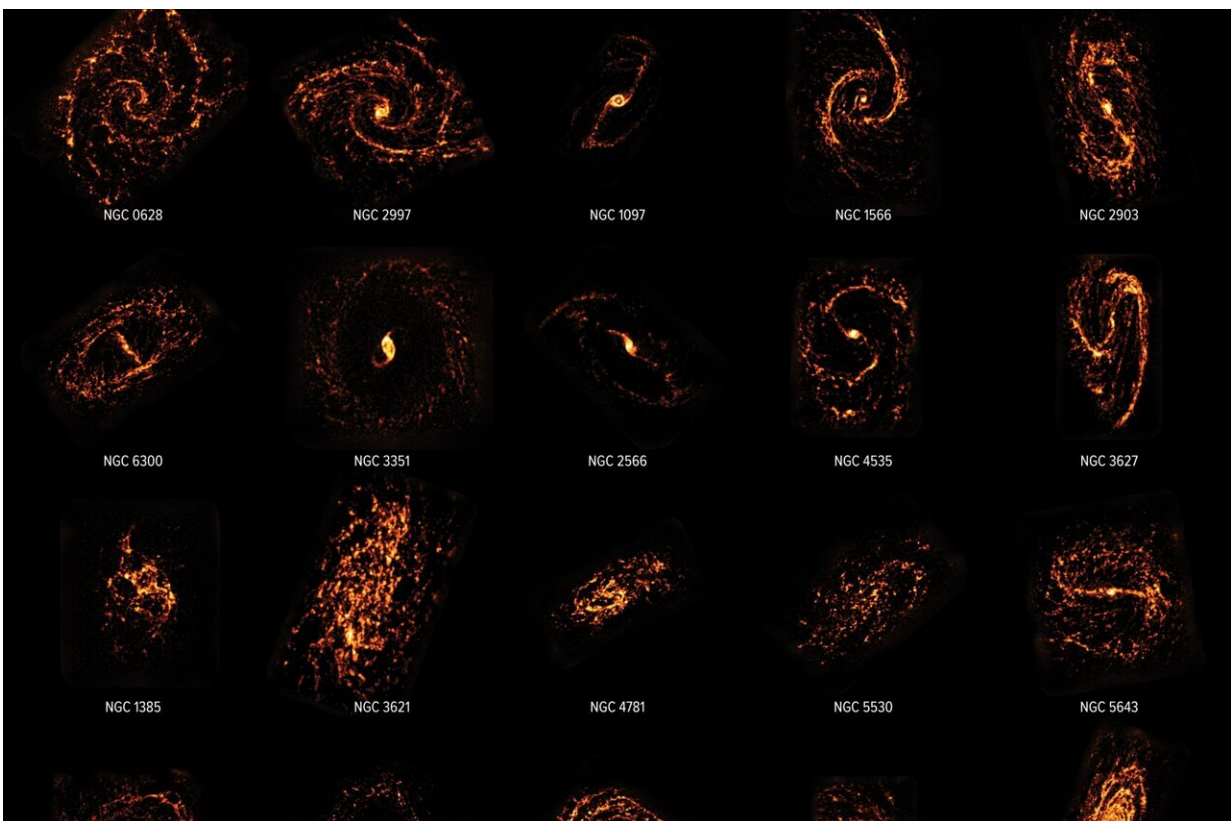


# Cosmic cartographers map nearby Universe revealing the diversity of star-forming galaxies

June 8 2021, by Amy C. Oliver

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Using the Atacama Large Millimeter/submillimeter Array (ALMA), scientists completed a census of nearly 100 galaxies in the nearby Universe, showcasing their behaviors and appearances. The scientists compared ALMA data to that of the Hubble Space Telescope, shown in composite here. The survey concluded that contrary to popular scientific opinion, stellar nurseries do not all look and act the same. In fact, as shown here, they are as different as the neighborhoods,

cities, regions, and countries that make up our own world. Credit: ALMA (ESO/NAOJ/NRAO)/PHANGS, S. Dagnello (NRAO)

A team of astronomers using the Atacama Large Millimeter/submillimeter Array (ALMA) has completed the first census of molecular clouds in the nearby universe, revealing that contrary to previous scientific opinion, these stellar nurseries do not all look and act the same. In fact, they're as diverse as the people, homes, neighborhoods and regions that make up our own world.

Stars are formed out of [clouds](#) of dust and gas called molecular clouds, or stellar nurseries. Each stellar nursery in the universe can form thousands or even tens of thousands of [new stars](#) during its lifetime. Between 2013 and 2019, astronomers on the PHANGS project (Physics at High Angular Resolution in Nearby GalaxieS) conducted the first systematic survey of 100,000 stellar nurseries across 90 galaxies in the [nearby universe](#) to get a better understanding of how they connect back to their [parent galaxies](#).

