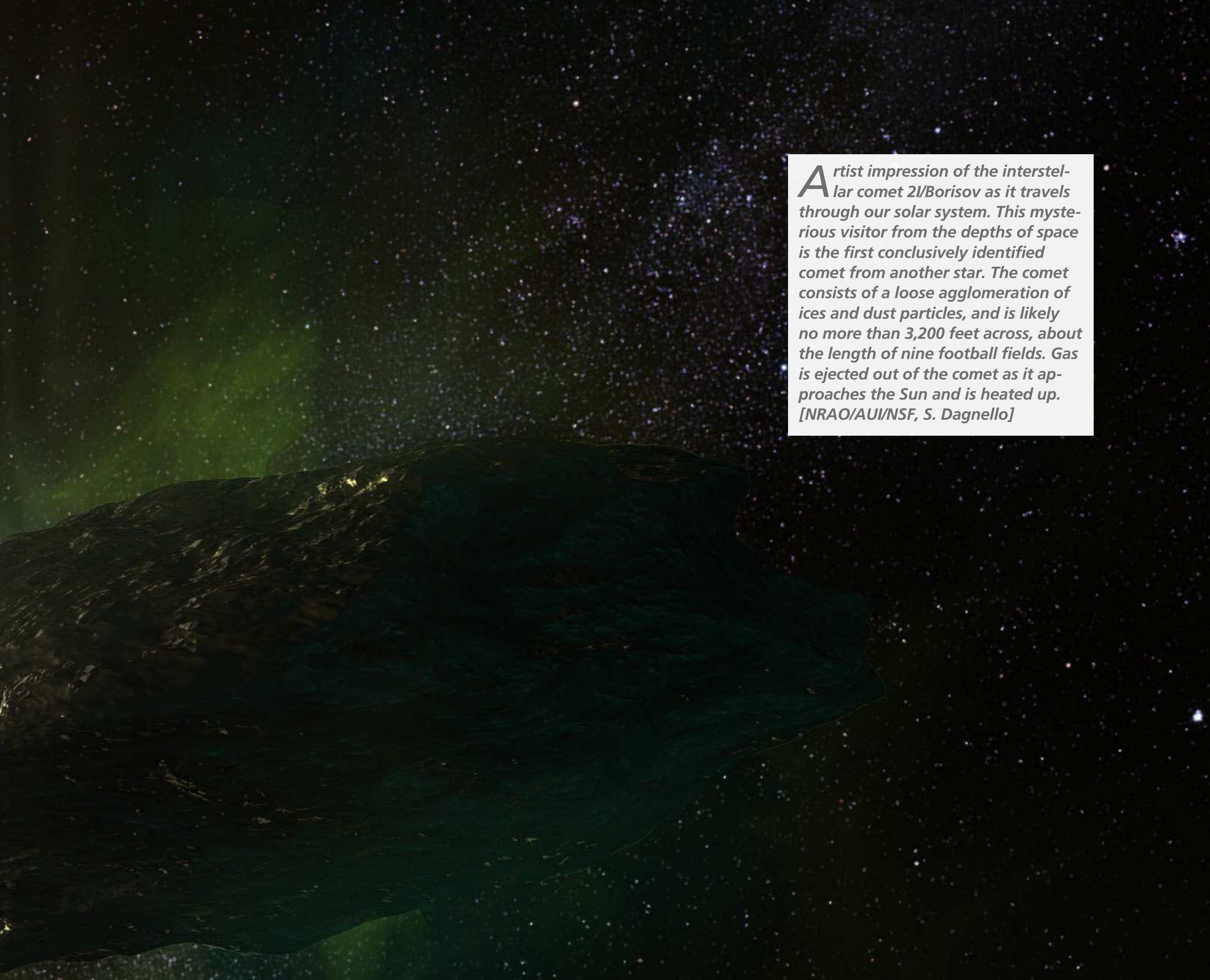
ALMA reveals unusual composition of interstellar comet 2I/Borisov

by ALMA Observatory

A galactic visitor entered our solar system last year – interstellar comet 2I/Borisov. When astronomers pointed the Atacama Large Millimeter/submillimeter Array (ALMA) toward the comet on 15 and 16 December 2019, for the first time they directly observed the chemicals stored inside an object from a planetary system other than our own. This research is published online in the journal *Nature Astronomy*.

The ALMA observations from a team of international scientists led by Martin Cordiner and Stefanie Milam at NASA's Goddard Space Flight Center in Greenbelt, Maryland, revealed that the gas coming out of the comet contained unusually high amounts of carbon monoxide (CO). The concentration of CO is higher than anyone has detected in any comet within 2 astronomical units (au) from the Sun, that is, within less than 186 million miles, or 300 million kilometers. 2I/Borisov's CO concentration was estimated to be between nine and 26 times higher than that of the average solar system comet.

Astronomers are interested to learn more about comets, because these objects spend most of their time at large distances from any star in very cold environments. Unlike planets, their interior compositions have not changed significantly since they were born. Therefore, they could reveal much about the processes that occurred during their birth in protoplanetary disks. *"This is the first time we've ever looked inside*

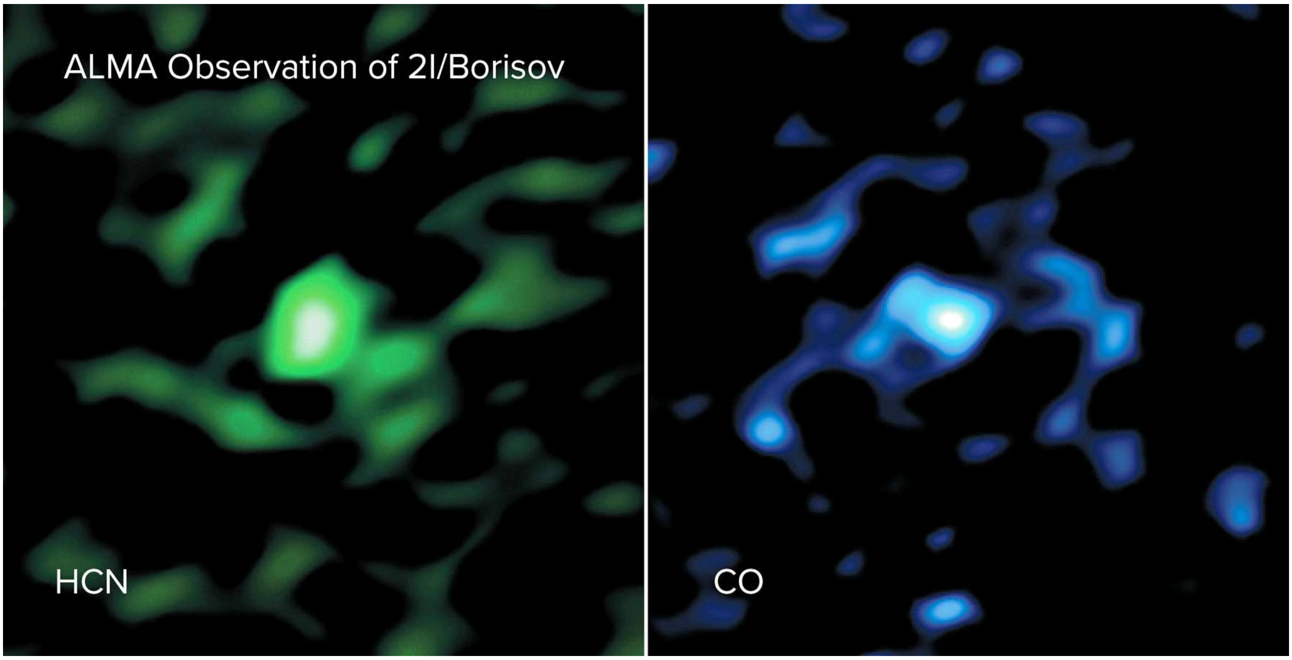


Artist impression of the interstellar comet 2I/Borisov as it travels through our solar system. This mysterious visitor from the depths of space is the first conclusively identified comet from another star. The comet consists of a loose agglomeration of ices and dust particles, and is likely no more than 3,200 feet across, about the length of nine football fields. Gas is ejected out of the comet as it approaches the Sun and is heated up. [NRAO/AUI/NSF, S. Dagnello]

a comet from outside our solar system," said astrochemist Martin Cordiner, *"and it is dramatically different from most other comets we've seen before."*

ALMA detected two molecules in the gas ejected by the comet: hydrogen cyanide (HCN) and carbon monoxide (CO). While the team expected to see HCN, which is present in 2I/Borisov at similar amounts to that found in solar system comets, they were surprised to see large amounts of CO. *"The comet must have formed from material very rich in CO ice, which is only present at the lowest temperatures found in space, below -420 degrees Fahrenheit (-250 degrees Celsius),"* said planetary scientist Stefanie Milam. *"ALMA has been instrumental in transforming our understanding of the nature of cometary material in our own solar system – and now with this unique object coming from our next-door neighbors. It is only because of ALMA's unprecedented sensitivity at submillimeter wavelengths that we are able to characterize the gas coming out of such unique objects,"* said Anthony Remijan of the National Radio Astronomy Observatory in Charlottesville, Virginia, and co-author of the paper.

Carbon monoxide is one of the most common molecules in space and is found inside most comets. Yet, there's a huge variation in the concentration of CO in comets and no one quite knows why. Some of this might be related to where in



ALMA observed hydrogen cyanide gas (HCN, left) and carbon monoxide gas (CO, right) coming out of interstellar comet 2I/Borisov. The ALMA images show that the comet contains an unusually large amount of CO gas. ALMA is the first telescope to measure the gases originating directly from the nucleus of an object that travelled to us from another planetary system. [ALMA (ESO/NAOJ/NRAO), M. Cordiner & S. Milam; NRAO/AUI/NSF, S. Dagnello]

the solar system a comet was formed; some has to do with how often a comet's orbit brings it closer to the Sun and leads it to release its more easily evaporated ices.

"If the gases we observed reflect the composition of 2I/Borisov's birthplace, then it shows that it may have formed in a different way than our own solar system comets, in an extremely cold, outer region of a distant planetary system," added Cordiner. This region can be compared to the cold region of icy bodies beyond Neptune, called the Kuiper Belt. The team can only speculate about the kind of star that hosted 2I/Borisov's planetary system. *"Most of the protoplanetary disks observed with ALMA are around younger versions of low-mass stars like the Sun,"* said Cordiner. *"Many of these disks extend well beyond the region where our own comets are believed to have formed, and contain large amounts of extremely cold gas and dust. It is possible that 2I/Borisov came from one of these larger disks."*

Due to its high speed when it traveled through our solar system (33 km/s or 21 miles/s) astronomers suspect that 2I/Borisov was kicked out from its host system, probably by interacting with a passing star or giant planet. It then spent millions or billions of years on a cold, lonely voyage through interstellar space before it was discovered on 30 August 2019 by amateur astronomer Gennady Borisov.

2I/Borisov is only the second interstellar object to be detected in our solar system. The first – 1I/'Oumuamua – was discovered in October 2017, at which point it was already on its way out, making it difficult to reveal details about whether it was a comet, asteroid, or something else. The presence of an active gas and dust coma surrounding 2I/Borisov made it the first confirmed interstellar comet.

Until other interstellar comets are observed, the unusual composition of 2I/Borisov cannot easily be explained and raises more questions than it answers. Is its composition typical of interstellar comets? Will we see more interstellar comets in the coming years with peculiar chemical compositions? What will they reveal about how planets form in other star systems?

"2I/Borisov gave us the first glimpse into the chemistry that shaped another planetary system," said Milam. *"But only when we can compare the object to other interstellar comets, will we learn whether 2I/Borisov is a special case, or if every interstellar object has unusually high levels of CO."* ■

Science in School aims to promote inspiring science teaching by encouraging communication between teachers, scientists, and everyone else involved in European science education. **Science in School** is published by EIROforum, a collaboration between eight European intergovernmental scientific research organisations, of which ESO is a member. The journal addresses science teaching both across Europe and across disciplines: highlighting the best in teaching and cutting-edge research.
Read more about **Science in School** at: http://www.scienceinschool.org/

