How galaxies and black holes grow together

May 21 2020, by Andreea Petric

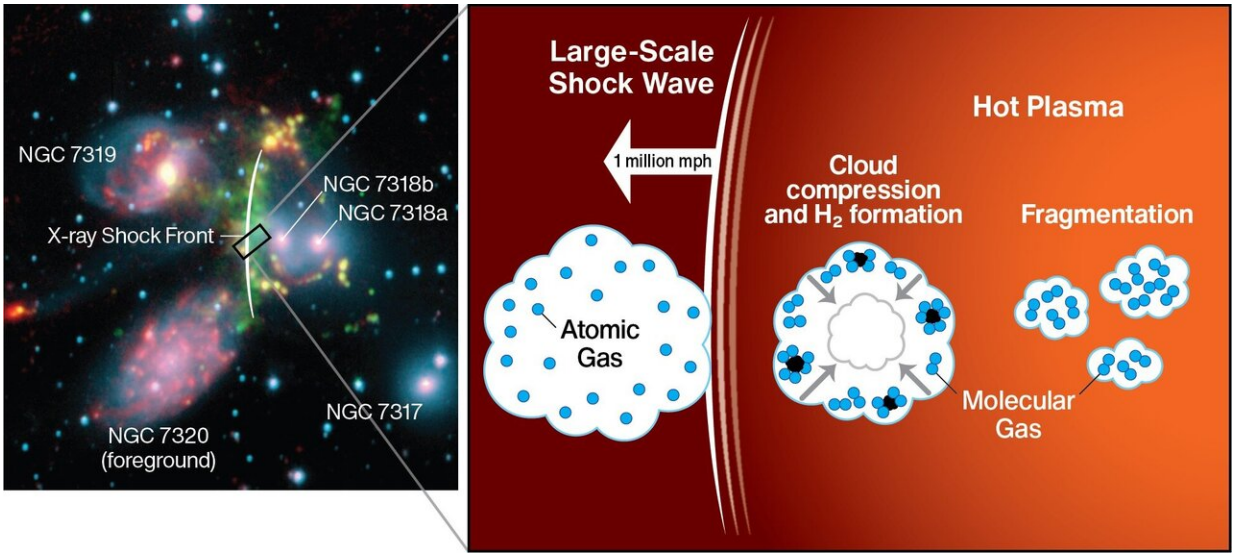


Image of a galaxy interaction (left) and a schematic (right) showing how galaxy interactions can produce shocks across an entire galaxy, enhancing molecular hydrogen emission. This component of the interstellar medium can be directly observed only in special circumstances, such as when it changes angular momentum through interactions with high energy photons or collisions with other particles. Credit: Guillard et al. 2009/B. Bays

Over the past two decades, astronomers have concluded that most, if not all, galaxies host massive black holes at their centers—and the masses of a black hole and its host galaxy are correlated. But how are the two connected? Now, a University of Hawai‘i at Mānoa Institute for Astronomy (IfA) student participating in the National Science

Foundation's (NSF) Research Experiences for Undergraduates (REU) program, may have revealed part of the answer.

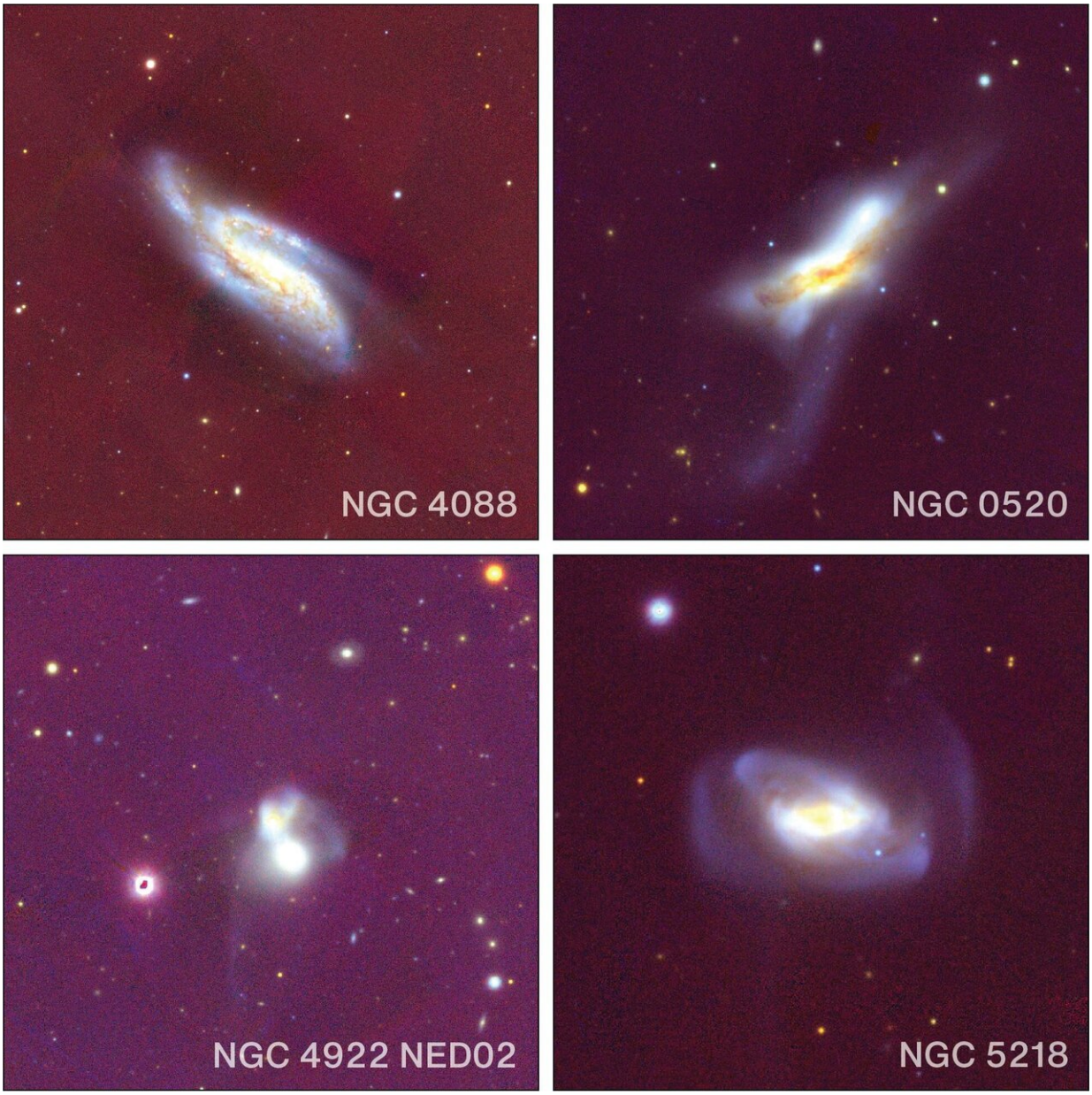
Undergraduate Rebecca Minsley, participated in IfA's 2019 REU program, working for 10 weeks with her mentor, Maunakea Spectroscopic Explorer Deputy Project Scientist Andreea Petric. Sifting meticulously though hundreds of images of galaxies, Minsley began to define a clearer picture of galaxy evolution. "Galaxy growth may be shaped by interactions with other galaxies which contributes to supermassive black holes (SMBH) that grow within the galaxy's center," Minsley explained.

