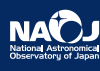
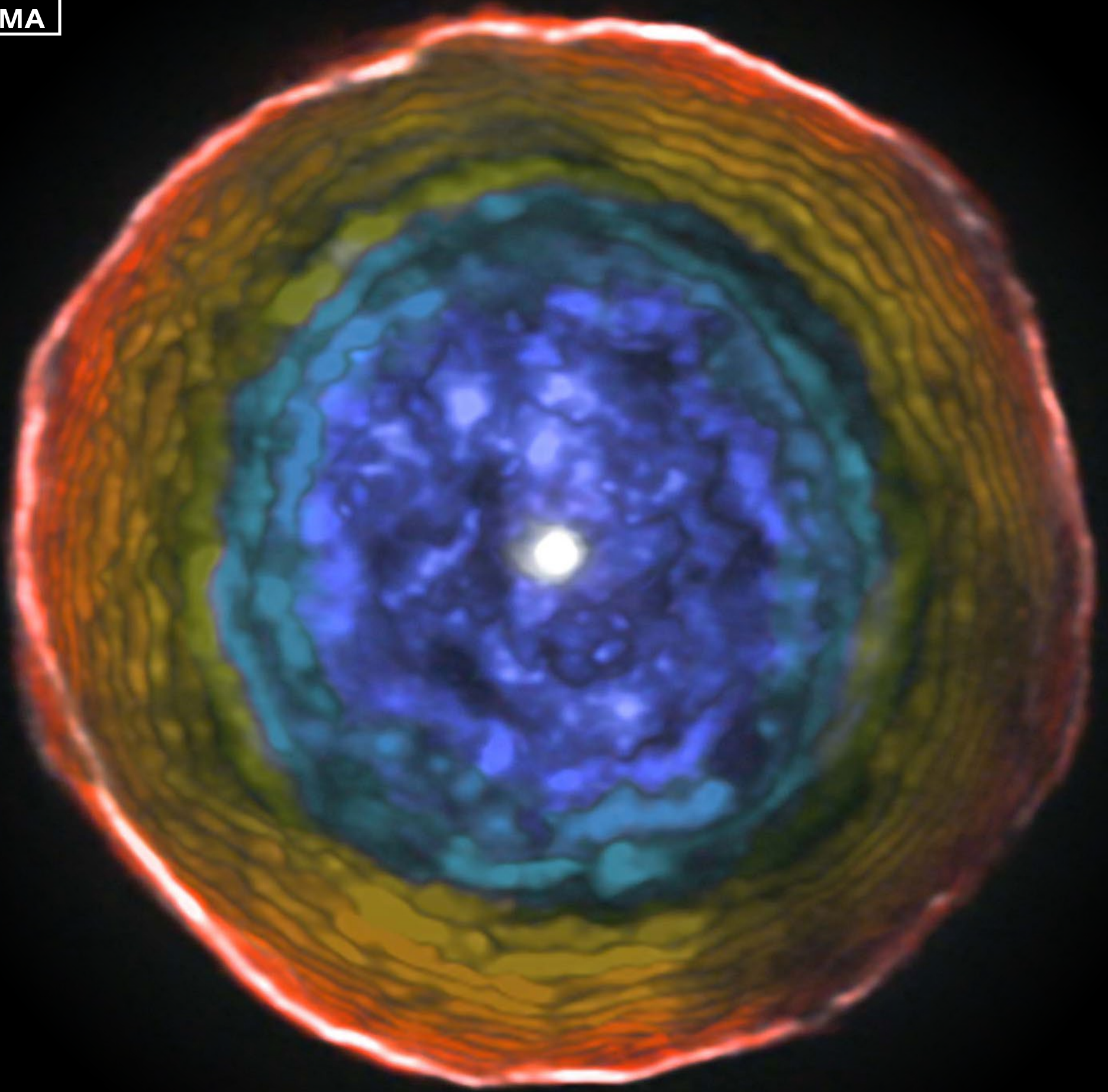




