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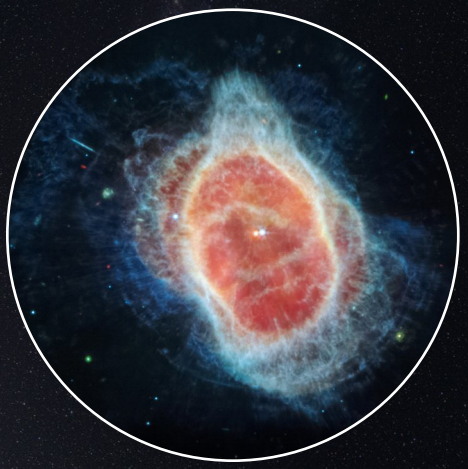
FREE ASTRONOMY magazine

Bi-monthly magazine of scientific and technical information ✶ September-October 2022

A new era of astronomy has begun



The Pentagon and NASA are on the hunt for UAPs

- Signs of rotation in a early galaxy
- Dead star caught ripping up planetary system
- Planet Nine increasingly unreachable
- A dormant black hole outside our galaxy
- First recording of a short GRB at millimeter wavelengths

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A new era of astronomy has begun

by NASA, ESA, CSA, STScI

The dawn of a new era in astronomy has begun as the world gets its first look at the full capabilities of NASA's James Webb Space Telescope, a partnership with ESA (European Space Agency) and CSA (Canadian Space Agency). The telescope's first full-color images and spectroscopic data were released during a televised broadcast at 10:30 a.m. EDT (14:30 UTC) on Tuesday, July 12, 2022, from NASA's Goddard Space Flight Center in Greenbelt, Maryland. These initial targets represent the first wave of full-color scientific images and spectra the observatory has gathered, and the official beginning of Webb's general science operations. They were selected by an international committee of representatives from NASA, ESA, CSA, and the Space Telescope Science Institute.

In the following pages, we present the best of the images so far sent to Earth by Webb. The world's largest and most powerful space telescope is ready to begin its mission to unfold the infrared universe. Stay tuned!

JAMES WEBB SPACE TELESCOPE

DEEP FIELD | SMACS 0723

Galaxy cluster SMACS 0723, affectionately known as Webb's First Deep Field, captured by Webb's Near-Infrared Camera (NIRCam), with compass arrows and color key for reference. All images taken by Webb show invisible near-infrared wavelengths of light that have been translated into visible-light colors. The color of each filter name is the visible light color used to represent the infrared light that passes through that filter. [NASA, ESA, CSA, STScI]

NIRCam Filters | F090W F150W F200W F277W F356W F444W

JAMES WEBB SPACE TELESCOPE

CARINA NEBULA | NGC 3324

The Carina Nebula (NGC 3324) captured by Webb's Near-Infrared Camera (NIRCam). What looks much like craggy mountains on a moonlit evening is actually the edge of a nearby, young, star-forming region. The field of view shown in this image is approximately 16 light-years across. [NASA, ESA, CSA, STScI]

NIRCam Filters | F090W F187N F200W F470N F335M F444W

JAMES WEBB SPACE TELESCOPE

CARINA NEBULA | NGC 3324

Composite image of the Carina Nebula (NGC 3324) captured by Webb's Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI), with compass arrows, scale bar, and color key for reference. [NASA, ESA, CSA, STScI]

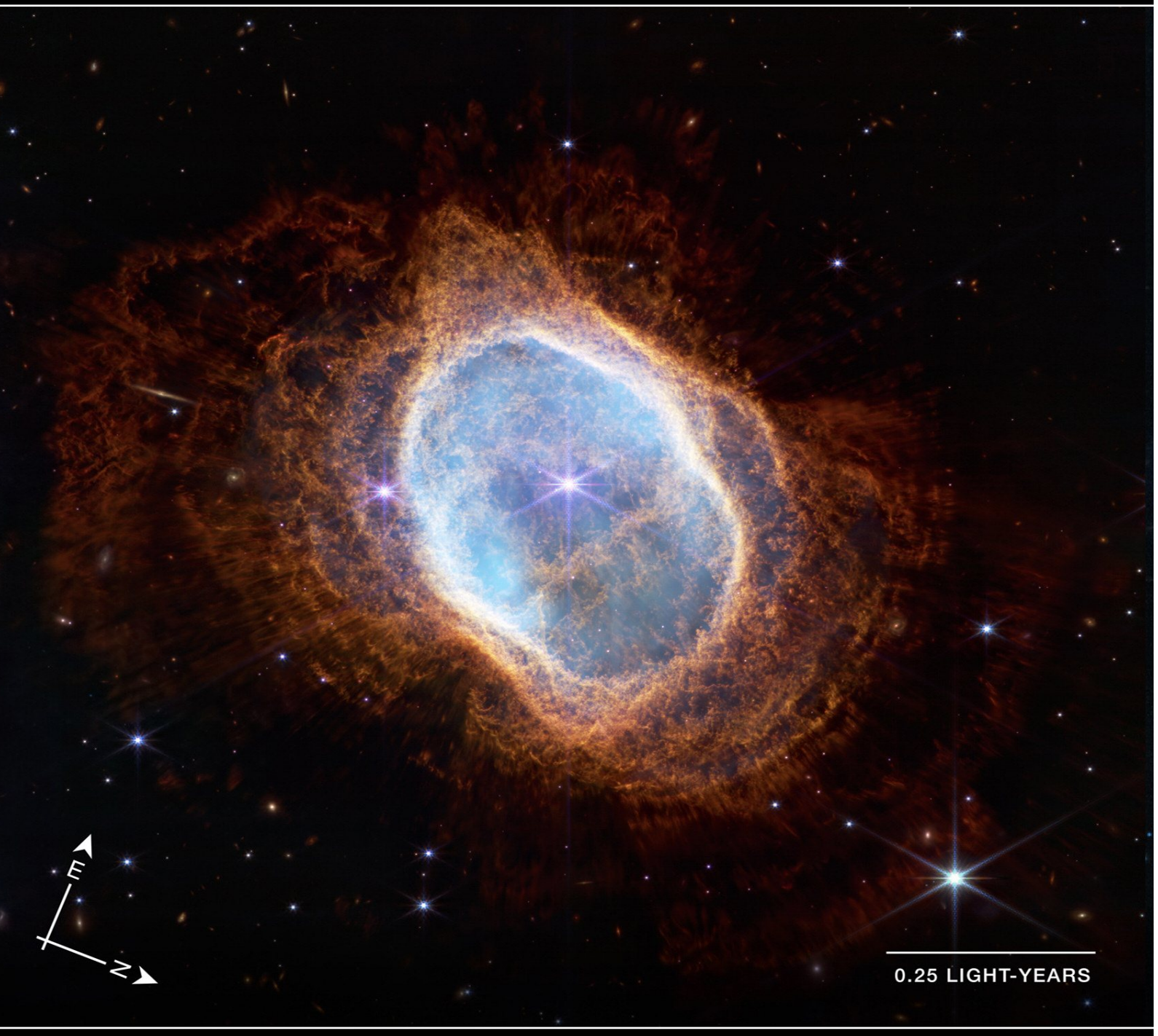
NIRCam Filters | F090W F200W F444W

MIRI Filters | F770W F1130W F1280W F1800W

JAMES WEBB SPACE TELESCOPE

SOUTHERN RING | NGC 3132

The Southern Ring Nebula (NGC 3132), captured by Webb's Near-Infrared Camera (NIRCam). The bright star at the center of NGC 3132, while prominent when viewed by NASA's Webb Telescope in near-infrared light, plays a supporting role in sculpting the surrounding nebula. The field of view shown in this image is approximately 1.4 light-years across. [NASA, ESA, CSA, STScI]



NIRCam Filters | F090W F187N F212N F356W F405N F470N

JAMES WEBB SPACE TELESCOPE

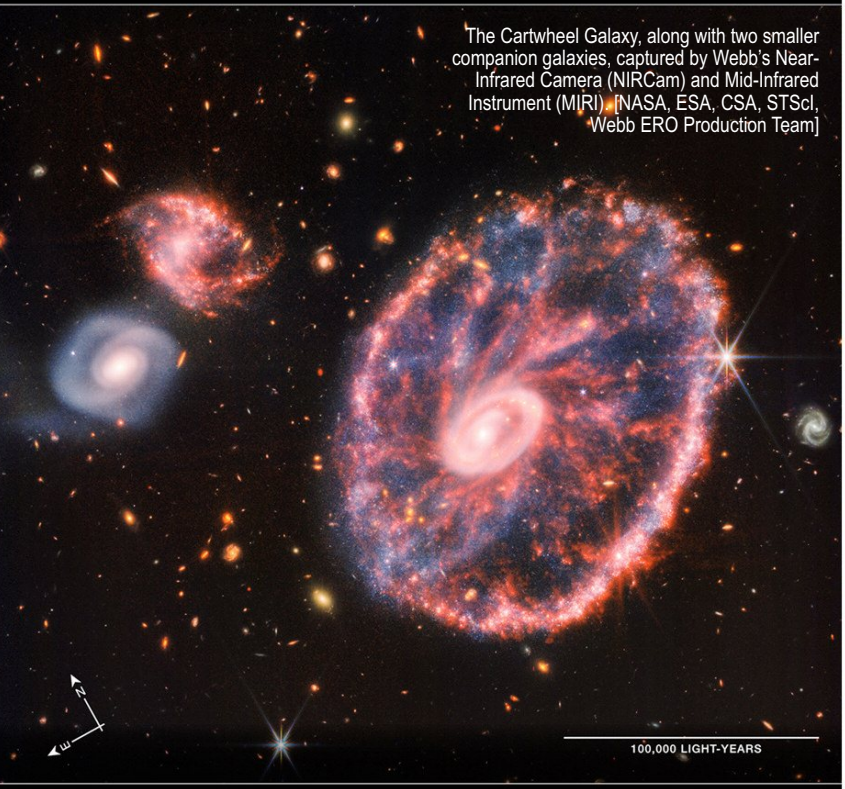
SOUTHERN RING | NGC 3132

The Southern Ring Nebula (NGC 3132), captured by Webb's Mid-Infrared Instrument (MIRI), shows compass arrows, scale bar, and color key for reference. NASA's Webb Telescope has revealed the cloak of dust around the second star, shown at left in red, at the center of the Southern Ring Nebula for the first time. It is a hot, dense white dwarf star. [NASA, ESA, CSA, STScI]

MIRI Filters F770W F1130W F1280W F1800W

JAMES WEBB SPACE TELESCOPE

CARTWHEEL GALAXY | ESO 350-40



The Cartwheel Galaxy, along with two smaller companion galaxies, captured by Webb's Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI). [NASA, ESA, CSA, STScI, Webb ERO Production Team]

NIRCam Filters | F090W F150W F200W F277W F356W F444W

MIRI Filters | F770W F1000W F1280W F1800W

JAMES WEBB SPACE TELESCOPE

CARTWHEEL GALAXY | ESO 350-40

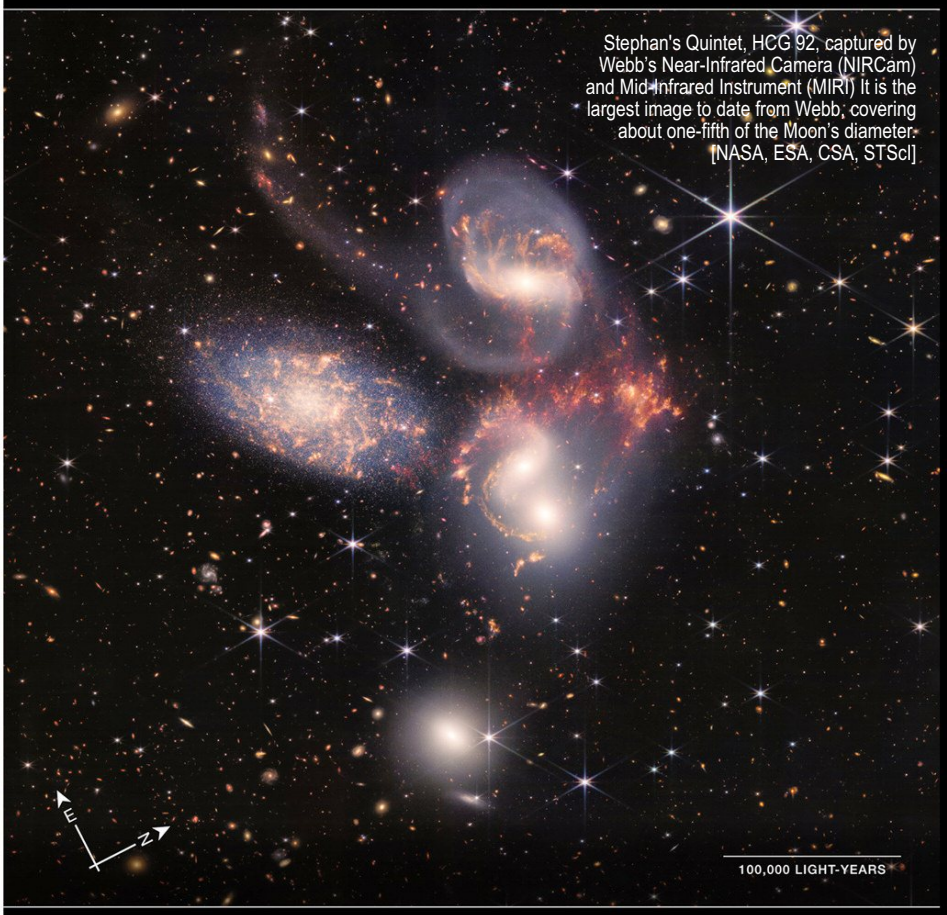
The Cartwheel Galaxy captured by Webb's Mid-Infrared Instrument (MIRI). The field of view shown in this image is approximately 305,000 light-years across. [NASA, ESA, CSA, STScI, Webb ERO Production Team]

MIRI Filters | F770W F1000W F1280W F1800W

In celebration of the release of NASA's James Webb Space Telescope's first images on July 12, 2022, they were displayed in Times Square. This image shows the Southern Ring Nebula. [NASDAQ (used with permission)]

JAMES WEBB SPACE TELESCOPE

STEPHAN'S QUINTET | HCG 92



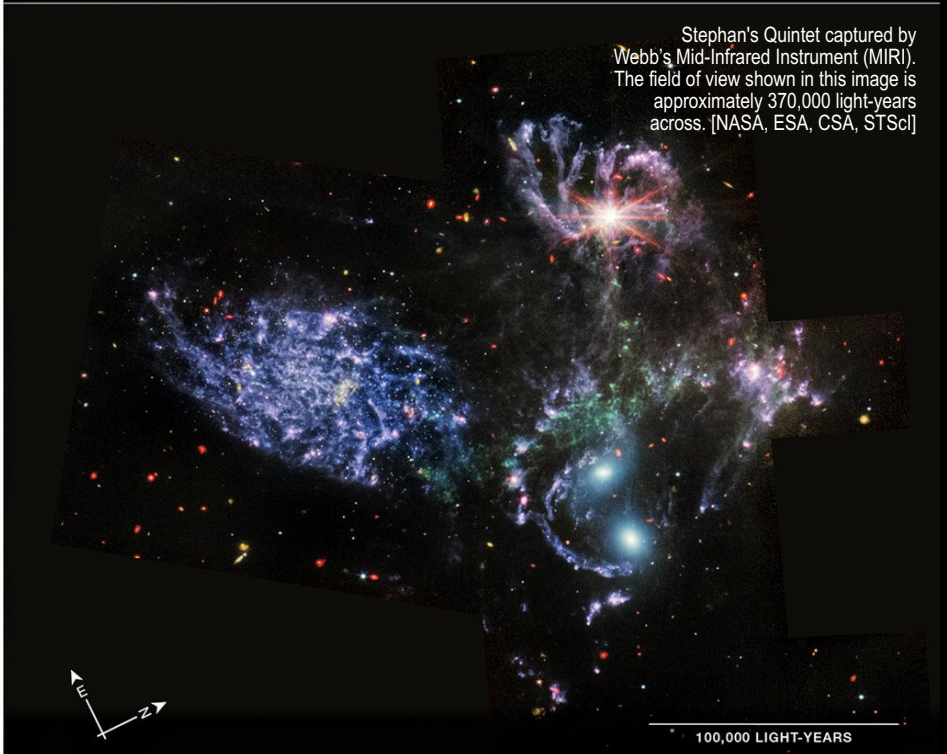
Stephan's Quintet, HCG 92, captured by Webb's Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI) It is the largest image to date from Webb, covering about one-fifth of the Moon's diameter. [NASA, ESA, CSA, STScI]

NIRCam Filters | F090W F150W F200W F277W F356W F444W

MIRI Filters | F770W F1000W

JAMES WEBB SPACE TELESCOPE

STEPHAN'S QUINTET | HCG 92



Stephan's Quintet captured by Webb's Mid-Infrared Instrument (MIRI). The field of view shown in this image is approximately 370,000 light-years across. [NASA, ESA, CSA, STScI]

MIRI Filters | F770W F1000W F1500W

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 optic allows for rapid acclimatization and ensures thermal stability throughout the night. Two bars equipped with sliding weights allow for the perfect balance of the telescope and accessories. On demand, it is also possible to modify the support to mount the telescope on an equatorial platform.
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It is undoubtedly the best altazimuth Newtonian on the market.