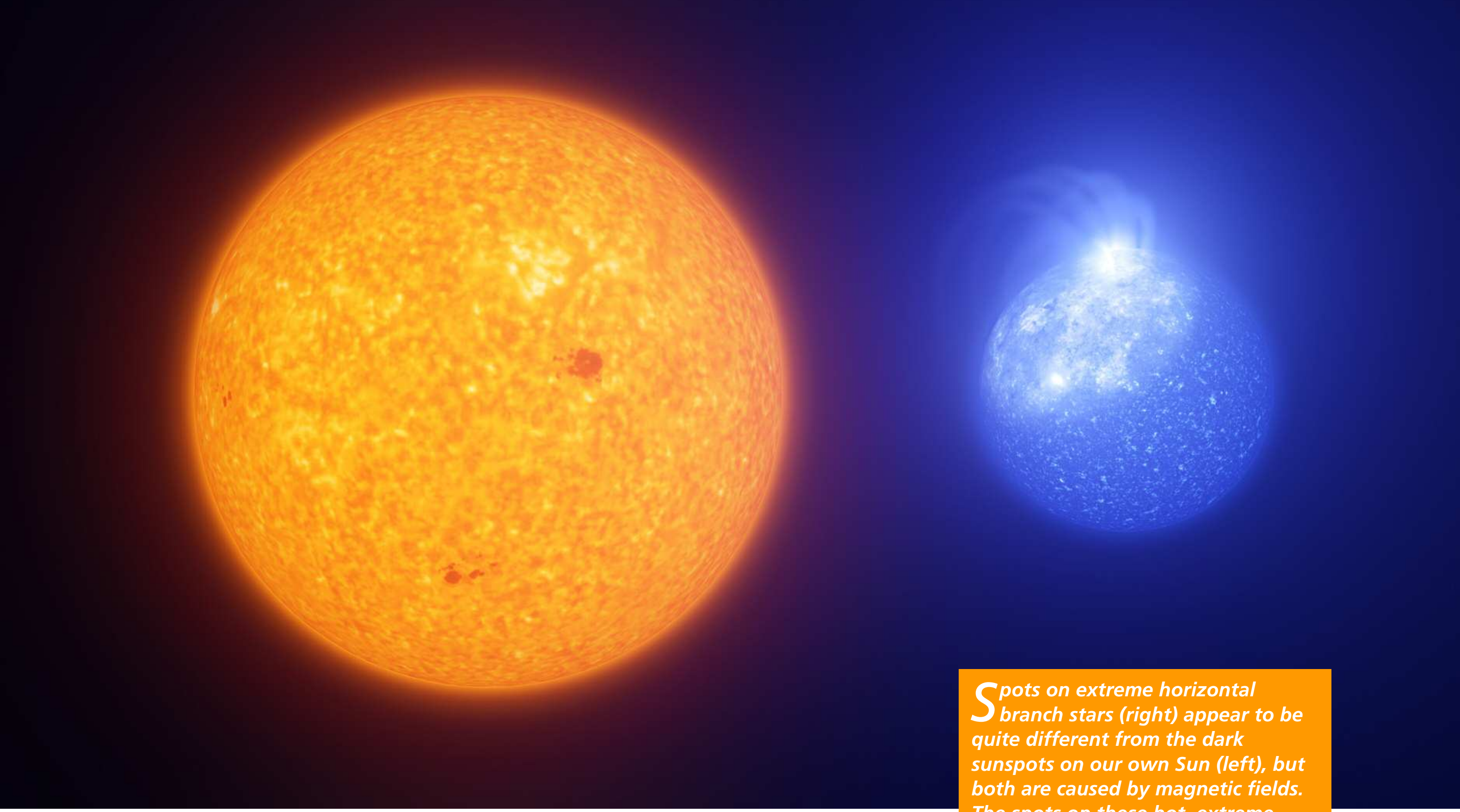
Hot stars are plagued by giant magnetic spots

by ESO

Astronomers using European Southern Observatory (ESO) telescopes have discovered giant spots on the surface of extremely hot stars hidden in stellar clusters. Not only are these stars plagued by magnetic spots, some also experience superflare events, explosions of energy several million times more energetic than similar eruptions on the Sun. The findings, published in *Nature Astronomy*, help astronomers better understand these puzzling stars and open doors to resolving other elusive mysteries of stellar astronomy. The team, led by Yazan Momany from the INAF Astronomical Observatory of Padua in Italy, looked at a particular type of star known as extreme horizontal branch stars — objects with about half the mass of the Sun but four to five times hotter. *"These hot and small stars are special because we know they will bypass one of the final phases in the life of a typical star and will die prematurely,"* says Momany, who was previously a staff astronomer at ESO's Paranal Observatory in Chile. *"In our Galaxy, these peculiar hot objects are generally associated with the presence of a close companion star."*

The background image and the video above show an artist's impression of what one of these stars, and its giant whitish spot, might look like. The spot is bright, takes up a quarter of the star's surface and is caused by magnetic fields. As the star rotates, the spot on its surface comes and goes, causing visible changes in brightness. Note that the movement does not represent the rotation of the star: it mimics the movement of a camera observing the star up close. [ESO/L. Calçada, INAF-Padua/S. Zaggia]

Surprisingly, however, the vast majority of these extreme horizontal branch stars, when observed in tightly packed stellar groups called globular clusters, do not appear to have companions. The team's long-term monitoring of these stars, made with ESO telescopes, also revealed that there was some-



Spots on extreme horizontal branch stars (right) appear to be quite different from the dark sunspots on our own Sun (left), but both are caused by magnetic fields. The spots on these hot, extreme stars are brighter and hotter than the surrounding stellar surface, unlike on the Sun where we see spots as dark stains on the solar surface that are cooler than their surroundings. The spots on extreme horizontal branch stars are also significantly larger than sunspots, covering up to a quarter of the star's surface. While sunspots vary in size, a typical size is around an Earth-size planet, 3000 smaller than a giant spot on an extreme horizontal branch star. [ESO/ L. Calçada, INAF-Padua/S. Zaggia]

thing more to these mysterious objects. When looking at three different globular clusters, Momany and his colleagues found that many of the extreme horizontal branch stars within them showed regular changes in their brightness over the course of just a few days to several weeks.

"After eliminating all other scenarios, there was only one remaining possibility to explain their observed brightness variations," concludes Simone Zaggia, a study co-author from the INAF Astronomical Observatory of Padua in Italy and a former ESO Fellow: *"these stars must be plagued by spots!"*

Spots on extreme horizontal branch stars appear to be quite different from the dark sunspots on our own Sun, but both are caused by magnetic fields. The spots on these hot, extreme stars are brighter and hotter than the surrounding stellar surface, unlike on the Sun where we see spots as dark stains on the solar surface that are cooler than their surroundings. The spots on extreme horizontal branch stars are also significantly larger than sunspots, covering up to a quarter of the star's surface. These spots are incredibly persistent, lasting for decades, while individual sunspots are temporary, lasting only a few days to months. As the hot stars rotate, the spots on the surface come and go, causing the visible changes in brightness.

Beyond the variations in brightness due to spots, the team also discovered a couple of extreme horizontal branch stars that showed superflares — sudden explosions of energy and another signpost of the presence of a magnetic field. *"They are similar to the flares we see on our own Sun, but ten million times more energetic,"* says study co-author Henri Boffin, an astronomer at ESO's headquarters in Germany. *"Such behaviour was certainly not expected and highlights the importance of magnetic fields in explaining the properties of these stars."*

After six decades of trying to understand extreme horizontal branch stars, astronomers now have a more complete picture of them. Moreover, this finding could help explain the origin of strong magnetic fields in many white dwarfs, objects that represent the final stage in the life of Sun-like stars and show similarities to extreme horizontal branch stars. *"The bigger picture though,"* says team member, David Jones, a former ESO Fellow now at the Instituto de Astrofísica de Canarias, Spain, *"is that changes in brightness of all hot stars — from young Sun-like stars to old extreme horizontal branch stars and long-dead white dwarfs — could all be connected. These objects can thus be understood as collectively suffering from magnetic spots on their surfaces."* To arrive at this result, the astronomers used several instruments on ESO's Very Large Telescope (VLT), including VIMOS, FLAMES and FORS2, as well as OmegaCAM attached to the VLT Survey Telescope at Paranal Observatory. They also employed ULTRACAM on the New Technology Telescope at ESO's La Silla Observatory, also in Chile. The breakthrough came as the team observed the stars in the near-ultraviolet part of the spectrum, allowing them to reveal the hotter, extreme stars standing out bright amongst the cooler stars in globular clusters.

MACRO COSMOS
bimestriel d'information scientifique et technique • Mars-Avril 2017
Tabby's star, un mystère non résolu
Deux sondes exploreront le système solaire primitif
ASTRONOMY magazine
May-June 2017 issue
Twin spends 340 days in orbit
Bloostar: space at your fingertips
ASTROFILO
gennaio-febbraio 2017 • € 0,00
strani segnali dalla Galassia
The second bigge
meteorite discove
ASTROFILO
LA RIVISTA MULTIMEDIALE GRATUITA DI ASTRONOMIA CHE TI AGGIORNA SUGLI ULTIMI AVVENIMENTI EXTRATERRESTRI
bimestrale di informazione scientifica e tecnica • settembre-ottobre 2017 • € 0,00
Missione PLATO, il passo decisivo
Le pulsar nel mirino di NICER
• Trovato un esopianeta con atmosfera di acqua rovente
• MASCARA vede la prima luce al La Silla Observatory
• Preparativi per Mercurio: BepiColombo completa i test
• ALMA conferma la chimica complessa dell'atmosfera di Titano
Cinque anni di Curiosity
Una sonda a
del Sol
MACRO COSMOS
LE MAGAZINE MULTIMÉDIA GRATUIT QUI VOUS TIENT AU COURANT DE L'ACTUALITÉ SPATIALE
bimestriel d'information scientifique et technique • Novembre-Décembre 2017
Une autre origine
la ceinture d'astéro
Deep Space Gateway, repartir de la Lune
• Hubble découvre un objet sans précédent dans le Système Solaire
• L'enfer sous un ciel de titane
• European Solar Telescope: première lumière en 2027
• Hubble observe une planète noire comme la nuit
ASTRONOMY magazine
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS HAPPENING IN SPACE
Bi-monthly magazine of scientific and technical information • January-February 2018 issue
The first interstellar asteroid
Chicxulub:
MACRO COSMOS
LE MAGAZINE MULTIMÉDIA GRATUIT QUI VOUS TIENT AU COURANT DE L'ACTUALITÉ SPATIALE
bimestriel d'information scientifique et technique • Juillet-Août 2018
L'industrie minière va au-delà de la Terre
Une nouvelle Supernova au-dessus de Munich
Curiosity
UNIVERS
Revista bimestral de información científica y técnica
Noticias desde el sistema TRAPPIST
ASTRONOMY magazine
September-October 2018
glacial lake
Mars
olution to the
ysteries of Uranus
ASTROFILO
maggio-giugno 2018 • € 0,00
Skylights, ritorno
alle caverne
Un hotel extra lusso in orbita terrestre
UNIVERSO
LA REVISTA GRATUITA DE ASTRONOMÍA QUE TE MANTIENE ACTUALIZADO SOBRE TODO LO QUE SUCEDE EN EL ESPACIO
Revista bimestral de información científica y técnica • Número de noviembre-diciembre 2018
Hayabusa2 trabajando en Ryugu
MACRO COSMOS
bimestriel d'information scientifique et technique • Mars-Avril 2019
Le projet Genesis
protection planétai
Le rover Opportunity
à la retraite
ASTROFILO
LA RIVISTA MULTIMEDIALE GRATUITA DI ASTRONOMIA CHE TI AGGIORNA SUGLI ULTIMI AVVENIMENTI EXTRATERRESTRI
bimestrale di informazione scientifica e tecnica • gennaio-febbraio 2019 • € 0,00
Barnard's Star b, la super-Terra più vicina
Bennu, Didymoon e la difesa planetaria
ASTRONOMY magazine
THE FREE MULTIMEDIA MAGAZINE THAT KEEPS YOU UPDATED ON WHAT IS HAPPENING IN SPACE
Bi-monthly magazine of scientific and technical information • May-June 2019
50 years ago, we walked on the Moon
PART ONE OF TWO

A supernova or Sagittarius – which should we thank?

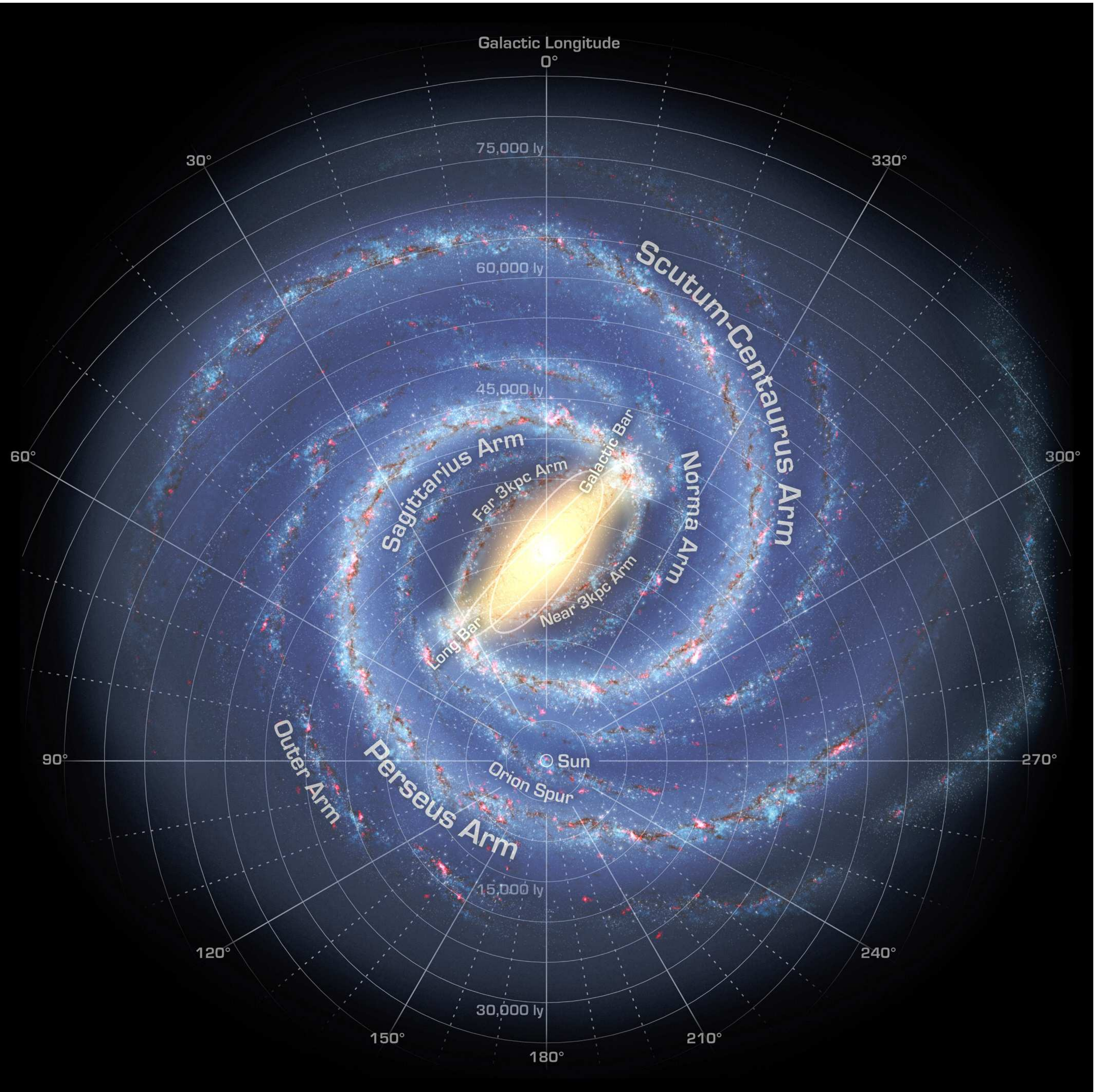
by Michele Ferrara

revised by Damian G. Allis
NASA Solar System Ambassador

The existence of the Sun and everything near it, including life on Earth, could be the result of a passage of the Sagittarius satellite galaxy near the disk of the Milky Way. A recent study suggests that this dwarf galaxy had profound effects on star formation in the Milky Way and probably also on the distribution of stellar masses.