# 2019 CALENDAR



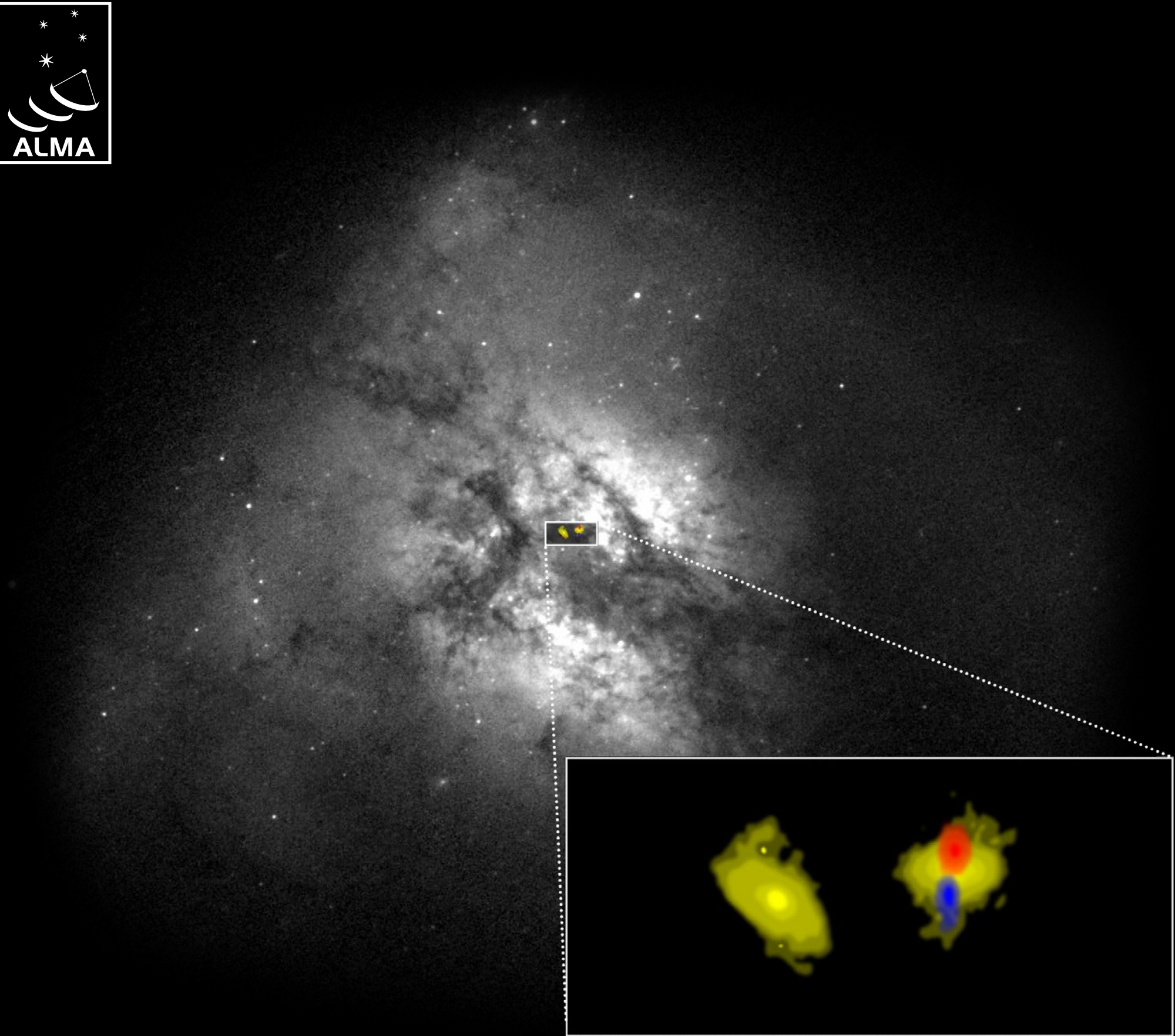




# JANUARY

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FEBRUARY

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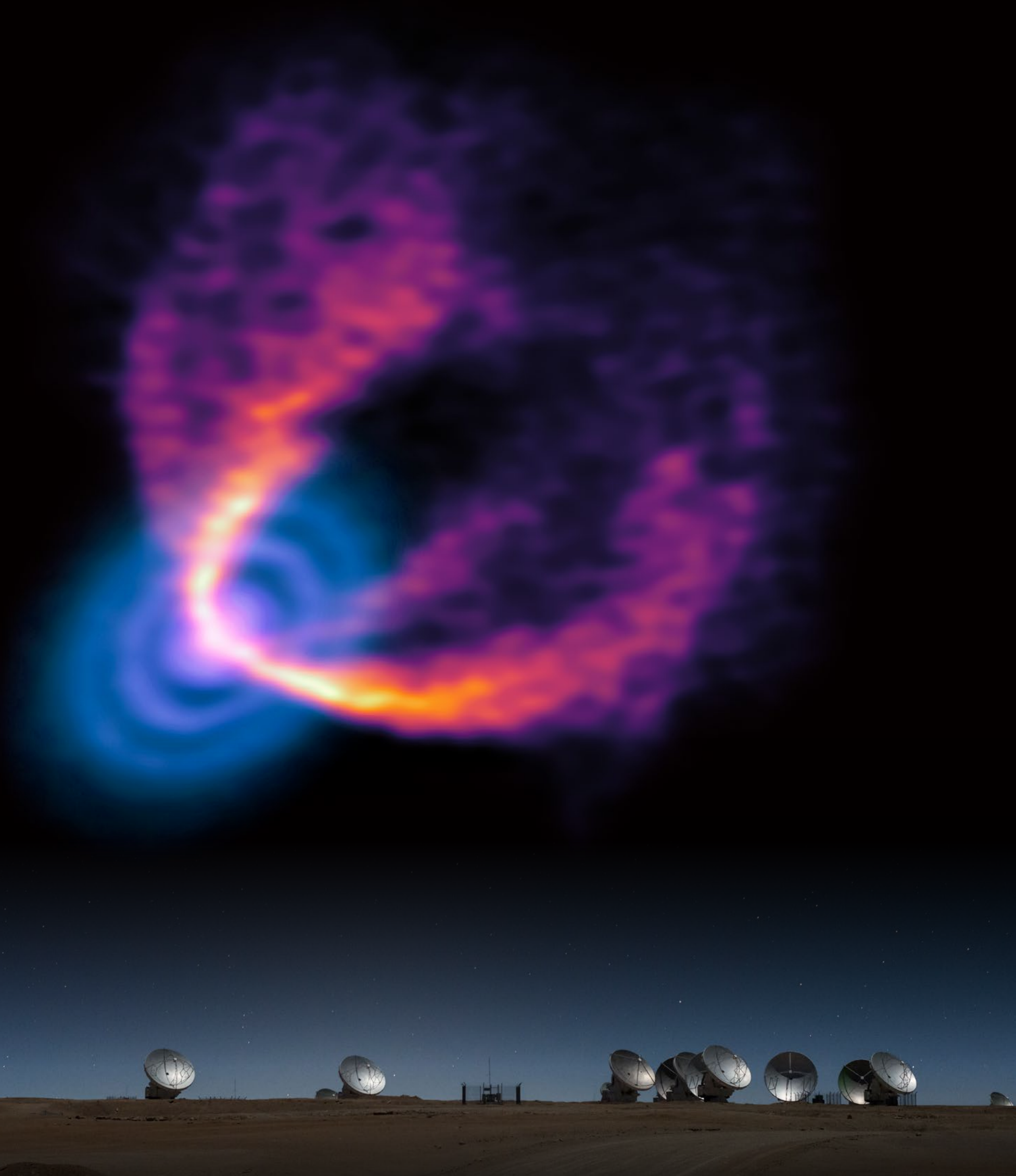




