How star formation is 'quenched' in galaxies

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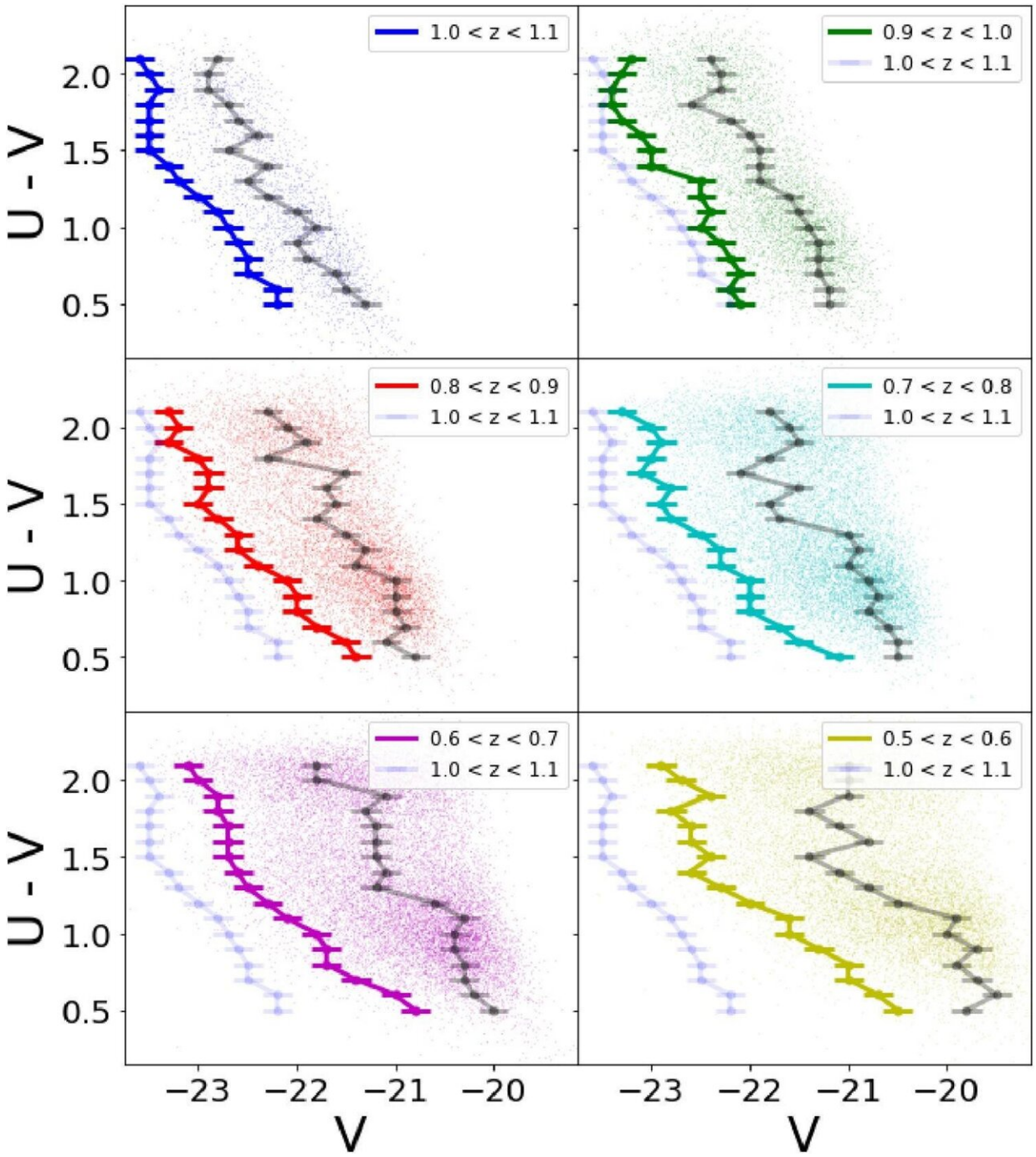

The colour-magnitude relation diagram used by the researchers to uncover the quenching mechanism that quickly halts star formation. Credit: Manzoni. G., Scodeggio. M., Baugh. C. M., et al.

