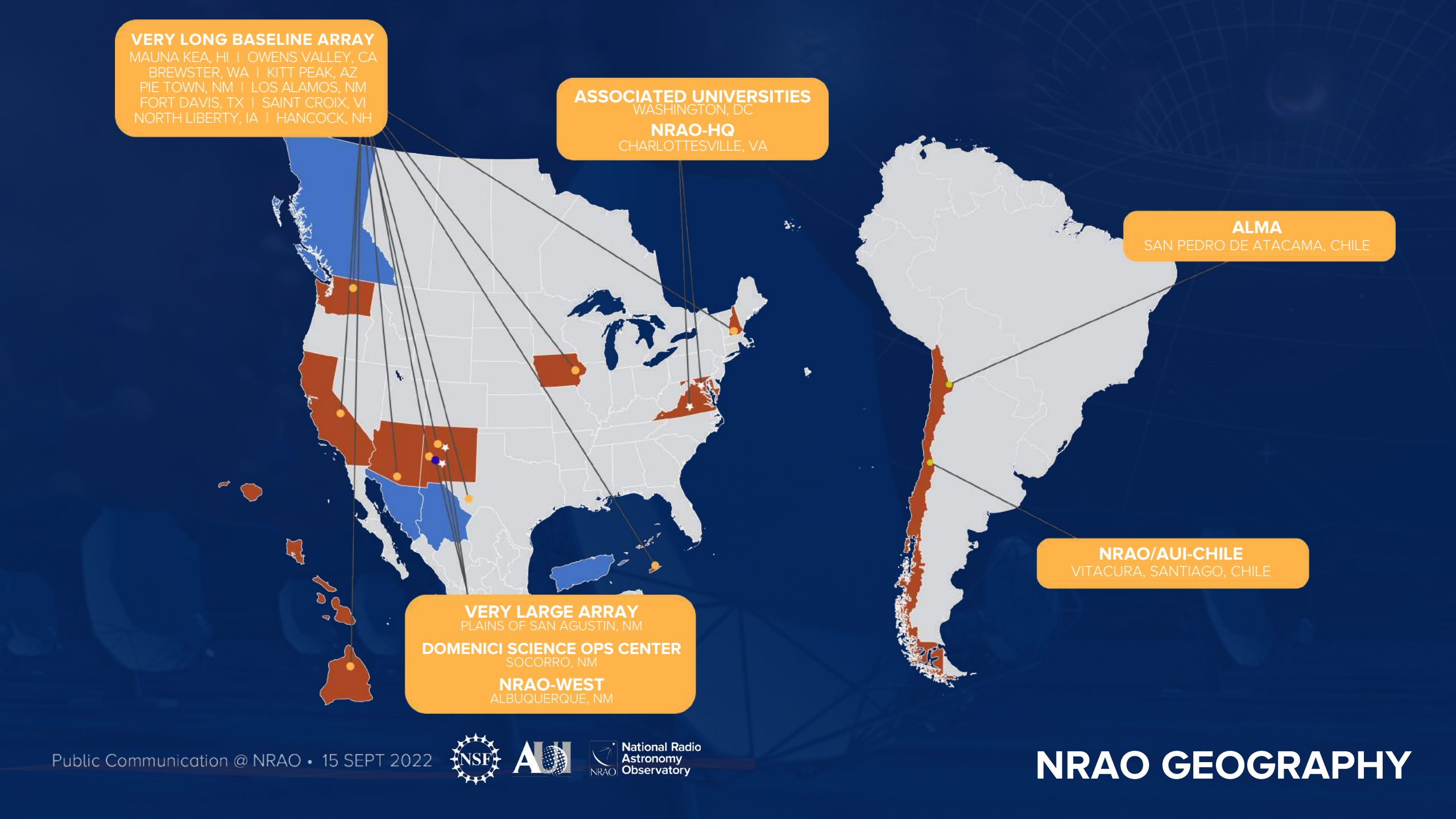
Public Communication @ NRAO

Amy C. Oliver, Public Information Manager

National Radio Astronomy Observatory

Do you ever wonder how science results end up on...

National Radio Astronomy Observatory



Public Communication @ NRAO • 15 SEPT 2022

National Radio Astronomy Observatory

NRAO GEOGRAPHY

Valeria Foncea

ALMA Chile (JAO)

valeria.foncea@alma.cl

Nicolás Lira

ALMA Chile (JAO)

nicolas.lira@alma.cl

Amy C. Oliver, FRAS

ALMA North America (NRAO)

aoliver@nrao.edu

Bárbara Ferreira, PhD

ALMA Europe (ESO)

barbara.ferreira@eso.org

Ney Fernandes

Translator: FR, IT, ES, PR

contractor

Junko Ueda, PhD

ALMA Asia (NAOJ)

junko.ueda@nao.ac.jp

National Radio Astronomy Observatory

ALMA PIOs

Recruiting
Comms Writer
contractor

Ney Fernandes
Translator: FR, IT, ES, PR
contractor

Amy C. Oliver, FRAS
Public Info. & News Mgr.
PIO: NRAO, ALMA-NA, CDL
aoliver@nrao.edu

Dave Finley
PIO: NM, VLA, VLBA
dfinley@nrao.edu

Thom Guengerich
Public Info. Specialist
ngVLA

Brian Koberlein, PhD
Science Writer

Brianne Angell
Social Media

NRAO

Public Comms

National Radio Astronomy Observatory

Melissa Weiss

Illustrator
contractor

Jeff Hellerman

Art Director

Sophia Dagnello

Sr. Visualization Spec.

Matt Chauta

Webmaster

Bill Saxton

Animator, Illustrator

National Radio Astronomy Observatory

Multi-Media Group

What we do

Press Releases,
Announcements,
Tip Sheets

Press conferences,
media training

Feature
Articles

Blog articles

Web site content
(with MMG)

Feature videos
(with MMG)

Social media

Local gov't
relations

Community &
media relations

National Radio
Astronomy
Observatory

483	25	13

It looks deceptively simple…

Draft version August 26, 2021
Typeset using LaTeX **twocolumn** style in AASTeX631

Molecular Line Observations in Two Dusty Star-Forming Galaxies at $z = 6.9$

Sreevani Jarugula,[1] Joaquin D. Vieira,[1,2,3] Axel Weiss,[4] Justin S. Spilker,[5,6] Manuel Aravena,[7] Melanie Archipley,[1,3] Matthieu Béthermin,[8] Scott C. Chapman,[9] Chenxing Dong,[10] Thomas R. Greve,[11,12] Kevin Harrington,[13] Christopher C. Hayward,[14] Yashar Hezaveh,[15,14] Ryley Hill,[16] Katrina C. Litke,[17] Matthew A. Malkan,[18] Daniel P. Marrone,[17] Desika Narayanan,[19,20,11] Kedar A Phadke,[1] Cassie Reuter,[1] and Kaja M. Rotermund[21]