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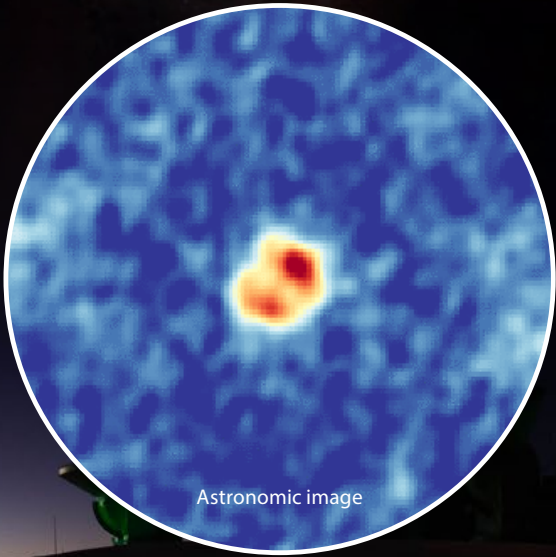
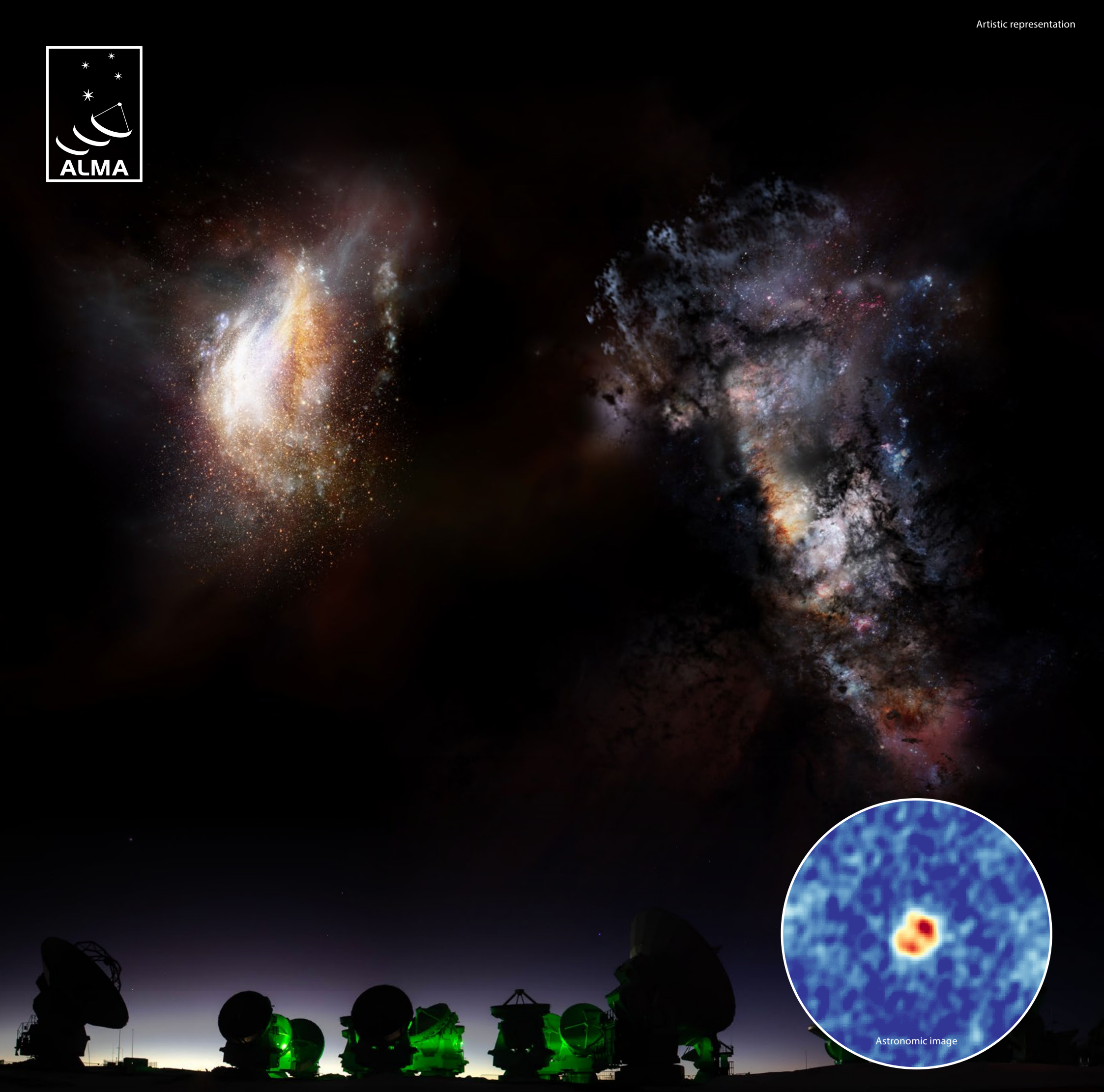
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# APRIL