In the background, a graphic reconstruction of our galaxy, made on the basis of NASA images. [Nick Risinger]

When we read a book or a popular article that discusses the formation of the solar system, we usually find the statement that it all started with the explosion of a supernova. The supernova hypothesis is commonly accepted right now – almost five billion years ago, the explosion of a very massive star compressed a nearby or surrounding interstellar cloud of gas and dust, creating regions with greater density that then collapsed in on themselves to generate new stars, including ours. In the accretion disk of the Sun, the Earth and the other planets would then have formed in a few tens of millions of years. A supernova is certainly an ideal trigger to produce instability within a cloud of gas and dust, but it is not the only one. Another mechanism capable of triggering the formation of new stars (and their associated planets) is the gravitational interaction between galaxies. An event of this kind oc-

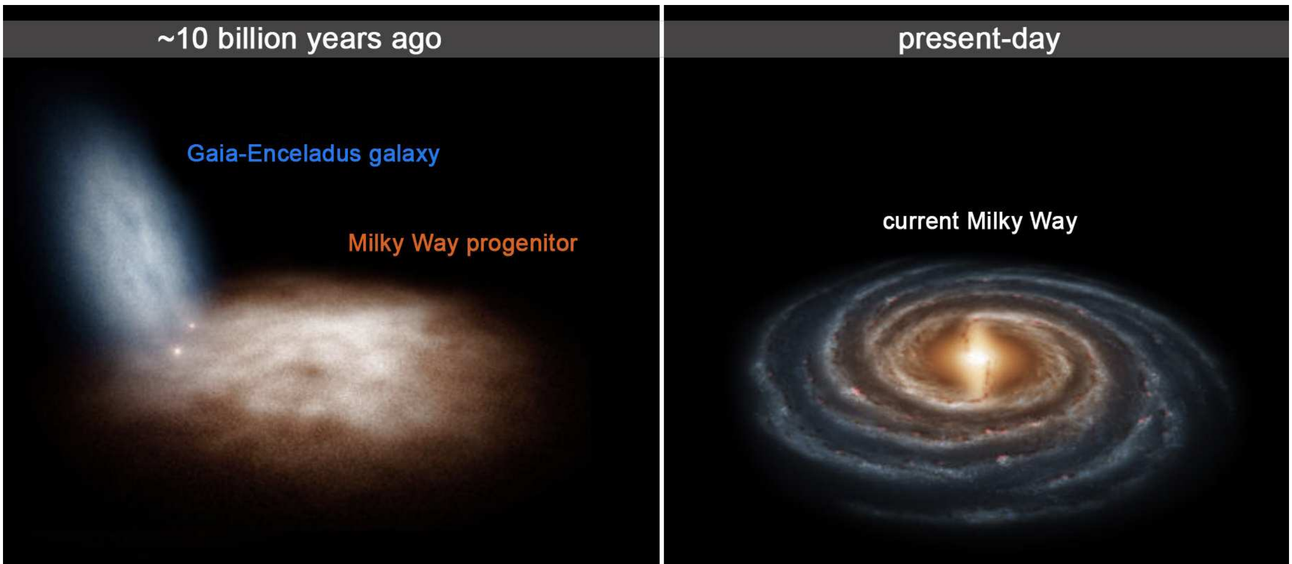


curs on a much larger scale than the distinctly local one of a supernova. The more intense the gravitational interaction between two galaxies is, the higher the star formation rate. The borderline case is the merging of galaxies, which represents the main triggering mechanism for star formation within the galaxies themselves, while also yielding significant changes in their chemical and dynamic evolution.

Like all galaxies, the Milky Way has experienced episodes of gravitational interactions and mergings, resulting in increased mass and the adoption of its current form.

As far as we know, the most relevant of these episodes happened approximately 10-11 billion years ago, when the young Milky Way collided with a galaxy four times less massive, called Gaia-Enceladus, completely engulfing it. Traces of this distant event are

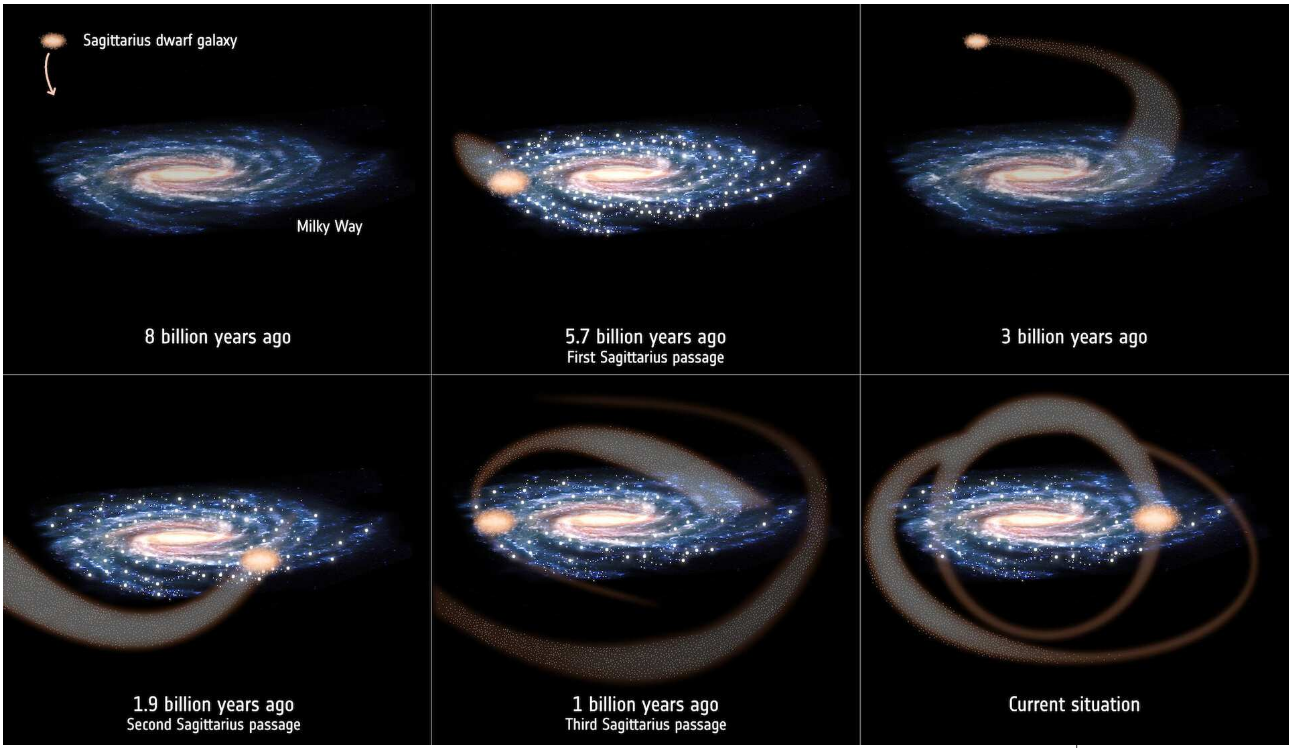
A schematic representation of the bar and spiral arms of the Milky Way. The Sun is near the so-called Orion Spur. [NASA/ JPL-Caltech/R. Hurt (SSC/Caltech)]



Above and in the video below we see the reconstruction of the dynamics of the Gaia-Enceladus event. Note that the current form of the Milky Way is also the result of minor interactions caused by small satellite galaxies. [Gabriel Pérez Díaz/SMM (IAC)]

still recognizable through the different dynamic and physical properties that the two sets of original stars show. Many studies have indeed highlighted that our galaxy is home to two distinct sets of stars, having the same age but different metallicity. The set of stars containing fewer metals (in astronomy, all of the elements heavier than hydrogen and helium) were carried by Gaia-Enceladus and are characterized by a chaotic motion. In the billions of years following the galactic merger, Gaia-Enceladus stars contributed to building up the halo of the current Milky Way. The dynamically-tidier set of stars is the original set of the young Milky Way. As is easy to imagine, the merging of the two galaxies was a slow and gradual process, nevertheless capable of triggering a star formation burst which, gradually decreasing, kept on for about four billion years. At the end of that process, the residual gas and dust entered the thin disk of the Milky Way.

The cannibalization of Gaia-Enceladus is the most relevant event of its kind still recognizable, but not the last for which there remains a trace. Other star formation bursts have also been recognized, albeit less intense and more remote. However, until a few years ago, it was practically impossible go back to find the cause of those events. In order to do this, it is essential to know at least some fundamental properties (brightness, color, position, distance, direction of motion, speed) of numerous stars spread across a very significant fraction of the Milky Way. If the sampling is done in a too-narrow region, say in a sphere with a radius of a few hundred



This illustration and the video below summarize the last passages to the pericenter of the Sagittarius dwarf galaxy, the results of which were an observed increase in star formation in the Milky Way during each. [ESA, IAC]

light-years around the Sun, it is not at all possible to obtain sufficient temporal resolution to isolate individual star formation events and place them precisely in the evolutionary history of the Milky Way.

The ability to investigate these merger events has increased significantly in recent years, thanks to the release in 2016 and 2018 of the extremely accurate photometric, astrometric and spectroscopic data collected for over one billion stars by the Gaia Space Observatory. Gaia's data allowed for the test of an intriguing hypothesis, according to which some star formation bursts that occurred in the Milky Way might have been related to the pericentric passages of one of its satellites, the Sagittarius dwarf galaxy. This small and evanescent stellar agglomerate, vaguely spheroidal, was discovered in 1994 and turned out to be the then-closest galaxy to the Milky Way, a record that lasted until 2003. Sagittarius is currently about 70,000 light-years from Earth and about 50,000 light-years from the galactic center. It follows a spiraling polar orbit which, due to gravitational interac-

The globular cluster M54 is located in the center of the Sagittarius galaxy. It is its most striking component. [ESA/Hubble & NASA]

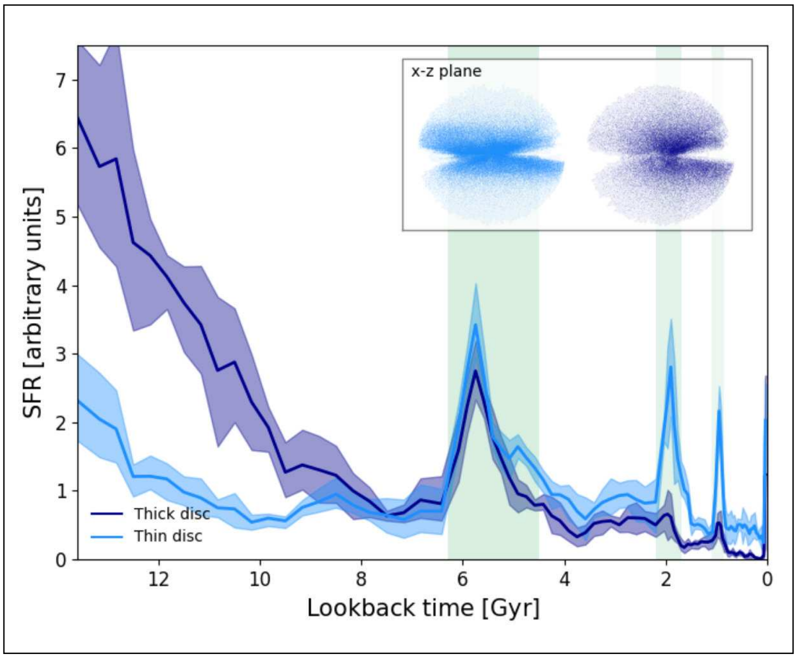
tions, narrows at each passage of the pericenter. Sagittarius has a diameter of about 10,000 light-years, a mass many times smaller than that of the Milky Way, is essentially composed of old and low-metal stars, and is almost gas-free. Its center is occupied by the globular cluster M54, the only easily observable Sagittarius component. Astronomers estimate that the first closed orbit of Sagittarius around the Milky Way began approximately 1 billion years ago and that, in the repeated and ever-closer pericenter passages, it has lost at least half of its mass to the Milky Way's advantage.

Direct observations of very peripheral stars of our galaxy and computer simulations lead us to believe that part of the mass lost by Sagittarius is scattered in large arcs along the orbits so far described. It was reasonable to expect that mass transfer and gravitational perturbations would have produced star formation events in the Milky Way, but convincing evidence was needed to associate their timing with that of the transits of the pericenter by Sagittarius. A decisive step in this direction has been performed recently by a team of researchers lead by Tomás Ruiz-Lara (Instituto de Astrofísica de Canarias), who combined data from Gaia and modeling techniques based on color-magnitude diagrams. With this procedure, the team was able to characterize with sufficient precision the stellar content in a sphere of space about 13,000 light-years in diameter, centered on the Sun; a sample certainly representative of the whole galactic disk. Ruiz-Lara and colleagues found that at the end of the Gaia-Enceladus event, the star formation in our galaxy had returned to the levels of other massive spiral galaxies, which are generally very low levels. Nevertheless, within this constant behavior, three well-defined star formation bursts are recognizable whose central phases date back to 5.7, 1.9 and 1.0 billion years ago with estimated durations of 0.8, 0.2 and 0.1 billion years, respectively. There are also traces of a possible fourth peak of star formation, which can be located in the last 100 million years. It is very interesting that the timings of these episodes coincide with the passages to the pericenter of Sagittarius deduced from simulations of the orbit, from the structure of the galactic disk and from the stellar contents of Sagittarius.

Tomás Ruiz-Lara, Postdoctoral Fellow, at the Instituto de Astrofísica de Canarias, coordinated the team of researchers who proposed the Sagittarius galaxy as the driving force for the formation of our Solar System.