[1] *Department of Astronomy, University of Illinois, 1002 West Green St., Urbana, IL 61801, USA*
[2] *Department of Physics, University of Illinois at Urbana-Champaign, 1110 W Green St Loomis Laboratory, Urbana, IL 61801, USA*
[3] *Center for AstroPhysical Surveys, National Center for Supercomputing Applications, Urbana, IL, 61801, USA*
[4] *Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69 D-53121 Bonn, Germany*
[5] *Department of Astronomy, University of Texas at Austin, 2515 Speedway, Stop C1400, Austin, TX 78712, USA*
[6] *NHFP Hubble Fellow*
[7] *Núcleo de Astronomía, Facultad de Ingeniería, Universidad Diego Portales, Av. Ejército 441, Santiago, Chile*
[8] *Aix Marseille Univ., CNRS, CNES, LAM, Marseille, France*
[9] *Eureka Scientific, Inc. 2452 Delmer Street Suite 100, Oakland, CA 94602-3017*
[10] *Department of Astronomy, University of Florida, Gainesville, FL 32611, USA*
[11] *Cosmic Dawn Center (DAWN), DTU-Space, Technical University of Denmark, Elektrovej 327, DK-2800 Kgs. Lyngby, Denmark*
[12] *Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK*
[13] *European Southern Observatory, Alonso de Córdova 3107, Vitacura, Casilla 19001, Santiago de Chile, Chile*
[14] *Center for Computational Astrophysics, Flatiron Institute, 162 Fifth Avenue, New York, NY 10010, USA*
[15] *Département de Physique, Université de Montréal, Montreal, Quebec, H3T 1J4, Canada*
[16] *Department of Physics and Astronomy, University of British Columbia, 6225 Agricultural Rd., Vancouver, V6T 1Z1, Canada*
[17] *Steward Observatory, University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721, USA*
[18] *Department of Physics and Astronomy, University of California, Los Angeles, CA 90095-1547, USA*
[19] *Department of Astronomy, University of Florida, 211 Bryant Space Sciences Center, Gainesville, FL 32611, USA*
[20] *University of Florida Informatics Institute, 432 Newell Drive, CISE Bldg E251, Gainesville, FL 32611, USA*
[21] *Department of Physics and Atmospheric Science, Dalhousie University, Halifax, Nova Scotia, Canada*

ABSTRACT

SPT0311-58 is the most massive infrared luminous system discovered so far during the Epoch of Reionization (EoR). In this paper, we present a detailed analysis of the molecular interstellar medium at $z = 6.9$, through high resolution observations of the CO$(6-5)$, CO$(7-6)$, CO$(10-9)$, [CI]$(2-1)$, and p-$H_2O(2_{1,1}-2_{0,2})$ lines and dust continuum emission with the Atacama Large Millimeter/submillimeter Array (ALMA). The system consists of a pair of intensely star-forming gravitationally lensed galaxies (labelled West and East). The intrinsic far-infrared luminosity is $(16 \pm 4)\times10^{12}$ $L_\odot$ in West and $(27 \pm 4)\times10^{11}$ $L_\odot$ in East. We model the dust, CO, and [CI] using non-local thermodynamic equilibrium radiative transfer models and estimate the intrinsic gas mass to be $(5.4 \pm 3.4)\times10^{11}$ $M_\odot$ in West and $(3.1 \pm 2.7)\times10^{10}$ $M_\odot$ in East. We find that the CO spectral line energy distribution in West and East are typical of high-redshift sub-millimeter galaxies (SMGs). The CO-to-H_2 conversion factor (α_{CO}) and the gas depletion time scales estimated from the model are consistent with the high-redshift SMGs in the literature within the uncertainties. We find no evidence of evolution of depletion time with redshift in SMGs at $z > 3$. This is the most detailed study of molecular gas content of a galaxy in the EoR to-date, with the most distant detection of H_2O in a galaxy without any evidence for active galactic nuclei in the literature.

[1] jarugul2@illinois.edu

ALMA Scientists Detect Signs of Water in a Galaxy Far, Far Away

New study marks most distant detection of required element for life as we know it in a regular star-forming galaxy

Credit: ALMA (ESO/NAOJ/NRAO)/S. Dagnello (NRAO)

Water has been detected in the most massive galaxy in the early Universe, according to new observations from the Atacama Large Millimeter/submillimeter Array (ALMA). Scientists studying SPT0311-58 found H2O, along with carbon monoxide in the galaxy, which is located nearly 12.86 billion light-years from Earth. Detection of these two molecules in abundance suggests that the molecular Universe was going strong shortly after the elements were forged in early stars. The new research comprises the most detailed study of molecular gas content of a galaxy in the early Universe to date and the most distant detection of H20 in a regular star-forming galaxy. The research is published in *The Astrophysical Journal*.

SPT0311-58 is actually made up of two galaxies and was first seen by ALMA scientists in 2017 at its location, or time, in the Epoch of Reionization. This epoch occurred at a time when the Universe was just 780 million years old—roughly 5 percent of its current age—and the first stars and galaxies were being born. Scientists believe that the two galaxies may be merging, and that their rapid star formation is not only using up their gas, or star-forming fuel but that it may eventually evolve the pair into massive elliptical galaxies like those seen in the Local Universe.

"Using high-resolution ALMA observations of molecular gas in the pair of galaxies known collectively as SPT0311-58 we detected both water and carbon monoxide molecules in the larger of the two galaxies. Oxygen and carbon, in particular, are first-generation elements, and in the molecular forms of carbon monoxide and water, they are critical to life as we know it," said Sreevani Jarugula, an astronomer at the University of Illinois and the principal investigator on the new research. "This galaxy is the most massive galaxy currently known at high redshift, or the time when the Universe was still very young. It has more gas and dust compared to other galaxies in the early Universe, which gives us plenty of potential opportunities to observe abundant molecules and to better understand how these life-creating elements impacted the development of the early Universe."

Water, in particular, is the third most abundant molecule in the Universe after molecular hydrogen and carbon monoxide. Previous studies of galaxies in the local and early Universe have correlated water emission and the far-infrared emission from dust. "The dust absorbs the ultraviolet radiation from the stars in the galaxy and re-emits it as far-infrared photons," said Jarugula. "This further excites the water molecules, giving rise to the water emission that scientists are able to observe. In this case, it helped us to detect water emissions in this massive galaxy. This correlation could be used to develop water as a tracer of star formation, which could then be applied to galaxies on a cosmological scale."