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# MAY

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# JUNE

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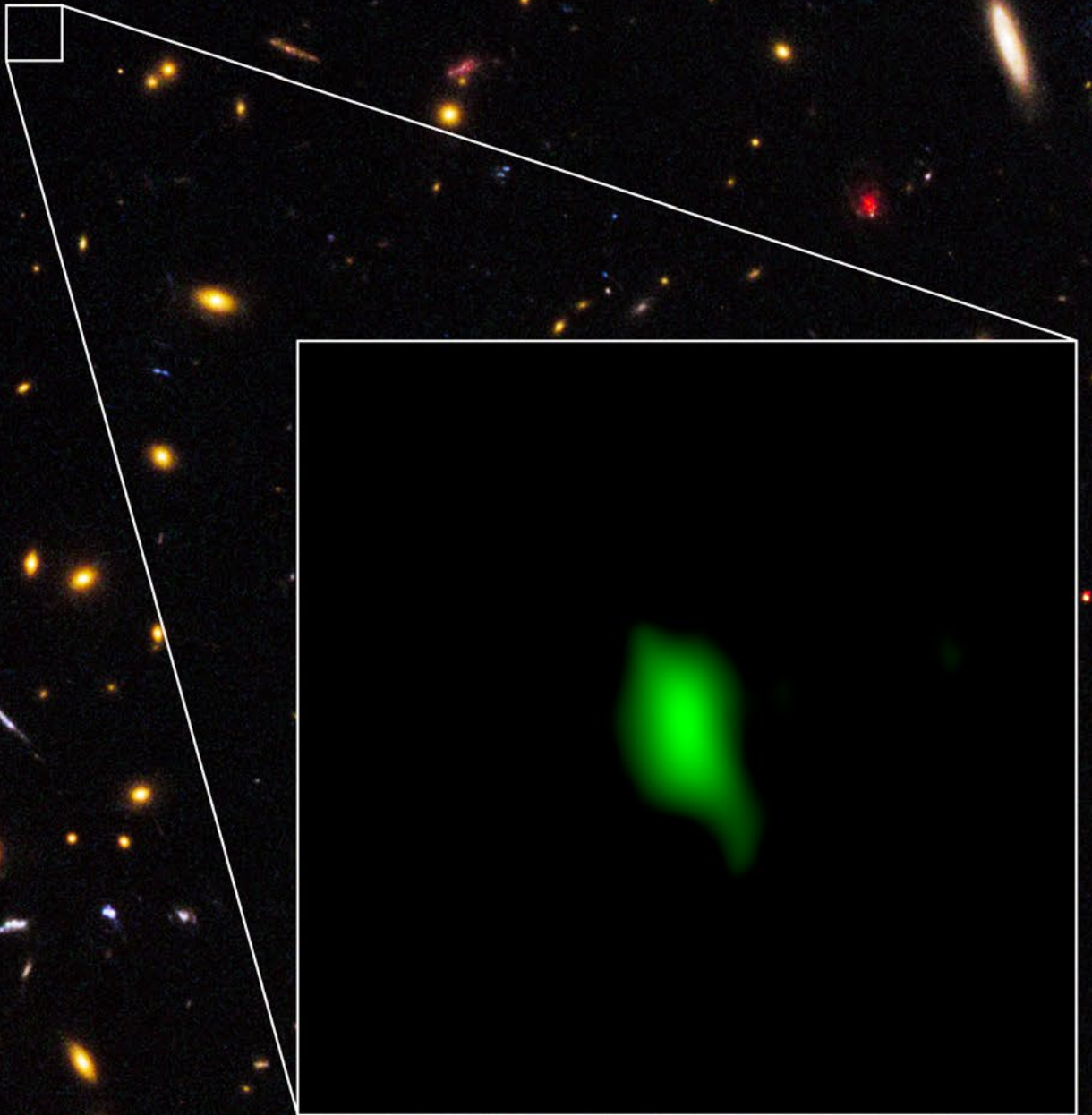