Gas and dust between stars, called the interstellar medium (ISM), is the fuel for both SMBH growth and the formation of new stars. But recent work shows that the ISM may have different properties—especially being warmer—in galaxies that host a growing supermassive black hole in their nuclei, compared to those galaxies that do not. Warmer gas is less likely to collapse into new stars, so this finding may suggest that a growing central SMBH diminishes a galaxy's ability to make new stars.

What might be responsible for heating the ISM? Starlight, especially from hot stars, can do this. But interactions between galaxies—when they collide or even just pass close to each other—can produce large-scale shock waves that compress less dense gas, making it more likely to form stars. Minsley studied the shapes of 630 galaxies using images from the Pan-STARRS survey. She classified the galaxies into mergers, early mergers, and non-mergers. And then compared the shapes to the light output of the same galaxies at longer mid-infrared wavelengths, where she could study the properties of the ISM.

"When galaxies get close enough they go through a sort of galactic dance until they eventually coalesce into a singular entity. These interactions have well documented signatures that allowed me to categorize our set of

galaxies," Minsley said. "This project gave me a greater appreciation for the complexity and entanglement of all the processes taking place inside galaxies and the research being done to deconstruct galactic systems is fascinating."



Pan-STARRS images of NGC 4088, NGC 0520, NGC 5218, NGC 4922 NED02, illustrating the different features used to classify galaxy mergers,

including galaxy asymmetry, tidal tails, galactic shells, multiple nuclei and early/possible mergers for galaxies of similar brightness within 50 kpc of each-other. Credit: A. Petric/B. Bays

Minsley and collaborators found that within galaxies with active black holes, the ISM is warmer, the ratios of warm molecular gas to other coolants are larger, and other features from dust particles have a wider range of values than in galaxies where the black holes are dormant.

"In the nearby universe we find that the warm ISM of galaxies which host growing supermassive black holes at their centers differs from those that do not," explains Petric. "We speculate that the same processes that funnel fuel to the SMBH also allow us to detect the energy transfer back into the galaxy's ISM." Petric adds that future, more detailed observations, will allow researchers confirm these energy transfer processes.

IfA has been part of the prestigious REU program for almost 20 years, training over 130 students, some of whom are now leaders in different fields of astronomy. Because of this unique opportunity to work in Hawaii with world class facilities and scientists, the IfA receives over 500 applications each term. The focus of their REU program is on identifying students who have potential to succeed in research, but may not have the opportunity and resources.

Nader Haghighipour, the principal investigator of IfA's REU program, noted, "With our mentors among the world leaders in their respective fields, our REU students are engaged in cutting edge research. Rebecca's work is a prime example of this. We are very proud of our REU students, as almost all of them continued their studies in graduate school, and many of them have gained national recognition."

During the 2020 fall semester, Petric and UH Mānoa undergraduate Diana Castaneda will continue to investigate the ISM of galaxies hosting some of the most luminous growing SMBH in the nearby universe, using a spectrometer aboard the Stratospheric Observatory for Infrared Astronomy (SOFIA) aircraft. The SOFIA observations will allow Castaneda and Petric to gain more insight into the processes by which energy is being transferred between the growing SMBH and the ISM.

This work is published in the May 10th issue of the *Astrophysical Journal* and is available in preprint form on *ArXiv*.

More information: Rebecca Minsley et al. Molecular Gas and Dust Heating in Active Galaxies: Growing Black Holes or Tidal Shocks?, *The Astrophysical Journal* (2020). DOI: 10.3847/1538-4357/ab86a1

Molecular Gas Heating and Modified Dust Properties in Active Galaxies: Growing Black Holes or Tidal Shocks? arxiv.org/abs/2004.01695 arXiv:2004.01695v1 [astro-ph.GA]

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