Photomontage of the Gaia Space Observatory against the background of the Milky Way. [ESA/ATG medialab; background: ESO/S. Brunier]

Star formation history in the two kpc bubble around the Sun, with distinction between the thin and thick galactic disks. The star formation rate is expressed in arbitrary units for both disk substructures. The inset shows the spatial distribution of the stars belonging to each substructure in the x-z plane. Some regions close to the galactic plane were not included in the analysis due to the strong extinction of the signal in those directions. The stars were divided into thin disk or thick disk stars based on their tangential velocity. The four star formation peaks of the last six billion years are evident, including the current one, still not well-defined. [T. Ruiz-Lara et al.]



have been born as a result of that close passage of the dwarf galaxy. The Sun is located in the thin disk and could therefore fall within that 24%. The subsequent passages of Sagittarius produced less relevant effects in the thin disk, and almost imperceptible effects in the thick disk, but they nonetheless contributed to increasing the stellar mass of our galaxy.

The opposite happened instead to Sagittarius. In fact, an analysis of its stellar content shows that, between five and seven billion years ago, the formation of new stars and chemical enrichment were those typical of dwarf galaxies. After moving to the pericenter 5.7 billion years ago, the star formation rate collapsed, a sign of a remarkable loss of gas that was likely acquired by the Milky Way.

At this point, can we say that the spark that gave rise to the Sun, the Earth and ourselves arose from a close passage of Sagittarius? Not with certainty, due to the difficulties researchers encounter in representing the orbital dynamics of the dwarf galaxy.

However, it is undeniable that the current shape of the Milky Way and its stellar mass are at least, in part, the result of the action of a crowd of satellite galaxies (about sixty are known), among which Sagittarius has certainly played an important role – more than that of the Magellanic Clouds, which are only on their first approach. Sagittarius could also have indirectly started the formation of the solar system by contributing to the birth of that massive star that would later produce the supernova many astronomers considered the source of our existence. All hypotheses remain open.

If the results of the Ruiz-Lara team are correct, we can deduce that Sagittarius played a non-marginal role in the building up of the stellar mass of the Milky Way's disk, and that probably the Sun and its planetary system were formed as a consequence of a pericentric passage of the dwarf galaxy and not because of the explosion of a supernova. The passage of about 5.7 billion years ago could be the one that created the conditions for the subsequent birth of the solar system. It is true that the Sun was formed about a billion years after the apex of that event, but several factors may have intervened to delay its formation. For example, not a short time must have elapsed before gravitational perturbations generated a sufficient degree of inhomogeneity in the distribution of gas and dust to trigger the collapse of clouds of matter and the consequent birth of new stars.

Although it seems impossible to accurately reconstruct the sequence of events, the star formation burst caused by Sagittarius before, during and after the pericenter passing of 5.7 billion years ago is very evident both in the thick disk and in the thin disk. In these two kinematic components of our galaxy, the Ruiz-Lara team found that, respectively, 16% and 24% of the component stars could

ESO instrument finds closest black hole to Earth

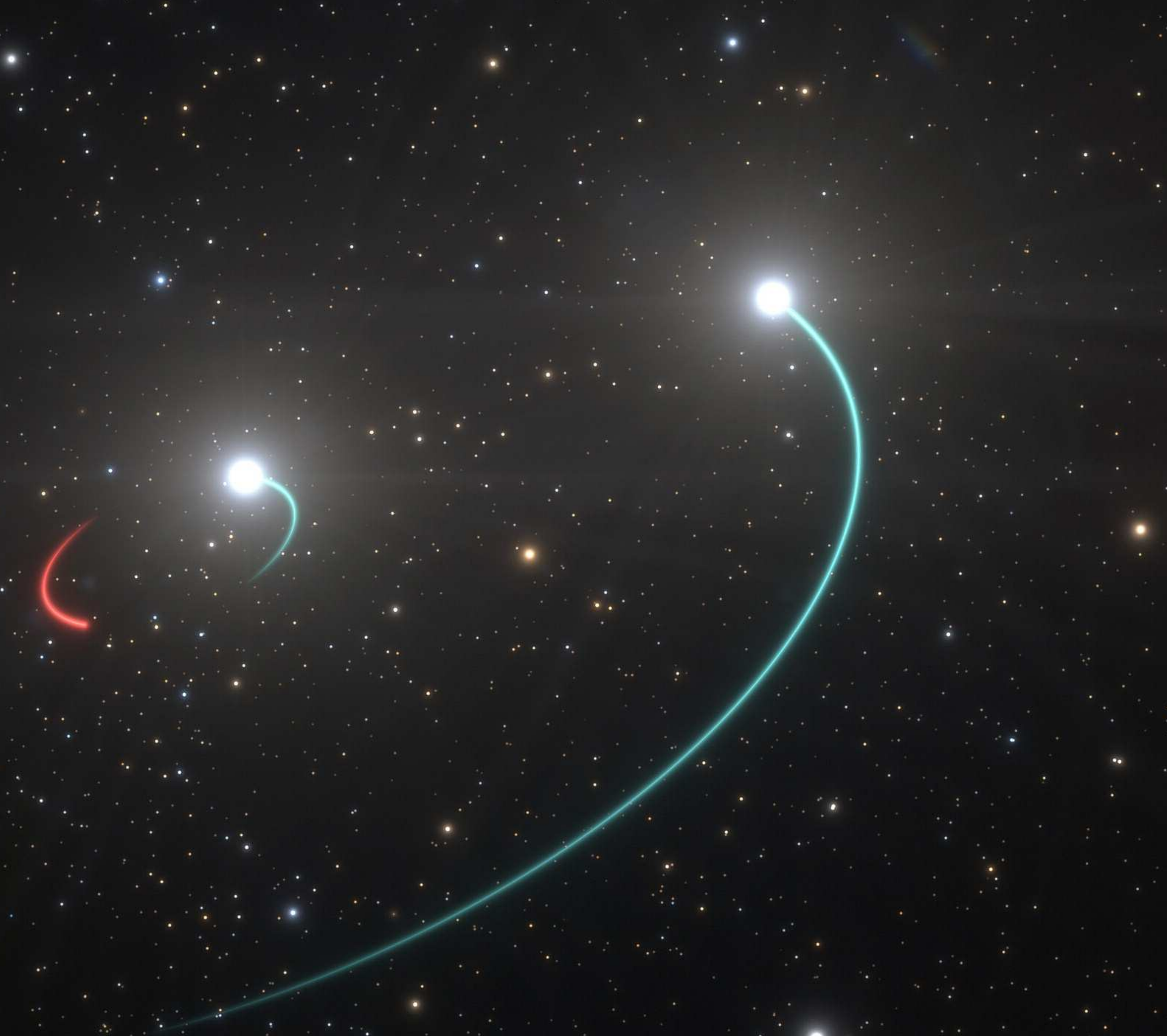
by ESO

A team of astronomers from the European Southern Observatory (ESO) and other institutes has discovered a black hole lying just 1000 light-years from Earth. The black hole is closer to our Solar System than any other found to date and forms part of a triple system that can be seen with the naked eye. The team found evidence for the invisible object by tracking its two companion stars using the MPG/ESO 2.2-metre telescope at ESO's La Silla Observatory in Chile. They say this system could just be the tip of the iceberg, as many more similar black holes could be found in the future.

"We were totally surprised when we realised that this is the first stellar system with a black hole that can be seen with the unaided eye," says Petr Hadrava, Emeritus Scientist at the Academy of Sciences of the Czech Republic in Prague and co-author of the research. Located in the constellation of Telescopium, the system is so close to us that its stars can be viewed from the southern hemisphere on a dark, clear night without binoculars or a telescope. *"This system contains the nearest black hole to Earth that we know of,"* says ESO scientist Thomas Rivinius, who led the study published today in *Astronomy & Astrophysics*.

The team originally observed the system, called HR 6819, as part of a study of double-star systems. However, as they analysed their observations, they were stunned when they revealed a third, previously undiscovered body in HR 6819: a black hole. The observations with the FEROS spectrograph on the MPG/ESO 2.2-metre telescope at La Silla showed that one of the two visible stars orbits an unseen object every 40 days, while the second star is at a large distance from this inner pair.

Dietrich Baade, Emeritus Astronomer at ESO in Garching and co-author of the study, says: *"The observations needed to determine*



This artist's impression shows the orbits of the objects in the HR 6819 triple system. This system is made up of an inner binary with one star (orbit in blue) and a newly discovered black hole (orbit in red), as well as a third object, another star, in a wider orbit (also in blue). [ESO/L. Calçada]

the period of 40 days had to be spread over several months. This was only possible thanks to ESO's pioneering service-observing scheme under which observations are made by ESO staff on behalf of the scientists needing them."

The hidden black hole in HR 6819 is one of the very first stellar-mass black holes found that do not interact violently with their environment and, therefore, appear truly black. But the team could spot its presence and calculate its mass by studying the orbit of the star in the inner pair. *"An invisible object with a mass at least 4 times that of the Sun can only be a black hole,"* concludes Rivinius, who is based in Chile. Astronomers have spotted only a couple of dozen black holes in our galaxy to date, nearly all of which strongly interact with their environment and make their presence known by releasing powerful X-rays in this interaction. But scientists estimate that, over the Milky Way's lifetime, many more stars collapsed into black holes as they ended their lives. The discovery of a silent, invisible black hole in HR 6819 provides clues about where the many hidden black holes in the Milky Way might be. *"There must be hundreds of millions of black holes out there, but we know about only very few. Knowing what to look for should put us in a better position to find them,"* says Rivinius. Baade adds that finding a black hole in a triple system so close by indicates that we are seeing just *"the tip of an exciting iceberg."*

Already, astronomers believe their discovery could shine some light on a second system. *"We realised that another system, called LB-1, may also be such a triple, though we'd need more observations to say for sure,"* says Marianne Heida, a postdoctoral fellow at ESO and co-author of the paper. *"LB-1 is a bit further away from Earth but still pretty close in astronomical terms, so that means that probably many more of these systems exist. By finding and studying them we can learn a lot about the formation and evolution of those rare stars that begin their lives with more than about 8 times the mass of the Sun and end them in a supernova explosion that leaves behind a black hole."*

This wide-field view shows the region of the sky, in the constellation of Telescopium, where HR 6819 can be found, a triple system consisting of two stars and the closest black hole to Earth ever found. This view was created from images forming part of the Digitized Sky Survey 2. While the black hole is invisible, the two stars in HR 6819 can be viewed from the southern hemisphere on a dark, clear night without binoculars or a telescope. [ESO/Digitized Sky Survey 2]

The discoveries of these triple systems with an inner pair and a distant star could also provide clues about the violent cosmic mergers that release gravitational waves powerful enough to be detected on Earth. Some astronomers believe that the mergers can happen in systems with a similar configuration to HR 6819 or LB-1, but where the inner pair is made up of two black holes or of a black hole and a neutron star. The distant outer object can gravitationally impact the inner pair in such a way that it triggers a merger and the release of gravitational waves.

Although HR 6819 and LB-1 have only one black hole and no neutron stars, these systems could help scientists understand how stellar collisions can happen in triple star systems.

This animation shows the orbits and movements of the objects in the HR 6819 triple system. This system includes an inner binary with one star (orbit indicated in blue) and a newly discovered black hole (orbit indicated in red). As we move away from this inner pair, we see the outer object in the system, another star in a much wider orbit (in blue). [ESO/L. Calçada]

The **ESO Annual Report 2019** is now available. It presents a summary of ESO's many activities throughout the year.
The contents include:

✦ Research highlights from ESO facilities, including the first image of the shadow of a supermassive black hole, groundbreaking investigations of exoplanets and how the shapes and characteristics of asteroids are being uncovered in unprecedented detail from the ground.

✦ A summary of activities at ESO's front-line observatories in Chile: 2019 was a very special year for the La Silla Observatory, marking 50 years since its inauguration. The celebrations of this anniversary were further distinguished by the opportunity to witness a rare total solar eclipse at the observatory.

✦ The latest news from the Atacama Large Millimeter/submillimeter Array (ALMA) and ESO's Extremely Large Telescope (ELT).

✦ News about ESO staff and infrastructure, and recommendations from the ESO Visiting Committee.

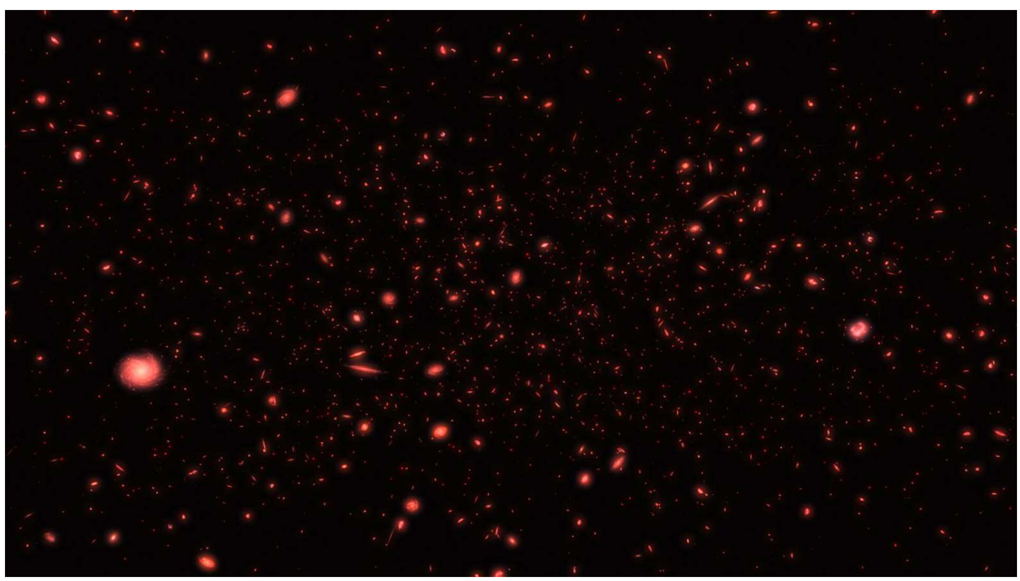
This product is available to download **for free** and will soon be available to buy in the ESOshop.

Download PDF 133 pages:
https://www.eso.org/public/usa/products/annualreports/ar_2019/

Hubble makes surprising find in the early Universe

by NASA/ESA

New results from the NASA/ESA Hubble Space Telescope suggest the formation of the first stars and galaxies in the early Universe took place sooner than previously thought. A European team of astronomers have found no evidence of the first generation of stars, known as Population III stars, as far back as when the Universe was just 500 million years old.



