ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# Galaxies: Numerical Experiments

## Introduction to Astrophysics; Chapter 6.2

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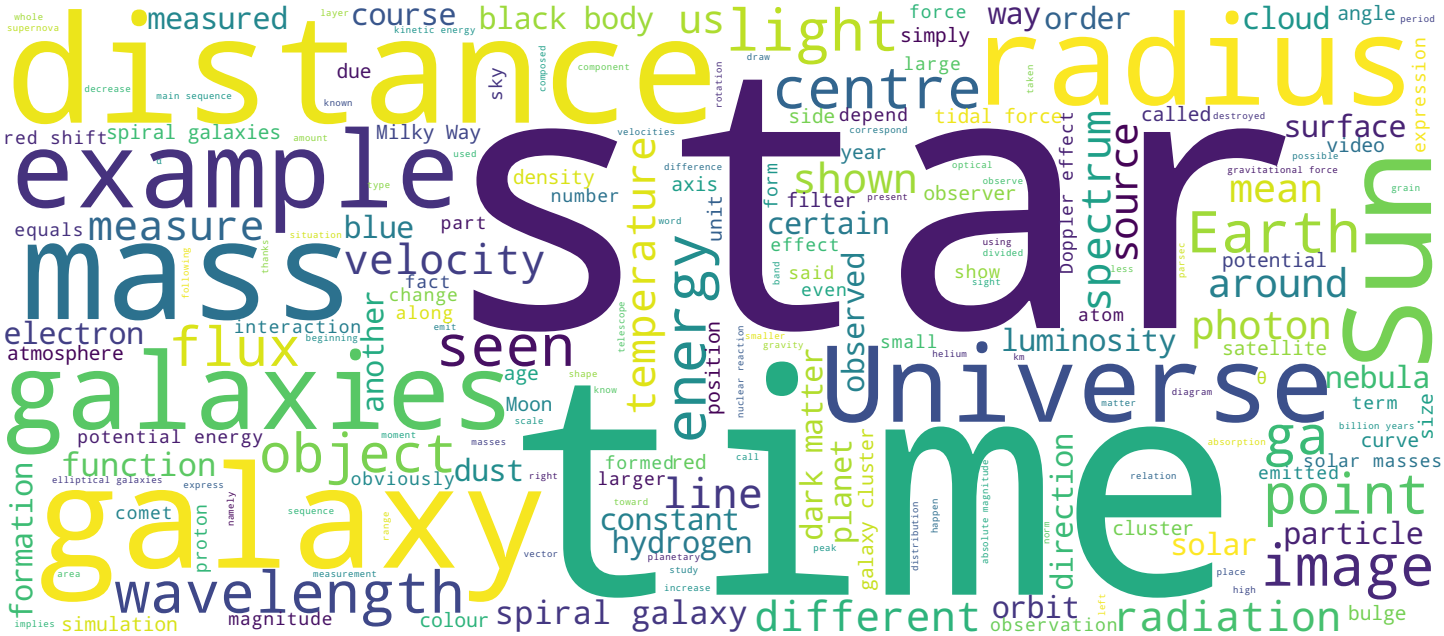
Evolution of a (simulated) spiral galaxy

Images: Yves Revaz (EPFL)

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Video

EPFL

Galaxies can be formed in various ways. At the beginning of the 20th century, Hubble thought that elliptic galaxies evolve into spiral galaxies according to the morphological sequence. As it was shown before, this sequence is incorrectly called “the evolutionary sequence”. Now, it is known that spiral galaxies can become elliptical galaxies and vice versa. Collisions of galaxies may play a significant part, but also that the amount of dark matter and its kinetic properties play a crucial role in the formation and future of a galaxy, whatever its morphological type. Indeed, the more the matter (dark or luminous) is dynamically cold - or the weaker the thermal agitation of particles within a massive object, the larger its ability to collapse easily, as we have seen through the Viriel theorem and the Jeans criteria so the colder the matter, the greater number of compact structures can be formed, i.e. galaxies or galaxy clusters. What can be seen in the video is a simulation containing 33 millions of massive particles interacting with each other in a piece of universe about 20 Mpc in size, of which only the central Mpc is shown. The particles represent the gas, the stars and the cold dark matter, but in the video only the gas is shown.