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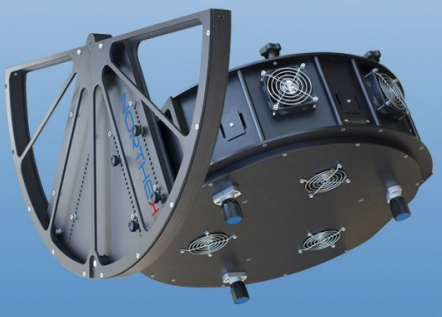
images by Massimo Vesnaver

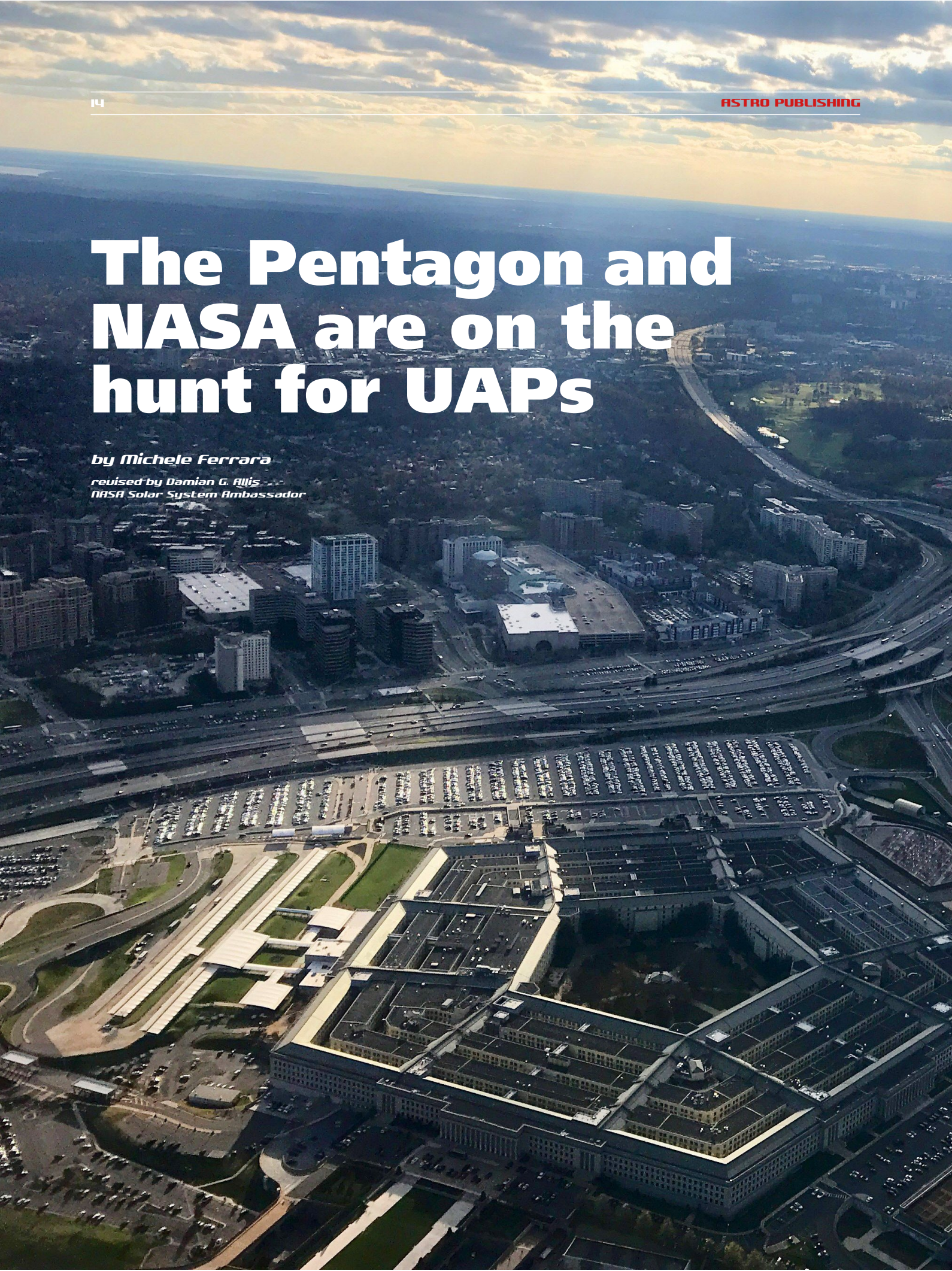


M P O S I T E S - O P T I C S

The Pentagon and NASA are on the hunt for UAPs

by Michele Ferrara

revised by Damian G. Allis
NASA Solar System Ambassador

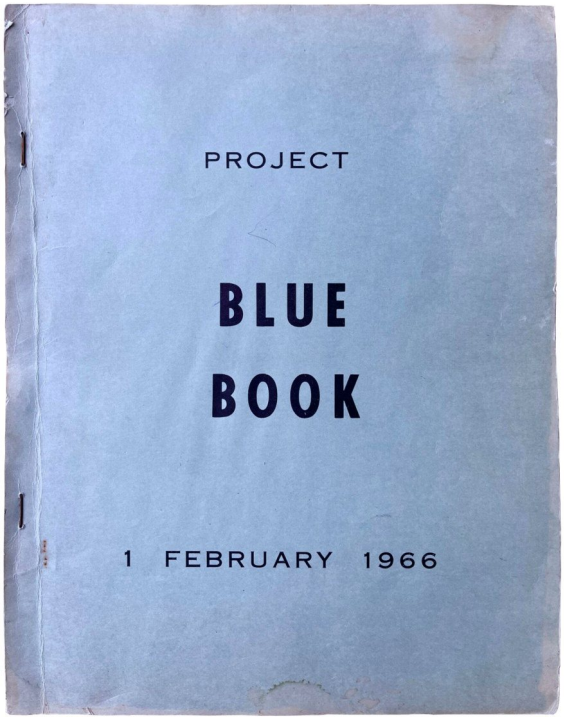


In the background is the Pentagon, headquarters of the United States Department of Defense. [Kiyoshi Tanno] Above, NASA headquarters, or "NASA HQ", formally known as the Mary W. Jackson NASA Headquarters and formerly called Two Independence Square. Hidden Figures Way is a dedication to all those who worked as computers and made possible the first space missions of the USA.

The less-young readers (or the better-informed ones) may remember "Project Blue Book." This was the code name of a systematic study of unidentified flying objects (UFOs) conducted between 1952 and 1969 by the US Air Force. Project Blue Book had the dual task of establishing whether those mysterious "aircraft" could pose a threat to national security and of scientifically analyzing the data collected after each sighting.

Curiously, but not coincidentally, the phenomenon of UFOs originated during the Second World War and grew exponentially in the following two decades, parallel to the need for military superpowers to develop new technologies to strengthen their geopolitical dominance. It is true that even in the centuries preceding the twentieth century there was evidence of unusual celestial sightings in the chronicles of some civilizations. That said, the mysticism that often characterized their documentation allows now for only rarely reasonable interpretations of what was reported.

Project Blue Book collected over 12,000 reports, highlighting how most of all reported sightings were explainable by natural phenomena,



PROJECT BLUE BOOK

The United States Air Force has the responsibility under the Department of Defense for the investigation of unidentified flying objects (UFOs). The name of this program, which has been in operation since 1948, is Project Blue Book. It has been identified in the past as Project Sign and Project Grudge.

Air Force interest in unidentified flying objects is related directly to the Air Force responsibility for the air defense of the United States. Procedures for conducting this program are established by Air Force Regulation 200-2.

The objectives of Project Blue Book are two-fold: first, to determine whether UFOs pose a threat to the security of the United States; and, second, to determine whether UFOs exhibit any unique scientific information or advanced technology which could contribute to scientific or technical research. In the course of accomplishing these objectives, Project Blue Book strives to identify and explain all UFO sightings reported to the Air Force.

CONCLUSIONS

To date, the firm conclusions of Project Blue Book are: (1) no unidentified flying object reported, investigated, and evaluated by the Air Force has ever given any indication of threat to our national security; (2) there has been no evidence submitted to or discovered by the Air Force that sightings categorized as unidentified represent technological developments or principles beyond the range of present day scientific knowledge; and (3) there has been no evidence indicating that sightings categorized as unidentified are extraterrestrial vehicles.

The Air Force will continue to investigate all reports of unusual aerial phenomena over the United States. The services of qualified scientists and technicians will continue to be used to investigate and analyze these reports, and periodic reports on the subject will be made.

The Air Force does not deny the possibility that some form of life may exist on other planets in the universe. However, to date, the Air Force has neither received nor discovered any evidence which proves the existence and intra-space mobility of extraterrestrial life. The Air Force continues to extend an open invitation to anyone who feels that he possesses any evidence of extraterrestrial vehicles operating within the earth's near space envelope to submit his evidence for analysis. Initial contact for this purpose is through the following address:

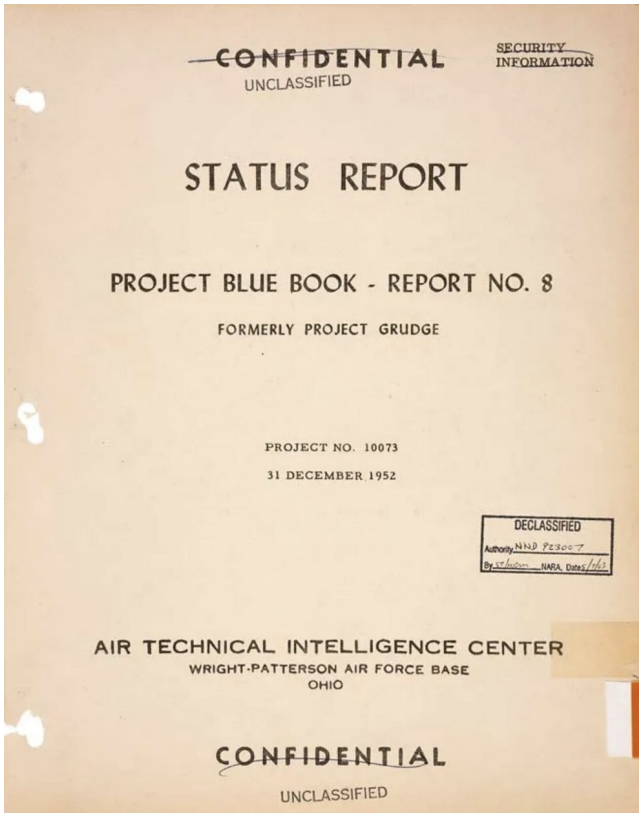
PROJECT BLUE BOOK INFORMATION OFFICE
SAFOI
WASHINGTON, D C 20330

One of the many periodic reports of Project Blue Book, with which the USAF took stock of unidentified flying objects. In the excerpt on the side, in addition to the introductory presentation of the project, conclusions practically coinciding with those drawn in the following decades by all the data analysis programs collected are reported.

conventional aircraft, and mystification. A small fraction of the sightings could be traced back to flight tests of experimental military aircraft, while about 700 cases remain unexplained. "Unexplained" should be interpreted as there simply not being enough elements to define the nature of what was observed. For many science fiction enthusiasts, "unexplained" became synonymous with aliens. "Coincidently," in the second half of the 1950s and with Project Blue Book fully operational, the "field" of ufology was born. The followers of this pseudoscience appropriately ignored the conclusions of the USAF, summarized in the famous Condon Report: 1) no investigated sightings indicated possible threats to national security; 2) there was no evidence that the sightings classified as "unidentified" were attributable to technologies and scientific knowledge superior to those of the time; 3) there was no evidence to believe that the unidenti-

Captain Edward Ruppelt (standing in the center, at a 1952 press conference) was the first director of Project Grudge (1951) and then director of Project Blue Book (from March 1952 until the end of 1953).

A report relating to the first year of activity of Project Blue Book, with the guidelines of a questionnaire (right) that the sightings investigators had to fill out based on the collected testimonies. Below is a form completed on January 30, 1956, following the sighting of what turned out to be a meteorological balloon. All such documents were initially covered by military secrecy.



CONFIDENTIAL
UNCLASSIFIED

SECURITY INFORMATION

STATUS REPORT

PROJECT BLUE BOOK - REPORT NO. 8

FORMERLY PROJECT GRUDGE

PROJECT NO. 10073

31 DECEMBER 1952

DECLASSIFIED
Authority NND 963007
By jrh NARA, Date 7/6/2

AIR TECHNICAL INTELLIGENCE CENTER
WRIGHT-PATTERSON AIR FORCE BASE
OHIO

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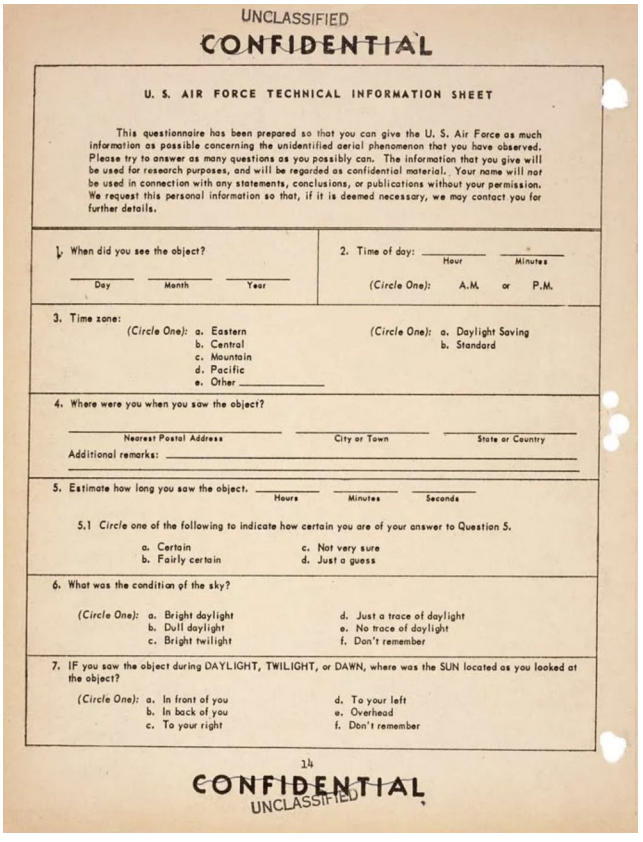

UNCLASSIFIED
CONFIDENTIAL

U. S. AIR FORCE TECHNICAL INFORMATION SHEET

This questionnaire has been prepared so that you can give the U. S. Air Force as much information as possible concerning the unidentified aerial phenomenon that you have observed. Please try to answer as many questions as you possibly can. The information that you give will be used for research purposes, and will be regarded as confidential material. Your name will not be used in connection with any statements, conclusions, or publications without your permission. We request this personal information so that, if it is deemed necessary, we may contact you for further details.

1. When did you see the object? Day / Month / Year
2. Time of day: Hour / Minutes (Circle One): A.M. or P.M.
3. Time zone: (Circle One): a. Eastern b. Central c. Mountain d. Pacific e. Other ____ (Circle One): a. Daylight Saving b. Standard
4. Where were you when you saw the object? Nearest Postal Address / City or Town / State or Country
Additional remarks: ____
5. Estimate how long you saw the object. Hours / Minutes / Seconds
5.1 Circle one of the following to indicate how certain you are of your answer to Question 5.
a. Certain b. Fairly certain c. Not very sure d. Just a guess
6. What was the condition of the sky?
(Circle One): a. Bright daylight b. Dull daylight c. Bright twilight d. Just a trace of daylight e. No trace of daylight f. Don't remember
7. IF you saw the object during DAYLIGHT, TWILIGHT, or DAWN, where was the SUN located as you looked at the object?
(Circle One): a. In front of you b. In back of you c. To your right d. To your left e. Overhead f. Don't remember

14

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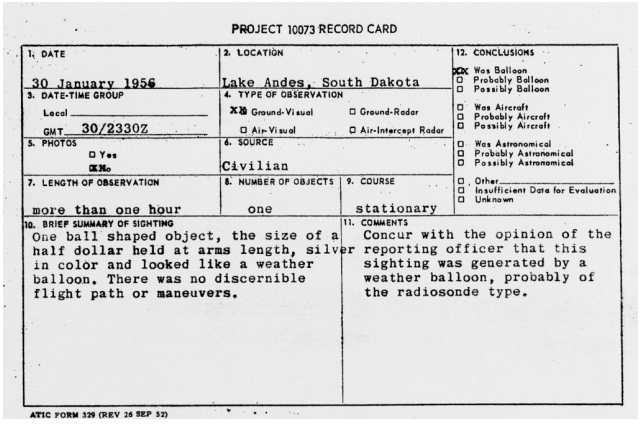


PROJECT 10073 RECORD CARD

1. DATE: 30 January 1956	2. LOCATION: Lake Andes, South Dakota	12. CONCLUSIONS: XX Was Balloon; ☐ Probably Balloon; ☐ Possibly Balloon
3. DATE-TIME GROUP: Local ____ GMT 30/2330Z	4. TYPE OF OBSERVATION: XX Ground-Visual; ☐ Ground-Radar; ☐ Air-Visual; ☐ Air-Intercept Radar	☐ Was Aircraft; ☐ Probably Aircraft; ☐ Possibly Aircraft
5. PHOTOS: ☐ Yes XX No	6. SOURCE: Civilian	☐ Was Astronomical; ☐ Probably Astronomical; ☐ Possibly Astronomical
7. LENGTH OF OBSERVATION: more than one hour	8. NUMBER OF OBJECTS: one	9. COURSE: stationary; ☐ Other ____; ☐ Insufficient Data for Evaluation; ☐ Unknown

10. BRIEF SUMMARY OF SIGHTING: One ball shaped object, the size of a half dollar held at arms length, silver in color and looked like a weather balloon. There was no discernible flight path or maneuvers.

11. COMMENTS: Concur with the opinion of the reporting officer that this sighting was generated by a weather balloon, probably of the radiosonde type.

ATIC FORM 329 (REV 26 SEP 52)

fied flying objects were extraterrestrial vehicles.

During and after Project Blue Book, other nations besides the USA launched study campaigns into the phenomenon, obtaining the same inconclusive results.

With the sole exception of ufology fanatics (often also lovers of conspiracy), no government, no military force and no scientist has ever seriously believed that the Earth's atmosphere has been repeatedly visited by a jumble of alien technologies. In the USA, this awareness, coupled with the fact that some sightings have taken place near military facilities, has gradually reinforced the suspicion that a not-insignificant part of the reported episodes might have to do with technologies from other nations, China in particular. This scenario led, in 2007, to the financing by the US government (and to the management by the Defense Intelligence Agency, or DIA) of the Advanced Aviation Threat Identification Program (AATIP), a five-year investigation that was supposed to establish the level of danger of that phenomenon, which was now indicated with the less equivocal acronym UAP – Unidentified Aerial Phenomena. Officially, the AATIP ended in 2012 without adding any-

thing significant to what was already known about UAPs. However, as revealed at the end of 2017 by the *New York Times* and *Politico*, the AATIP continued its activity even after the scheduled deadline thanks to funding from the Pentagon, an arrangement officially confirmed only in June 2020 when the investigation program was rebranded as the Unidentified Aerial Phenomena Task Force (UAPTF) and it had its management transferred to the Office of Naval Intelligence. The aims of this "new" program were the usual ones: to deepen the knowledge of the UAP phenomenon and understand the nature and origin of the sightings, all for the benefit of national security. The UAPTF program continued until November 2021, after which it was replaced by the Airborne Object Identification and Management Synchronization Group (AOIMSG), overseen by a group of experts from the military and intelligence communities.

The three famous videos recorded in 2004 and 2015 by US Navy pilots aboard planes that took off from the aircraft carriers USS Nimitz and USS Theodore Roosevelt. The videos, called "FLIR", "GIMBAL" and "GO-FAST", show nothing that transcend our current knowledge of physics. According to astrophysicist Adam Frank, maybe the objects framed in the videos are "drones deployed by rivals like Russia and China to examine our defenses — luring our pilots into turning on their radar and other detectors, thus revealing our electronic intelligence capabilities." [United States Navy]

In April 2020, to silence imaginative rumors, the Pentagon confirmed the authenticity of three videos recorded by US Navy pilots, showing encounters with what appear to be unusual aircraft. The videos had been previously released by some

The associate administrator for the direction of NASA's scientific mission, Thomas Zurbuchen, on June 9, 2022, announced the agency's entry into the field of the study of unidentified aerial phenomena. NASA's program will be independent of all others.

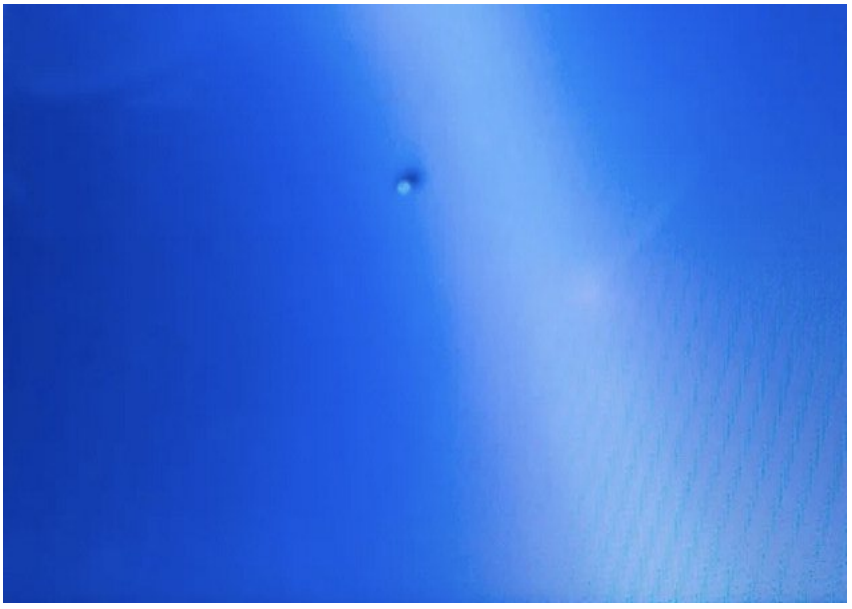
media, so much so that Sue Gough, spokesman for the Department of Defense, specified that the Pentagon's statement was aimed at *"clarifying any misconceptions from the public on the fact that the footages circulated were real or not."*
One of the videos is from November 2004, while the other two are from February 2015. Unlike what was reported by several sources, none of the three alleged objects visible in the recordings exhibited extraordinary aerodynamic capabilities or were disrespectful of the laws of physics as we know it.
After this demonstration of transparency by the Pentagon (which added nothing to what was already known), the cold shower of reality rained down upon enthusiastic ufologists in June of last year: a report by the US Intelligence Community defined as "largely inconclusive" the set of evidence collected on UAPs between 2004 and 2021. Among the thousands of sightings reported in that long period, there are 144 made by military and other personnel linked to the US government. Eighteen unidentified objects were observed from different angles that performed unexplainable maneuvers. It is widely believed at the Pentagon that a non-negligible percentage of all objects sighted by USAF pilots that escaped identification might be drones with advanced technologies, developed secretly by China or Russia. Hypersonic missiles are an example of technology developed in advance by these two superpowers compared to the US, which only successfully tested them last July. The US, for its part, built the so-called stealth aircraft several years in advance. Now the competition seems to have shifted to military drones, which is why there is more terrestrial interest than ever in the study of UAPs.