This artist's impression presents the early Universe. [ESA/Hubble, M. Kornmesser]

The exploration of the very first galaxies remains a significant challenge in modern astronomy. We do not know when or how the first stars and galaxies in the Universe formed. These questions can be addressed with the Hubble Space Telescope through deep imaging observations. Hubble allows astronomers to view the Universe back to within 500 million years of the Big Bang.

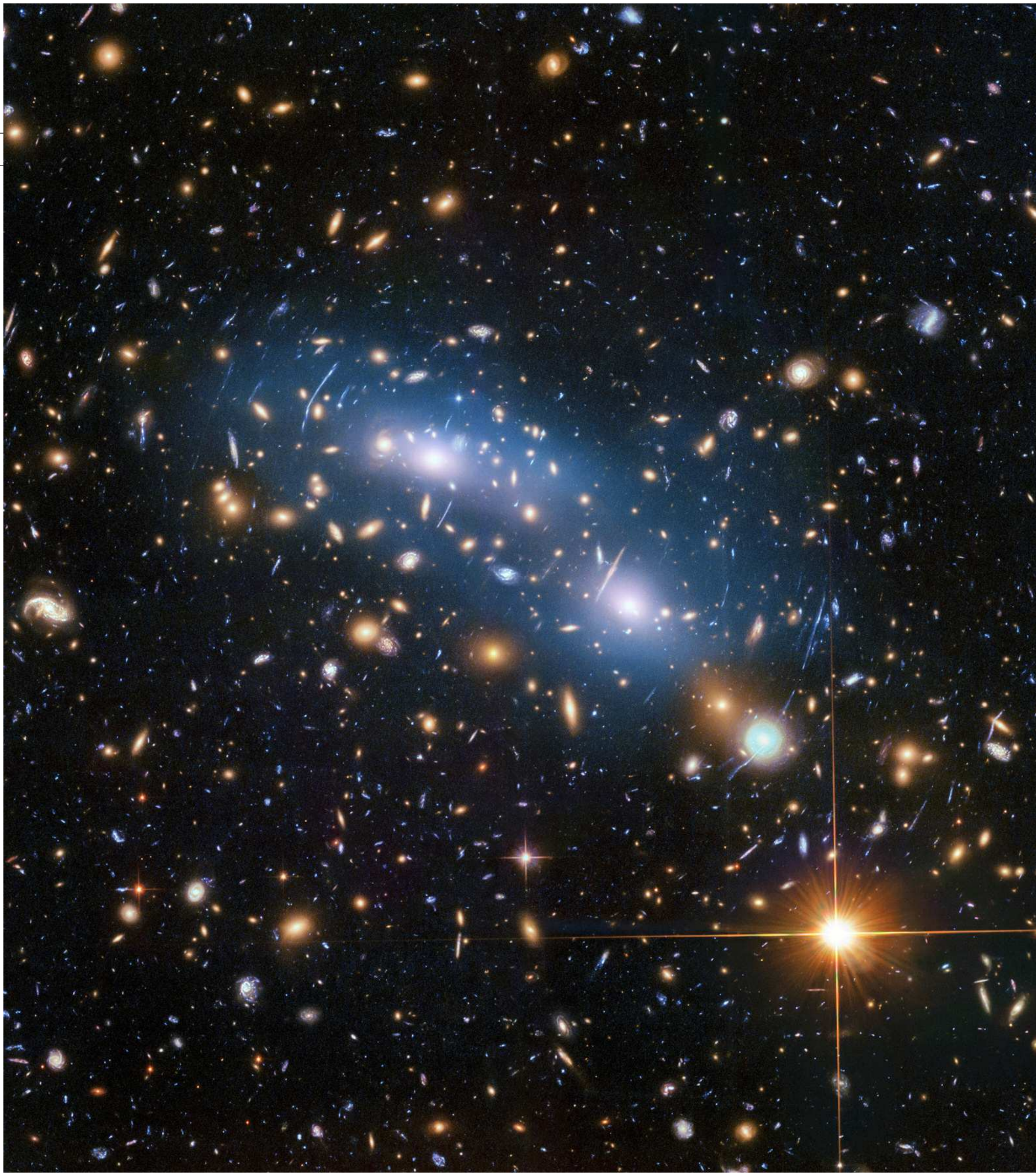
A team of European researchers, led by Rachana Bhatawdekar of the European Space Agency, set out to study the first generation of stars in the early Universe. Known as Population III stars, these stars were forged from the primordial material that emerged from the Big Bang. Population III stars must have been made solely out of hydrogen, helium and lithium, the only elements that existed before processes in the cores of these stars could create heavier elements, such as oxygen, nitrogen, carbon and iron.

Bhatawdekar and her team probed the early Universe from about 500 million to 1 billion years after the Big Bang by studying the cluster MACSJ0416 and its parallel field with the Hubble Space Telescope (with supporting data from NASA's Spitzer Space Telescope and the ground-based Very Large Telescope of the European Southern Observatory). *"We found no evidence of these first-generation Population III stars in this cosmic time interval"* said Bhatawdekar of the new results.

The result was achieved using the Hubble's Space Telescope's Wide

Field Camera 3 and Advanced Camera for Surveys, as part of the Hubble Frontier Fields programme.

This programme (which observed six distant galaxy clusters from 2012 to 2017) produced the deepest observations ever made of galaxy clusters and the galaxies located behind them which were magnified by the gravitational lensing effect, thereby revealing galaxies 10 to 100 times fainter than any previously observed. The masses of foreground galaxy clusters are large enough to bend and magnify the light from the more distant objects behind them. This allows Hubble to use these cosmic magnifying glasses to study objects that are beyond its nominal operational capabilities.



This image from the NASA/ESA Hubble Space Telescope shows the galaxy cluster MACS J0416. This is one of six clusters that was studied by the Hubble Frontier Fields programme, which yielded the deepest images of gravitational lensing ever made. Scientists used intracluster light (visible in blue) to study the distribution of dark matter within the cluster. [NASA, ESA, and M. Montes (University of New South Wales, Sydney, Australia)]

Bhatawdekar and her team developed a new technique that removes the light from the bright foreground galaxies that constitute these gravitational lenses. This allowed them to discover galaxies with lower masses than ever previously observed with Hubble, at a distance corresponding to when the Universe was less than a billion years old. At this point in cosmic time, the lack of evidence for exotic stellar populations and the identification of many low-mass galaxies supports the suggestion that these galaxies are the most likely candidates for the reionisation of the Universe. This period of reionisation in the early Universe is when the neutral intergalactic medium was ionised by the first stars and galaxies.

"These results have profound astrophysical consequences as they show that galaxies must have formed much earlier than we thought," said Bhatawdekar. *"This also strongly supports the idea that low-mass/faint galaxies in the early Universe are responsible for reionisation."*

These results also suggest that the earliest formation of stars and galaxies occurred much earlier than can be probed with the Hubble Space Telescope.

This leaves an exciting area of further research for the upcoming NASA/ESA/CSA James Webb Space Telescope — to study the Universe's earliest galaxies.

SPHERE sees signs of planet birth

by ESO

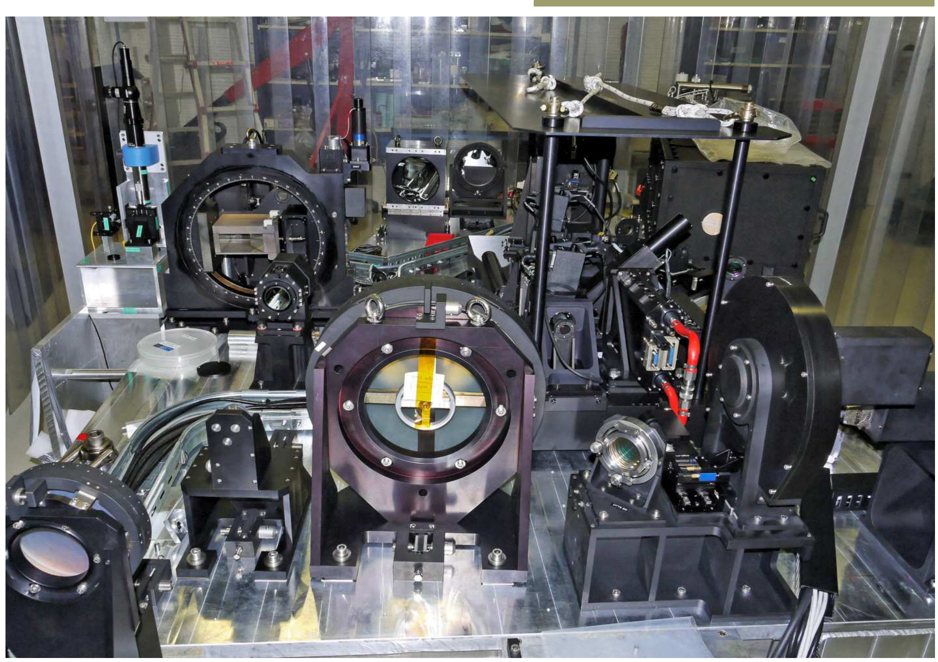
Observations made with the European Southern Observatory's Very Large Telescope (ESO's VLT) have revealed the telltale signs of a planetary system being born. Around the young star AB Aurigae lies a dense disc of dust and gas in which astronomers have spotted a prominent spiral structure with a 'twist' that marks the site where a planet may be forming. The observed feature could be the first direct evidence of a baby planet coming into existence.

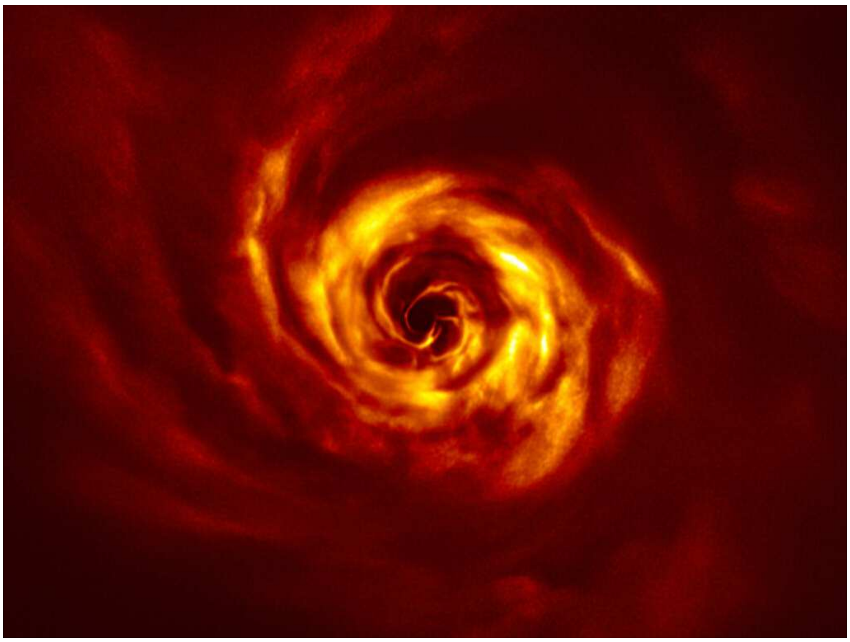
"Thousands of exoplanets have been identified so far, but little is known about how they form," says Anthony Boccaletti who led the study from the Observatoire de Paris, PSL University, France. Astronomers know planets are born in dusty discs surrounding young stars, like AB Aurigae, as cold gas and dust clump together. The new observations with ESO's VLT, published in *Astronomy & Astrophysics*, provide crucial clues to help scientists better understand this process.

"We need to observe very young systems to really capture the moment when planets form," says Boccaletti. But until now astronomers had been unable to take sufficiently sharp and deep images of these young discs to find the 'twist' that marks the spot where a baby planet may be coming to existence.

The new images feature a stunning spiral of dust and gas around AB Aurigae, located 520 light-years away from Earth in the constellation of Auriga (The Charioteer). Spirals of this type signal the presence of baby planets, which 'kick' the gas, creating *"disturbances in the disc in the form of a wave, somewhat like the*

Detailed view of the SPHERE optical bench is shown with the main subsystems clearly visible. SPHERE (Spectro-Polarimetric High-contrast Exoplanet REsearch) is installed on the ESO Very Large Tele- scope, and operates in direct imaging of exoplanets larger than Jupiter. [ESO]





This image shows the disc around the young AB Aurigae star, where ESO's Very Large Telescope (VLT) has spotted signs of planet birth. Close to the centre of the image, in the inner region of the disc, we see the 'twist' (in very bright yellow) that scientists believe marks the spot where a planet is forming. This twist lies at about the same distance from the AB Aurigae star as Neptune from the Sun. The image was obtained with the VLT's SPHERE instrument in polarised light. [ESO/Boccaletti et al.]

wake of a boat on a lake," explains Emmanuel Di Folco of the Astrophysics Laboratory of Bordeaux (LAB), France, who also participated in the study. As the planet rotates around the central star, this wave gets shaped into a spiral arm. The very bright yellow 'twist' region close to the centre of the new AB Aurigae image, which lies at about the same distance from the star as Neptune from the Sun, is one of these disturbance sites where the team believe a planet is being made. Observations of the AB Aurigae system made a few years ago with the Atacama Large Millimeter/submillimeter Array (ALMA), in which ESO is a partner, provided the first hints of ongoing planet formation around the star. In the ALMA images, scientists spotted two spiral arms of gas close to the star, lying within the disc's inner region. Then, in 2019 and early 2020, Boccaletti and a team of astronomers from France, Taiwan, the US and Belgium set out to capture a clearer picture by turning the SPHERE instrument on ESO's VLT in Chile toward the star. The SPHERE images are the deepest images of the AB Aurigae system obtained to date.

