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Earth and Space

Watching the death of a distant galaxy

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ABSTRACT

Galaxies' gas is the fuel to form new stars. The formation process stops when galaxies run out of this fuel. However, the mechanisms that cause a galaxy to run out of gas, and hence quench star formation, are not yet clear. We discovered a galaxy that is ejecting a large fraction of its gas, and that will quickly stop forming new stars. This ejection has likely been produced by the collision between two galaxies.

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A large fraction of the stars of the present-day Universe is enclosed in giant, round-shaped galaxies, called "ellipticals". Elliptical galaxies host very old stars, formed more than 10 billion years ago when the universe was still young. Despite the large availability of gas (the fuel from which new stars are formed), at their formation epoch, ellipticals ceased forming stars for a long time. Understanding what stopped star formation in those galaxies would address one of the main challenges in galaxy evolution.

We believe that supermassive black holes can stop star formation within galaxies by releasing energy into the galaxy surroundings and launching very powerful winds. Numerical models suggest that these winds can wipe out the gas from a galaxy. Because of this activity, the galaxy would stop forming stars because it will lack the raw material to form new stars. This idea is supported by several observations, showing that fast winds are common in galaxies of the distant Universe. However, we have not yet observed winds that are powerful enough to remove large quantities of gas from galaxies.

In our study, we used the Atacama Large Millimetre Array (ALMA) telescope to collect carbon monoxide (CO) spectra for a sample of about 100 galaxies located roughly 10 billion years in the past. The CO emission traces the gas in galaxies. Therefore, the analysis of these spectra allowed us to study star formation in galaxies of the younger Universe.

While inspecting this large sample of galaxies, we found an interesting object, galaxy ID2299. The spectrum of this galaxy presents two components, a narrow and bright component associated with the galaxy, and a broad, fainter component. The larger width of this additional component indicates the presence of material that is moving away from the galaxy at high speed. By comparing the flux of the broad component with the one measured for the narrow component, we were able to demonstrate that about half of the total gas mass of ID2299 is being ejected.

We used the velocity of this ejected material (measured from the CO spectrum) and its spatial extension (measured from the CO map) to calculate the rate at which the gas in the broad component is expelled, and we found that this is about 50 times faster than the rate at which galaxy ID2299 is forming stars. We thus estimate that the galaxy will run out of gas and cease to form new stars in about 40 million years. This is ~100 times faster than the typical duration of star formation episodes in galaxies.

To understand the cause of such dramatic ejection, we compared its energetics with the energy released from the black hole hosted in the nucleus of ID2299. We found that this black hole is not powerful enough to trigger the massive gas ejection observed. We also studied the physical properties of the expelled gas and we found that its density and temperature are much lower than expected for a wind generated by a supermassive black hole. Finally, we compared our observations with models of feedback-driven winds and we found that these models cannot reproduce our data.

On the other hand, galaxy ID2299 has an irregular shape and is forming stars at an exceptional rate, about 500 times faster than our galaxy, the Milky Way. This indicates that galaxy ID2299 is the result of a “major merger”, that is the collision between two galaxies of nearly equal mass. By studying numerical models of galaxy mergers, we found that the interaction of two galaxies produces tidal forces that, in turn, can launch elongated streams of stars and gas called “tidal tails”. The observational features of these tidal tails are very similar to the broad component that we detected in ID2299. Therefore, we concluded that the ejection observed in ID2299 is a tidal tail produced by the merger with another galaxy.

Tidal tails of gas and stars are commonly observed in nearby merging galaxies. However, it is difficult to identify such tidal tails in galaxies of the distant universe because of their intrinsic low luminosity. The tidal tail discovered in ID2299 is an exceptionally massive one, which we caught nearly at the moment of launching.

Our observations suggest that galaxies interactions have a fundamental role in their evolutionary cycle. Future studies will allow us to better understand the link between these interactions and the formation of elliptical galaxies.