Images & Videos

This artist's conception shows the dust continuum and molecular lines of carbon monoxide and water... Read More

Credit: ALMA (ESO/NAOJ/NRAO)/S. Dagnello (NRAO)

USA TODAY

WORLD

Water has been detected in a galaxy roughly 12.8 billion light years away, researchers say

Jordan Mendoza
USA TODAY

Published 3:46 p.m. ET Nov. 3, 2021 | **Updated 4:15 p.m. ET Nov. 3, 2021**

Hubble just captured the early moments of two galaxies colliding
It's a glimpse at the fate our own galaxy will eventually endure. *Buzz60, Buzz60*

Scientists said they have discovered evidence of water in a galaxy roughly 12.8 billion light-years from Earth, making it one of the most distant discoveries of water in the universe.

The properties of the galaxy, named SPT0311-58, were discovered by scientists from the University of Illinois at Urbana-Champaign at the Atacama Large Millimeter/submillimeter Array in Chile. The galaxy had first been discovered at the observatory in 2017.

Not only were water molecules found, but the galaxy where it was found comes from the early parts of the universe, when it was only 780 million years old. Scientists said in 2020 that the universe is 13.8 billion years old.

ABSTRACT

SPT0311-58 is the most massive infrared luminous system discovered so far during the Epoch of Reionization (EoR). In this paper, we present a detailed analysis of the molecular interstellar medium at $z = 6.9$, through high resolution observations of the CO$(6-5)$, CO$(7-6)$, CO$(10-9)$, [CI]$(2-1)$, and p-$H_2O(2_{1,1}-2_{0,2})$ lines and dust continuum emission with the Atacama Large Millimeter/submillimeter Array (ALMA). The system consists of a pair of intensely star-forming gravitationally lensed galaxies (labelled West and East). The intrinsic far-infrared luminosity is $(16 \pm 4)\times10^{12}$ $L_\odot$ in West and $(27 \pm 4)\times10^{11}$ $L_\odot$ in East. We model the dust, CO, and [CI] using non-local thermodynamic equilibrium radiative transfer models and estimate the intrinsic gas mass to be $(5.4 \pm 3.4)\times10^{11}$ $M_\odot$ in West and $(3.1 \pm 2.7)\times10^{10}$ $M_\odot$ in East. We find that the CO spectral line energy distribution in West and East are typical of high-redshift sub-millimeter galaxies (SMGs). The CO-to-H_2 conversion factor (α_{CO}) and the gas depletion time scales estimated from the model are consistent with the high-redshift SMGs in the literature within the uncertainties. We find no evidence of evolution of depletion time with redshift in SMGs at $z > 3$. This is the most detailed study of molecular gas content of a galaxy in the EoR to-date, with the most distant detection of H_2O in a galaxy without any evidence for active galactic nuclei in the literature.

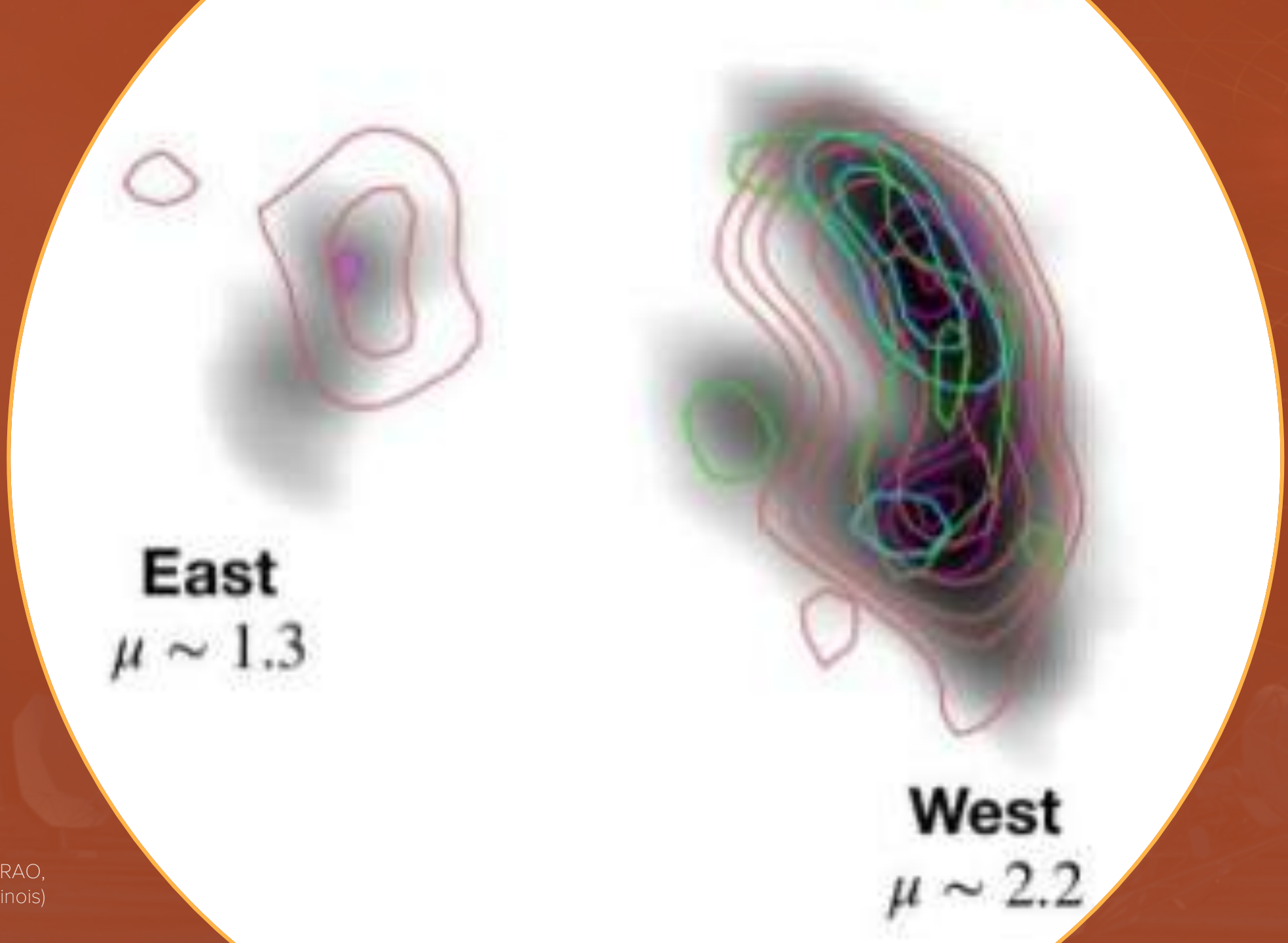
Water has been detected in the most massive galaxy in the early Universe, according to new observations from the Atacama Large Millimeter/submillimeter Array (ALMA). Scientists studying SPT0311-58 found H2O, along with carbon monoxide in the galaxy, which is located nearly 12.88 billion light-years from Earth. Detection of these two molecules in abundance suggests that the molecular Universe was going strong shortly after the elements were forged in early stars. The new research comprises the most detailed study of molecular gas content of a galaxy in the early Universe to date and the most distant detection of H2O in a regular star-forming galaxy. The research is published in *The Astrophysical Journal*.