With SPHERE's powerful imaging system, astronomers could see the fainter light from small dust grains and emissions coming from the inner disc. They confirmed the presence of the spiral arms first detected by ALMA and also spotted another remarkable feature, a 'twist', that points to the presence of ongoing planet formation in the disc. *"The twist is expected from some theoretical models of planet formation,"* says co-author Anne Dutrey, also at LAB. *"It corresponds to the connection of two spirals — one winding inwards of the planet's orbit, the other expanding outwards — which join at the planet location. They allow gas and dust from the disc to accrete onto the forming planet and make it grow."*

ESO is constructing the 39-metre Extremely Large Telescope, which will draw on the cutting-edge work of ALMA and SPHERE to study extrasolar worlds. As Boccaletti explains, this powerful telescope will allow astronomers to get even more detailed views of planets in the making. *"We should be able to see directly and more precisely how the dynamics of the gas contributes to the formation of planets,"* he concludes.

This video starts by showing a wide-field view of a region of the sky in the constellation of Auriga. It then zooms in to show AB Auriga, a young star system where ESO's Very Large Telescope has spotted signs of planet birth. [ESO/Boccaletti et al./L. Calçada, Digitized Sky Survey 2, N. Risinger (skysurvey.org). Music: Konstantino Polizois]

The principle of mediocrity and the habitability of galaxies

by Michele Ferrara

revised by Damian G. Allis
NASA Solar System Ambassador

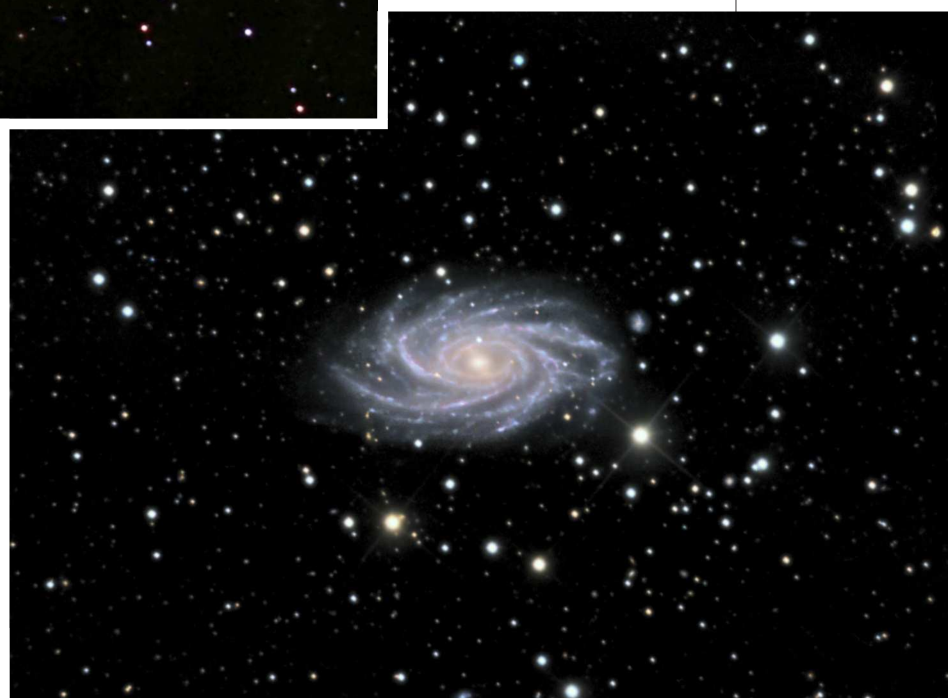
Since the time of Copernicus, astronomers have adopted a statistical concept called the "principle of mediocrity" to help us understand the cosmos that surrounds us. This principle extends, to all members of a category of appropriately selected objects, the attributes of only one of them that we consider to be a typical member of that category. It seems entirely legitimate today to extend the principle of mediocrity to the search for extraterrestrial life, but how far can we go?

Is life more typical in elliptical or spiral galaxies? In the background, two worthy representatives of those categories: M60 (in the center) and NGC 4647 (top right). [NASA, ESA and the Hubble Heritage (STScI/AURA)]

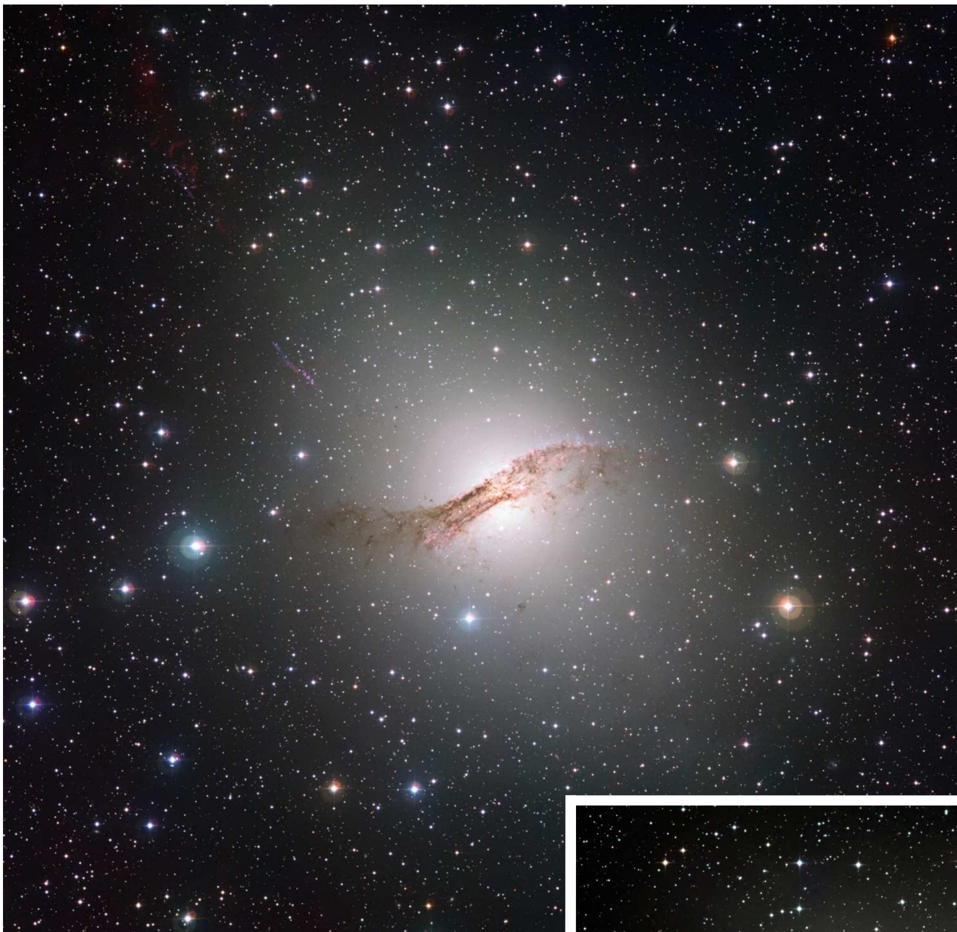
There are at least 2,000 billion galaxies in the observable universe, each of which contains, on average, many billions of stars. Many of these billions of stars are assumed to host planets. This means that, already in the region of the universe closest to us (where the cosmological redshift, z, is near or at zero), there are probably trillions of planets, and we can expect that a small fraction of them (millions) are very similar to Earth and therefore are habitable by terrestrial life forms. Depending on how hospitable a planet might be, life could evolve to develop technological species, those which by definition are "biological species that have developed electronic devices and are capable of significantly influencing their planetary environment."

In order for an intelligent species to have the time necessary to evolve up to a technological level, it is necessary that the host star resides in the main sequence for billions

of years without showing a significant variability. One might assume that it doesn't matter if the star and its planetary system are in a spiral galaxy or an elliptical galaxy, but this is not so. The typology of the host galaxy seems to be able to influence the habitability of planets. A well-known theoretical work in this area was conducted in 2015 by researchers coordinated by astronomer Pratika Dayal (University of Durham). The team modeled the number of potentially habitable planets in the local universe relative to the planets within the Milky Way. The conclusion was that large elliptical galaxies, with at least double the mass of the Milky Way, should contain 100 to 10,000 times more terrestrial planets than galaxies similar to ours. Dayal and colleagues interpreted this high proportion as a consequence of three properties that typically distinguish large elliptical galaxies from spiral ones: the greater stellar mass, the very low supernovae rate, and the very high metallicity. Large elliptical galaxies have, in fact, already transformed almost all the gas available into stars, while the most massive stars have aged and died more or less rapidly, enriching the interstel-

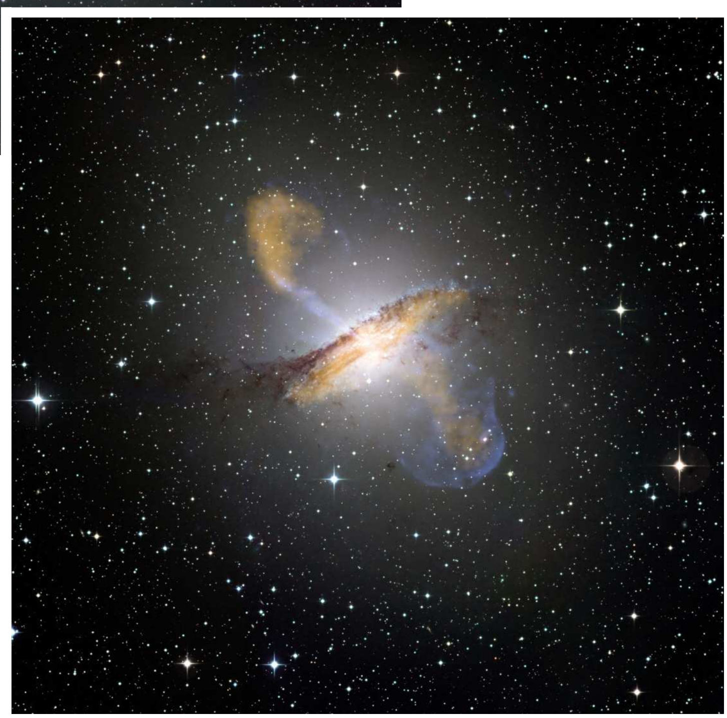


Three spiral galaxies similar in size to the Milky Way or slightly larger: on the side is M61 in the constellation Virgo; below is NGC 2336 in Camelopardalis; to the lower left is M109 in Ursa Major. The latter galaxy is a barred spiral, morphologically very similar to ours. [Cima Rest Astronomical Observatory, Magasa, Valvestino, Italy]



so-called "principle of mediocrity." According to this principle, if an element is randomly extracted from a well-defined category of elements, it is very likely that it is representative of the whole category. Applied to astronomy, the principle of mediocrity tells us that there are no privileged realities in the universe and, in the absence of contrary evidence, the evolution of our solar system, our planet, and all life on it have to each be considered typical scenarios of the reference classes to which they belong.

An example will clarify the concept. Three famous astronomers of the past, James Gregory, Isaac Newton and Christiaan Huygens (also known for the optical schemes they each gave



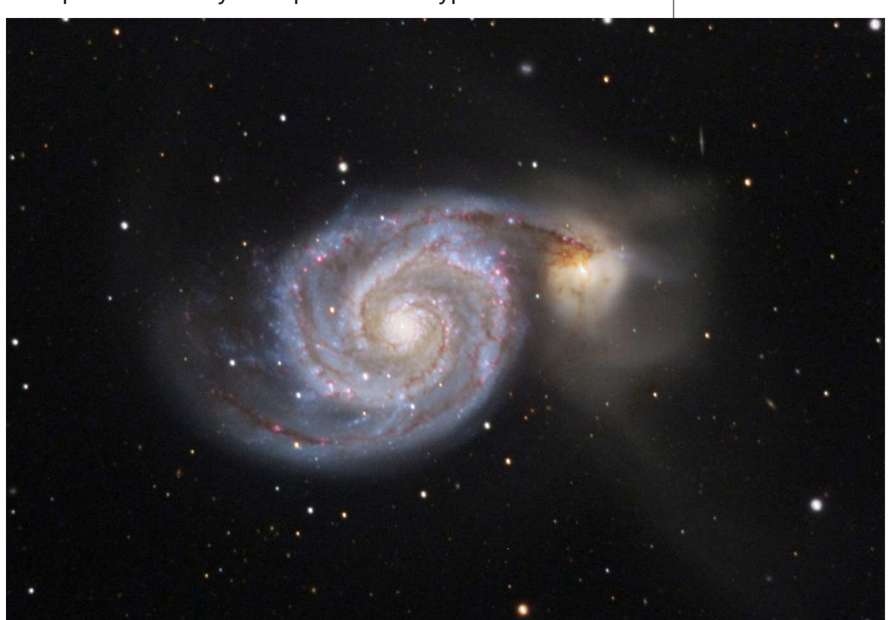
NGC 5128, in the constellation Centaur, is an intermediate class between ellipticals and spirals. The photo above, taken in visible light with the 2.2-meter MPG/ESO telescope at La Silla Observatory, does not show the violent activity of the SMBH evident in other wavelengths (right). [ESO/WFI (Optical); MPIfR/ESO/APEX/ A.Weiss et al. (Submillimetre); NASA/CXC/CfA/R. Kraft et al. (X-ray)]

lar medium with metals. The latter would favor the formation of planets, while the shortage (or absence) of supernovae would preserve any life forms present on those planets from being cut down by the radiation released in the explosions.

The surprising results reached by Dayal's team have obviously been the subject of discussion among astronomers, and just recently their hypothesis has regained the limelight thanks to a critical reworking based on the

M81, in Ursa Major, is a spiral galaxy slightly smaller than ours, housing an SMBH almost 20 times more massive than Sgr A* – still much lighter than those typical of large elliptical galaxies. Below, the famous Whirlpool Galaxy, M51, in Canes Venatici, the Hunting Dogs constellation, a spiral galaxy par excellence. One of its arms interacts gravitationally with its companion NGC 5195 – a clash between galaxies. [Cima Rest Astronomical Observatory, Magasa, Valvestino, Italy]

us), ventured into calculating the distance from the Earth to the star Sirius by assuming that the Sun was a typical star and representative of all stars. From the differences between the apparent brightness of the two stars and the assumption that both were similar, they obtained a distance of about half a light-year – a value proven to be underestimated (by just over eight light years) only after the subsequent awareness of the multiplicity of the stellar classes. That said, the calculated distance of about half a light-year provided a realistic idea of the depth of the cosmos at the time.



