PRESS RELEASE

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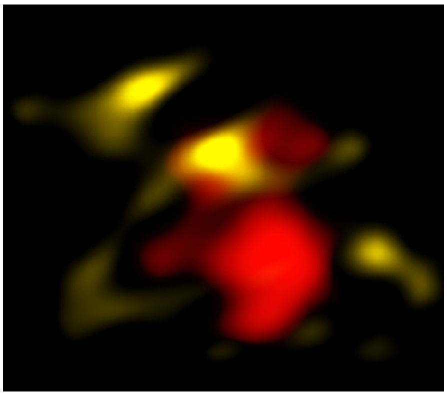
The cosmic network feeds early galaxies

The galaxies in the early universe are much more mature than astrophysicists first thought: their existence at such an early stage is due to their interactions with the cosmos.

The first galaxies were formed 200 million years after the birth of the universe. These galaxies accumulated the vast majority of the stars, dust particles and metals they consist of between one and three billion years after the Big Bang, a crucial period for our understanding of how the galaxies were formed. Astronomers from the University of Geneva (UNIGE), based at the Geneva Observatory – together with the ALPINE project's international consortium of astronomers – have studied 118 galaxies from this period using the ALMA telescope in the highlands of Atacama in Chile. In a total of eight joint articles (four of which were undertaken largely at UNIGE), the astrophysicists succeeded in going back nearly 13 billion years in time to identify the gas and dust composition of the galaxies. Their analyses, featured in the journal *Astronomy & Astrophysics*, show that early galaxies are mature already, lending support to the existence of a cosmic network capable of supplying them with resources.

The ideal way to understand how galaxies are formed, including our own Milky Way, would be to follow them throughout their life, which is impossible. "Fortunately," begins Daniel Schaerer, an astronomer in UNIGE's Department of Astronomy, "we can observe them at different times. By looking very far into space, we can go back in time and study them as they were in the past. The period between one and three billion years after the Big Bang is especially interesting, since it corresponds to the growth peak of the galaxies."



A galaxy in the early universe observed by the ALMA telescope. The galaxy is considered already mature, because it contains large amounts of dust (yellow) and gas (red).

High resolution pictures

Galactic acquisition

Large galaxies, such as our Milky Way, Andromeda, and others, attained their size and mass by merging with other galaxies. In addition, they had to receive additional gas from outside in order to ensure their past growth. This gas, which is probably present in the intergalactic medium, is transported to the galaxies via cosmic filaments. In other words, astronomers think that "the history of galaxies is governed by what we call the 'cosmic network', a kind of galactic ecosystem," continues Daniel Schaerer. Despite the fact that this theoretical model has been accepted by scientists, the presence of gas in the intergalactic medium and the existence of cosmic filaments has never been proven by concrete measurements.

Gas follow sare key component for the growth of galaxies, and the ALMA telescope has been specially designed to observe it using a sys-

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tem that captures distant infrared light. “The telescope is an interferometer with 66 antennas, each 7 m to 12 m in diameter, positioned at an altitude of 5,000m on a plateau in Chile. The vast number of antennas means we can collect the maximum amount of light”, says Miroslava Dessauges-Zavadsky – the astronomer at the Geneva Observatory – with reference to a telescope that is unique in the world.

Excess gas

Drawing on eight studies, the international astrophysicists from the ALPINE consortium became aware that early galaxies contained much more gas than expected, which served to indicate their early development. “Some of them are very large, and almost all already contain heavy elements, such as carbon, in the interstellar medium. This was a sign that these elements were formed by generations of stars that existed prior to one billion years ago, because carbon was not generated during the Big Bang,” continues Daniel Schaerer.

Spotlighting the Geneva contribution

The gas quantification was carried out by a team from UNIGE and is the central theme of one of the eight publications. The work has helped demonstrate that distant galaxies – by extension at an early stage of their development – have much more gas than nearby galaxies. However, since the gas is consumed very quickly by forming new stars, the quantities of gas detected are not enough to explain the observed extended growth of galaxies. “This means that the galaxies must be replenished with gas from the cosmic network”, says Dessauges-Zavadsky, first author of this study.

Another study carried out by the Geneva Observatory compared the galaxies from our time (13.8 billion years) to those present 800 million years after the Big Bang. This research highlights the similarities between some of the properties of the galaxies across the ages, such as the relationship between the emission of the carbon line and the quantity of stars formed. The study demonstrates the consistency of these properties over 13 billion years, an important piece of information for quantifying the growth of galaxies throughout the history of the universe.

The analysis of galactic dust is the subject of the third Geneva study. The researchers succeeded in showing the presence of dust in 20% of early galaxies. “This indicates that these galaxies are already quite mature and that previous generations of stars created the elements incorporated into the dust,” explains Pascal Oesch, an astrophysicist at UNIGE and lead investigator of this article.

The analysis of gas movements lies at the heart of the fourth study carried out at UNIGE. The researchers demonstrated that heavy elements, such as carbon, are found not only inside but also at a great

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distance from the galaxies, and that they move at high speed. “The enriched gas indicates the presence of significant routes to and probably also from intergalactic space. This once again supports the thesis of the cosmic network,” concludes Daniel Schaerer.

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of the European Organisation for Astronomical Research in the Southern Hemisphere (ESO), the U.S. National Science Foundation (NSF) and the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Republic of Chile. ALMA is funded by ESO on behalf of its Member States, by NSF in cooperation with the National Research Council of Canada (NRC) and the Ministry of Science and Technology (MOST) and by NINS in cooperation with the Academia Sinica (AS) in Taiwan and the Korea Astronomy and Space Science Institute (KASI).

ALMA construction and operations are led by ESO on behalf of its Member States; by the National Radio Astronomy Observatory (NRAO), managed by Associated Universities, Inc. (AUI), on behalf of North America; and by the National Astronomical Observatory of Japan (NAOJ) on behalf of East Asia. The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

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