Young, thin and hyperactive—that's what outlier galaxies look like

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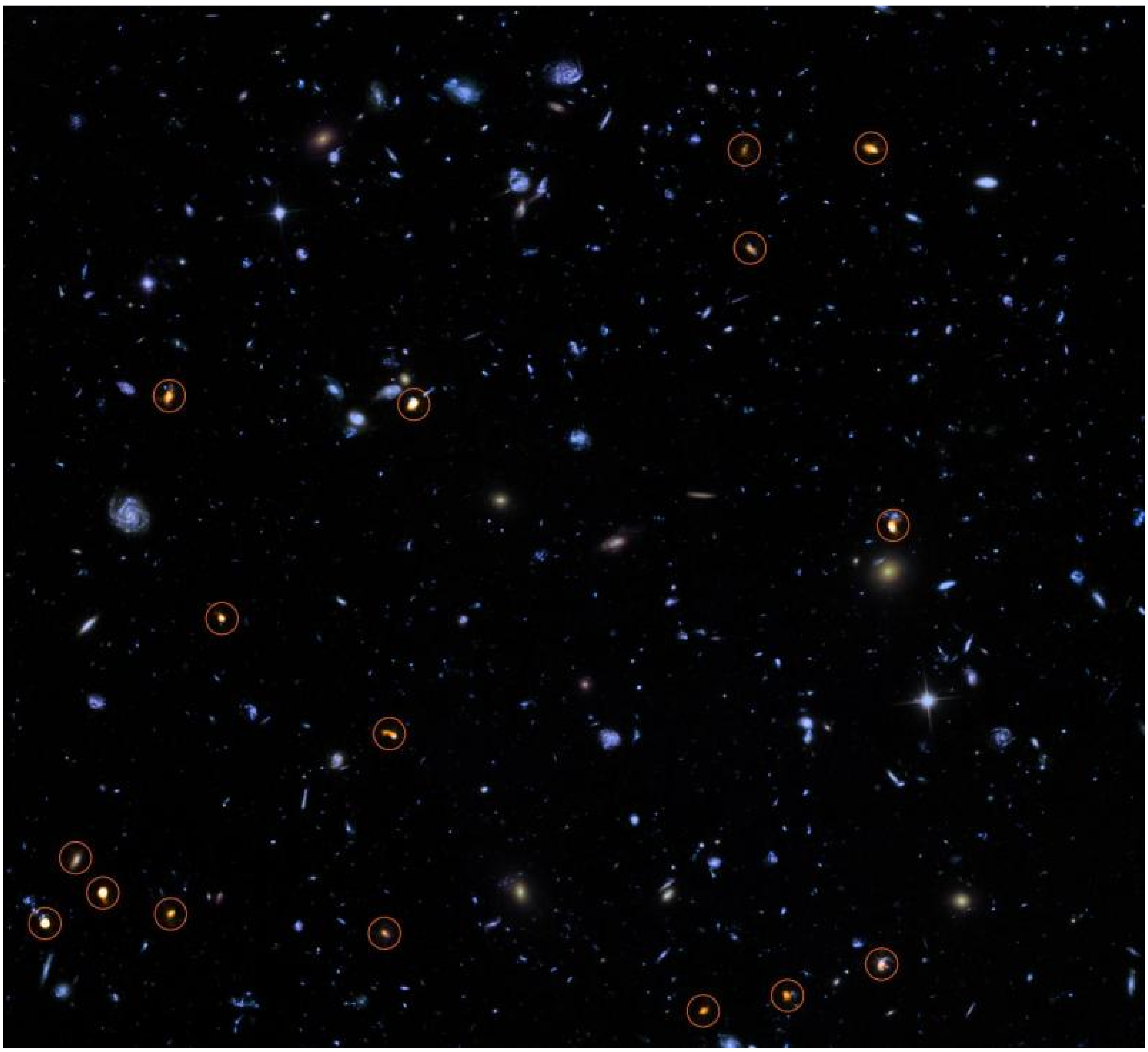