# JULY

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# AUGUST

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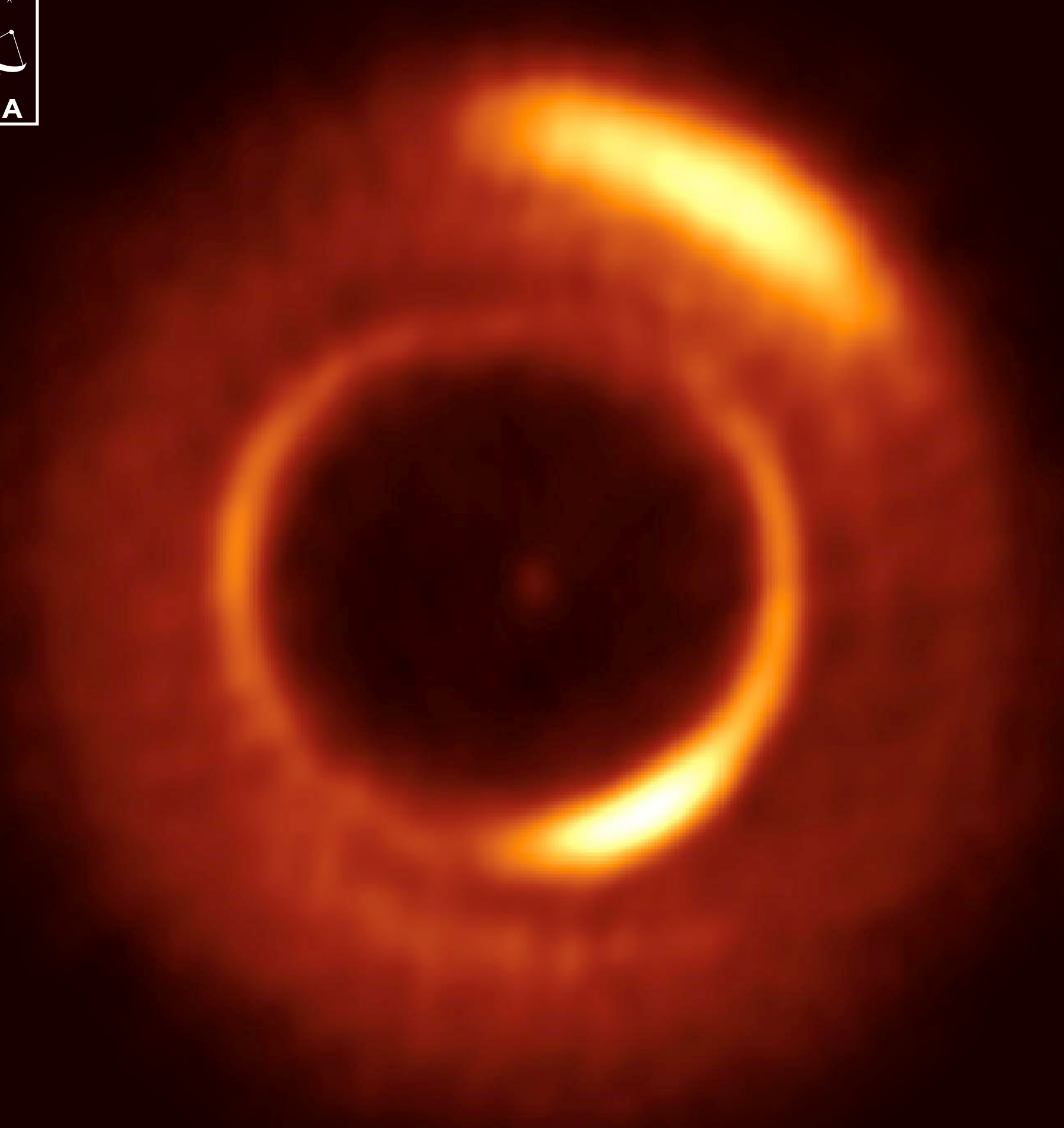