Galaxies die quickly—that is the conclusion of a new study that examines the mechanism that switches galaxies from an active star-forming phase to one of quiescence.

Over a few short decades, our understanding of the evolution of galaxies and how stars and planets form has grown exponentially. But, in many cases, this increase in understanding serves to highlight the questions that still remain. One of the most pressing of those questions arises from the fact that older galaxies seem to be birthing less stellar objects. How does star formation cease in some galaxies? In a new study published in New Astronomy, Giorgio Manzoni from the Institute for Computational Cosmology, Durham University, UK, and his co-authors examine the timings of this halt in star formation to select a mechanism that could possibly be used to answer this and other cosmological questions.

"The evolution of galaxies, although studied for a long time, still holds unanswered questions, and sometimes very basic ones. For example, how do galaxies stop forming new stars? Why do similar galaxies behave in different ways? What is the mechanism that makes them die? All of these are questions that the general public often asks, but that still there are no clear answers to," says Manzoni. "My research gives a hint to the mystery of the death of galaxies: it shows that whatever the mechanism is, it has to be fast, almost instantaneous; less than 100 million years seeming instantaneous in comparison to the time-scales at which the universe evolves."

The researchers came to the conclusion that star formation ceases quickly by studying two properties of galaxies: their intrinsic luminosity and their color, combined together in a 'color-magnitude diagram'. They were also able to conclude that there is some mechanism that drives the transition between an active star-forming phase in galaxies to a quieter stage with less or no star formation—a mechanism referred to by astronomers as 'quenching.' "In the field of galaxy evolution, it is clearly established that galaxies form from gas falling into the gravity of a dark matter halo and then collapsing into new stars—the active stage of galaxies. When the gas is spent, the galaxies die—the passive stage of galaxies," says Manzoni. "My research shows that this natural process of gas exhaustion can't be the only thing responsible for the death of galaxies."

Manzoni explains that he and his colleagues actually found that every galaxy, at a random point in their life, experiences a process that empties the reservoir of gas and kills—or quenches—star formation, thus bringing the galaxy into its passive stage very quickly. "To introduce some constraints into the timing of the quenching of star formation, I used two properties of galaxies combined together in the color-magnitude diagram. When studied at different distances from us—different redshift—this diagram tells us a lot about the population of galaxies that were present at different epochs of the universe," Manzoni says.

The researcher gives the example that, in the very past at high redshift and greater distances, galaxies were forming stars at a rapid rate that is not present anymore in our epoch, thus showing bluer colors and higher luminosities. Today, that population of galaxies has moved into a redder and weaker luminosity part of the diagram.

"Several mechanisms have been proposed as candidates for the quenching of star formation, such as active galactic nuclei feedback,

galaxy harassment, and galaxy mergers, but, since different quenching mechanisms have different time-scales, my study can help to identify the main mechanism responsible for quenching over a large number of galaxies," Manzoni says. "This study is based on a simple concept we observe: the color-magnitude diagram evolves with redshift, meaning the average properties of galaxies are changing with time."

In order to reach their conclusion Manzoni and colleagues used a sample of about 90,000 galaxies taken from the VIMOS Public Extragalactic Redshift Survey (VIPERS) survey, now available publicly, which were observed with one of the eight-meter Very Large Telescope instruments in Chile.

Manzoni compares the quest to answer such cosmological questions to hunting for clues at a crime scene. "Studying the evolution of galaxies is for me similar to the job of a detective," he says. "We can't change the scene of the crime, as we can't modify the universe or move a galaxy as we want, but we have to observe every little detail to try and understand what happened in the past 13 billion years of the universe's life."

More information: G. Manzoni et al. Modelling the quenching of star formation activity from the evolution of the colour-magnitude relation in VIPERS, *New Astronomy* (2020). DOI: 10.1016/j.newast.2020.101515

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