Credit: ALMA (ESO/NAOJ/NRAO)/NASA/ESA

The more massive, or full of stars, a galaxy is, the faster the stars in it are formed. This seems to be the general rule, which is contradicted, however, by some abnormal cases, for example thin (not massive) galaxies that are hyperactive in their star formation. Until now the phenomenon had been explained by catastrophic external events like galaxies colliding and merging, but a new theory offers an alternative explanation, related to an in situ (internal) process of galaxy evolution. The new theory correctly reproduces the behaviour of both normal and abnormal (or outlier) galaxies, and may be further tested by new observations. A study conducted by the International School for Advanced Studies (SISSA) in Trieste, already posted on the astro.ph archive, is soon to be published in the *Astrophysical Journal*.

If we put the galaxies for which we have the relevant data into a graph relating the mass of stars in each galaxy with the star formation rate of that galaxy, most of them would appear as a compact cloud, which could be described by using a simple function. This graph is known as the Galaxy Main Sequence (GMS), a fundamental observational relation for scientists who study galaxies. The picture that emerges is simple: the more massive the galaxy, the faster its star formation process tends to be.

But straightforward as it seems, there's a problem. There are some exceptions (abnormal or outlier cases) that do not seem to follow the rule. Certain galaxies, in fact, while not containing many stars have very intense rates of star formation. The most accredited hypothesis to explain these abnormal cases invokes collision and merging between two galaxies: these outliers would therefore be nothing but galaxies captured during their collision, a phenomenon that would lead to a sudden, though transient, increase in their star formation rate.

Claudia Mancuso, SISSA researcher and first author of the study together with SISSA professors Andrea Lapi and Luigi Danese, suggested a fascinating alternative explanation: "According to the approach we developed at SISSA and published only a few months ago, collision and merging, while possible, are not so relevant as to be able to account for the formation and evolution of galaxies, including the outliers observed in GMS," says the scientist. "Our approach offers an in situ explanation based solely on processes internal to the evolving galaxy."

The role of the central black hole

In particular, the explanation given by Mancuso and colleagues is based on the close relation that exists between star formation and the growth of the central black hole inside massive galaxies. "These two events are simultaneous and inter-related. As the galaxy forms stars and increases its mass in a constant and substantial manner, its black hole grows as well, and does so at an even faster rate," explains Mancuso. "At a certain point the black hole becomes so big as to develop an 'energetic wind', which sweeps away gas and dust from its surrounding environment. Since these are materials that go into forming new stars, the star formation process comes to an abrupt halt."

Based on this scenario, Mancuso and colleagues formulated a prediction on GMS and demonstrated that their results are in excellent agreement with the observed mean relation, while providing a new interpretation for outliers. "They are simply very young galaxies," explains Mancuso. "A galaxy at its very early stages of life, full of dust and gas, has a very high star formation rate but at the same time it still contains very few stars because it hasn't had the time to form them yet, that's all." A simple and elegant explanation that does not require any external intervention. As evolution proceeds, the scientist goes on, the galaxies move closer and closer to the mean of the GMS, where they will spend most of their lives, before being "turned off" by the black hole's energetic wind. "That's why the data cloud is so dense in that part of the diagram," she adds.

"Clearly, the acid test comes from the observations," concludes Mancuso. "We checked the age, estimated by observation, of some outliers in the GMS, and indeed they are always very young galaxies." More than that, further validation could arrive very soon: "Out theory in fact implies that outlier galaxies, which are young and have very high star formation rates, are still rich in gas, and this will allow us to study them in depth by using the ALMA interferometer."

More information: The Main Sequences of Starforming Galaxies and Active Galactic Nuclei at High Redshift, arxiv.org/abs/1610.05910

Provided by International School of Advanced Studies (SISSA)

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