# SEPTEMBER

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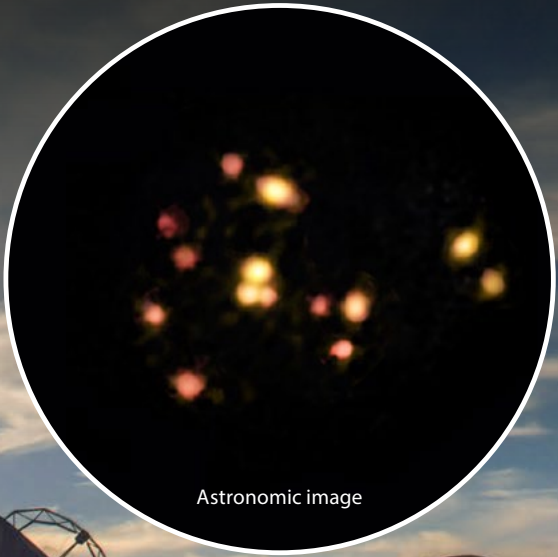
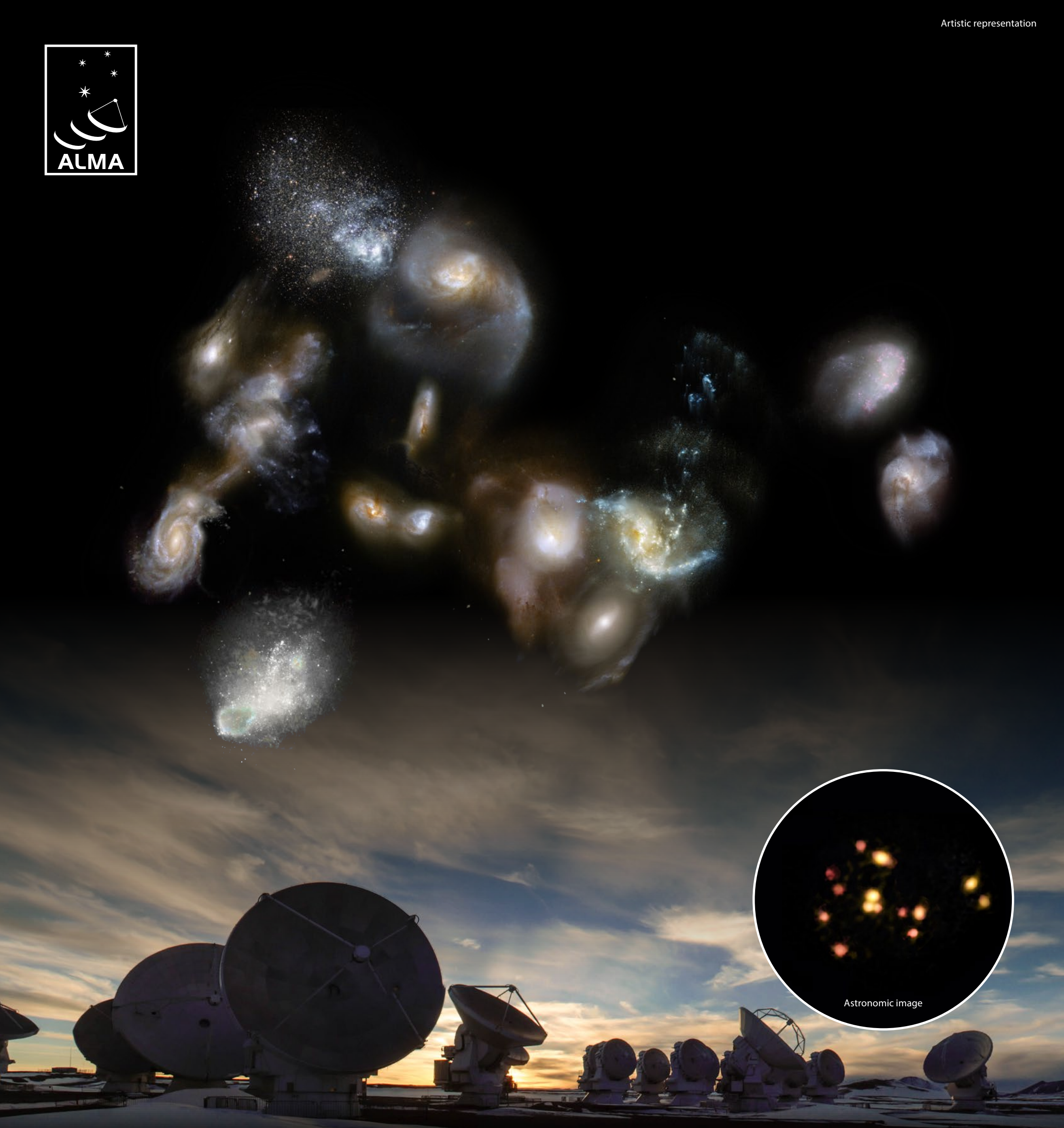




# OCTOBER

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# NOVEMBER

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# DECEMBER

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### Ageing star blows off smoky bubble

U Antliae is a giant carbon star, an evolved, cool and luminous star. Around 2,700 years ago, U Antliae went through a short period of rapid mass loss. During this period of only a few hundred years, the material making up the shell seen with ALMA was ejected at high speed. Examination of this shell in further detail also shows some evidence of thin, wispy gas clouds, known as filamentary substructures.

Astronomers have used ALMA to capture a strikingly beautiful view of a delicate bubble of expelled material around the exotic star. These observations will help astronomers to better understand how stars evolve during the later stages of their life-cycles.

But ALMA data are not just a single image: ALMA produces a three-dimensional dataset (a data cube), which shows images of gas moving at different speeds towards or away from the observer. This shell is also remarkable as it is very symmetrically round and also remarkably thin. By displaying the different velocities, we can cut this cosmic bubble into virtual slices just as we do in computer tomography of a human body.

**Credit:** ALMA (ESO/NAOJ/NRAO); F. Kerschbaum.

### ALMA observes outflow in ultraluminous infrared galaxy

Astronomers using ALMA observed for the first time an outflow emerging from one of the nuclei in Arp 220, the closest ultraluminous infrared galaxy to Earth, resulting from the collision of two galaxies which are now in the process of merging. Although this object has been extensively studied, its compactness and obscurity have been a challenge for astronomers until now: ALMA observed the outflow from one of its nuclei in three dimensions (velocity and 2D spatial information).

The presence of an outflow has been previously detected in Arp 220. However, this is the first time it has been imaged and its kinematics and morphological characteristics determined. The flow is collimated, instead of the wide-angle morphology that is usually observed. With this discovery, it is possible now to start studying extragalactic outflows at smaller scales (with better resolution), giving the opportunity to research feedback processes in these galaxy nuclei.