Just as the astronomers of the seventeenth century once did, even today's astronomers are in the position of having to apply the principle of mediocrity to a restricted class of an appropriately chosen reference – that of the technological species. The only representative that we know to fall into this class is the human species, and it goes without saying that any extrapolation to hypothetical real-

for other technological species?" It would be reasonable to expect a typical species to inhabit a galaxy that offers life more development opportunities. As a result, either we are not typical, or the results that Dayal and colleagues have reached are wrong. Recently, Daniel P. Whitmire (University of Arkansas) conducted a study published in the *Monthly Notices of the Royal Astronomical Society* that substantially challenges the results of Dayal's team. The main objection raised by Whitmire is that the previous work only considers the evolutionary stage of the galaxies of the local universe, ignoring the fact that the time it takes for life to evolve into a technological species is probably billions of years throughout the universe, periods during

M87, in the constellation Virgo, is a giant elliptical galaxy, one of the most massive in the local universe. Its SMBH is proportionally massive (about seven billion solar masses) and is the engine of the powerful jet of plasma erupting from the active galactic nucleus. [ESO] Right, the Dragon Trio: NGC 5981, NGC 5982, and NGC 5985, containing two barred spirals, one cutting view and the other almost in front, and an elliptical cross in the middle. [Stephen Leshin]

ities different from ours risks being a mere philosophical speculation. Nonetheless, a single datum is better than nothing and, according to the principle of mediocrity, we must consider our technological species as typical, having no comparison that suggests the opposite.
At this point a question arises: "If we consider our technological species to be typical, but a large elliptical galaxy may contain up to 10,000 times more potentially habitable planets than a spiral galaxy, why would we, and spiral galaxies in general, not instead be considered outliers in the search

which galaxies undergo profound transformations. Observations show that today's large and quiescent elliptical galaxies may have been shocked billions of years ago by the quasar phenomenon produced by supermassive black holes (SMBH) nestled at their centers. In those times, the elliptical galaxies were, on average, more compact. As a result, the activity of the nucleus most likely led to the inhibition of star formation and the sterilization of a large number of planets.

Consequently, if the large elliptical galaxies relatively close to us may seem safer right now for possible forms of advanced life compared to conditions in spiral galaxies (in which the supernovae rate is decidedly higher), the fact remains that ellipticals were by no means safe when life would have had to conquer the mainland of any habitable planets.

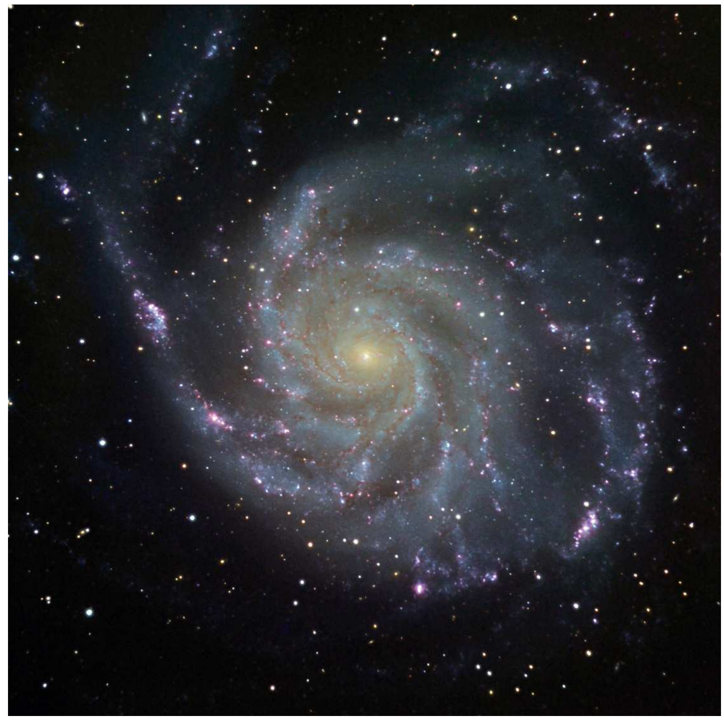
It is true that nearly all larger galaxies, including spirals, have gone through active phases during which their SMBHs have produced a quasar. That said, the effects have been much more intense in elliptical galaxies due to the proportionately greater mass of the black holes.

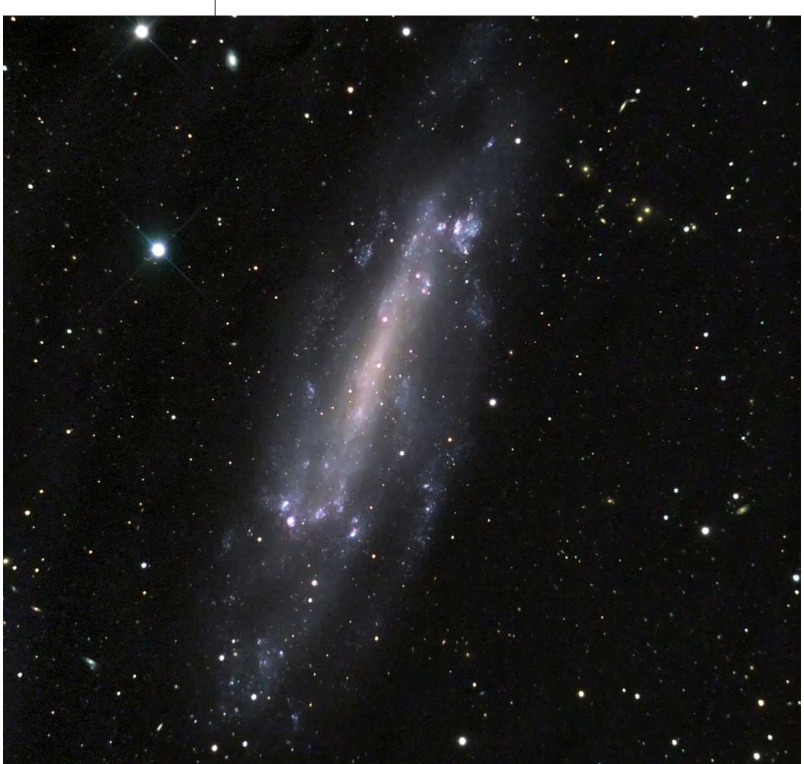
In a paper published in *Nature* in 2017, Amedeo Balbi and Francesco Tombesi (University of Rome "Tor Vergata") investigated the habitability of the Milky Way during the active phase of our SMBH, Sgr A*, to understand up to which distances and to what extent UV and X-ray radiation may have affected the loss of mass of planetary atmospheres and the development of life. The two researchers found that only within a few kiloparsecs (1 kpc = 3,262 light-years) of Sgr A* would the radiation have been lethal for any life forms hosted on the surface of Earth-like planets. Beyond about 7 kpc, all

A majestic group of galaxies dominated by the spiral NGC 7331 in the constellation Pegasus. [Cima Rest Astronomical Observatory, Magasa, Valvestino, Italy]

On the right is M101, also known as the Pinwheel Galaxy. It is located in Ursa Major and is about 1.5 times the size of the Milky Way. Below, the barred spiral NGC 4236 in the constellation Draco. [Cima Rest Astronomical Observatory, Magasa, Valvestino, Italy]

rocky planets with an atmosphere even less thick than that of the Earth would not have undergone permanent sterilization (our planet is located 8.2 kpc from the galactic center). According to Balbi and Tombesi, during the nearly 50 million years of strong activity of our galactic core, any Earth-like planet within the 7 kpc critical radius may have lost a significant part of its atmosphere, but probably not all. For large elliptical galaxies, the story is different, as their SMBHs are typically hundreds or thousands of times more massive than Sgr A* and are proportionally more intense – the radiation flux in the





past that flooded potentially habitable planets would have been biologically lethal. Since the progenitors of the current ellipticals were more compact, the devastating action of quasars must have necessarily affected almost all of the planets in those galaxies. If billions of years ago the Earth had been about 8 kpc from the quasar of an elliptical galaxy, it would have lost much of its atmosphere and perhaps today would be sterile.

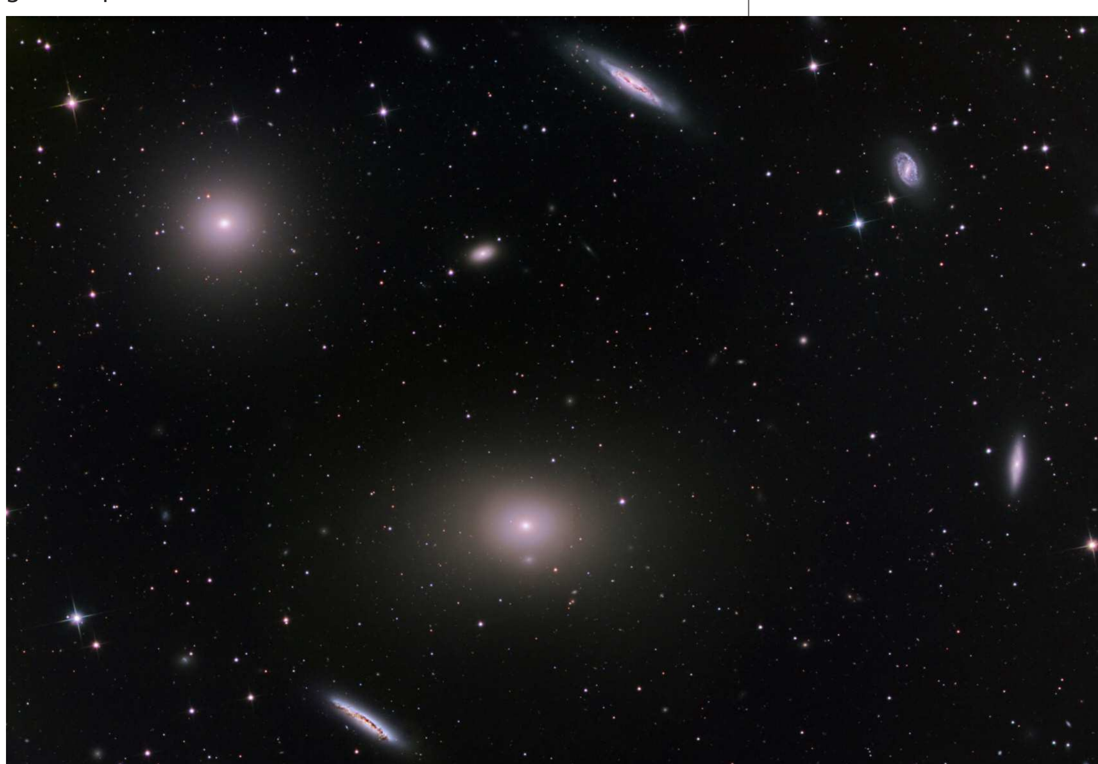
To argue that technological species are more likely to exist in elliptical galaxies, therefore, does not seem realistic, especially if we consider that the high metallicity of those galaxies, one of the strengths of Dayal and colleagues' work, is also one of its weakest points.

According to that same team, the relative number of gaseous planets in large elliptical galaxies is up to a thousand times that of the Milky Way. Hence, there would be a considerable disproportion between gaseous planets and terrestrial planets, caused by the high metallicity that, despite how one might associate the terms "metallicity" and "terrestrial," favors the

other technological species out there, why haven't they come into contact with us yet? Maybe they don't exist, maybe they don't want to contact us, maybe they don't know we exist, or maybe we are the most advanced at the moment.
The worst alternative is the last one, because the Milky Way is more than double the age of the Earth. Even if the metallicity has grown over time (thanks to

On the left, the spiral galaxy NGC 772 in the constellation Aries. It is twice the size of our own and has an asymmetric shape caused by gravitational interactions with its numerous satellite galaxies. [Cima Rest Astronomical Observatory, Magasa, Valvestino, Italy] Below, a part of the Virgo Cluster, dominated by the two large ellipticals M86 (near the center) and M84. [Greg Morgan (Sierra Remote Observatories)]

formation of the former in planetary systems. Various studies indicate that gaseous planets generally formed beyond the water condensation radius (4-6 AU for solar-type stars) and subsequently migrated into the interior of their planetary system. If the migration is relatively slow, the gaseous planets push the planetesimals of the less massive planets that are still forming in the warmer regions towards the star, preventing the birth of future potentially habitable planets.
In short, living in a spiral galaxy is arguably the more typical scenario for a technological species, while the existence of technological species within elliptical galaxies should be considered more of a violation of the principle of mediocrity.
Even so, our supposed "typical-ness" may not be good news. In fact, since we have only been technological for a century or so, if we are not among the very first in the Milky Way to reach this level, it means that those who preceded us did not last long. Paraphrasing the Fermi Paradox, if there are



the death of countless stars), it is difficult to imagine that life never appeared and evolved to the point of reaching an awareness of itself and the cosmos during our galaxy's first five or six billion years.
According to Whitmire, if our species were to become extinct within a much shorter

The spiral galaxy NGC 6946, located along the Cygnus-Cepheus border, is also known as the Fireworks Galaxy for the numerous star-forming regions. This is the main feature that distinguishes spirals from ellipticals (in addition to their shape). The elliptical galaxies are, in fact, considered dead from the point of view of the formation of new stars and new planets. What type of galaxy will be most suitable for hosting evolved life forms? [Cima Rest Astronomical Observatory, Magasa, Valvestino, Italy]

period of time than that during which the Sun will allow for the habitability of the emerged lands (1-2 billion years), it is possible that dozens of species might evolve up to a technological phase and then also quickly be extinguished.

Taking this into consideration, the striking contrast between the number of potentially habitable planets that likely exist in the Milky Way and the total absence of communications from alien civilizations could suggest that the extinction of a technological species coincides with the extinction of its entire biosphere, or at least of the animal species that populate the emerged lands. In this case, it is understandable that a few million or tens of millions of years would no longer be enough to go from a wild being to a technological being.

However questionable the principle of mediocrity is, especially if applied to a single datum, the fact is that we exist, that other evolved species like ours do not seem to exist, and that we are doing everything to destroy the biosphere that hosts us. In this sense, the principle of mediocrity would seem to have a predictive capacity which is perhaps the case to interpret to our advantage.