Senator Mark Warner (center), chairman of the Senate Intelligence Committee, is one of the politicians most committed to UAP study efforts. [Chip Somodevilla/ Getty Immagini]

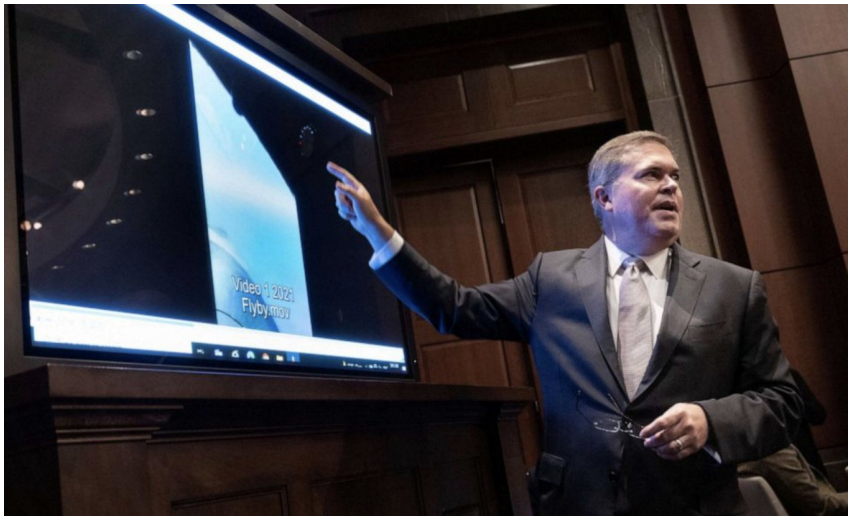
The nine-page US Intelligence Community report does not discuss any specific case and is the public version of a more detailed classified version being supplied to the armed services and intelligence committees of Congress. Mark Warner, chairman of the Senate Intelligence Committee, said the frequency of UAP reports *"appears to be increasing since 2018."*

"The rather inconclusive intelligence report marks the beginning of efforts to understand and illuminate what is causing these risks to aviation in many areas around the country and the world," Warner said in a statement. *"The United States must be able to understand and mitigate threats to our pilots, whether they're from drones or weather balloons or adversary intelligence capabilities."*

In recent years, interest in unidentified aerial phenomena has grown beyond just the US Department of Defense. NASA is interested as well, officially joining the hunt for UAPs a few months ago to study the sightings from a scientific perspective. This happened on June 9, when Thomas Zurbuchen (associate administrator for NASA's Science Mission Directorate) presented an update on the agency's program at a joint meeting of the National Academies Space Studies Board and the Aeronautics and Space Engineering Board, which included an independent study scheme of UAPs. The study will focus on collecting available data, how best to collect future data, and how NASA can use that data to advance scientific understanding of UAPs. Daniel Evans, the NASA scientist responsible for coordinating the study (which begins this fall and will run for at least nine months) stressed that *"over the decades, NASA has answered the call to tackle some of the most perplexing mysteries we know of, and this is no different."*



Frame from a video of a UAP shown during a hearing of the Internal Intelligence, Counterterrorism, Counterintelligence and Counterproliferation Subcommittee on "Unidentified Aerial Phenomena", at Capitol Hill on Tuesday, May 17, 2022, in Washington. As usual, all that it is shown is an indistinct stain that lends itself to the most imaginative of interpretations.



Deputy Director of Naval Intelligence Scott Bray comments on a video of unidentified aerial phenomena during a House Intelligence Subcommittee hearing at the U.S. Capitol on May 17, 2022, in Washington, DC. It was the first public congressional hearing on UAPs in 50 years.

"With its access to a broad range of scientific tools, NASA is well-placed not just to demystify UFOs and deepen scientific understanding, but also to find ways to mitigate the phenomena, a key part of its mission to ensure the safety of aircraft," Zurbuchen added.

The NASA study will be independent of the Pentagon's Airborne Object Identification and Management Synchronization Group and will help stem the set of falsehoods and speculations that typically characterize sightings of unidentified flying objects. ■

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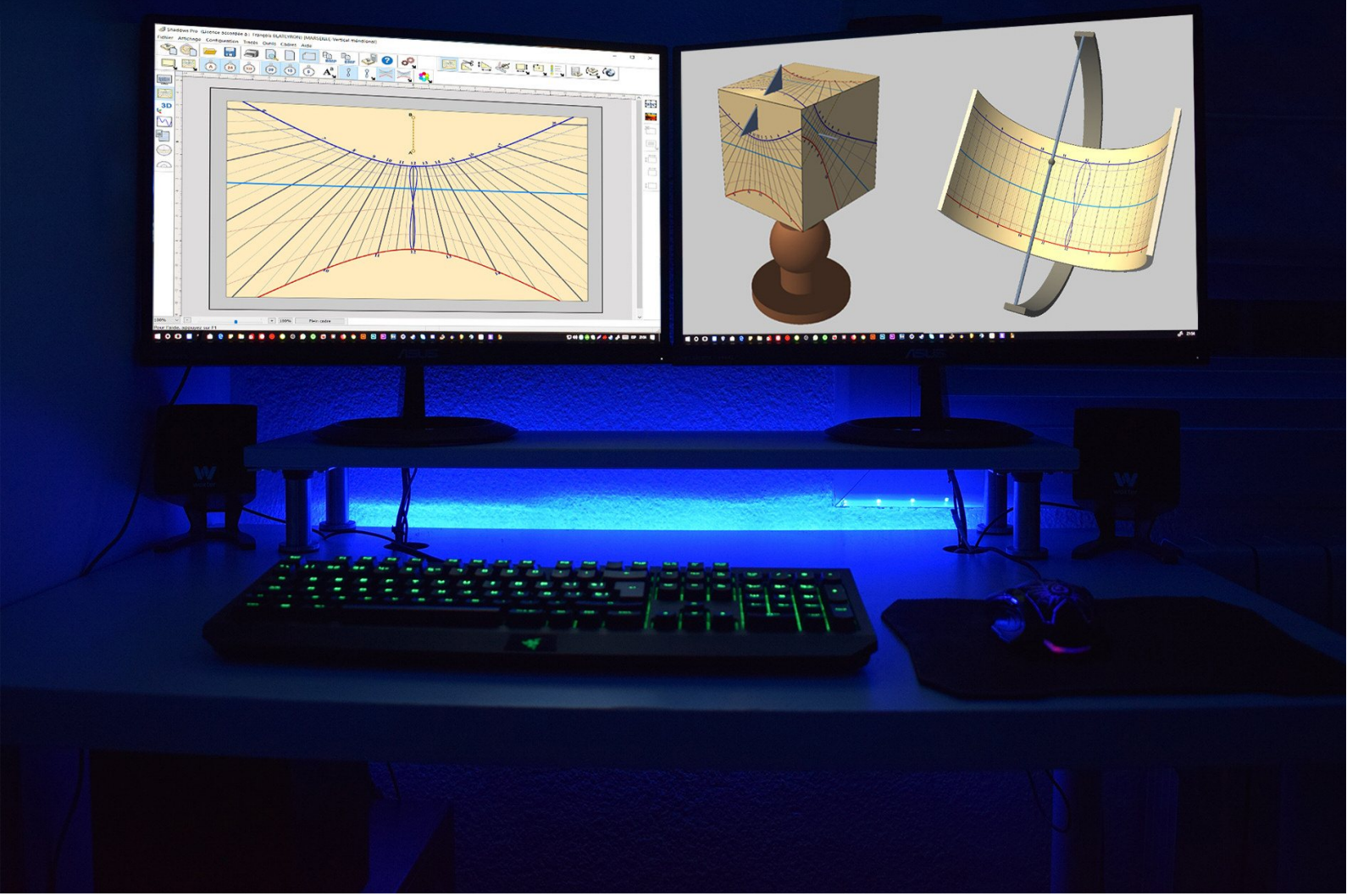
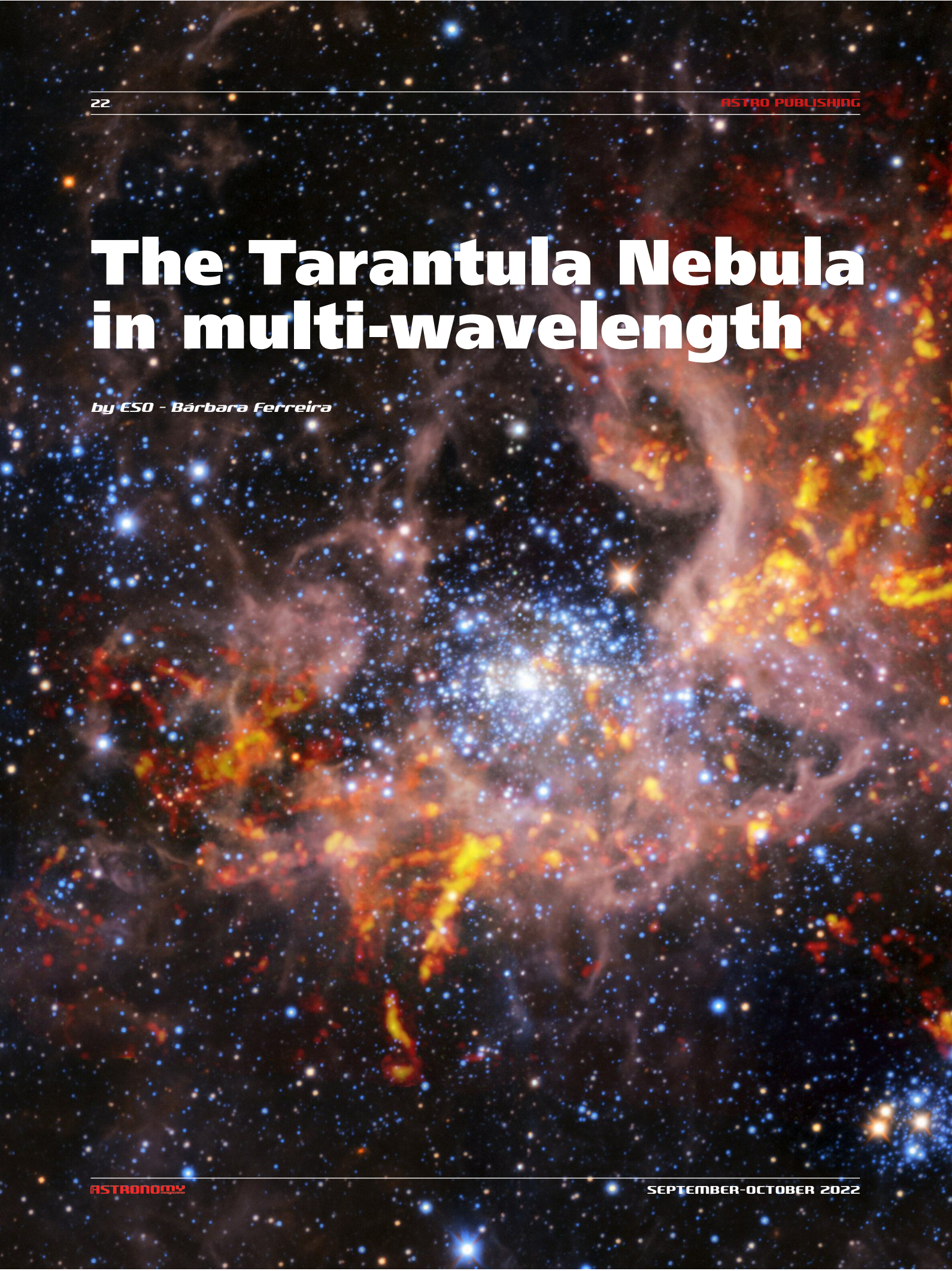


The Tarantula Nebula in multi-wavelength

by ESO - Bárbara Ferreira



Astronomers have unveiled intricate details of the star-forming region 30 Doradus, also known as the Tarantula Nebula, using new observations from the Atacama Large Millimeter/submillimeter Array (ALMA). In a high-resolution image released by the European Southern Observatory (ESO) and including ALMA data, we see the nebula in a new light, with wispy gas clouds that provide insight into how massive stars shape this region.

"These fragments may be the remains of once-larger clouds that have been shredded by the enormous energy being released by young and massive stars, a process dubbed feedback," says Tony Wong, who led the research on 30 Doradus presented at the American Astronomical Society (AAS) meeting and published in *The Astrophysical Journal*. Astronomers originally thought the gas in these areas would be too sparse and too overwhelmed by this

This composite image shows the star-forming region 30 Doradus, also known as the Tarantula Nebula. The background image, taken in the infrared, is itself a composite: it was captured by the HAWK-I instrument on ESO's Very Large Telescope (VLT) and the Visible and Infrared Survey Telescope for Astronomy (VISTA), shows bright stars and light, pinkish clouds of hot gas. The bright red-yellow streaks that have been superimposed on the image come from radio observations taken by the Atacama Large Millimeter/submillimeter Array (ALMA), revealing regions of cold, dense gas which have the potential to collapse and form stars. The unique web-like structure of the gas clouds led astronomers to the nebula's spidery nickname. [ESO, ALMA (ESO/NAOJ/NRAO)/Wong et al., ESO/M.-R. Cioni/VISTA Magellanic Cloud survey. Acknowledgment: Cambridge Astronomical Survey Unit]

This video starts with a wide view of the Milky Way and ends with a close-up look at a rich region of star formation in the nearby Large Magellanic Cloud, in the southern constellation of Dorado. The specific region shown, 30 Doradus, is also known as the Tarantula Nebula. During the video, the image shifts over different wavelengths of the Tarantula Nebula. [ESO/Digitized Sky Survey 2/N. Risinger (skysurvey.org)/R. Gendler – ESO/M. Kornmesser, ALMA (ESO/NAOJ/NRAO)/Wong et al., ESO/M.-R. Cioni/VISTA Magellanic Cloud survey. Ack: Cambridge Astronomical Survey Unit]

turbulent feedback for gravity to pull it together to form new stars. But the new data also reveal much denser filaments where gravity's role is still significant. *"Our results imply that even in the presence of very strong feedback, gravity can exert a strong influence and lead to a continuation of star formation,"* adds Wong, who is a professor at the University of Illinois at Urbana-Champaign, USA.

Located in the Large Magellanic Cloud, a satellite galaxy of our own Milky Way, the Tarantula Nebula is one of the brightest and most active star-forming regions in our galactic neighbourhood, lying about 170,000 light-years away from Earth.

At its heart are some of the most massive stars known, a few with more than 150 times the mass of our Sun, making the region perfect for studying how gas clouds collapse under gravity to form new stars. *"What makes 30 Doradus unique is that it is close enough for us to study in detail how stars are forming, and yet its properties are similar to those found in very distant galaxies, when the Universe was young,"* said Guido De Marchi, a scientist at the European Space Agency (ESA) and a co-author of the paper presenting the new research. *"Thanks to 30 Doradus, we can study how stars used to form 10 billion years ago when most stars were born."*

While most of the previous studies of the Tarantula Nebula have focused on its centre, astronomers have long known that massive star formation is happening elsewhere too. To better understand this process, the team conducted high-resolution observations covering a large region of the nebula. Using ALMA, they measured the emission of light from carbon monoxide gas. This allowed them to map the large, cold gas clouds in the nebula that collapse to give birth to new stars — and how they change as huge amounts of energy are released by those young stars.

"We were expecting to find that parts of the cloud closest to the young massive stars would show the clearest signs of gravity being overwhelmed by feedback," says Wong. *"We found instead that gravity is still important in these feedback-exposed regions — at least for parts of the cloud that are sufficiently dense."*

In the image released by ESO, we see the new ALMA data overlaid on a previous infrared image of the same region that shows bright stars and light pinkish clouds of hot gas, taken with ESO's Very Large Telescope (VLT) and ESO's Visible and Infrared Survey Telescope for Astronomy (VISTA).

The composition shows the distinct, web-like shape of the Tarantula Nebula's gas clouds that gave rise to its spidery name. The new ALMA data comprise the bright red-yellow streaks in the image: very cold and dense gas that could one day collapse and form stars.

The new research contains detailed clues about how gravity behaves in the Tarantula Nebula's star-forming regions, but the work is far from finished. *"There is still much more to do with this fantastic data set, and we are releasing it publicly to encourage other researchers to conduct new investigations,"* Wong concludes. ■

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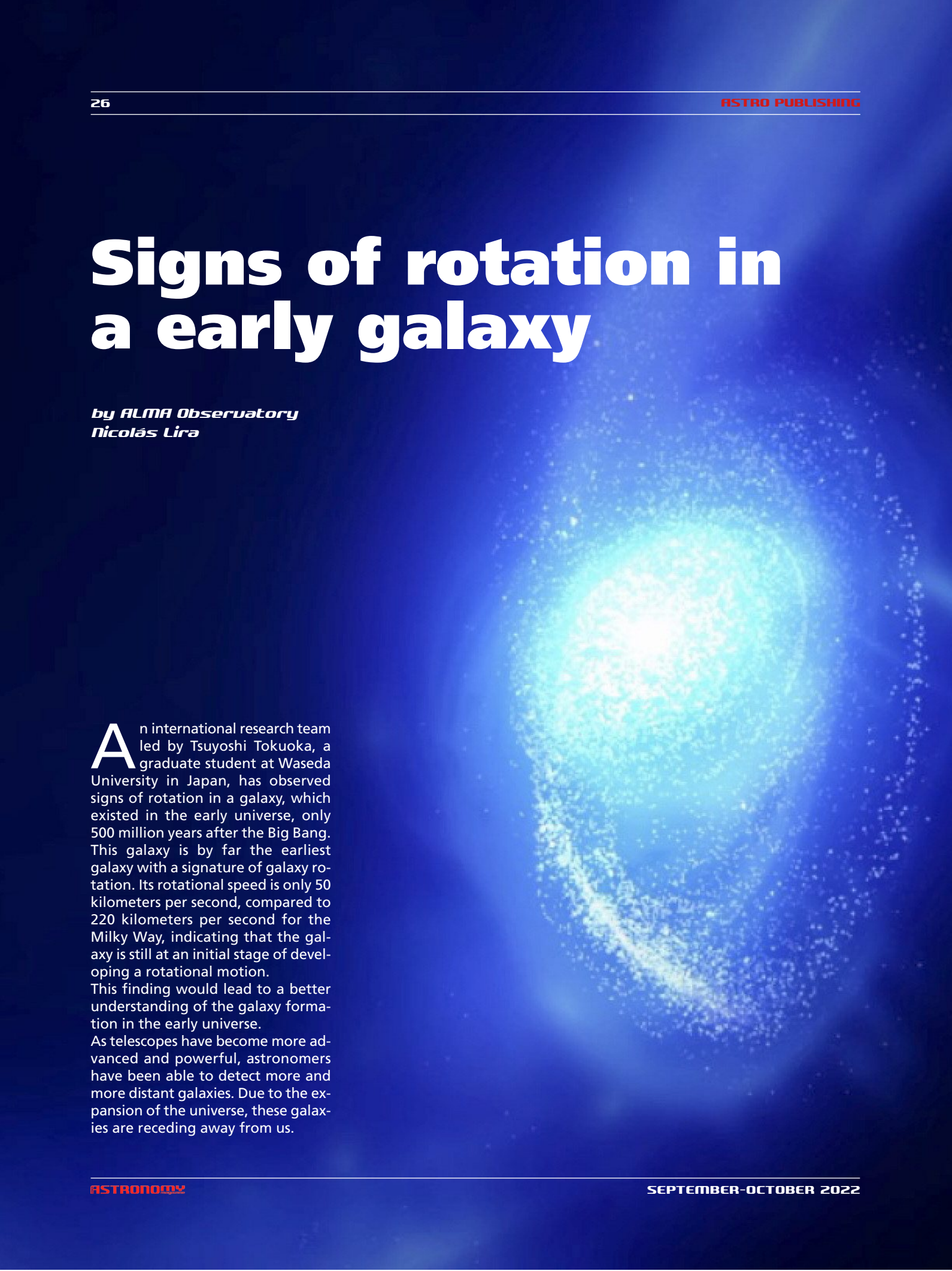
Signs of rotation in a early galaxy

by ALMA Observatory
Nicolás Lira



An international research team led by Tsuyoshi Tokuoka, a graduate student at Waseda University in Japan, has observed signs of rotation in a galaxy, which existed in the early universe, only 500 million years after the Big Bang. This galaxy is by far the earliest galaxy with a signature of galaxy rotation. Its rotational speed is only 50 kilometers per second, compared to 220 kilometers per second for the Milky Way, indicating that the galaxy is still at an initial stage of developing a rotational motion.