**Credit:** NASA/ESA Hubble space telescope; Inset: L. Barcos-Muñoz, N. Lira, J. Pinto - ALMA (NRAO/NAOJ/ESO)



### Vicuñas on the way to ALMA

The ALMA astronomic observatory is located amidst an extremely complex ecosystem, with a wide variety of flora and fauna. Vicuñas are often seen along the road that connects the base camp (OSF) and the antenna site (AOS) at 5,000 meters above sea level.

These slender vicuñas are among the many groups of the species that can be found within the ALMA concession and its surroundings. This species is the smallest of the camelids, measuring about 80 centimeters and weighing between 40 and 50 kilos. Their wool is among the finest in the world and is highly regarded. They live only in the Puna, above 3,200 meters in altitude in the Andean Altiplano of Argentina, Chile, Bolivia, Ecuador and Peru, with the largest population in Peru.

According to the Atacameño people, vicuñas belong to Pachamama (Mother Earth) and their herdsman is Coquena, a benign mythological being, protector of the hill animals, specifically vicuñas and guanacos.

In addition to vicuñas, at ALMA there are also frequent sightings of foxes, caranchos, vizcachas and donkeys among the cactus and llaretas.

**Credit:** J. Guarda - ALMA (ESO/NAOJ/NRAO)

### ALMA discovers trio of infant planets around newborn star

ALMA has transformed our understanding of protoplanetary discs, the gas- and dust-filled planet factories that encircle young stars. The rings and gaps in these discs provide intriguing evidence for the presence of planets in formation.

Using a novel planet-hunting technique that identifies unusual patterns in the flow of gas within a protoplanetary disc around a young star, two teams of astronomers have each confirmed distinct telltale hallmarks of newly formed planets orbiting the infant star HD163296. This star is about twice the mass of the Sun but is only a thousandth of its age: 4 million years.

This new technique allows astronomers to estimate protoplanetary masses more precisely and is less likely to produce false positives.

**Credit:** Image of blue disc: ESO, ALMA (ESO/NAOJ/NRAO); Image of yellow and purple arms: A. Isella; B. Saxton (NRAO/AUI/NSF); Pinte et al.

**Image** of antennas: S. Otárola - ALMA (ESO/NAOJ/NRAO)

### Massive primordial galaxies found swimming in vast ocean of dark matter

Astronomers expected that the first galaxies, those that formed just a few hundred million years after the Big Bang, would share many similarities with some of the dwarf galaxies we see in the nearby Universe today. These agglomerations of stars would then become the building blocks of the largest galaxies that came to dominate the Universe after the first few billion years.

However, the latest observations push back this epoch of massive-galaxy formation even further to when the Universe was only about 5% of its current age. ALMA also revealed that these uncommonly large galaxies are nestled inside an even-more-massive cosmic structure: a halo of dark matter with as much mass as several trillion suns.

The two galaxies are in such close proximity (less than the distance from the Earth to the center of our galaxy) that they will shortly merge to form the largest galaxy ever observed at that period in cosmic history. This discovery provides new details about the emergence of large galaxies and the role that dark matter plays in assembling the most massive structures in the Universe.

**Credit:** Artistic representation: NRAO/AUI/NSF; D. Berry | Image of antennas: J. C. Rojas - ALMA (ESO/NAOJ/NRAO) | Astronomic image: ALMA (ESO/NAOJ/NRAO); D. Marrone et al.

### Researchers supported by ALMA identify Inca calendar in the Atacama Desert

A multidisciplinary team made up of archaeologists, historians and documentalists from the Chilean Museum of Pre-Colombian Art, supported by ALMA astronomers, and an Atacameño researcher (Jimena Cruz) ascertained the existence of astronomic structures in the Atacama Desert, bordering the Inca Trail. This discovery reveals that, far from being an “empty void,” this desert continues to be a place loaded with sacred significance.

Through the shadow they project on the ground during sunrise, the saywas, stone structures built by the Incas, identify and predict equinoxes, solstices and other astronomic events.

ALMA engaged in the project through its astronomers Sergio Martín and Juan Cortés, who were able to verify firsthand the incredible precision in the prediction of natural phenomena through supposedly primitive tools used by the Inca culture over 500 years ago.

**Credit:** R. Bennett - ALMA (ESO/NAOJ/NRAO)



### Too many massive stars found in starburst galaxies.

The mass of a star is the most important factor in determining how it will evolve. Massive stars shine brilliantly and have short lives, while less massive ones, such as the Sun, shine more modestly for billions of years. Consequently, this gives us crucial insights about the chemical elements available to form new stars and planets and, ultimately, the number of seed black holes that may coalesce to form the supermassive black holes that we see in the centers of many galaxies, such as in our Milky Way.

Astronomers using ALMA and the Very Large Telescope (VLT) have discovered that both starburst galaxies in the early Universe and star-forming regions in a nearby galaxy contain a much higher proportion of massive stars than is found in more peaceful galaxies. These findings challenge current ideas about how galaxies evolved, changing our understanding of star-formation and chemical elements.