Notes

Summary

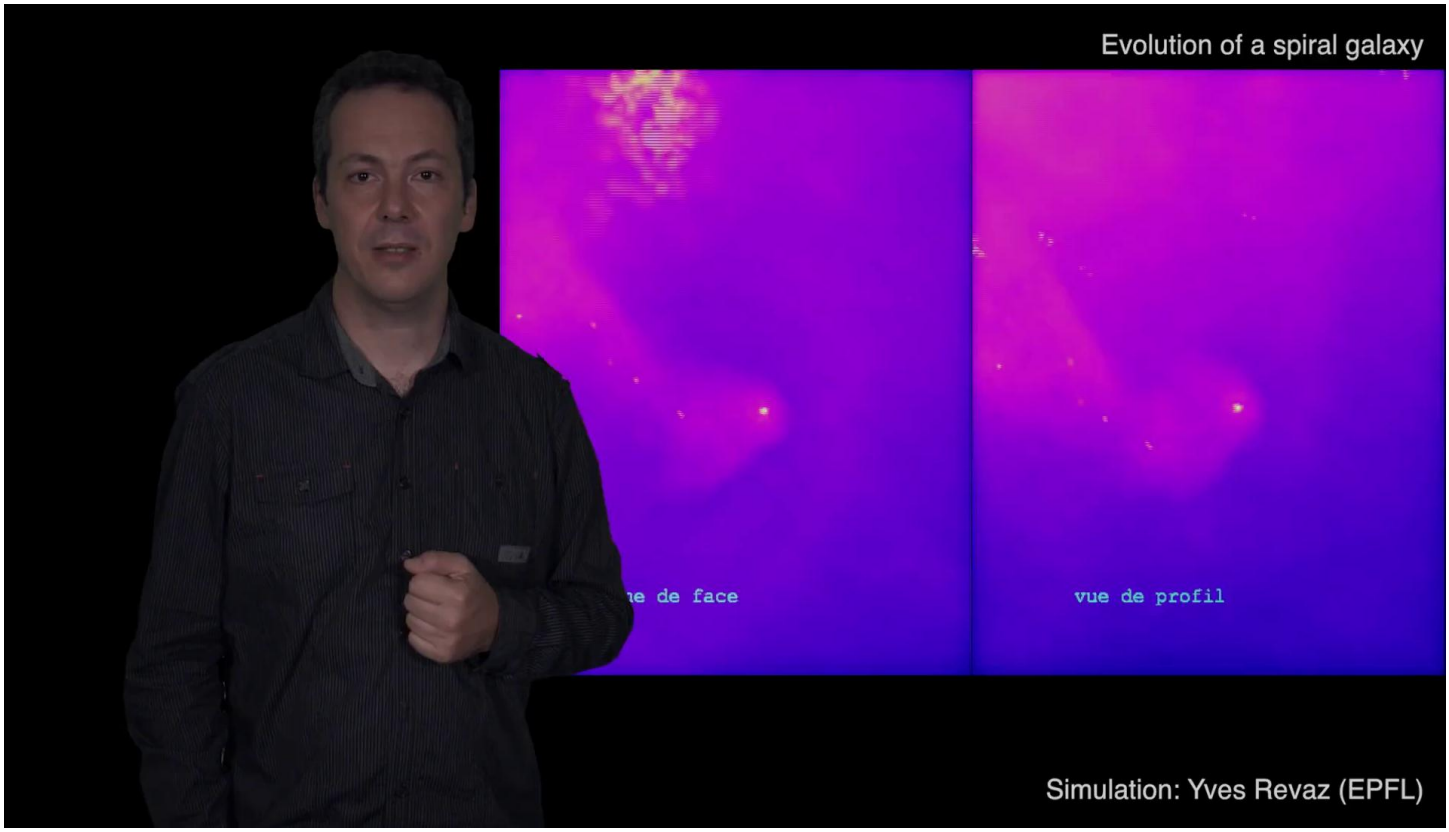
0m 07s

When the simulation starts at zero age, the universe is almost homogeneous but next to the slightly denser regions, matter begins to collapse, nodules and filaments appear. In the centre of the image, one can see a spiral galaxy being formed, become stable for a moment - a few billion years which is not an insignificant fraction of the age of the Universe, which amounts to 13.7 billions of years. Then, interactions with other galaxies almost lead to its disruption while passing through the cluster.