This finding would lead to a better understanding of the galaxy formation in the early universe.

As telescopes have become more advanced and powerful, astronomers have been able to detect more and more distant galaxies. Due to the expansion of the universe, these galaxies are receding away from us.

This causes their emissions to be redshifted (shifted towards longer wavelengths). Interestingly, we can estimate how fast a galaxy is moving and, in turn, when it was formed based on how redshifted the emission appears. ALMA is particularly well-suited for observing such redshifts in galaxy emission.

The international research team has observed the redshifted emissions in the distant galaxy MACS1149-JD1, or JD1 for short, which has led them to some interesting conclusions. *"Beyond finding high-redshift, namely very distant, galaxies, studying their internal motion of gas and stars provides motivation for understanding the process of galaxy formation in the earliest possible universe,"* explained Richard S. Ellis, a professor at University College London.

Galaxy formation begins with the accumulation of gas and proceeds with forming stars from that gas. With time, star formation progresses from the center outward, a galactic disk develops, and the galaxy acquires a particular shape. As star formation continues, newer stars form in the rotating disk while older stars remain in the central part. It is possible to determine the evolutionary stage of the galaxy by studying the age of the stellar objects and the motion of the stars and gas.

The team successfully measured small differences in the "redshift" from position to position inside the galaxy, showing that JD1 satisfied the criterion for a galaxy dominated by rotation. As already mentioned, the calculated rotational speed was about 50 kilometers per second, compared to the rotational speed of the Milky Way disk of 220 kilometers per second. The team also measured the diameter of JD1 at only 3,000 light-years, which is much smaller than that of the Milky Way at 100,000 light-years across.

The galaxy the team observed is by far the most distant source yet found that has a rotating disk. Together with similar measurements of nearer systems in the research literature, this has allowed the team to delineate the gradual development of rotating galaxies over more than 95% of our cosmic history.

Furthermore, the mass estimated from the rotational speed was in line with the stellar mass estimated previously from the spectral signature, and came predominantly from that of "mature" stars that formed about 300 million years ago. *"This shows that the stellar population in JD1 formed at an even earlier epoch of the cosmic age,"* said Takuya Hashimoto, an assistant professor at Univesity of Tsukuba.

"The rotational speed of JD1 is much slower than those found in galaxies in later epochs and the Milky Way, and JD1 is likely at an initial stage of developing a rotational motion," said Akio Inoue, a professor at Waseda University. With the James Webb Space Telescope, the team now plans to identify the locations of young and older stars in the galaxy to refine their scenario for its formation. ■

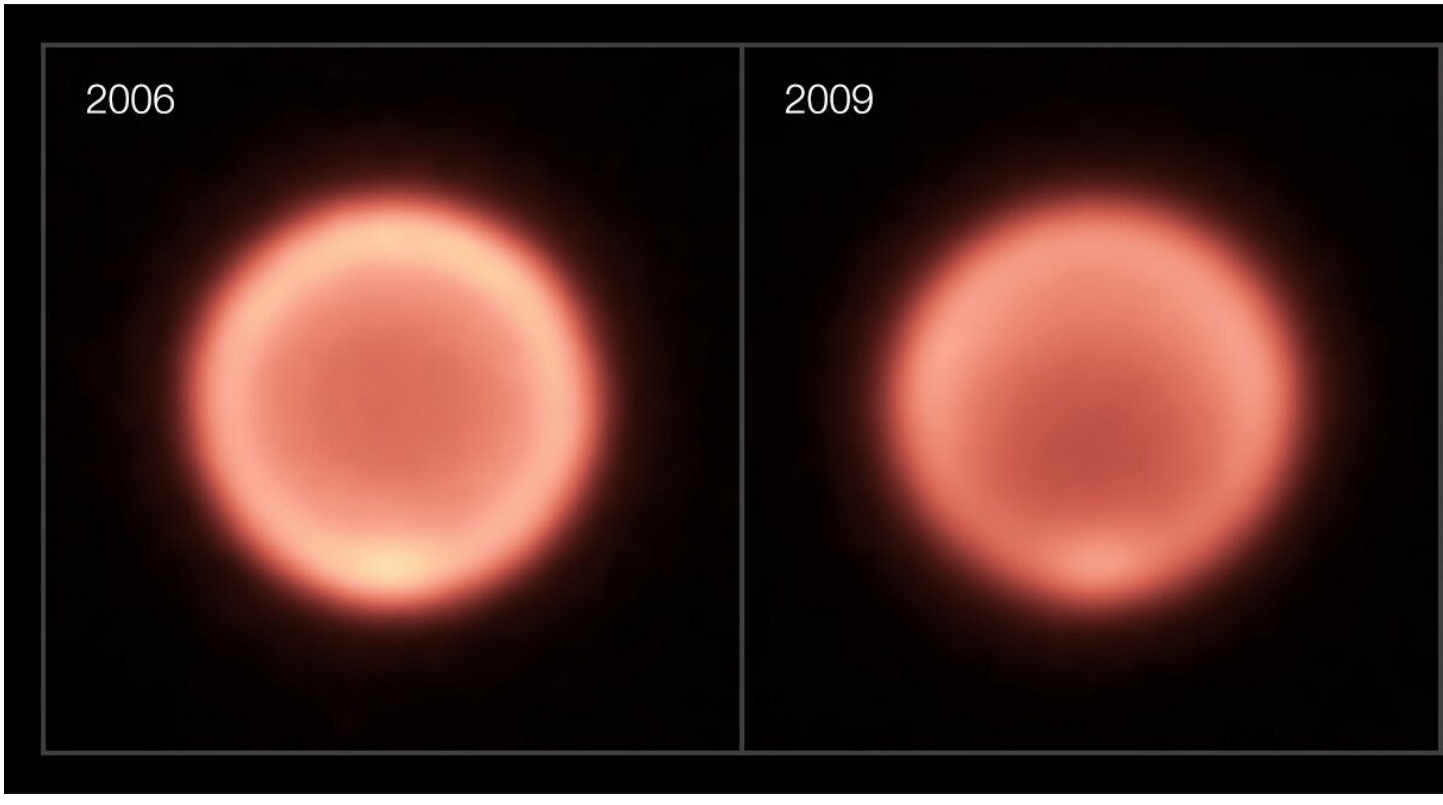
Conceptual image of MACS1149-JD1 forming and spinning up to speed in the early universe. [ALMA (ESO/NAOJ/NRAO)]

Surprising changes in Neptune's temperatures

by ESO - Bárbara Ferreira

An international team of astronomers have used ground-based telescopes, including the European Southern Observatory's Very Large Telescope (ESO's VLT), to track Neptune's atmospheric temperatures over a 17-year period. They found a surprising drop in Neptune's global temperatures

This composite shows thermal images of Neptune taken between 2006 and 2020. The first three images (2006, 2009, 2018) were taken with the VISIR instrument on ESO's Very Large Telescope while the 2020 image was captured by the COMICS instrument on the Subaru Telescope (VISIR wasn't in operation in mid-late 2020 because of the pandemic). After the planet's gradual cooling, the south pole appears to have become dramatically warmer in the past few years, as shown by a bright spot at the bottom of Neptune in the images from 2018 and 2020. [ESO/M. Roman, NAOJ/Subaru/COMICS]



followed by a dramatic warming at its south pole.

"This change was unexpected," says Michael Roman, a postdoctoral research associate at the University of Leicester, UK, and lead author of the study published in *The Planetary Science Journal*. *"Since we have been observing Neptune during its early southern summer, we expected temperatures to be slowly growing warmer, not colder."*

Like Earth, Neptune experiences seasons as it orbits the Sun. However, a Neptune season lasts around 40 years, with one Neptune year lasting 165 Earth years. It has been summertime in Neptune's southern hemisphere since 2005, and the astronomers were ea-ger to see how temperatures were changing following the southern summer solstice.

Astronomers looked at nearly 100 thermal-infrared images of Neptune, captured over a 17-year period, to piece together overall trends in the planet's temperature in greater detail than ever before.

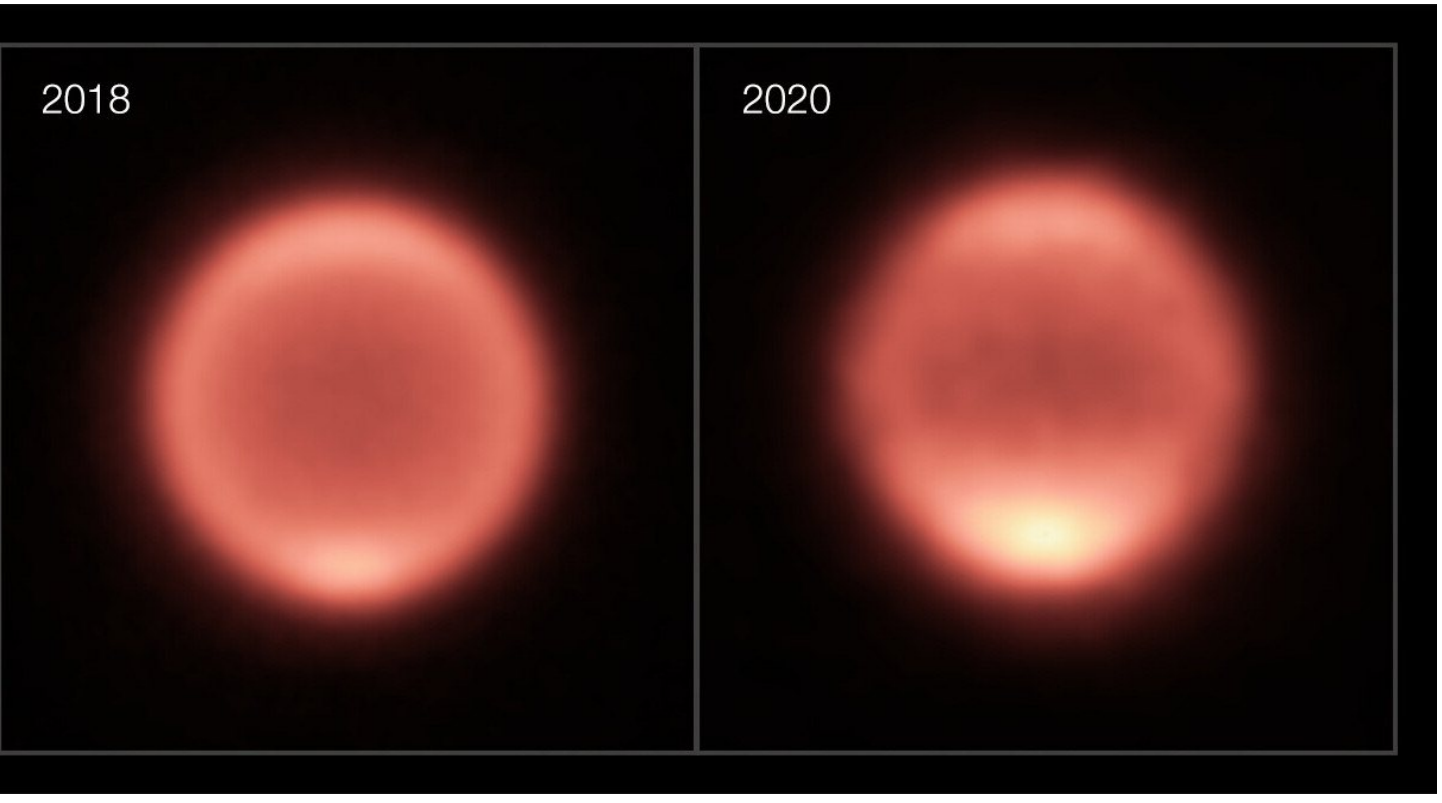
These data showed that, despite the onset of southern summer, most of the planet had gradually cooled over the last two decades. The globally averaged temperature of Neptune dropped by 8 °C between 2003 and 2018.

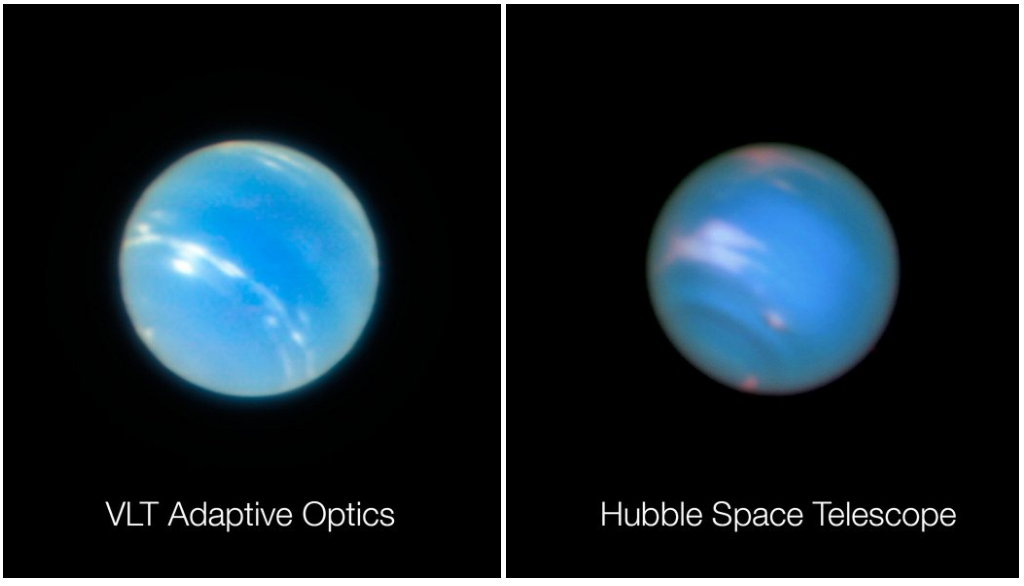
The astronomers were then surprised to discover a dramatic warming of Neptune's south pole during the last two years of their observations, when temperatures rapidly rose 11 °C between 2018 and 2020. Although Neptune's warm polar vortex has been known for many years, such rapid polar warming has never been previously observed on the planet.

"Our data cover less than half of a Neptune season, so no one was expecting to see large and rapid changes," says co-author Glenn Orton, senior research scientist at Caltech's Jet Propulsion Laboratory (JPL) in the US.

The astronomers measured Neptune's temperature using thermal cameras that work by measuring the infrared light emitted from astronomical objects. For their analysis the team combined all existing images of Neptune gathered over the last two decades by ground-based telescopes. They investigated infrared light emitted from a layer of Neptune's atmosphere called the stratosphere. This allowed the team to build up a picture of Neptune's temperature and its variations during part of its southern summer.

Because Neptune is roughly 4.5 billion kilometres away and is very cold, the planet's average temperature reaching around –220 °C, meas-





The image of the planet Neptune on the left was obtained during the testing of the Narrow-Field adaptive optics mode of the MUSE instrument on ESO's Very Large Telescope. The image on the right is a comparable image from the NASA/ESA Hubble Space Telescope. Note that the two images were not taken at the same time so do not show identical surface [ESO/P. Weilbacher (AIP)/NASA, ESA, and M.H. Wong and J. Tollefson (UC Berkeley)]

uring its temperature from Earth is no easy task. *"This type of study is only possible with sensitive infrared images from large telescopes like the VLT that can observe Neptune clearly, and these have only been available for the past 20 years or so,"* says co-author Leigh Fletcher, a professor at the University of Leicester.

Around one third of all the images taken came from the VLT Imager and Spectrometer for mid-InfraRed (VISIR) instrument on ESO's VLT in Chile's Atacama Desert. Because of the telescope's mirror size and altitude, it has a very high resolution and data quality, offering the clearest images of Neptune. The team also used data from NASA's Spitzer Space Telescope and images taken with the Gemini South telescope in Chile, as well as with the Subaru Telescope, the Keck Telescope, and the Gemini North telescope, all in Hawai'i.

Because Neptune's temperature variations were so unexpected, the astronomers do not know yet what could have caused them. They could be due to changes in Neptune's stratospheric chemistry, or random weather patterns, or even the solar cycle. More observations will be needed over the coming years to explore the reasons for these fluctuations. Future ground-based telescopes like ESO's Extremely Large Telescope (ELT) could observe temperature changes like these in greater detail, while the NASA/ESA/CSA James Webb Space Telescope will provide unprecedented new maps of the chemistry and temperature in Neptune's atmosphere.

"I think Neptune is itself very intriguing to many of us because we still know so little about it," says Roman. *"This all points towards a more complicated picture of Neptune's atmosphere and how it changes with time."* ■

The evolution of thermal images taken from Neptune using the VLT's VISIR instrument. The images, taken between 2006 and 2021, show Neptune gradually cooling down, before a dramatic heating of its south pole in the last few years. [ESO/M. Roman]

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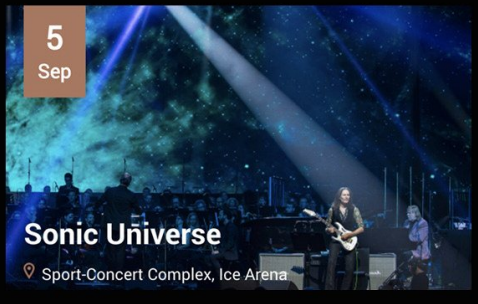
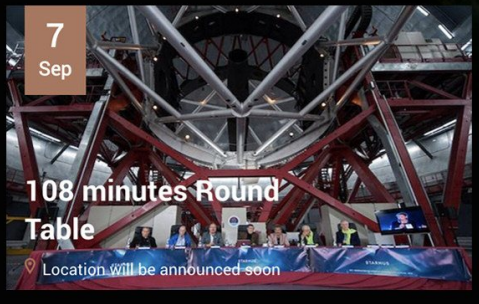




Dead star caught ripping up planetary system

by NASA/ESA
Claire Blome

A star's death throes have so violently disrupted its planetary system that the dead star left behind, called a white dwarf, is siphoning off debris from both the system's inner and outer reaches. This is the first time astronomers have observed a white dwarf star that is consuming both rocky-metallic and icy material, the ingredients of planets.