Water has been detected in a galaxy roughly 12.8 billion light years away, researchers say

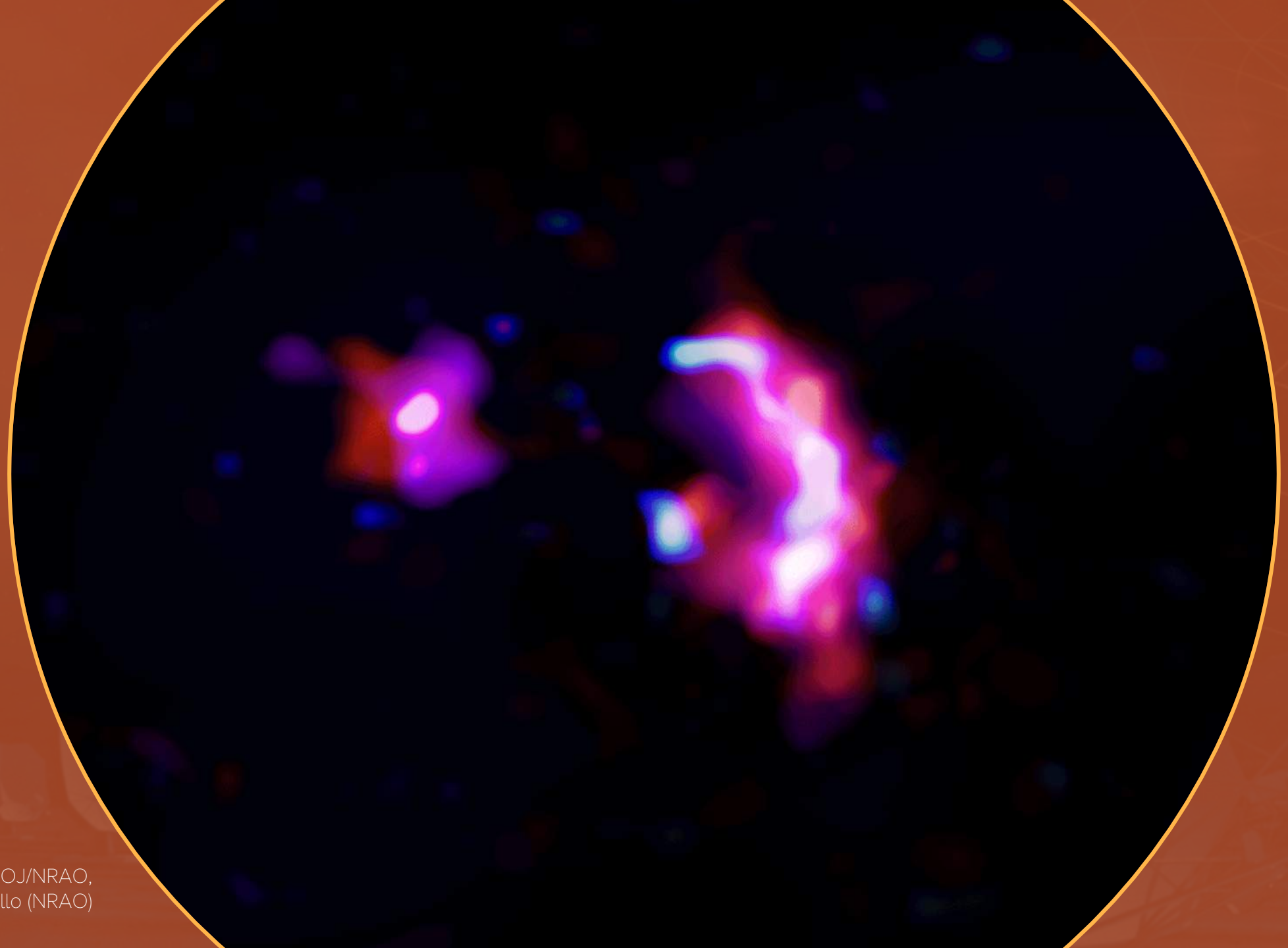
Scientists said they have discovered evidence of water in a galaxy roughly 12.8 billion light-years from Earth, making it one of the most distant discoveries of water in the universe.

The properties of the galaxy, named SPT0311-58, were discovered by scientists from the University of Illinois at Urbana-Champaign at the Atacama Large Millimeter/submillimeter Array in Chile. The galaxy had first been discovered at the observatory in 2017.

Not only were water molecules found, but the galaxy where it was found comes from the early parts of the universe, when it was only 780 million years old. Scientists said in 2020 that the universe is 13.8 billion years old.