**Credit:** ESO/M. Kornmesser | Image of antennas: S. Otárola - ALMA (ESO/NAOJ/NRAO)

### ALMA finds most-distant oxygen in the Universe

A team of astronomers detected a faint but definite signal of oxygen molecules in a galaxy located 13.28 billion light-years away from us, using ALMA. Breaking their records, this marks the most distant oxygen molecules ever detected. Referencing infrared observations, the team determined that this star formation in the galaxy started at an unexpectedly early stage, only 250 million years after the Big Bang.

For a period after the Big Bang, there was no oxygen in the Universe. Oxygen was created later in stars and then released when the stars died. The detection of oxygen in MACS1149-JD1 indicates that an earlier generation of stars had already been formed and expelled processed oxygen by the epoch of observation, which is only about 500 million years after the beginning of the Universe.

ALMA has set the record for the most distant oxygen several times. In 2016, Akio Inoue at Osaka Sangyo University and his colleagues found the signal of oxygen at 13.1 billion light-years away. Several months later, Nicolas Laporte from University College London and the University of Toulouse and his team observed oxygen at 13.2 billion light-years away. Now, the two teams merged into one and achieved this new record.

**Credit:** Background image: ALMA (ESO/NAOJ/NRAO), NASA/ESA Hubble space telescope | Inset: W. Zheng (JHU), M. Postman (STScI), the CLASH Team Hashimoto et al.

### Reaching full growth

In 2018, for the first time since its construction, ALMA operated for several months at maximum efficiency in observation time, with all of its 66 antennas available for observation. This is a major milestone for such a complex observatory, which was but a shared dream among the astronomical community until just over a decade ago. In 2018, ALMA also hit a symbolic number of 1,000 scientific publications in specialized journals, which were based on data obtained from observations with ALMA. These milestones show that the most important radio telescope in the world is reaching full growth.

The image shows one of the transporters designed and manufactured especially for ALMA, as it brings the first antenna to the Chajnantor plateau exactly 10 years ago (September 2009). By changing the distribution of the antenna array, different scientific targets can be observed. The antenna transporters can only relocate one antenna per day, so any position changes for the antennas array must be carefully planned in advance.

**Credit:** R. Bennett - ALMA (ESO/NAOJ/NRAO)

### Tell-tale signs of planets in young protoplanetary disc

Since early 2000, rich structures, including gaps and rings, dust clumps, and spiral arm-like features, have been discovered in a few tens of discs surrounding newborn stars. With the belief that planets are forming inside, astronomers named these discs protoplanetary discs.

The origin of these structures is in hot debate among astronomers. In one scenario, they are thought to be produced by unseen planets forming inside and gravitationally interacting with the host disks, as planets open gaps, shepherd dust clumps, and excite spiral arms.

Astronomers used ALMA to discover tell-tale signs of planets in the young protoplanetary disc around the star MWC 758. They obtained an ultra high resolution image revealing the disk having not only an off-centered cavity but also a spiral arm corresponding to one previously seen with another technique (reflected light).

**Credit:** ALMA (ESO/NAOJ/NRAO); Dong et al.

### Ancient galaxy megamergers

ALMA and ESO’s Atacama Pathfinder Experiment (APEX) have peered into deep space and witnessed the beginnings of gargantuan cosmic pileups: the impending collision of young, starburst galaxies. Astronomers thought that these events occurred around three billion years after the Big Bang, so they were surprised when the new observations revealed them happening when the Universe was only half that age. These ancient systems of galaxies are thought to be building the most massive structures in the known Universe: galaxy clusters.

The individual galaxies in this dense cosmic pileup are starburst galaxies and the concentration of this vigorous star formation in such a compact region makes this by far the most active region ever observed in the young Universe. Thousands of stars are born there every year, compared to just one in our own Milky Way.

ALMA and APEX observations showed that these clusters, called SPT2349-56, had an unusual structure and confirmed that their light originated much earlier than expected, only 1.5 billion years after the Big Bang.

**Credit:** Artistic representation: ESO/M. Kornmesser | Image of antennas: J. C. Rojas - ALMA (ESO/NAOJ/NRAO) | Astronomic image: ESO/ALMA (ESO/NAOJ/NRAO)/Miller et al.



### Water channeled through the desert

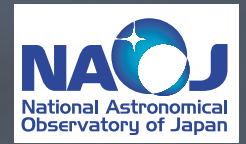
At 5,400 meters above sea level, an area known as “Paso Jama” is home to one of the community development projects supported by ALMA Funds in the 2106-2017 period. This picture shows the 3-kilometer pipeline installed by members of the Paso Jama Indigenous Association of Farmers and Irrigators to carry water from the Pajarito watershed to their homes.

ALMA Funds are an agreement with the Regional Government of Antofagasta for the development of the territory known as Atacama la Grande, which seeks to improve the living conditions of its inhabitants through initiatives designed and implemented by the different communities, associations and organizations that form part of this territory.

These are funds that indigenous associations recognized by the National Indigenous Development Corporation (CONADI) can apply for, as well as social organizations made up of at least 80% indigenous people, with legal status issued by the Municipality of San Pedro de Atacama.

**Credit:** R. Bennett - ALMA (ESO/NAOJ/NRAO)





The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Organisation for Astronomical Research in the Southern Hemisphere (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the Ministry of Science and Technology (MOST) in Taiwan and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI).

ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.