Archival data from NASA's Hubble Space Telescope and other NASA observatories were essential in diagnosing this case of cosmic cannibalism. The findings help describe the violent nature of evolved planetary systems and can tell astronomers about the makeup of newly forming systems.

The findings are based on analyzing material captured by the atmosphere of the nearby white dwarf star G238-44. A white dwarf is what remains of a star like our Sun after it sheds its outer layers and stops burning fuel though nuclear fusion. *"We have never seen both of these kinds of objects accreting onto a white dwarf at the same time,"* said Ted Johnson, the lead researcher and recent University of California, Los Angeles (UCLA) bachelor's graduate. *"By studying these white dwarfs, we hope to gain a better understanding of planetary systems that are still intact."*

The findings are also intriguing because small icy objects are credited for crashing into and "irrigating" dry, rocky planets in our solar system. Billions of years ago comets and asteroids are thought to have delivered water to Earth, sparking the conditions necessary for life as we know it. The makeup of the bodies detected raining onto the white dwarf implies that icy reservoirs might be common among planetary systems, said Johnson.

"Life as we know it requires a rocky planet covered with a variety of elements like carbon, nitrogen, and oxygen," said Benjamin Zuckerman, UCLA professor and co-author. *"The abundances of the elements we see on this white dwarf appear to require both a rocky and a volatile-rich parent body – the first example we've found among studies of hundreds of white dwarfs."*

Theories of planetary system evolution describe the transition between a red giant star and white dwarf phases as a chaotic process. The star quickly loses its outer layers and its planets' orbits dramatically change. Small objects, like asteroids and dwarf planets, can venture too close to giant planets and be sent plummeting toward the star. This study confirms the true scale of this vio-

lent chaotic phase, showing that within 100 million years after the beginning of its white dwarf phase, the star is able to simultaneously capture and consume material from its asteroid belt and Kuiper belt-like regions.

The estimated total mass eventually gobbled up by the white dwarf in this study may be no more than the mass of an asteroid or small moon. While the presence of at least two objects that the white dwarf is consuming is not directly measured, it's likely one is metal-rich like an asteroid and another is an icy body similar to what's found at the fringe of our solar system in the Kuiper belt. Though astronomers have cataloged over 5,000 exoplanets, the only planet where we have some direct knowledge of its interior makeup is Earth. The white dwarf cannibalism provides a unique opportunity to take planets apart and see what they were made of when they first formed around the star.

The team measured the presence of nitrogen, oxygen, magnesium, silicon and iron, among other elements. The detection of iron in a very high abundance is evidence for metallic cores of terrestrial planets, like Earth, Venus, Mars and Mercury. Unexpectedly high nitrogen abundances led them to conclude the presence of icy bodies. *"The best fit for our data was a nearly two-to-one mix of Mercury-like material and comet-like material, which is made up of ice and dust,"* Johnson said. *"Iron metal and nitrogen ice each suggest wildly different conditions of planetary formation. There is no known solar system object with so much of both."* ■

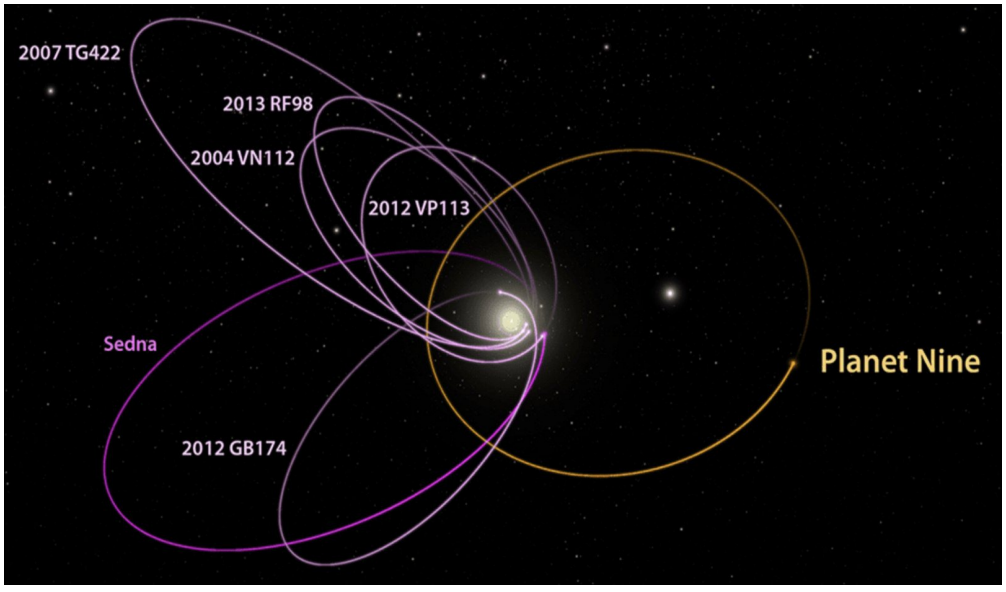
This illustration shows a white dwarf star siphoning off debris from shattered objects in a planetary system. The Hubble Space Telescope detects the spectral signature of the vaporized debris that revealed a combination of rocky-metallic and icy material, the ingredients of planets. The findings help describe the violent nature of evolved planetary systems and the composition of its disintegrating bodies. [NASA, ESA, Joseph Olmsted (STScI)]

Planet Nine increasingly unreachable

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

Astronomers have been searching for a large trans-Neptunian planet for over a century. This search began when they determined that Neptune's mass and orbital properties were inadequate to explain the anomalies previously found in the orbital motion of Uranus, whose position in the sky appeared to deviate from theoretical calculations. The belief that another planet should exist grew further after the almost accidental discovery of Pluto, whose mass turned out to be too small to significantly influence the motion of Uranus or the orbit of Neptune, itself also not perfectly respectful of the astronomical calculations of the time. However, it became evident in the early 1990s that the anomalies detected in the positions of the two icy giants could be explained even

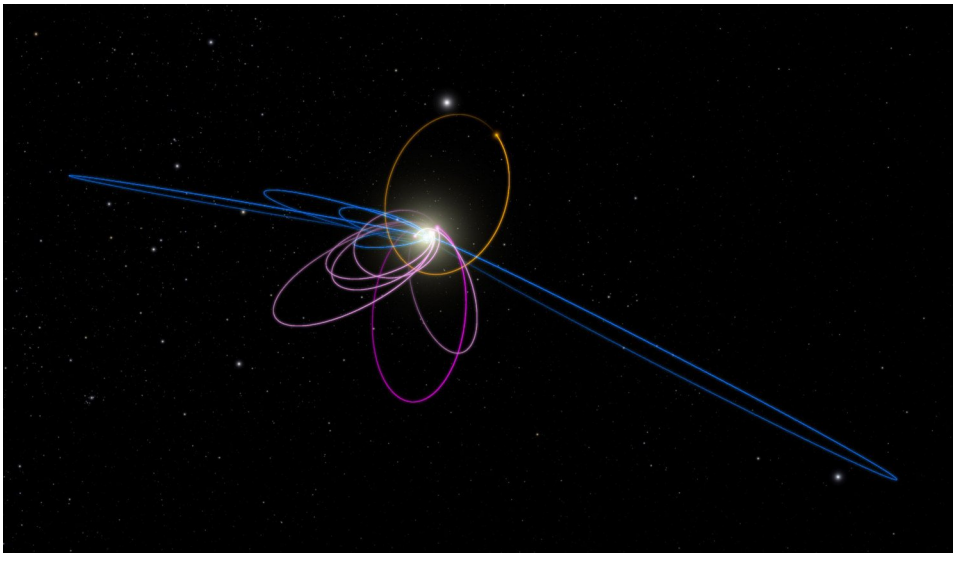
Fantasy representation of the hypothetical Planet Nine as seen from very far from the rest of the solar system, which appears as a patch of indistinct light on the side.



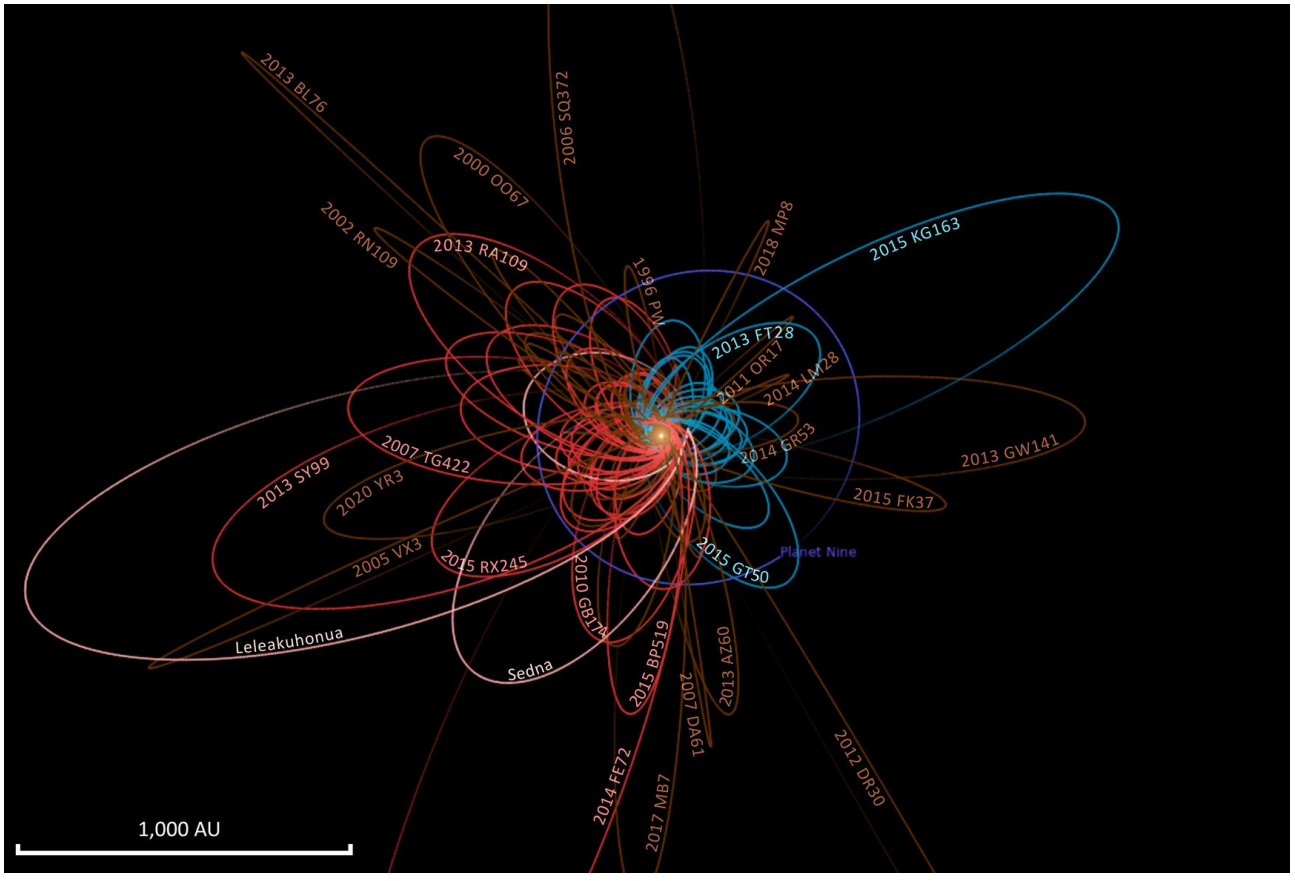
The six most distant known objects in the solar system, with orbits exclusively beyond that of Neptune (magenta-pink), all mysteriously line up in a single direction. Also, when viewed in 3D, they tilt nearly identically away from the plane of the solar system. Caltech's Konstantin Batygin and Mike Brown have shown that a planet with 10 times the mass of the Earth in a distant eccentric orbit anti-aligned with the other six objects (orange) is required to maintain this configuration. [Caltech/R. Hurt (IPAC)]

without assuming the existence of the phantom Planet X. A study of the measurements made by the Voyager 2 probe revealed that the irregularities observed in the motion of Uranus were simply due to a slight overestimation of the mass of Neptune. Subsequent improvements in our understanding of the latter's orbit made the existence of another planet completely superfluous. Without a starting point in the form of gravitational perturbations of the outer planets, there was no longer any way to calculate to an acceptable approximation the position in the sky of some possible Planet X and then go out and look for it. The most stubborn astronomers still searching for Planet X could only make rough assumptions about its mass and orbital properties given the instrumental, temporal and spatial limits of all the surveys carried out up to that time.

A planet of 4-5 Earth masses at least 200 AU from the Sun, or a proportionately larger planet even further out, would have been undetectable using the technology of the 1990s even in the infrared, the domain of wavelengths where a body so far away would be expected to peak in its electromagnetic radiation. In the last thirty years, many works have been published that have placed further restrictions on the exis-



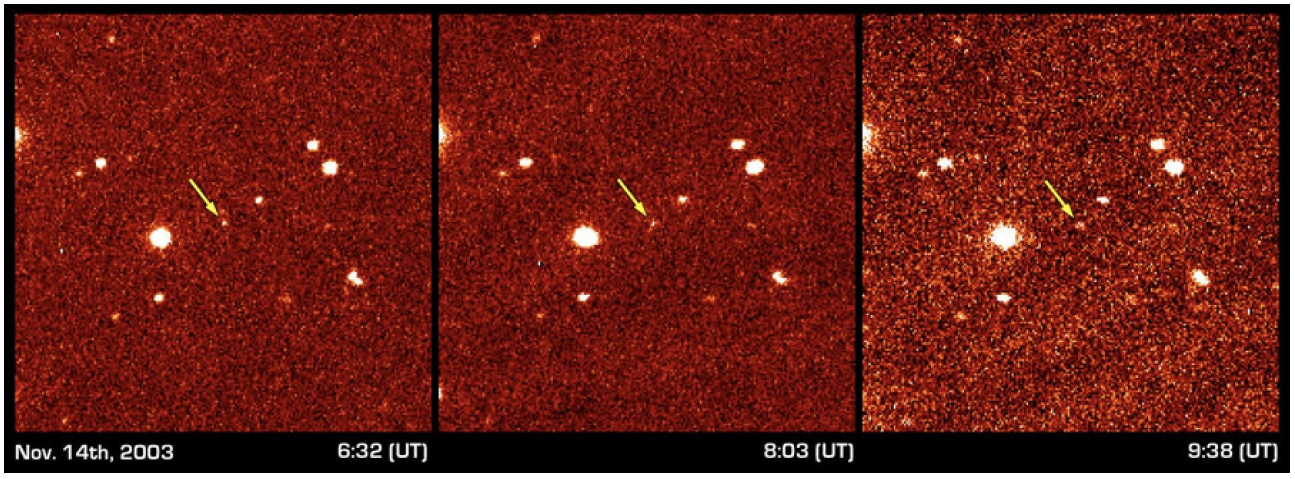
A predicted consequence of the existence of Planet Nine is that a second set of confined objects should also exist. These objects are forced into positions at right angles to Planet Nine and in orbits perpendicular to the plane of the solar system. Five known objects (blue) fit this prediction exactly. [Caltech/R. Hurt (IPAC) – Diagram was created using WorldWide Telescope]



Orbits of 96 of the 109 known distant asteroids and extreme Trans-Neptunian Objects (eTNOs) with aphelion distances Q > 200 AU as of January 2021. Orbits are from JPL's Small Body Database based on the epoch 31 May 2020. The remaining 13 asteroids are excluded from this diagram, as their orbits are too uncertain. The red orbits are those of eTNOs with longitudes of the pericenter aligned with the hypothetical Planet Nine, while the blue ones are those of eTNOs anti-aligned with Planet Nine. The pink orbits are those of the three known sednoids (Sedna, 2012 VP113, Leleakuhonua), while the brown ones are of the scattered centaurs and damocloids, with perihelion distances within the orbit of Neptune (q < 29.9 AU). For comparison, the predicted orbit of Planet Nine is shown in purple (a~500, e~0.25, i~20). [Wikimedia Commons]

tence of Planet X without, however, excluding it definitively. In fact, it is still possible to hypothesize different combinations of mass, albedo and orbital properties capable of placing a possible ninth planet (not tenth, because Pluto is still officially classified as a dwarf planet) beyond the capabilities of observation among the campaigns conducted so far. The main intervening factors that limit the chance of a discovery are the small apparent magnitude of a body so far away from the Sun, as well as its very slow apparent motion among the stars. We are talking about shifts on the celestial vault on the order of one arc minute per year if the planet is about 800 AU away from the Sun; proportionally less for increasing distances. At this point, it is obvious that the best strategy for discovering Planet Nine (as it is widely known today) is by comparing infrared images of the same areas of the sky acquired several years apart from each other. This strategy is the basis of a recent study conducted by Chris Sedgwick and Stephen Serjeant (School of Physical Sciences, The Open University, Milton Keynes, UK), published in the *Monthly Notices of the Royal Astronomical Society*.