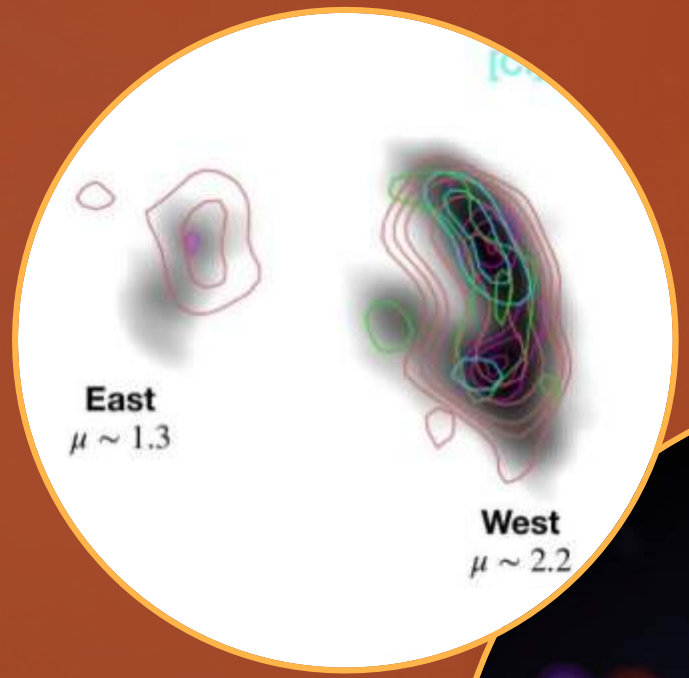


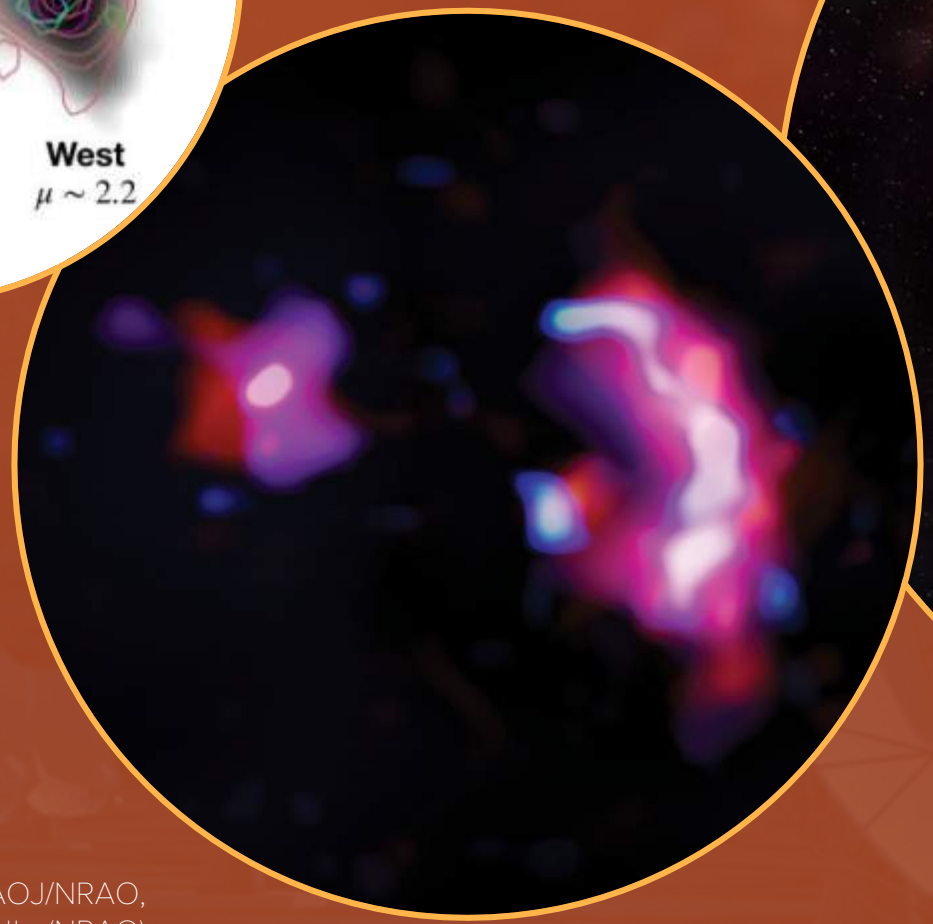
ALMA (ESO/NAOJ/NRAO,
S. Jarugula (U. Illinois)

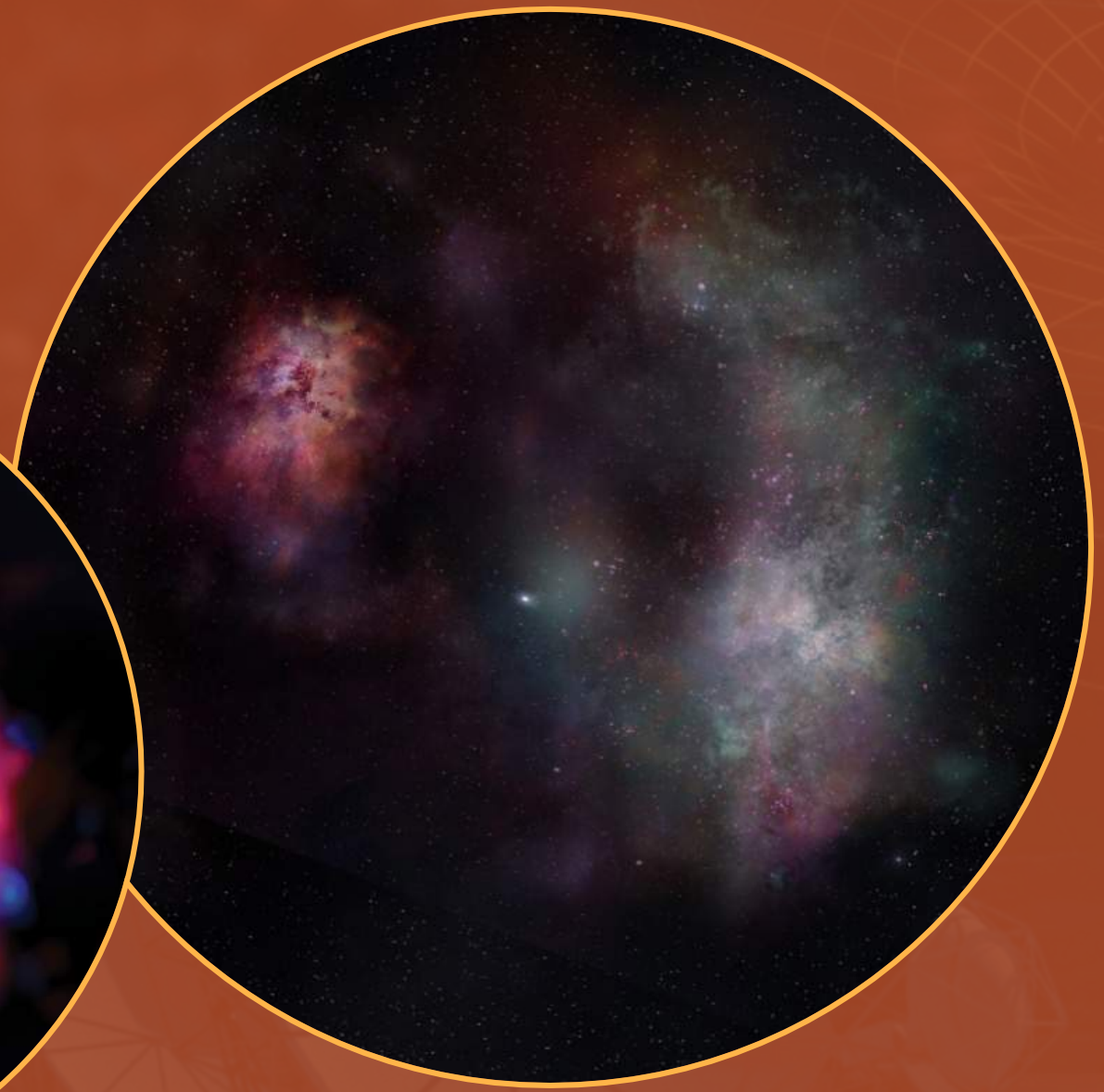


ALMA (ESO/NAOJ/NRAO),
S. Dagnello (NRAO)

ALMA (ESO/NAOJ/NRAO,
S. Dagnello (NRAO)







ALMA (ESO/NAOJ/NRAO,
S. Jarugula (U. Illinois), S. Dagnello (NRAO)

ALMA Gets Front-Row Seat to an Ongoing Star-Formation Standoff in the Large Magellanic Cloud

While using the **Atacama Large Millimeter/submillimeter Array** (ALMA) to observe large star-forming regions in the **Large Magellanic Cloud** (LMC), scientists **discovered a turbulent push-and-pull dynamic in the star-forming region**, 30 Doradus. Observations revealed that despite **intense stellar feedback**, gravity is shaping the molecular cloud, **and against scientific odds**, is driving the **ongoing formation of young, massive stars.**

BIG PICTURE: NSF facilities are helping scientists to uncover previously hidden truths about star formation and what drives the process of stellar evolution.