"We used to think that all stellar nurseries across every galaxy must look more or less the same, but this survey has revealed that this is not the case, and stellar nurseries change from place to place," said Adam Leroy, associate professor of astronomy at Ohio State University (OSU), and lead author of the paper presenting the PHANGS ALMA survey. "This is the first time that we have ever taken millimeter-wave images of many nearby galaxies that have the same sharpness and quality as optical pictures. And while optical pictures show us light from [stars](#), these ground-breaking new images show us the molecular clouds that form those stars."

The scientists compared these changes to the way that people, houses,

neighborhoods and cities exhibit like-characteristics but change from region to region and country to country.

"To understand how stars form, we need to link the birth of a single star back to its place in the universe. It's like linking a person to their home, neighborhood, city and region. If a galaxy represents a city, then the neighborhood is the spiral arm, the house the star-forming unit, and nearby galaxies are neighboring cities in the region," said Eva Schinnerer, an astronomer at the Max Planck Institute for Astronomy (MPIA) and principal investigator for the PHANGS collaboration

"These observations have taught us that the 'neighborhood' has small but pronounced effects on where and how many stars are born."



NGC4535 is a galaxy in the nearby Universe featuring grand-design spiral plus stellar bar morphology. It was catalogued along with nearly 100 other galaxies during a recent census by the PHANGS project. The census revealed that contrary to commonly accepted scientific theory, not all stellar nurseries look or act the same way. In fact, they're quite diverse. NGC4535 is shown here as an ALMA (orange) composite with Hubble Space Telescope (HST/red) data. Credit: ALMA (ESO/NAOJ/NRAO)/PHANGS, S. Dagnello (NRAO)

To better understand [star formation](#) in different types of galaxies, the team observed similarities and differences in the molecular gas properties and star formation processes of galaxy disks, stellar bars, spiral arms, and galaxy centers. They confirmed that the location, or neighborhood, plays a critical role in star formation.

"By mapping different types of galaxies and the diverse range of environments that exist within galaxies, we are tracing the whole range of conditions under which star-forming clouds of gas live in the present-day universe. This allows us to measure the impact that many variables have on the way star formation happens," said Guillermo Blanc, an astronomer at the Carnegie Institution for Science, and a co-author on the paper.

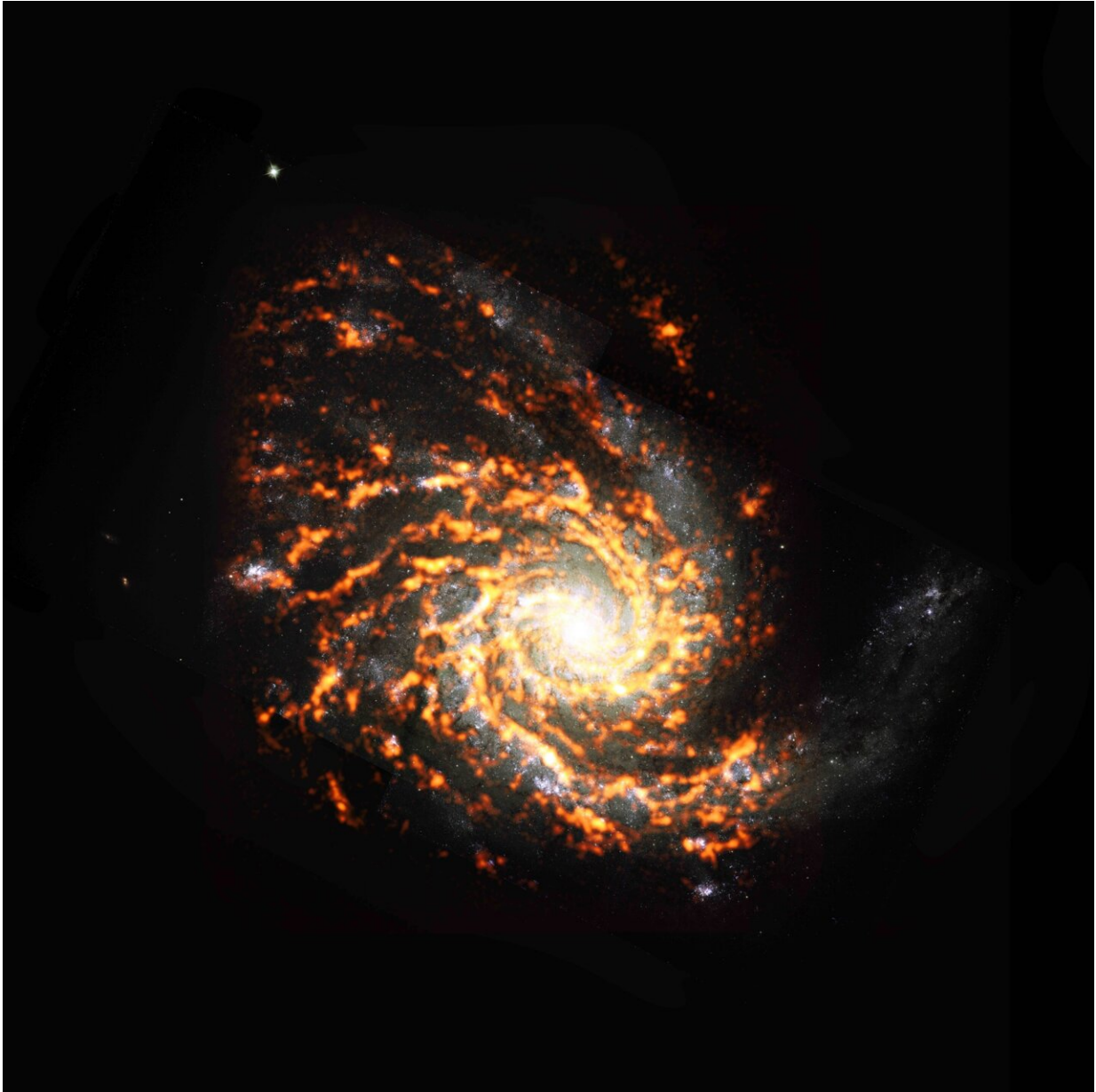
"How stars form, and how their galaxy affects that process, are fundamental aspects of astrophysics," said Joseph Pesce, National Science Foundation's program officer for NRAO/ALMA. "The PHANGS project utilizes the exquisite observational power of the ALMA observatory and has provided remarkable insight into the story of star formation in a new and different way."