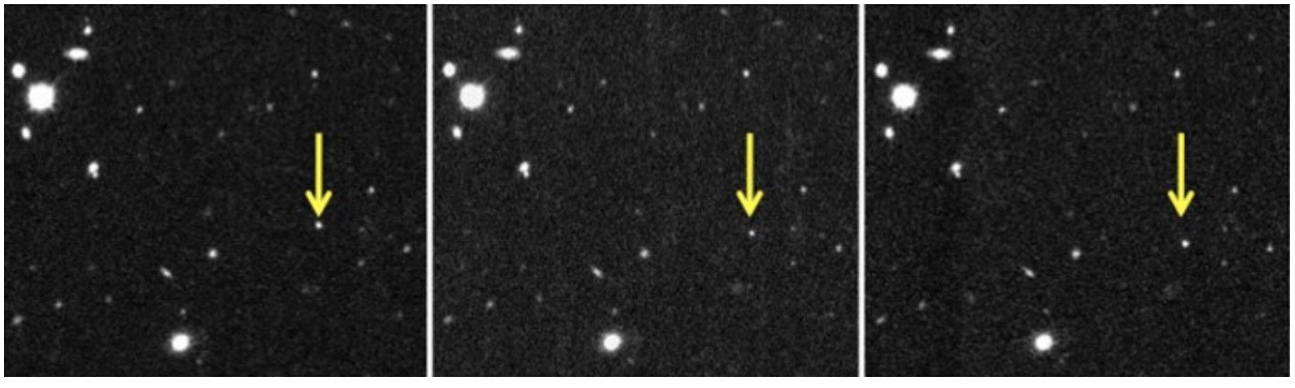
Sedgwick and Serjeant compared the databases of two major surveys of the whole sky in the far-infrared, separated by 23.4 years (taking midpoints of the survey periods in each case). The two surveys are those carried out by the Infrared Astronomical Satellite (IRAS), operational from



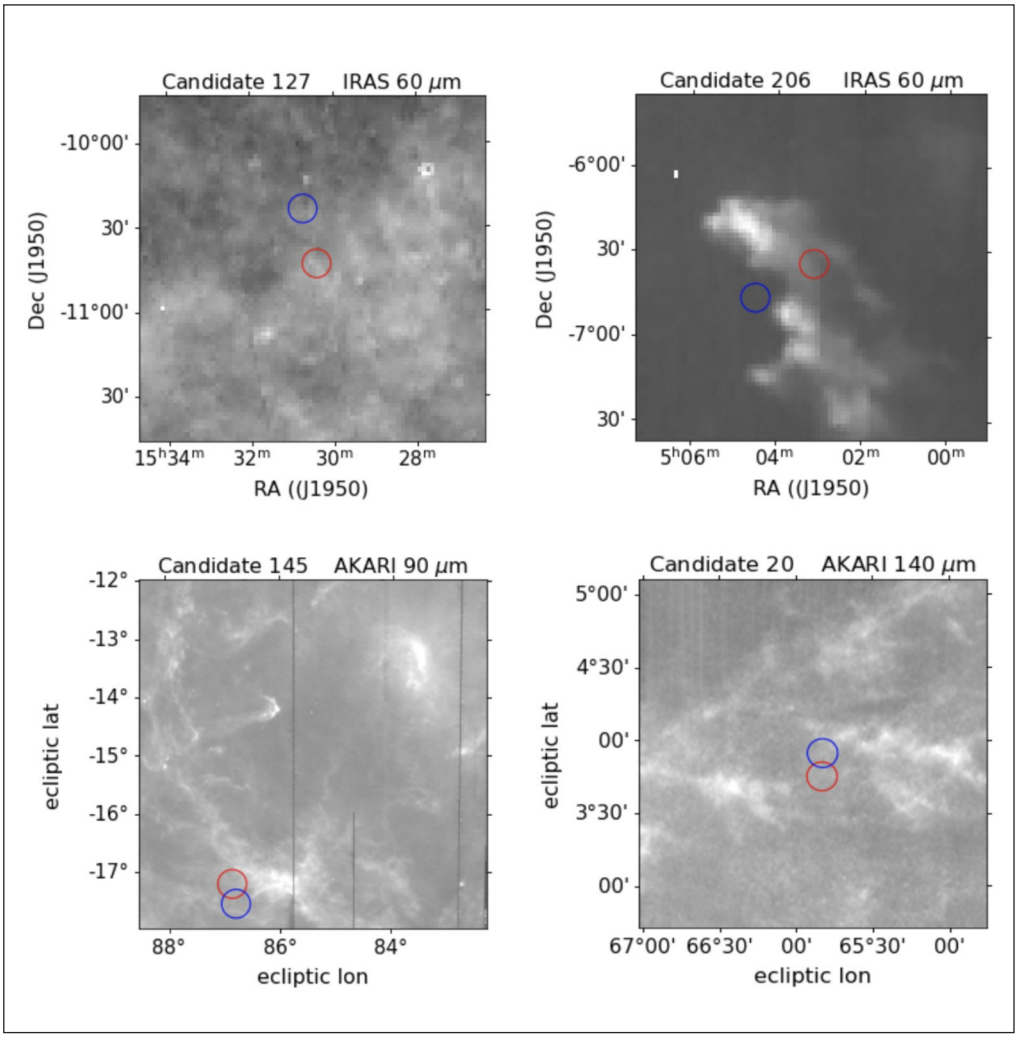
The images that allowed the discovery of the dwarf planet Sedna. This object could be the most massive of those most directly perturbed by the hypothetical large planet that would exist at the outer borders of our solar system. [Palomar Observatory]

January to November 1983, and by the AKARI Space Telescope, operational from February 2006 to November 2011. In addition to the temporal separation, these two databases were chosen for the relative homogeneity of the data they contain: both cover far-infrared wavelengths close to the flux peaks of known giant planets in our solar system. It is reasonable to expect that the flux peak of the hypothetical Planet Nine would also fall within that range.

But why start a search of this type if, as mentioned above, the positions in the sky of the known planets are now harmonizing with those calculated? One would assume that the existence of a large planet on the outer borders of the solar system would no longer seem necessary. In reality, this is not the case. Since 2012, astronomers have known that a non-negligible number of discovered Trans-Neptunian objects (TNOs, a category that includes dwarf planets, large asteroids and cometary nuclei) share the properties of having their perihelion near the ecliptic and on the same side of the Sun, orbits oriented in the same direction and inclined by about 30°, and they are physically grouped. In short, at least a dozen TNOs, including the dwarf planet Sedna, are concentrated in a statistically very unlikely way. Supercomputer simulations performed in 2015 by Konstantin Batygin and Mike Brown (California Institute of Technology) show that there is only one chance in nearly 15,000 that the orbital clustering of those TNOs is random. That scenario could instead be explained by one



These images from November 5, 2012, spaced about 2 hours apart from each other, allowed for the discovery of 2012 VP113, the most distant TNO known to date, with aphelion at 446 AU and an orbital period of 4274 years. 2012 VP113 appears to move slowly between the stars and galaxies in the background. [Scott Sheppard/Carnegie Institution for Science]

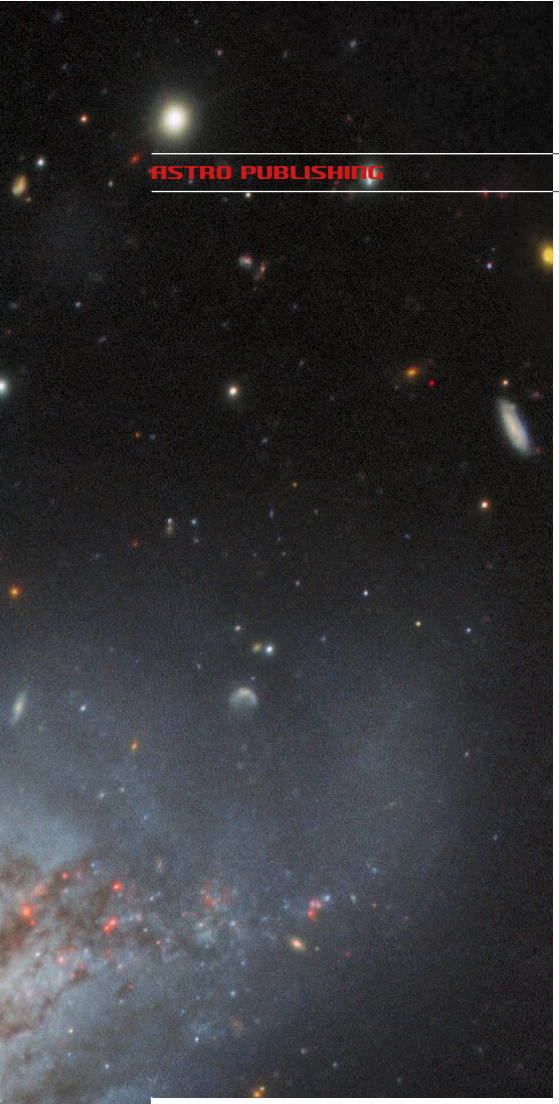


Examples of images from IRAS and AKARI showing "Planet Nine" candidates within galactic cirrus clouds, which are almost certainly the cause of the far-infrared flux. The circles indicate the coordinates of the targets: red for IRAS; blue for AKARI. The size of the circles is arbitrary. IRAS images are in J1950 equatorial coordinates; AKARI are in ecliptic coordinates. [C. Sedgwick and S. Serjeant]

of the many possible combinations of a planet of 5-15 Earth masses, between 200 AU and 1000 AU from the Sun, with an orbital period between 10,000 and 20,000 years. According to the two Caltech researchers, the most likely combination is that of a planet as large as Neptune with an orbit at an average distance from the Sun of about 700 AU. This distance corresponds to the lower limit adopted by Sedgwick and Serjeant in their study, since for shorter distances a planet of that size would have already been located based on the perturbations of the orbits of many TNOs. The two researchers also set the upper limit of the survey to around 8000 AU based on the sensitivity limits of the IRAS and AKARI detectors and the distance of the potential target, whose proper motion, at greater distances, would be too small to be detectable. Surprisingly, the comparison between the databases of IRAS and AKARI highlighted more than 500 possible candidates, sources that mostly appeared to be at distances fewer than 1000 AU and to have masses similar to or smaller than that of Neptune, both values exactly in the expected range for Planet Nine. However, when the team manually examined the individual infrared sources, they found that none of them were convincing. Most were located in-or-near faint integrated flow nebulae, structures also known as "galactic cirrus clouds." These are diffuse clouds of interstellar gas not easily detectable at visible wavelengths, but relatively bright in the far-infrared. Nothing to do, therefore, with nearby Neptunian-sized planets. Although the work of Sedgwick and Serjeant did not produce the desired results, the idea of comparing databases of surveys widely spaced over time appears to be the main road to follow in the search for Planet Nine. The only alternative is to calculate its position in the sky starting from the strange orbital concentrations of some TNOs. Currently, the selection of TNOs is still too limited to follow this path. ■

A stunning image of merging spiral galaxies

by NOIRLab
Charles Blue



Gemini North, one of the twin telescopes of the International Gemini Observatory, operated by NSF's NOIRLab, has observed the initial stages of a cosmic collision approximately 60 million light-years away in the direction of the constellation Virgo. The two stately spiral galaxies, NGC 4568 (bottom) and NGC 4567 (top), are poised to undergo one of the most spectacular events in the Universe, a galactic merger. At present, the centers of these galaxies are still 20,000 light-years apart (about the distance from Earth to the center of the Milky Way) and each galaxy still retains its original, pinwheel shape. Those placid conditions, however, will change.

As NGC 4568 and NGC 4567 draw together and coalesce, their dueling gravitational forces will trigger bursts of intense stellar formation and wildly distort their once-majestic structures.

Over millions of years, the galaxies will repeatedly swing past each other in ever-tightening loops, drawing out long streamers of stars and gas until their individual structures are so thoroughly mixed that a single, essentially spherical, galaxy emerges from the chaos. By that point, much of the gas and dust (the fuel for star formation) in this system will have been used up or blown away.

This merger is also a preview of what will happen when the Milky Way and its closest large galactic neighbor the Andromeda Galaxy collide in about 5 billion years.

A bright region in the center of one of NGC 4568's sweeping spiral arms is the fading afterglow of a supernova — known as SN 2020fqv — that was detected in 2020. The new Gemini image was produced from data taken in 2020.

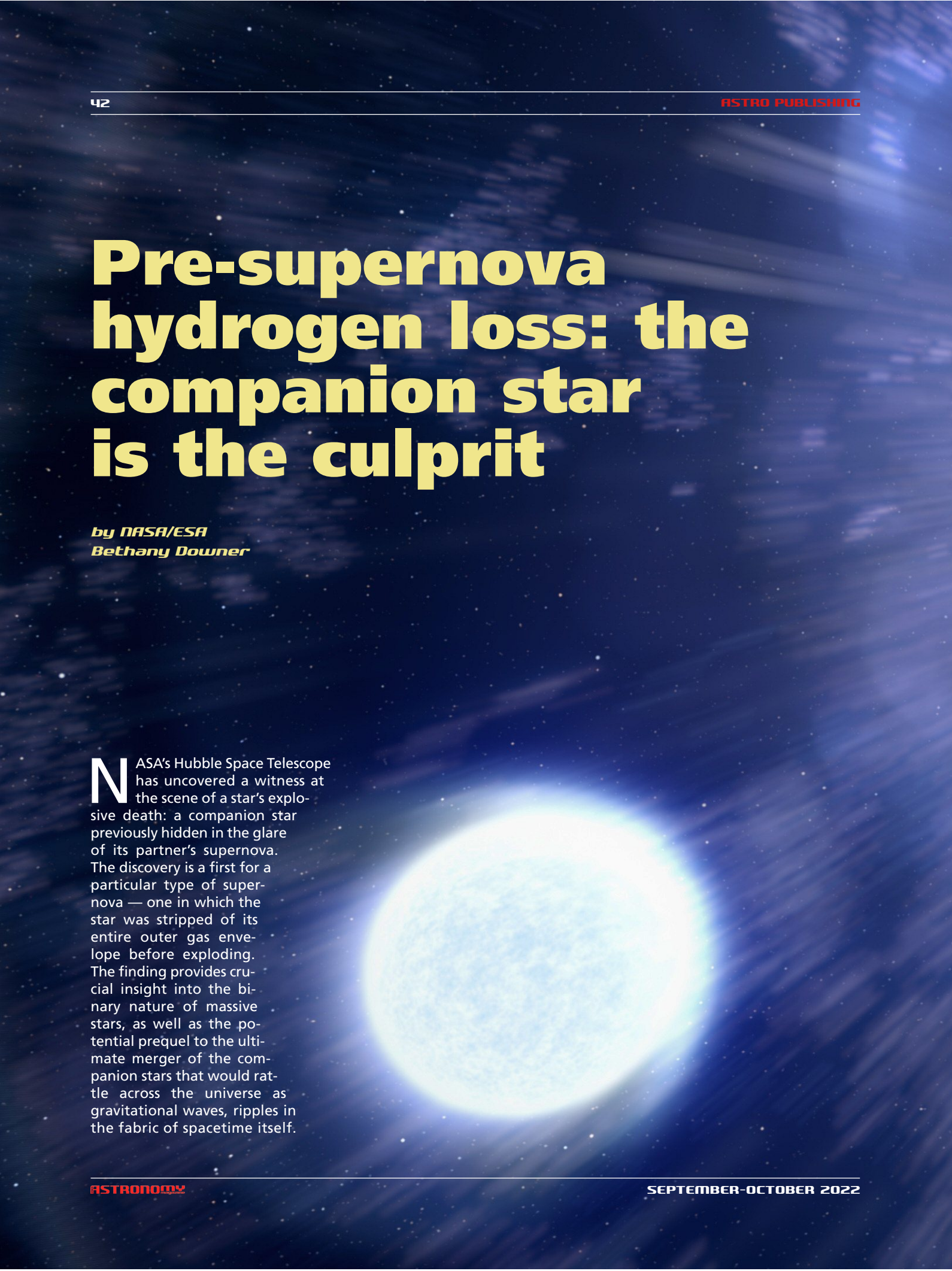
By combining decades of observations and computer modeling, astronomers now have compelling evidence that merging spiral galaxies like these go on to become elliptical galaxies. It is likely that NGC 4568 and NGC 4567 will eventually resemble their more-mature neighbor Messier 89, an elliptical galaxy that also resides in the Virgo Cluster. With its dearth of star-forming gas, Messier 89 now exhibits minimal star formation and is made up primarily of older, low-mass stars and ancient globular clusters.

Advanced technology on the Gemini North telescope, including the Gemini Multi-Object Spectrograph North (GMOS-N) and the dry air above the summit of Maunakea, allowed astronomers to capture this spectacular image. The image was obtained by NOIRLab's Communication, Education & Engagement team, as part of the NOIRLab Legacy Imaging Program. ■

The left image from the Gemini North telescope in Hawai'i reveals a pair of interacting spiral galaxies — NGC 4568 (bottom) and NGC 4567 (top) — as they begin to clash and merge. These galaxies are entangled by their mutual gravitational field and will eventually combine to form a single elliptical galaxy in around 500 million years. Also visible in the image and in the above video is the glowing remains of a supernova that was detected in 2020. [Images and Videos: International Gemini Observatory/NOIRLab/NSF/AURA/F. Summers (STScI), G. Besla (Columbia University), and R. van der Marel (STScI) — Image Processing: T.A. Rector (University of Alaska Anchorage/NSF's NOIRLab), J. Miller (Gemini Observatory/NSF's NOIRLab), M. Zamani (NSF's NOIRLab) — Music: Stellardrone – A Moment of Stillness]

Pre-supernova hydrogen loss: the companion star is the culprit

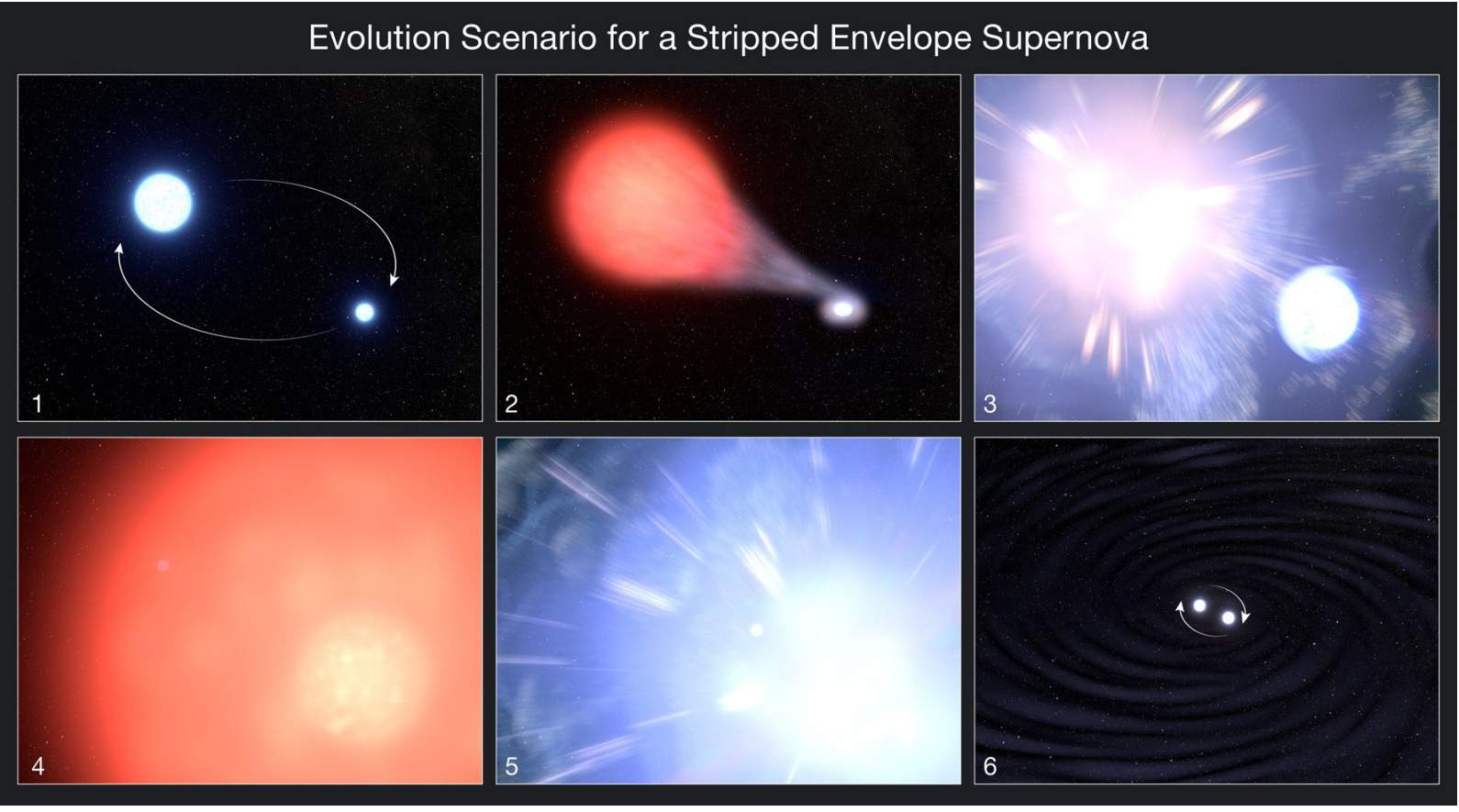
by NASA/ESA
Bethany Downer



NASA's Hubble Space Telescope has uncovered a witness at the scene of a star's explosive death: a companion star previously hidden in the glare of its partner's supernova. The discovery is a first for a particular type of supernova — one in which the star was stripped of its entire outer gas envelope before exploding. The finding provides crucial insight into the binary nature of massive stars, as well as the potential prequel to the ultimate merger of the companion stars that would rattle across the universe as gravitational waves, ripples in the fabric of spacetime itself.