1.4 BILLION reach

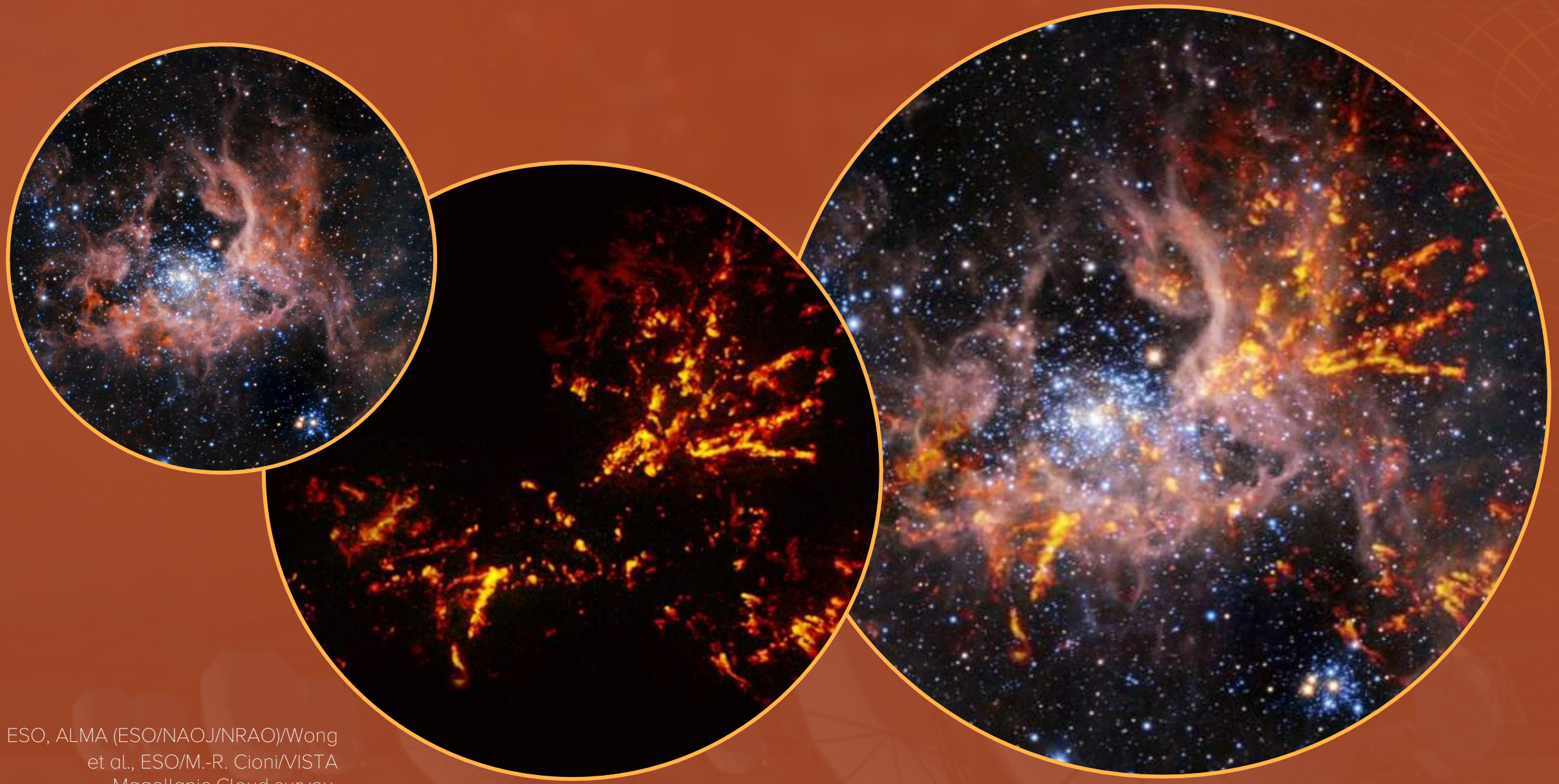
and **425 global media hits**

YAHOO! UK & IRELAND · msn · INDIA TODAY · Daily Mail · c|net

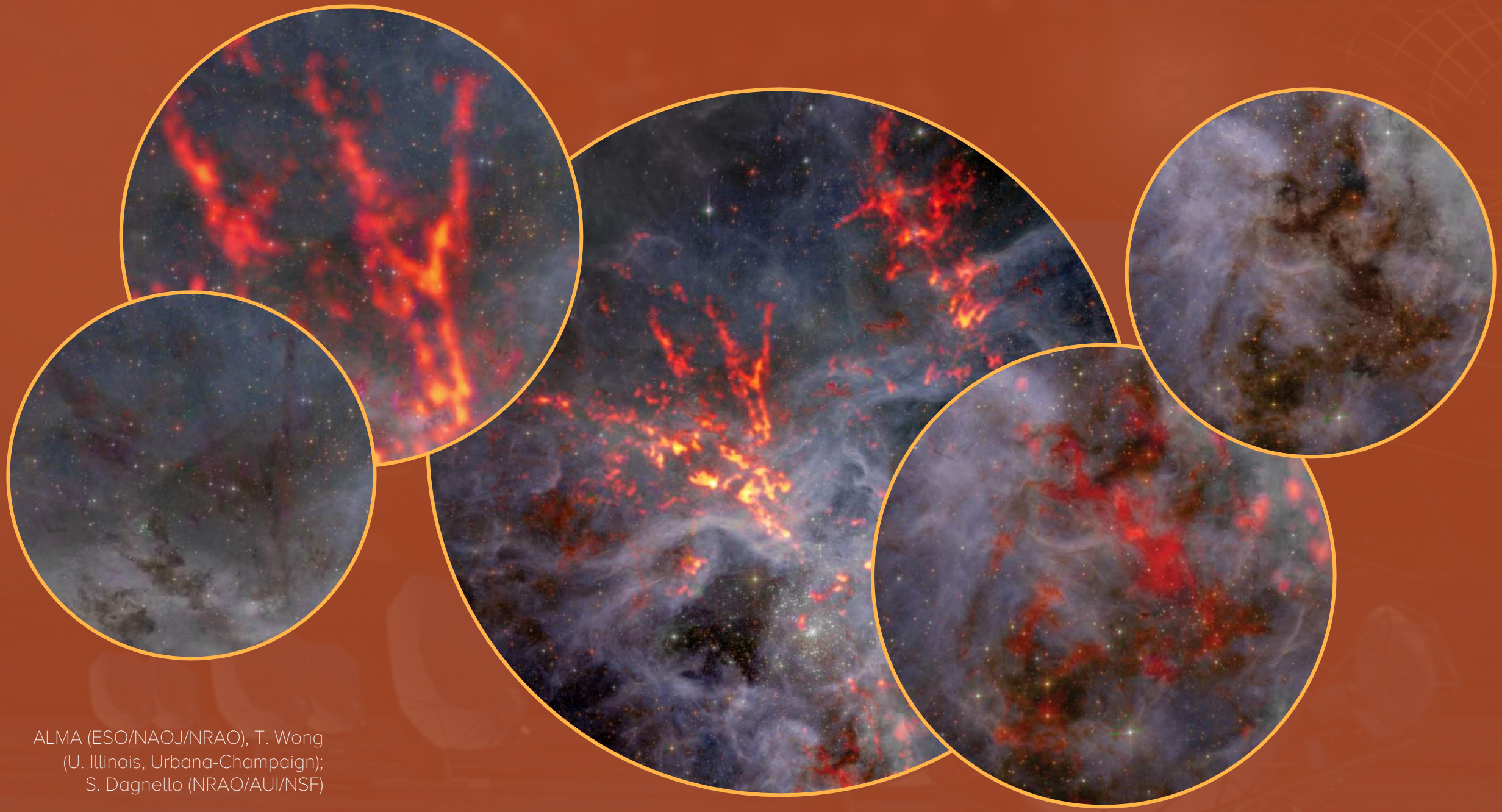
REUTERS · BIG THINK · NCYT · Forbes

Hindustan Times · The Peninsula · FOLHA DE S.PAULO

NSF · AUI · NRAO National Radio Astronomy Observatory



ESO, ALMA (ESO/NAOJ/NRAO)/Wong et al., ESO/M.-R. Cioni/VISTA Magellanic Cloud survey. Acknowledgment: Cambridge Astronomical Survey Unit



ALMA (ESO/NAOJ/NRAO), T. Wong
(U. Illinois, Urbana-Champaign);
S. Dagnello (NRAO/AUI/NSF)

But what's the process to get here?

National Radio Astronomy Observatory

- **Whose story is it?**

- **Establish lead.**

  Establishes who sets timelines and embargoes, and who has the priority.

PennState

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

NRAO

ALMA

ALMA Scientists Uncover the Mystery of Early Massive Galaxies Running on Empty

Early massive galaxies— those that formed in the three billion years following the Big Bang— should have contained large amounts of cold hydrogen gas, the fuel required to make