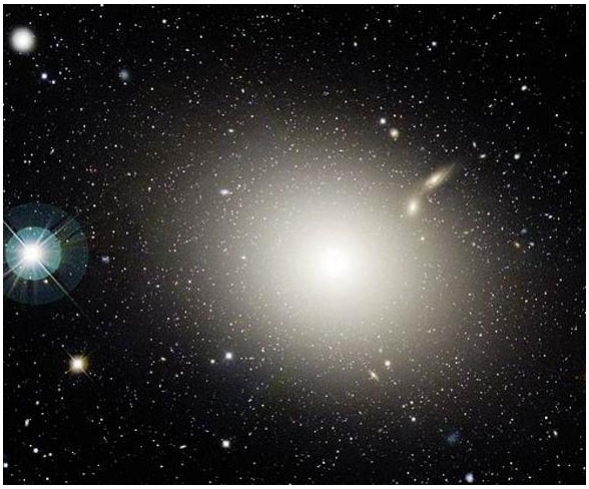
Galaxies

As systems of stars, gas clouds and dark matter bound together by gravity, the hundred billion galaxies populating the visible Universe concentrate most of the matter – both atomic matter and dark matter. They can be observed at great distances in all domains of the electromagnetic spectrum.

The two main types of galaxies

Top: M74, a typical spiral galaxy. Bottom: M87, a giant elliptical galaxy.

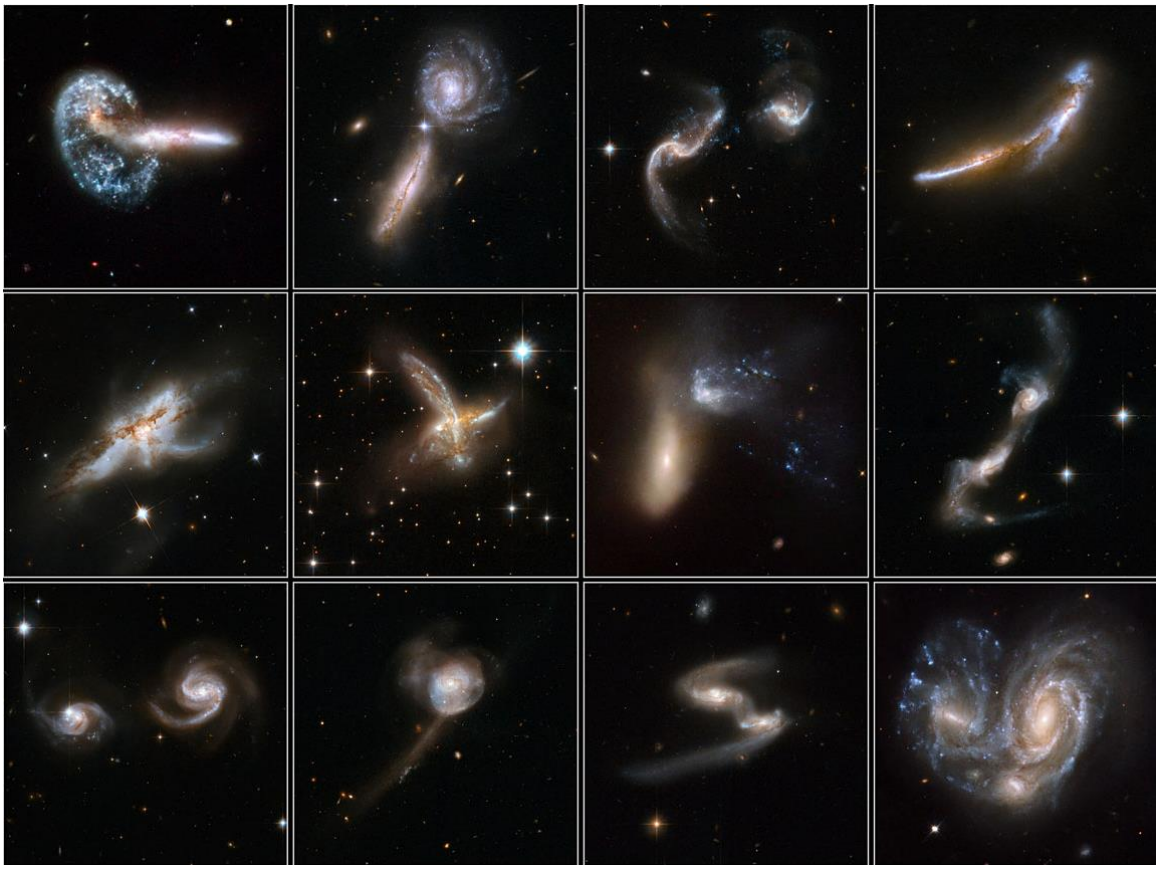


Credit: Gemini Observatory/GMOS Team; Canada-France-Hawaii Telescope/J.-C. Cuillandre

The discovery of galaxies coincided with the discovery of the Big Bang and the expansion of the Universe. As soon as nebulae in our galaxy (supernova remnants, star nurseries) could be distinguished from nebulae outside it (in fact, other galaxies), scientists found that, on a larger scale, the latter seemed to be moving away at a speed proportional to their distance, and that the Universe was therefore expanding.

Based on morphological considerations alone, the classification of the galaxy is quite straightforward: 95% of the galaxies in the 'local' Universe, those located at distances smaller than 5 x 108 ly (light-years) belong either to the spiral category (61%) or to the elliptical category (34%). However, since ellipticals are 10 to 100 times more massive than spirals, the proportions are reversed when the two types are compared in mass rather than number: 73% of the total mass of stars in the local Universe is contained in elliptical galaxies.

The difference between the two types of galaxy is not just morphological. Spirals are bluer, indicating the presence of massive, young and hot stars. They contain a lot of interstellar gas, which feeds the formation of new stars. Ellipticals



Credit: NASA/ESA/The Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration/A. Evans (University of Virginia/NRAO/Stony Brook University)

Example of a merger of two galaxies

These images were captured by the Hubble Space Telescope.

are red, because they contain mainly low-mass, old and cold stars. They are almost devoid of the interstellar gas that could be used to form new stars. Why did the Universe give rise to these two galaxy types? What mechanisms explain such morphological difference? Why do elliptical galaxies no longer form stars and have no interstellar gas? Even today, astronomers have only some partial and contradictory answers to offer…

The further back in time we go, the denser the Universe was, and, therefore, the closer galaxies were to one another. It is thus legitimate to think that some of them merged, a phenomenon that can still be observed today. Computer simulations have shown that during these processes, spiral galaxies lose their arms and become elliptical. Elliptical galaxies could thus be remnants of galaxy mergers.

In this hierarchical scenario of galaxy formation, where the largest galaxies result from the merging of smaller ones, one might expect the most massive galaxies to form last, at the end of the process. Yet, observations reveal exactly the opposite: the more massive a galaxy is, the earlier its stars formed in the history of the Universe! This is a paradox that future observations will seek to solve.

Translated from 'Les galaxies',* Passeport pour les deux infinis, *IN2P3/Dunod, https://pass2i.ijclab.in2p3.fr/ (French); updated with ICHEP2024 conference (https://ichep2024.org) for IPPOG