Astronomers detect the signature of various elements in supernova explosions. These elements are layered like an onion pre-supernova. Hydrogen is found in the outermost layer of a star, and if no hydrogen is detected in the aftermath of the supernova, that means it was stripped away before the explosion occurred.

This artist's illustration shows supernova 2013ge, with its companion star at lower left. The companion star is impacted by the blast wave from the supernova, but not destroyed. Over time astronomers observed the ultraviolet (UV) light of the supernova fading, revealing a nearby second source of UV light that maintained brightness. The theory is that the two massive stars evolved together as a binary pair, and that the current survivor siphoned off its partner's outer hydrogen gas shell before it exploded. Eventually, the companion star will also go supernova. [NASA, ESA, Leah Hustak (STScI)]



This infographic shows the evolution astronomers propose for supernova (SN) 2013ge. Panels 1-3 show what has already occurred, and panels 4-6 show what may take place in the future. 1) A binary pair of massive stars orbit one another. 2) One star ages into its red giant stage, getting a puffy outer envelope of hydrogen that its companion star siphons off with gravity. Astronomers propose this is why Hubble found no trace of hydrogen in the supernova debris. 3) The stripped-envelope star goes supernova (SN 2013ge), jostling but not destroying its companion star. After the supernova, the dense core of the former massive star remains either as neutron star or black hole. 4) Eventually the companion star also ages into a red giant, maintaining its outer envelope, some of which came from its companion. 5) The companion star also undergoes a supernova. 6) If the stars were close enough to each other not to be flung from their orbits by the supernova blast wave, the remnant cores will continue to orbit one another and eventually merge, creating gravitational waves in the process. [NASA, ESA, Leah Hustak (STScI)]

The cause of the hydrogen loss had been a mystery, and astronomers have been using Hubble to search for clues and test theories to explain these stripped supernovae. The new Hubble observations provide the best evidence yet to support the theory that an unseen companion star siphons off the gas envelope from its partner star before it explodes.

"This was the moment we had been waiting for, finally seeing the evidence for a binary system progenitor of a fully stripped supernova," said astronomer Ori Fox of the Space Telescope Science Institute in Baltimore, Maryland, lead investigator on the Hubble research program. *"The goal is to move this area of study from theory to working with data and seeing what these systems really look like."* Fox's team used Hubble's Wide Field Camera 3 to study the region of supernova (SN) 2013ge in ultraviolet light, as well as previous Hubble observations in the Barbara A. Mikulski Archive for Space Telescopes (MAST). Astronomers saw the light of the supernova fading over time from 2016 to 2020 — but another nearby source of ultraviolet light at the same position maintained its brightness. This underlying source of ultraviolet emission is what the team proposes is the surviving binary companion to SN 2013ge.

Previously, scientists theorized that a massive progenitor star's strong winds could blow away its hydrogen gas envelope, but observational evidence didn't support that. To explain the disconnect, astronomers developed theories and models in which a binary companion siphons off the hydrogen. *"In recent years many different lines of evidence have told us that stripped supernovae are likely formed in binaries, but we had yet to actually see the companion. So much of studying cosmic explosions is like forensic science — searching for clues and seeing what theories match. Thanks to Hubble, we are able to see this directly,"* said Maria Drout of the University of Toronto, a member of the Hubble research team.

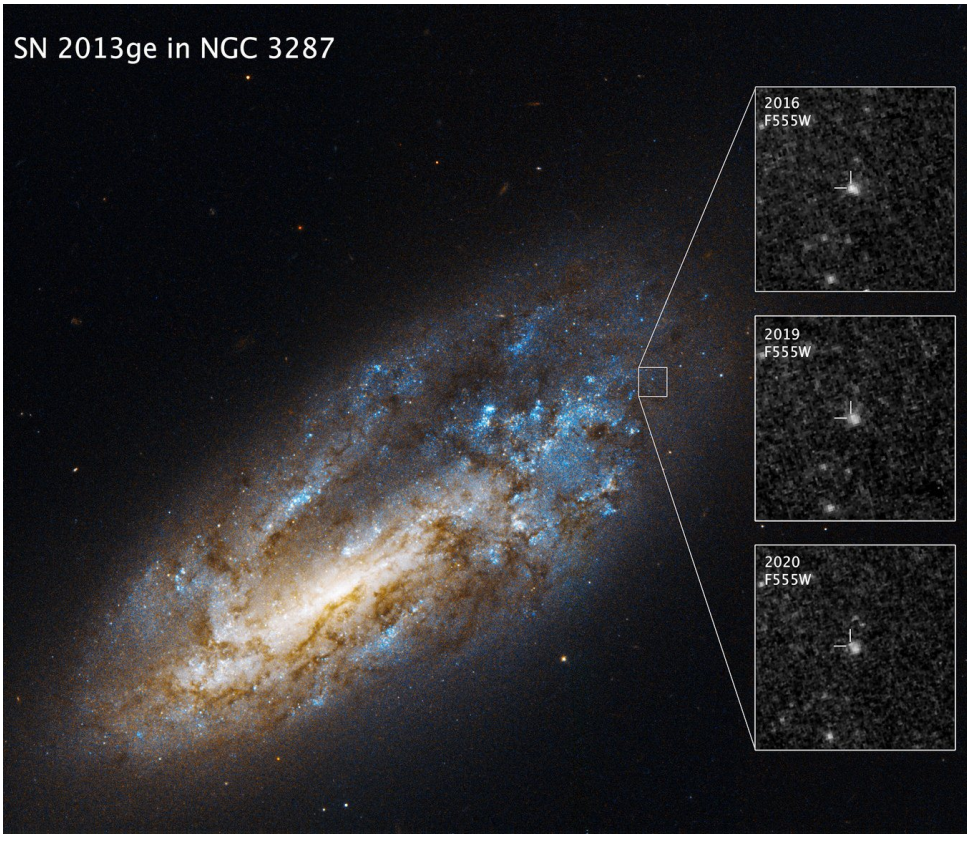
In prior observations of SN 2013ge, Hubble saw two peaks in the ultraviolet light, rather than just the one typically seen in most supernovae. Fox said that one explanation for this double brightening was that the second peak shows when the supernova's shock wave hit a companion star, a possibility that now seems much more likely. Hubble's latest observations indicate that while the companion star was significantly jostled, including the hydrogen gas it had siphoned off its partner, it was not destroyed. Fox likens the effect to a jiggling bowl of jelly, which will eventually settle back to its original form. While additional confirmation and similar supporting discoveries need to be found, Fox said that the

implications of the discovery are still substantial, lending support to theories that the majority of massive stars form and evolve as binary systems.

Unlike supernovae that have a puffy shell of gas to light up, the progenitors of fully stripped-envelope supernovae have proven difficult to identify in pre-explosion images.

Now that astronomers have been lucky enough to identify the surviving companion star, they can use it to work backward and determine characteristics of the star that exploded, as well as the unprecedented opportunity to watch the aftermath unfold with the survivor.

As a massive star itself, SN 2013ge's companion is also destined to undergo a supernova. Its former partner is now likely a compact object, such as a neutron star or black hole, and the companion will likely go that route as well.



Hubble images of galaxy NGC 3287 show supernova 2013ge fading over time, revealing the steady source of ultraviolet light astronomers have identified as its binary companion star. [NASA, ESA, Ori Fox (STScI), Joseph DePasquale (STScI)]

The closeness of the original companion stars will determine if they stay together. If the distance is too great, the companion star will be flung out of the system to wander alone across our galaxy, a fate that could explain many seemingly solitary supernovae. However, if the stars were close enough to each other pre-supernova, they will continue orbiting each other as black holes or neutron stars. In that case, they would eventually spiral toward each other and merge, creating gravitational waves in the process.

That is an exciting prospect for astronomers, as gravitational waves are a branch of astrophysics that has only begun to be explored. They are waves or ripples in the fabric of spacetime itself, predicted by Albert Einstein in the early 20th century. Gravitational waves were first directly observed by the Laser Interferometer Gravitational-Wave Observatory (LIGO). *"With the surviving companion of SN 2013ge, we could potentially be seeing the prequel to a gravitational wave event, although such an event would still be about a billion years in the future,"* Fox said. Fox and his collaborators will be working with Hubble to build up a larger sample of surviving companion stars to other supernovae, in effect giving SN 2013ge some company again. *"There is great potential beyond just understanding the supernova itself. Since we now know most massive stars in the universe form in binary pairs, observations of surviving companion stars are necessary to help understand the details behind binary formation, material-swapping, and co-evolutionary development. It's an exciting time to be studying the stars,"* Fox said. *"Understanding the lifecycle of massive stars is particularly important to us because all heavy elements are forged in their cores and through their supernovae. Those elements make up much of the observable universe, including life as we know it,"* added co-author Alex Filippenko of the University of California at Berkeley. ■

Four of our galactic neighbors in a different light

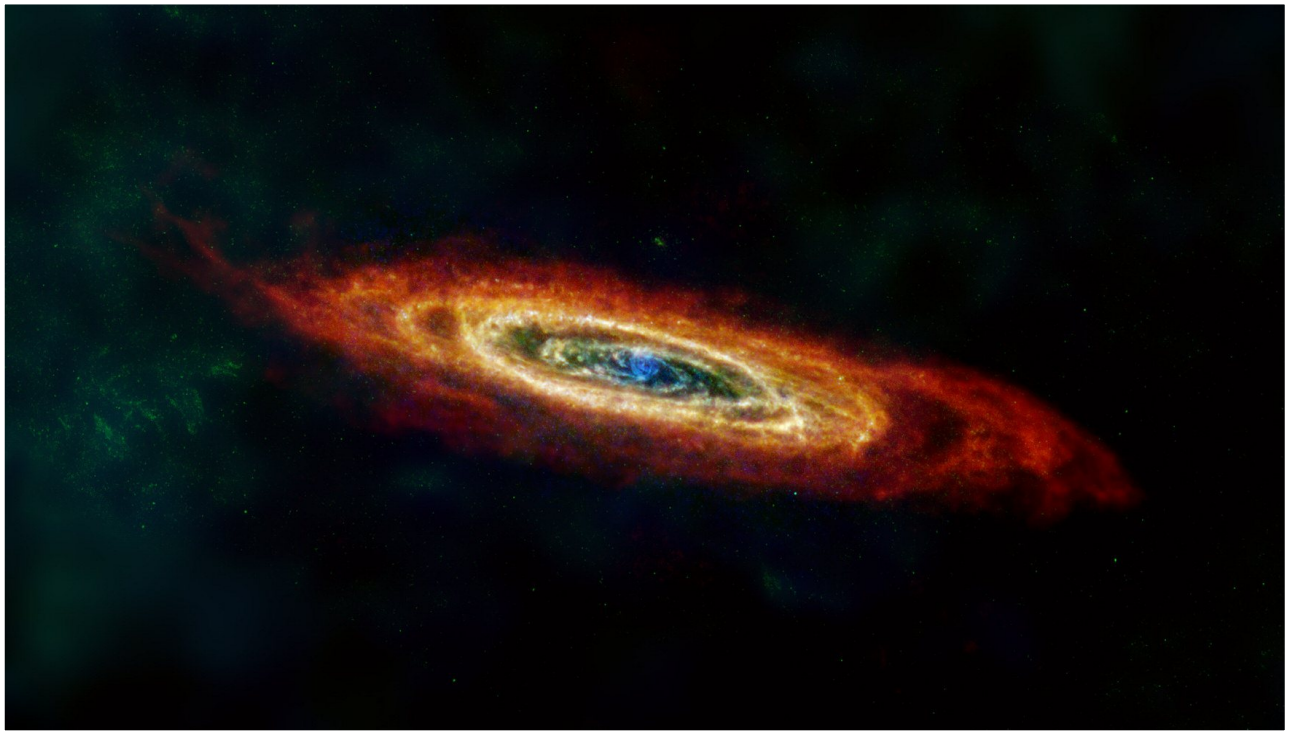
by NASA/ESA
Calla E. Cofield

New images using data from European Space Agency (ESA) and NASA missions showcase the gas and dust that fill the space between stars in four of the galaxies closest to our own Milky Way. More than striking, the snapshots are also a scientific trove, lending insight into how dramatically the density of dust clouds can vary within a galaxy. With a consistency similar to smoke, dust is created by dying stars and is one of the materials that forms new stars. The dust clouds observed by space telescopes are constantly shaped and molded by exploding stars, stellar winds, and the effects of gravity. Almost half of all the starlight in the universe is absorbed by dust.

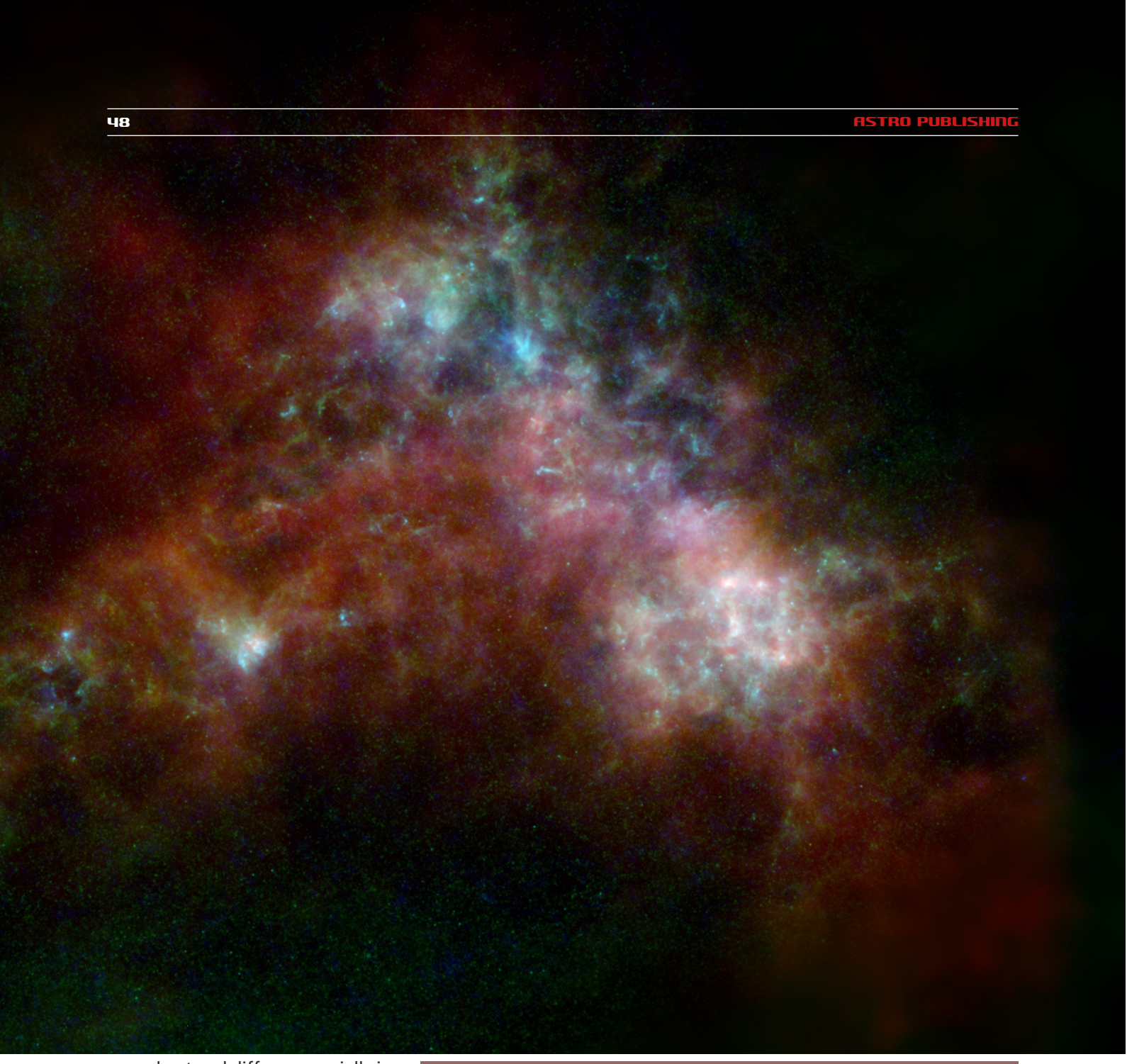
The Large Magellanic Cloud (LMC) is a satellite of the Milky Way, containing about 30 billion stars. Seen here in a far-infrared and radio view, the LMC's cool and warm dust are shown in green and blue, respectively, with hydrogen gas in red. The image is composed of data from the European Space Agency (ESA) Herschel mission, supplemented with data from ESA's retired Planck observatory and two retired NASA missions: the Infrared Astronomy Survey and Cosmic Background Explorer, as well as the Parkes, ATCA, and Mopra radio telescopes. [ESA, NASA, NASA-JPL, Caltech, Christopher Clark (STScI), S. Kim (Sejong University), T. Wong (UIUC)]

Many of the heavy chemical elements essential to forming planets like Earth are locked up in dust grains in interstellar space. Understanding dust is an essential part of understanding our universe.

The observations were made possible through the work of ESA's Herschel Space Observatory, which operated from 2009 to 2013. Herschel's super-cold instruments were able to detect the thermal glow of dust, which is emitted as far-infrared light, a range of wavelengths longer than what human eyes can detect. Herschel's images of interstellar dust provide high-resolution views of fine details in these clouds, revealing intricate substructures. But the way the space telescope was designed meant that it often couldn't detect light from clouds that are more

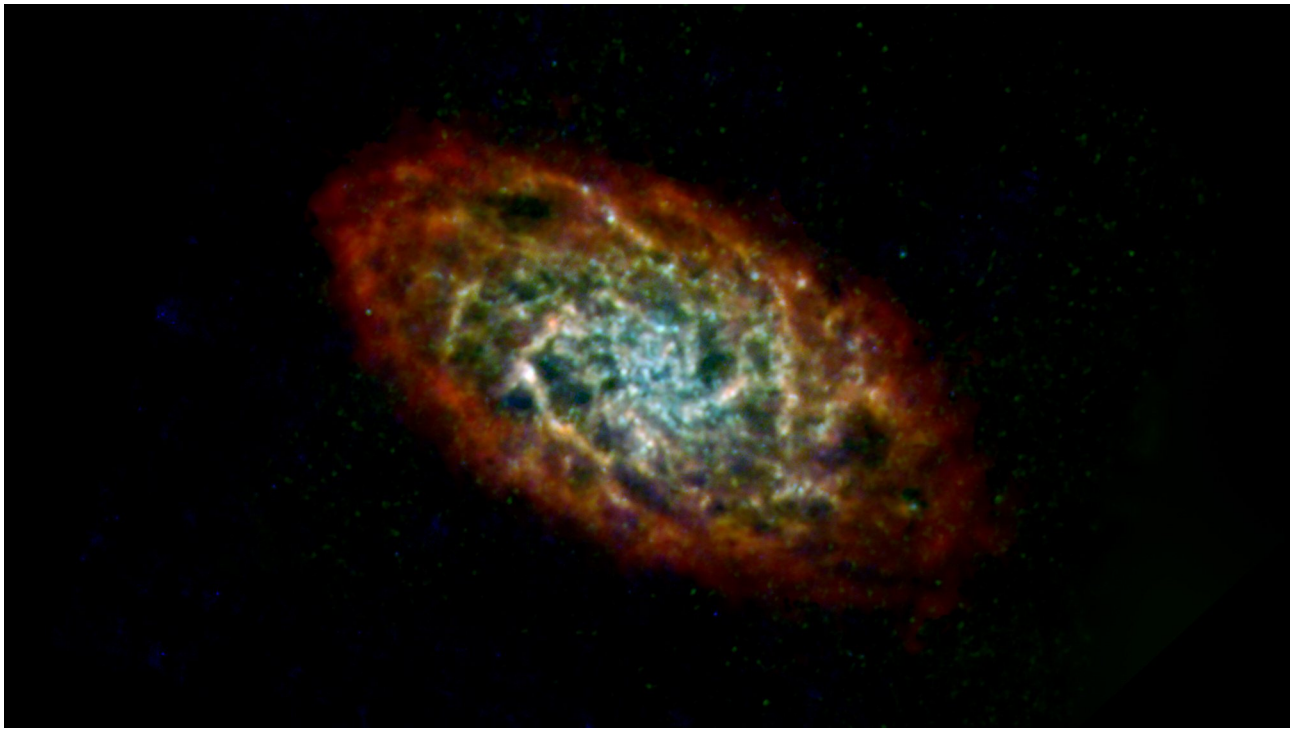


The Andromeda galaxy, or M31, is shown here in far-infrared and radio wavelengths of light. Some of the hydrogen gas (red) that traces the edge of Andromeda's disc was pulled in from intergalactic space, and some was torn away from galaxies that merged with Andromeda far in the past. The image is composed of data from the European Space Agency (ESA) Herschel mission, supplemented with data from ESA's retired Planck observatory and two retired NASA missions: the Infrared Astronomy Survey and Cosmic Background Explorer, as well as the Green Bank Telescope, WRST, and IRAM radio telescopes. [ESA, NASA, NASA-JPL, Caltech, Christopher Clark (STScI), R. Braun (SKA Obs.), C. Nieten (MPI Radioastronomie), Matt Smith (Cardiff Univ.)]