stars. But scientists observing the early Universe with the Atacama Large Millimeter/submillimeter Array (ALMA) and the Hubble Space Telescope have spotted something strange: half a dozen early massive galaxies that ran out of fuel.

BIG PICTURE: NSF facilities are helping scientists to figure out how galaxies die, and perhaps more importantly, what's killing them.

223.8 MILLION reach

and **140 global media hits**

Science AAAS

EL TIEMPO

Daily Mail

BIG THINK

EXTREMETECH

IFLSCIENCE!

yahoo! nvestimentos

Dhaka Tribune

NSF

AUI

NRAO National Radio Astronomy Observatory

- **Is the result newsworthy?**

- **Were we given enough notice to help?**

National Radio Astronomy Observatory

- **Is the science sound?**

- **Is a press release really the right way for NRAO to tell this story?**

A Strange Tale of an SMBH proves that a PR isn't always the way to go.

- **Is a press release really the right way for NRAO to tell this story?**

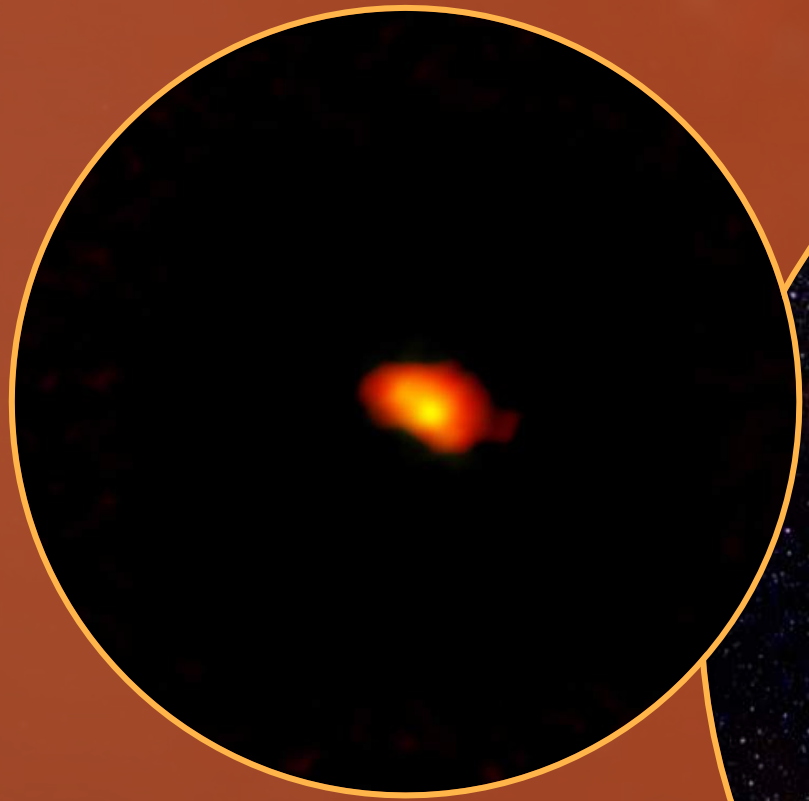
  Tip Sheets, like this one for J. Bae et al's CPD and Young Exoplanet, and Research Alerts are also an option.