Annie Hughes, an astronomer at L'Institut de Recherche en Astrophysique et Planétologie (IRAP), added that this is the first time scientists have a snapshot of what star-forming clouds are really like across such a broad range of different galaxies. "We found that the properties of star-forming clouds depend on where they are located: clouds in the dense central regions of galaxies tend to be more massive, denser, and more turbulent than clouds that reside in the quiet outskirts of a galaxy. The lifecycle of clouds also depends on their environment. How fast a cloud forms stars and the process that ultimately destroys the cloud both seem to depend on where the cloud lives."

This is not the first time that stellar nurseries have been observed in

other galaxies using ALMA, but nearly all previous studies focused on individual galaxies or part of one. Over a five-year period, PHANGS assembled a full view of the nearby population of galaxies. "The PHANGS project is a new form of cosmic cartography that allows us to see the diversity of galaxies in a new light, literally. We are finally seeing the diversity of star-forming gas across many [galaxies](#) and are able to understand how they are changing over time. It was impossible to make these detailed maps before ALMA," said Erik Rosolowsky, Associate Professor of Physics at the University of Alberta, and a co-author on the research. "This new atlas contains 90 of the best maps ever made that reveal where the next generation of stars is going to form."





Shown here as an ALMA (orange) composite with Hubble Space Telescope (HST/red) data, NGC4254 was among the nearly 100 galaxies included in the recent PHANGS project census of galaxies in the nearby Universe. The survey found that stellar nurseries within these galaxies vary widely in appearance and behavior, and that these characteristics heavily depend on where the stellar nurseries are located. NGC4254 is an example of a galaxy featuring M type morphology. Credit: ALMA (ESO/NAOJ/NRAO)/PHANGS, S. Dagnello (NRAO)

For the team, the new atlas doesn't mean the end of the road. While the survey has answered questions about what and where, it has raised others. "This is the first time we have gotten a clear view of the population of stellar nurseries across the whole nearby universe. In that sense, it's a big step towards understanding where we come from," said Leroy. "While we now know that [stellar nurseries](#) vary from place to place, we still do not know why or how these variations affect the stars and planets formed. These are questions that we hope to answer in the near future."

Ten papers detailing the outcomes of the PHANGS survey are presented this week at the 238th meeting of the American Astronomical Society.

**More information:** PHANGS-ALMA: Arcsecond CO(2-1) Imaging of Nearby Star-Forming Galaxies, Leroy et al. ApJS accepted, preview. [arxiv.org/abs/2104.07739](https://arxiv.org/abs/2104.07739)

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