The Small Magellanic Cloud is a satellite of the Milky Way, containing about 3 billion stars. This far-infrared and radio view of it shows the cool (green) and warm (blue) dust, as well as the hydrogen gas (red). The image is composed of data from the European Space Agency (ESA) Herschel mission, supplemented with data from ESA's retired Planck observatory and two retired NASA missions: the Infrared Astronomy Survey and Cosmic Background Explorer, as well as the Parkes, ATCA, and NANTEN radio telescopes. [ESA, NASA, NASA-JPL, Caltech, Christopher Clark (STScI), S. Stanimirovic (UW-Madison), N. Mizuno (Nagoya University)]

spread out and diffuse, especially in the outer regions of galaxies, where the gas and dust become sparse and thus fainter. For some nearby galaxies, that meant Herschel missed up to 30% of all the light given off by dust. With such a significant gap, astronomers struggled to use the Herschel data to understand how dust and gas behaved in these environments. To fill out the Herschel dust maps, the new images combine data from three other missions: ESA's retired Planck observatory, along with two retired NASA missions, the Infrared Astronomical Satellite (IRAS) and Cosmic Background Explorer (COBE). The images show the Andromeda galaxy, also known as M31; the Triangulum galaxy, or M33; and the Large and Small Magellanic Clouds – dwarf galaxies orbiting the Milky Way that do not have the spiral structure of the Andromeda and



The Triangulum galaxy, or M33, is shown here in far-infrared and radio wavelengths of light. Some of the hydrogen gas (red) that traces the edge of the Triangulum's disc was pulled in from intergalactic space, and some was torn away from galaxies that merged with Triangulum far in the past. The image is composed of data from the European Space Agency (ESA) Herschel mission, supplemented with data from ESA's retired Planck observatory and two retired NASA missions: the Infrared Astronomy Survey and Cosmic Background Explorer, as well as the Very Large Array, Green Bank Telescope, and IRAM radio telescope. [ESA, NASA, NASA-JPL, Caltech, Christopher Clark (STScI), E. Koch (University of Alberta), C. Druard (University of Bordeaux)]

Triangulum galaxies. All four are within 3 million light-years of Earth. In the images, red indicates hydrogen gas, the most common element in the universe.

The image of the Large Magellanic Cloud shows a red tail coming off the bottom left of the galaxy that was likely created when it collided with the Small Magellanic Cloud about 100 million years ago. Bubbles of empty space indicate regions where stars have recently formed, because intense winds from the newborn stars blow away the surrounding dust and gas. The green light around the edges of those bubbles indicates the presence of cold dust that has piled up as a result of those winds. Warmer dust, shown in blue, indicates where stars are forming or other processes have heated the dust.

Many heavy elements in nature – like carbon, oxygen, and iron – can get stuck to dust grains, and the presence of different elements changes the way dust absorbs starlight. This in turn affects the view astronomers get of events like star formation. In the densest dust clouds, almost all the heavy elements can get locked up in dust grains, which increases the dust-to-gas ratio. But in less dense regions, the destructive radiation from newborn stars or shockwaves from exploding stars will smash the dust grains and return some of those locked-up heavy elements back into the gas, changing the ratio once again. Scientists who study interstellar space and star formation want to better understand this ongoing cycle. The Herschel images show that the dust-to-gas ratio can vary within a single galaxy by up to a factor of 20, far more than previously estimated.

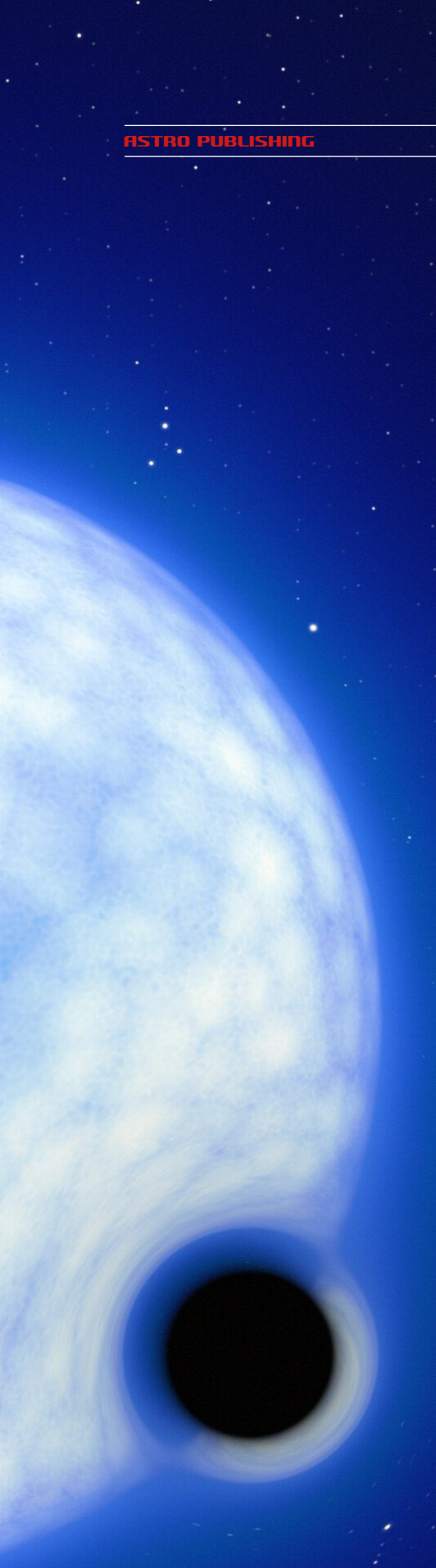
"These improved Herschel images show us that the dust 'ecosystems' in these galaxies are very dynamic," said Christopher Clark, an astronomer at the Space Science Telescope Institute in Baltimore, Maryland, who led the work to create the new images. These results were featured in a press conference at the summer meeting of the American Astronomical Society. ■

A dormant black hole outside our galaxy

by ESO - Bárbara Ferreira

A team of international experts, renowned for debunking several black hole discoveries, have found a stellar-mass black hole in the Large Magellanic Cloud, a neighbour galaxy to our own. *"For the first time, our team got together to report on a black hole discovery, instead of rejecting one,"* says study leader Tomer Shenar. Moreover, they found that the star that gave rise to the black hole vanished without any sign of a powerful explosion. The discovery was made thanks to six years of observations obtained with the European Southern Observatory's (ESO's) Very Large Telescope (VLT). *"We identified a 'needle in a haystack',"* says Shenar

This is what the VFTS 243 binary system might look like if we looked at it closely. The system is composed of a very hot blue star, 25 times more massive than the Sun, and a black hole of at least 9 solar masses. The representation is not to scale: in reality, the blue star is about 200,000 times larger than the black hole.



who started the study at KU Leuven in Belgium and is now a Marie-Curie Fellow at Amsterdam University, the Netherlands. Though other similar black hole candidates have been proposed, the team claims this is the first 'dormant' stellar-mass black hole to be unambiguously detected outside our galaxy.

Stellar-mass black holes are formed when massive stars reach the end of their lives and collapse under their own gravity. In a binary, a system of two stars revolving around each other, this process leaves behind a black hole in orbit with a luminous companion star. The black hole is 'dormant' if it does not emit high levels of X-ray radiation, which is how such black holes are typically detected. *"It is incredible that we hardly know of any dormant black holes, given how common astronomers believe them to be,"* explains co-author Pablo Marchant of KU Leuven. The newly found black hole is at least nine times the mass of our Sun, and orbits a hot, blue star weighing 25 times the Sun's mass. Dormant black holes are particularly hard to spot since they do not interact much with their surroundings. *"For more than two years now, we have been looking for such black-hole-binary systems,"* says co-author Julia Bodensteiner, a research fellow at ESO in Germany. *"I was very excited when I heard about VFTS 243, which in my opinion is the most convincing candidate reported to date."*

To find VFTS 243, the collaboration searched nearly 1000 massive stars in the Tarantula Nebula region of the Large Magellanic Cloud, looking for the ones that could have black holes as companions. Identifying these companions as black holes is extremely difficult, as so many alternative possibilities exist.

"As a researcher who has debunked potential black holes in recent years, I was extremely skeptical regarding this discovery," says Shenar. The skepticism was shared by co-author Kareem El-Badry of the Center for Astrophysics | Harvard & Smithsonian in the USA, whom Shenar calls the "black hole destroyer". *"When Tomer asked me to double check his findings, I had my doubts. But I could not find a plausible explanation for the data that did not involve a black hole,"* explains El-Badry.

The discovery also allows the team a unique view into the processes that accompany the formation of black holes. Astronomers believe that a stellar-mass black hole forms as the core of a dying massive star collapses, but it remains uncertain whether or not this is accompanied by a powerful supernova explosion. *"The star that formed the black hole in VFTS 243 appears to have collapsed entirely, with no sign of a previous explosion,"* explains Shenar. *"Evidence for this 'direct-collapse' scenario has been emerging recently, but our study arguably provides one of the most direct indications. This has enormous implications for the origin of black-hole mergers in the cosmos."*

The black hole in VFTS 243 was found using six years of observations of the Tarantula Nebula by the Fibre Large Array Multi Element Spectrograph (FLAMES) instrument on ESO's VLT. Despite the nickname 'black hole police', the team actively encourages scrutiny, and hopes that their work, published in *Nature Astronomy*, will enable the discovery of other stellar-mass black holes orbiting massive stars, thousands of which are predicted to exist in Milky Way and in the Magellanic Clouds. *"Of course I expect others in the field to pore over our analysis carefully, and to try to cook up alternative models,"* concludes El-Badry. *"It's a very exciting project to be involved in."*

First recording of a short GRB at millimeter wavelengths

by ALMA Observatory
Nicolás Lira

Scientists using the Atacama Large Millimeter/submillimeter Array (ALMA) have for the first time recorded millimeter-wavelength light from a fiery explosion caused by the merger of a neutron star with another star. The team also confirmed this flash of light to be one of the most energetic short-duration gamma-ray bursts ever observed, leaving behind one of the most luminous afterglows on record. The research results have been published in *The Astrophysical Journal Letters*.

Gamma-ray bursts (GRBs) are the brightest and most energetic explosions in the Universe, capable of emitting more energy in a matter of seconds than our Sun will emit during its entire lifetime.

GRB 211106A belongs to a GRB sub-class known as short-duration gamma-ray bursts. These explosions — which scientists believe are responsible for the creation of the heaviest elements in the Universe, such as platinum and gold — result from the catastrophic merger of binary star systems containing a neutron star. *"These mergers occur because of gravitational wave radiation that removes energy from the orbit of the binary stars, causing the stars to spiral in toward each other,"* said Tanmoy Laskar, who

In a first for radio astronomy, scientists have detected millimeter-wavelength light from a short-duration gamma-ray burst. This artist's conception shows the merger between a neutron star and another star (seen as a disk, lower left) which caused an explosion resulting in the short-duration gamma-ray burst, GRB 211106A (white jet, middle), and left behind what scientists now know to be one of the most luminous afterglows on record (semi-spherical shock wave mid-right). While dust in the host galaxy obscured most of the visible light (shown as colors), millimeter light from the event (depicted in green) was able to escape and reach the Atacama Large Millimeter/submillimeter Array (ALMA), giving scientists an unprecedented view of this cosmic explosion. From the study, the team confirmed that GRB 211106A is one of the most energetic short-duration GRBs ever observed. [ALMA (ESO/NAOJ/NRAO), M. Weiss (NRAO/AUI/NSF)]

will soon commence work as an Assistant Professor of Physics and Astronomy at the University of Utah. *"The resulting explosion is accompanied by jets moving at close to the speed of light. When one of these jets is pointed at Earth, we observe a short pulse of gamma-ray radiation or a short-duration GRB."*

A short-duration GRB usually lasts only a few tenths of a second. Scientists then look for an afterglow, an emission of light caused by the interaction of the jets with surrounding gas. Even still, they're difficult to detect; only half-a-dozen short-duration GRBs have been detected at radio wavelengths, and until now none had been detected in millimeter wavelengths.

Laskar, who led the research while an Excellence Fellow at Radboud University in The Netherlands, said that the difficulty is the immense distance to GRBs, and the technological capabilities of telescopes. *"Short-duration GRB afterglows are very luminous and energetic. But these explosions take place in distant galaxies which means the light from them can be quite faint for our telescopes on Earth. Before ALMA, millimeter telescopes were not sensitive enough to detect these afterglows."*

Having occurred when the Universe was just 40-percent of its current age, GRB 211106A is no exception. The light from this short-duration gamma-ray burst was so faint that while early X-ray observations with NASA's Neil Gehrels Swift Observatory saw the explosion, the host galaxy was undetectable at that wavelength, and scientists weren't able to determine exactly where the explosion was coming from. *"Afterglow light is essential for figuring out which galaxy a burst comes from and for learning more about the burst itself. Initially, when only the X-ray counterpart had been discov-*

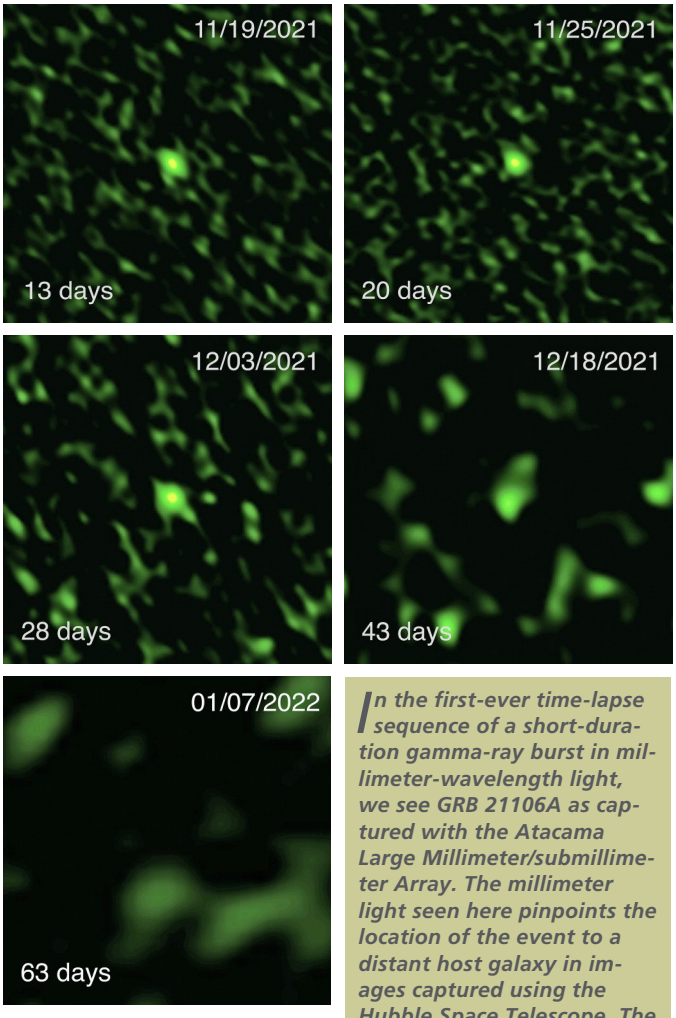
ered, astronomers thought that this burst might be coming from a nearby galaxy," said Laskar, adding that a significant amount of dust in the area also obscured the object from detection in optical observations with the Hubble Space Telescope.

Each wavelength added a new dimension to scientists' understanding of the GRB, and millimeter, in particular, was critical to uncovering the truth about the burst.

"The Hubble observations revealed an unchanging field of galaxies. ALMA's unparalleled sensitivity allowed us to pinpoint the location of the GRB in that field with more precision, and it turned out to be in another faint galaxy, which is further away. That, in turn, means that this short-duration gamma-ray burst is even more powerful than we first thought, making it one of the most luminous and energetic on record," said Laskar.

Wen-fai Fong, an Assistant Professor of Physics and Astronomy at Northwestern University added, *"This short gamma-ray burst was the first time we tried to observe such an event with ALMA. Afterglows for short bursts are very difficult to come by, so it was spectacular to catch this event shining so bright. After many years of observing these bursts, this surprising discovery opens up a new area of study, as it motivates us to observe many more of these with ALMA, and other telescope arrays, in the future."*

Joe Pesce, National Science Foundation Program Officer for NRAO/ALMA said, *"These observations are fantastic on many levels. They provide more information to help us understand the enigmatic gamma-ray bursts (and neutron-star astrophysics in general), and they demonstrate how important and complementary multi-wavelength observations with space- and ground-based telescopes are in understanding astrophysical phenomena."*



In the first-ever time-lapse sequence of a short-duration gamma-ray burst in millimeter-wavelength light, we see GRB 21106A as captured with the Atacama Large Millimeter/submillimeter Array. The millimeter light seen here pinpoints the location of the event to a distant host galaxy in images captured using the Hubble Space Telescope. The evolution of the millimeter light's brightness provides information on the energy and geometry of the jets produced in the explosion. [ALMA (ESO/NAOJ/ NRAO), T. Laskar (Utah), S. Dagnello (NRAO/AUI/NSF)]

And there's plenty of work still to be done across multiple wavelengths, both with new GRBs and with GRB 211106A, which could uncover additional surprises about these bursts. *"The study of short-duration GRBs requires the rapid coordination of telescopes around the world and in space, operating at all wavelengths,"* said Edo Berger, Professor of Astronomy at Harvard University. *"In the case of GRB 211106A, we used some of the most powerful telescopes available — ALMA, the National Science Foundation's Karl G. Jansky Very Large Array (VLA), NASA's Chandra X-ray Observatory, and the Hubble Space Telescope. With the now-operational James Webb Space Telescope (JWST), and future 20-40 meter optical and radio telescopes such as the next generation VLA (ngVLA) we will be able to produce a complete picture of these cataclysmic events and study them at unprecedented distances."* Laskar added, *"With JWST, we can now take a spectrum of the host galaxy and easily know the distance, and in the future, we could also use JWST to capture infrared afterglows and study their chemical composition. With ngVLA, we will be able to study the geometric structure of the afterglows and the star-forming fuel found in their host environments in unprecedented detail. I am excited about these upcoming discoveries in our field."* ■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