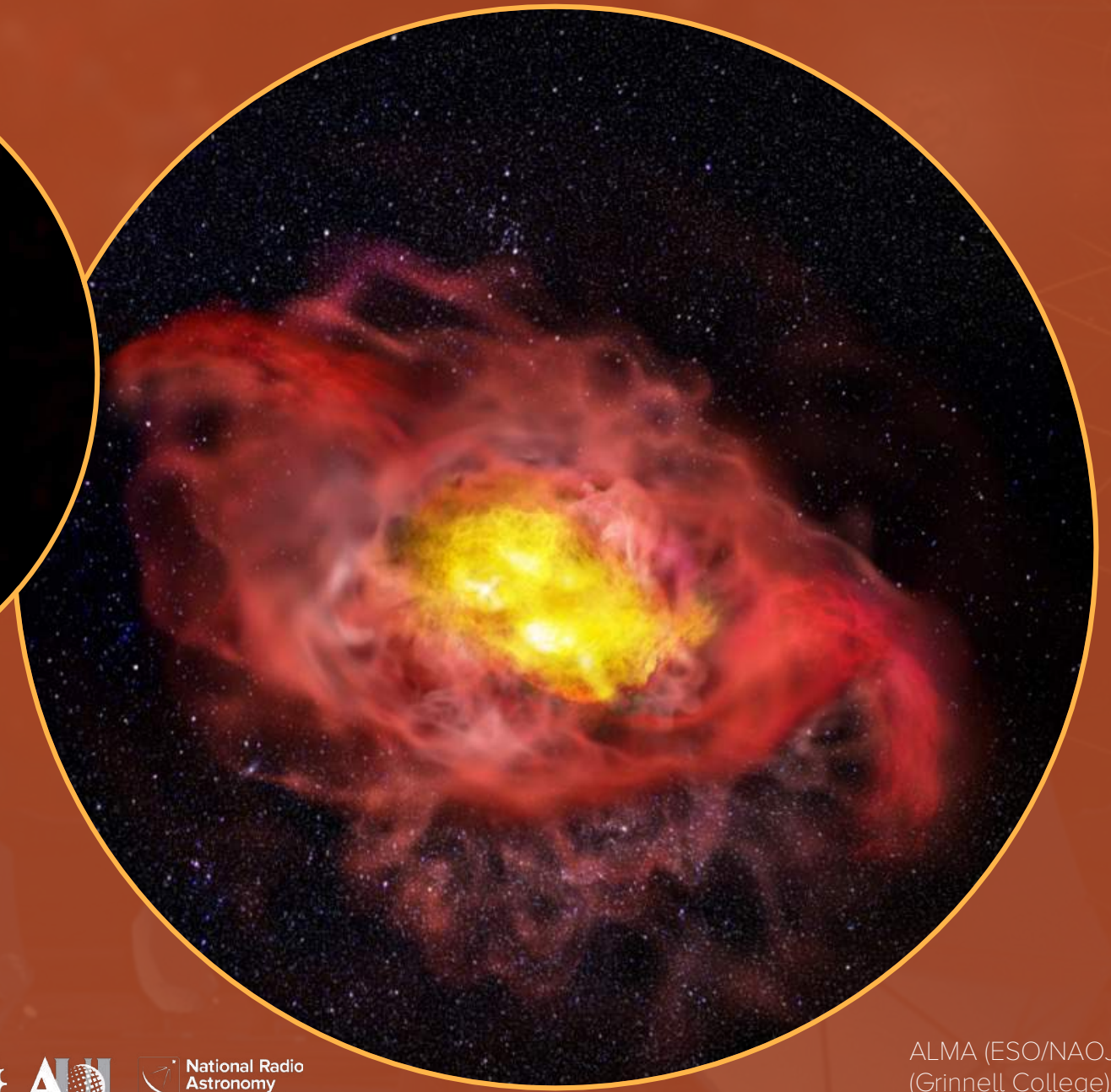
- **Did the research do something newer/better/faster/smarter?**

- **Can Sophia/Bill/Mel make this potato look like a galaxy?**

ALMA (ESO/NAOJ/NRAO)/H. Akins (Grinnell College), B. Saxton (NRAO/AUI/NSF)

National Radio Astronomy Observatory





National Radio Astronomy Observatory

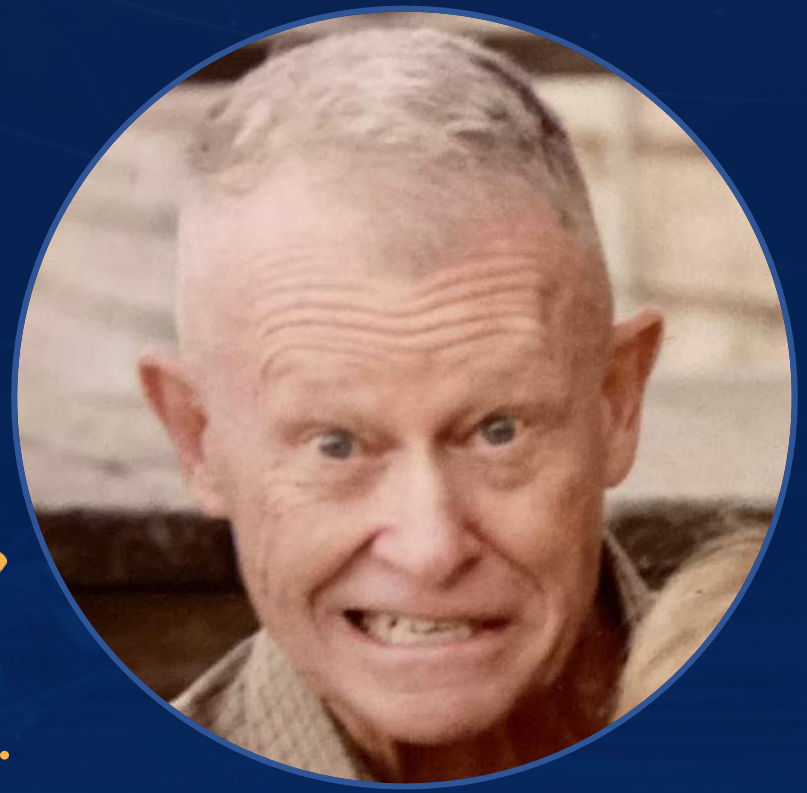
ALMA (ESO/NAOJ/NRAO)/H. Akins (Grinnell College), B. Saxton (NRAO/AUI/NSF)

- **Can the result be explained to the public in an accessible way?**

- **Will the public think it is interesting?**

  In other words, would my Dad think it's interesting even if I wasn't his kid?

My Dad.



- **Media relations.**

We work closely in tandem with other institutions when pitching so that journalists don’t receive multiple versions of the same story as if they’re unique.

National Radio Astronomy Observatory

- **Questions?**

Amy C. Oliver, FRAS
Public Info. & News Mgr.
PIO: ALMA-NA, CDL, NRAO
aoliver@nrao.edu

National Radio Astronomy Observatory