METIS instrument passes design milestone

by ESO

METIS, the powerful imager and spectrograph for ESO's Extremely Large Telescope (ELT), has passed its Preliminary Design Review at ESO's headquarters in Garching, Germany. METIS, short for Mid-infrared ELT Imager and Spectrograph, will make full use of the giant main mirror of the telescope to study a wide range of science topics, from objects in our Solar System to distant active galaxies. METIS will be extremely well suited to study the life cycle of stars, from infant stars and planet-forming discs to older stars near the end of their lifetime.

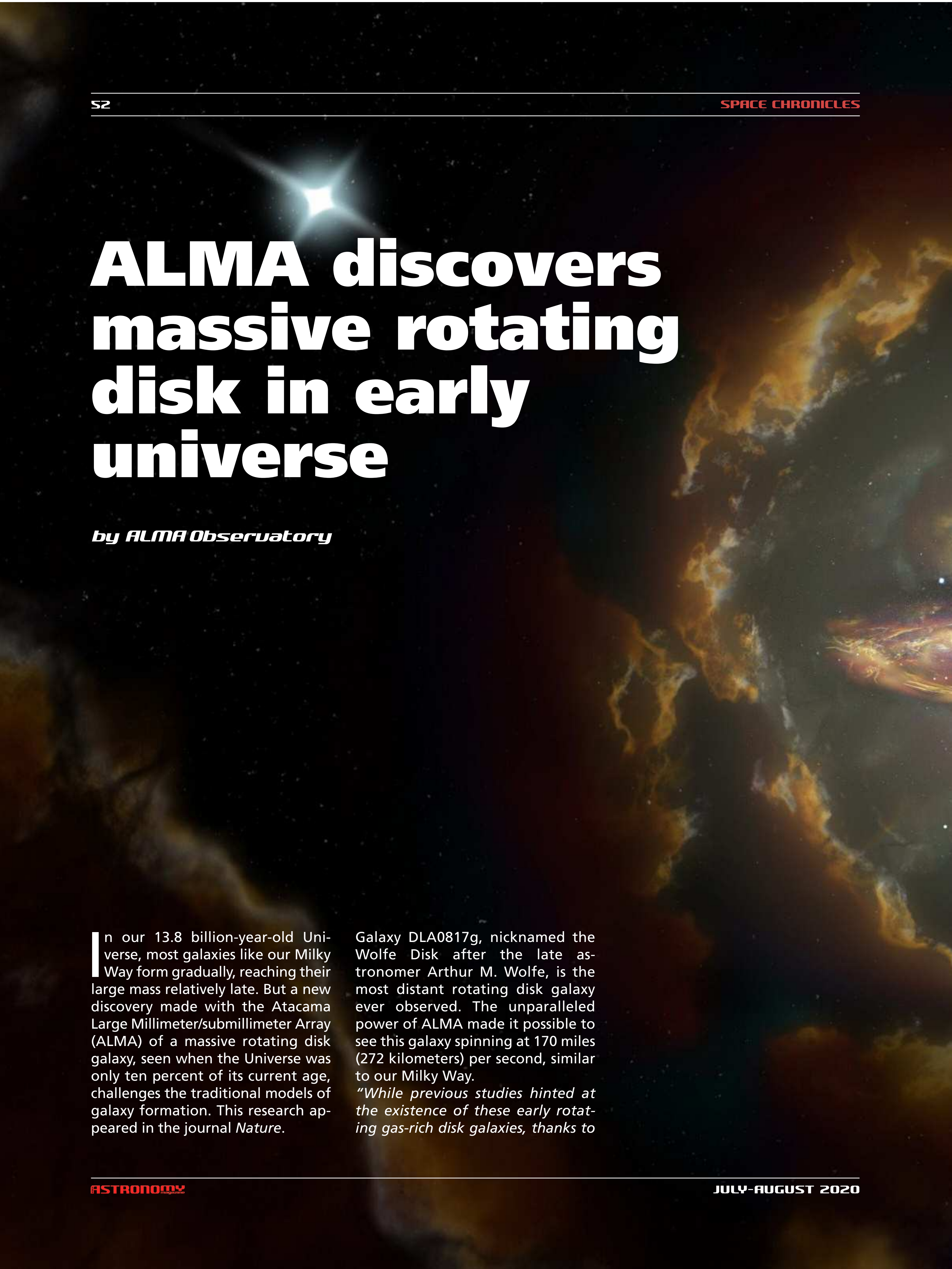
Group photo of the event "METIS Preliminary Design Review" (PDR), ESO Garching, 6-10 May 2019. [ESO]

Artist depiction of the METIS instrument set to be used with the Extremely Large Telescope upon completion. METIS, short for Mid-infrared ELT Imager and Spectrograph, will make full use of the giant main mirror of the telescope to study a wide range of science topics, from objects in our Solar System to distant active galaxies. [ESO/METIS Consortium/L. Calçada]

The ELT will be the largest optical to mid-infrared telescope on Earth when it starts operations towards the middle of this decade. With its 39-metre primary mirror and advanced adaptive-optics systems, it will have six times the resolution of the James Webb Space Telescope. METIS will take full advantage of this remarkable telescope and its adaptive optics to probe the structure and composition of objects with revolutionary precision.

Among others, METIS is expected to make large contributions to one of the most dynamic and exciting fields of astronomy for both scientists and the public, exoplanets. The instrument will be able to study the temperature, weather, and seasonal changes of the atmospheres of many giant exoplanets. Furthermore, METIS has the potential to directly detect terrestrial exoplanets around the nearest stars and, in favourable cases, investigate their atmospheric composition.

Now that the instrument has passed this Preliminary Design Review, the METIS consortium will continue to develop its design in further detail before construction on the instrument starts. ■



ALMA discovers massive rotating disk in early universe

by ALMA Observatory

In our 13.8 billion-year-old Universe, most galaxies like our Milky Way form gradually, reaching their large mass relatively late. But a new discovery made with the Atacama Large Millimeter/submillimeter Array (ALMA) of a massive rotating disk galaxy, seen when the Universe was only ten percent of its current age, challenges the traditional models of galaxy formation. This research appeared in the journal *Nature*.

Galaxy DLA0817g, nicknamed the Wolfe Disk after the late astronomer Arthur M. Wolfe, is the most distant rotating disk galaxy ever observed. The unparalleled power of ALMA made it possible to see this galaxy spinning at 170 miles (272 kilometers) per second, similar to our Milky Way.

"While previous studies hinted at the existence of these early rotating gas-rich disk galaxies, thanks to

Artist impression of the Wolfe Disk, a massive rotating disk galaxy in the early, dusty Universe. The galaxy was initially discovered when ALMA examined the light from a more distant quasar (top left). [NRAO/AUI/NSF, S. Dagnello]

ALMA we now have unambiguous evidence that they occur as early as 1.5 billion years after the Big Bang," said lead author Marcel Neeleman of the Max Planck Institute for Astronomy in Heidelberg, Germany. The discovery of the Wolfe Disk provides a challenge for many galaxy formation simulations, which predict that massive galaxies at this point in the evolution of the cosmos grew through many mergers of smaller galaxies and hot clumps of gas. *"Most galaxies that we find early in the Universe look like train wrecks because they underwent consistent and often 'violent' merging,"* explained Neeleman. *"These hot mergers make it difficult to form well-ordered, cold rotating disks like we observe in our present Universe."*

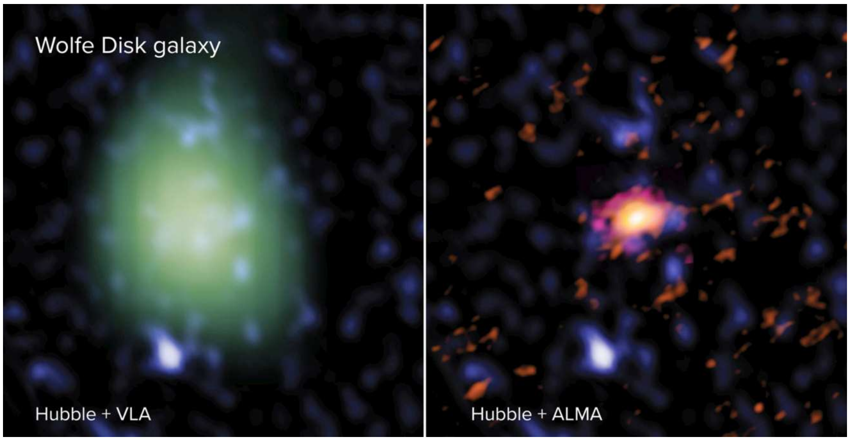
In most galaxy formation scenarios, galaxies only start to show a well-formed disk around 6 billion years after the Big Bang. The fact that the astronomers found such a disk galaxy when the Universe was only ten percent of its current age, indicates that other growth processes must have dominated.

"We think the Wolfe Disk has grown primarily through the steady accretion of cold gas," said J. Xavier Prochaska, of the University of California, Santa Cruz and coauthor of the paper. *"Still, one of the questions that remains is how to assemble such a large gas mass while maintaining a relatively stable, rotating disk."*

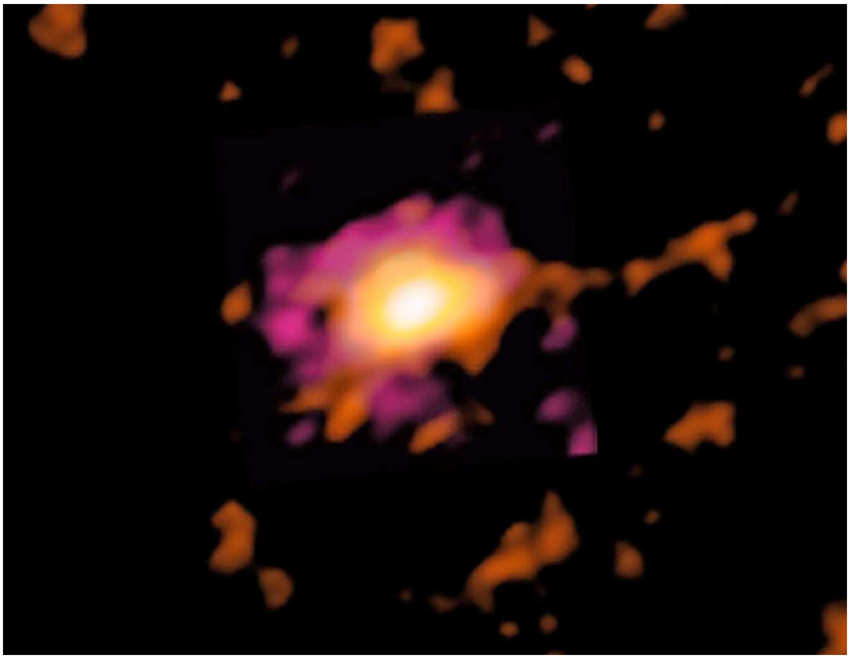
The team also used the National Science Foundation's Karl G. Jansky Very Large Array (VLA) and the NASA/ESA Hubble Space Telescope to learn more about star formation in the Wolfe Disk. In radio wavelengths, ALMA looked at the galaxy's movements and mass of atomic gas and dust while the VLA measured the amount of molecular mass – the fuel for star formation. In UV-light, Hubble observed massive stars.

"The star formation rate in the Wolfe Disk is at least ten times higher than in our own galaxy," explained Prochaska. *"It must be one of the most productive disk galaxies in the early Universe."*

The Wolfe Disk was first discovered by ALMA in 2017. Neeleman and his team found the galaxy when they examined the light from a more distant quasar. The light from the quasar was absorbed as it passed through a massive reservoir of hydrogen gas surrounding the galaxy – which is how it revealed itself. Rather than looking for direct light from extremely bright, but more rare galaxies, astronomers used this 'absorption' method to find fainter, and more 'normal' galaxies in the early Universe.



The Wolfe Disk as seen with ALMA (right – in red), VLA (left – in green) and the Hubble Space Telescope (both images – blue). In radio light, ALMA looked at the galaxy's movements and mass of atomic gas and dust and the VLA measured the amount of molecular mass. In UV-light, Hubble observed massive stars. The VLA image is made in a lower spatial resolution than the ALMA image, and therefore looks larger and more pixelated. [ALMA (ESO/NAOJ/NRAO), M. Neeleman; NRAO/AUI/NSF, S. Dagnello; NASA/ESA Hubble]



ALMA radio image of the Wolfe Disk, seen when the Universe was only ten percent of its current age. [ALMA (ESO/NAOJ/NRAO), M. Neeleman; NRAO/AUI/NSF, S. Dagnello]

"The fact that we found the Wolfe Disk using this method, tells us that it belongs to the normal population of galaxies present at early times," said Neeleman. *"When our newest observations with ALMA surprisingly showed that it is rotating, we realized that early rotating disk galaxies are not as rare as we thought and that there should be a lot more of them out there."*

"This observation epitomizes how our understanding of the Universe is enhanced with the advanced sensitivity that ALMA brings to radio astronomy," said Joe Pesce, astronomy program director at the National Science Foundation, which funds the telescope. *"ALMA allows us to make new, unexpected findings with almost every observation."*


NORTHEK
INSTRUMENTS - COMPOSITES - OPTICS
www.northek.it
www.facebook.com/northek.it
info@northek.it
phone +39 01599521
Ritchey-Chrétien
➤ SCHOTT Supremax 33 optics
➤ optical diameter 355 mm
➤ useful diameter 350 mm
➤ focal length 2800 mm
➤ focal ratio f/8
➤ 18-point floating cell
➤ customized focuser
Dall-Kirkham
➤ SCHOTT Supremax 33 optics
➤ optical diameter 355 mm
➤ useful diameter 350 mm
➤ focal length 7000 mm
➤ focal ratio f/20
➤ 18-point floating cell
➤ Feather Touch 2.5" focuser
Cassegrain
➤ SCHOTT Supremax 33 optics
➤ optical diameter 355 mm
➤ useful diameter 350 mm
➤ focal length 5250 mm
➤ focal ratio f/15
➤ 18-point floating cell
➤ Feather Touch 2.5" focuser
QUARTZ