Notes

Summary

1m 35s

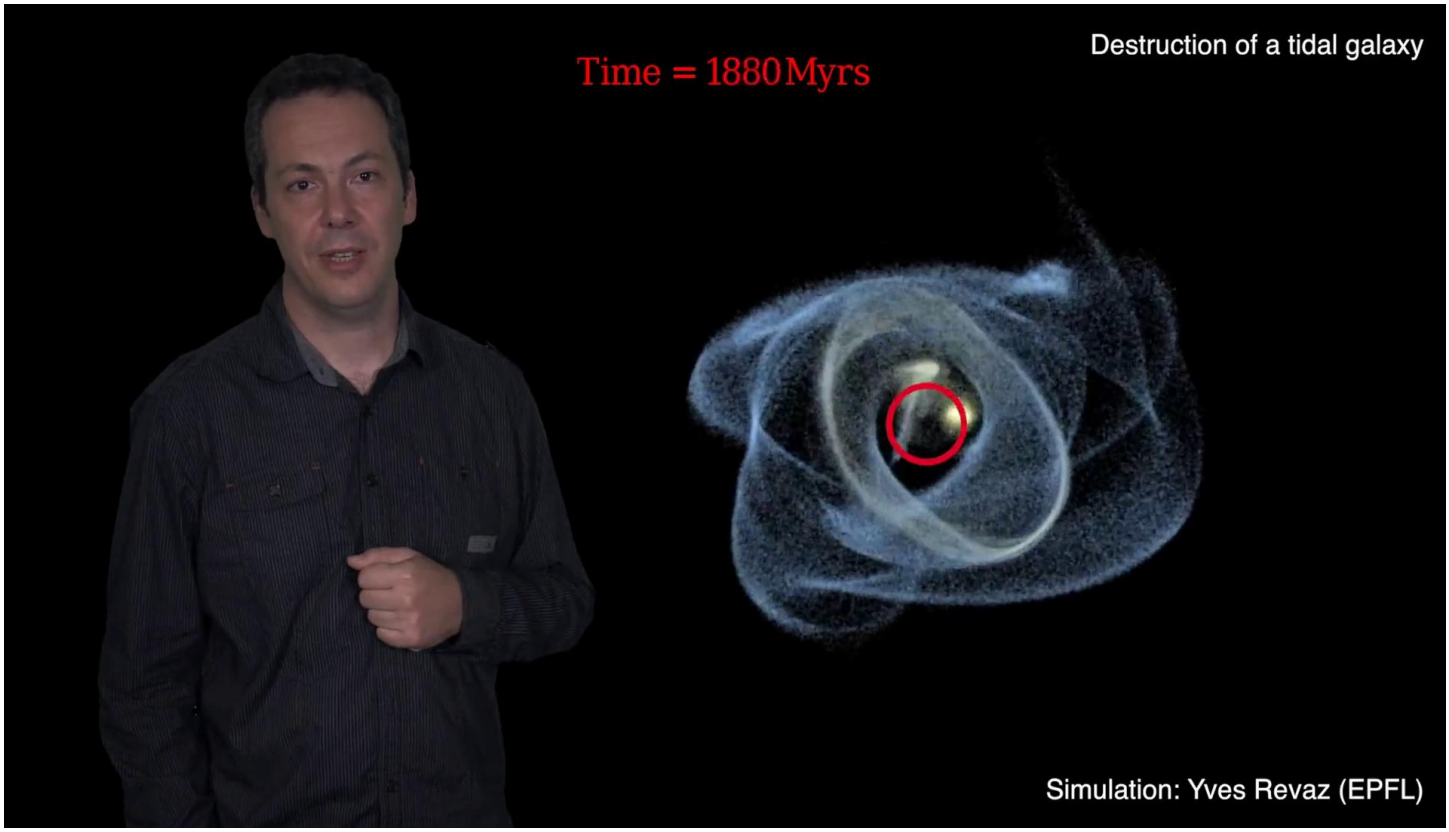



Let's take the same simulation, zooming now on the spiral galaxy that lied in the centre of the previous simulation. On the left the galaxy is shown face on while on the right, the same galaxy is shown edge on. At the beginning the matter collapses forming larger and larger clumps resulting in the formation of a spiral galaxy with a nice isolated disk which stays stable for a moment then partially destroyed as a consequence of interactions with other galaxies. Then, only the bulge of the galaxy remains while passing through a galaxy cluster. This video perfectly shows a multitude of evolutionary scenarios for a galaxy, from the very formation until its possible complete destruction.

Notes

Summary

2m 12s

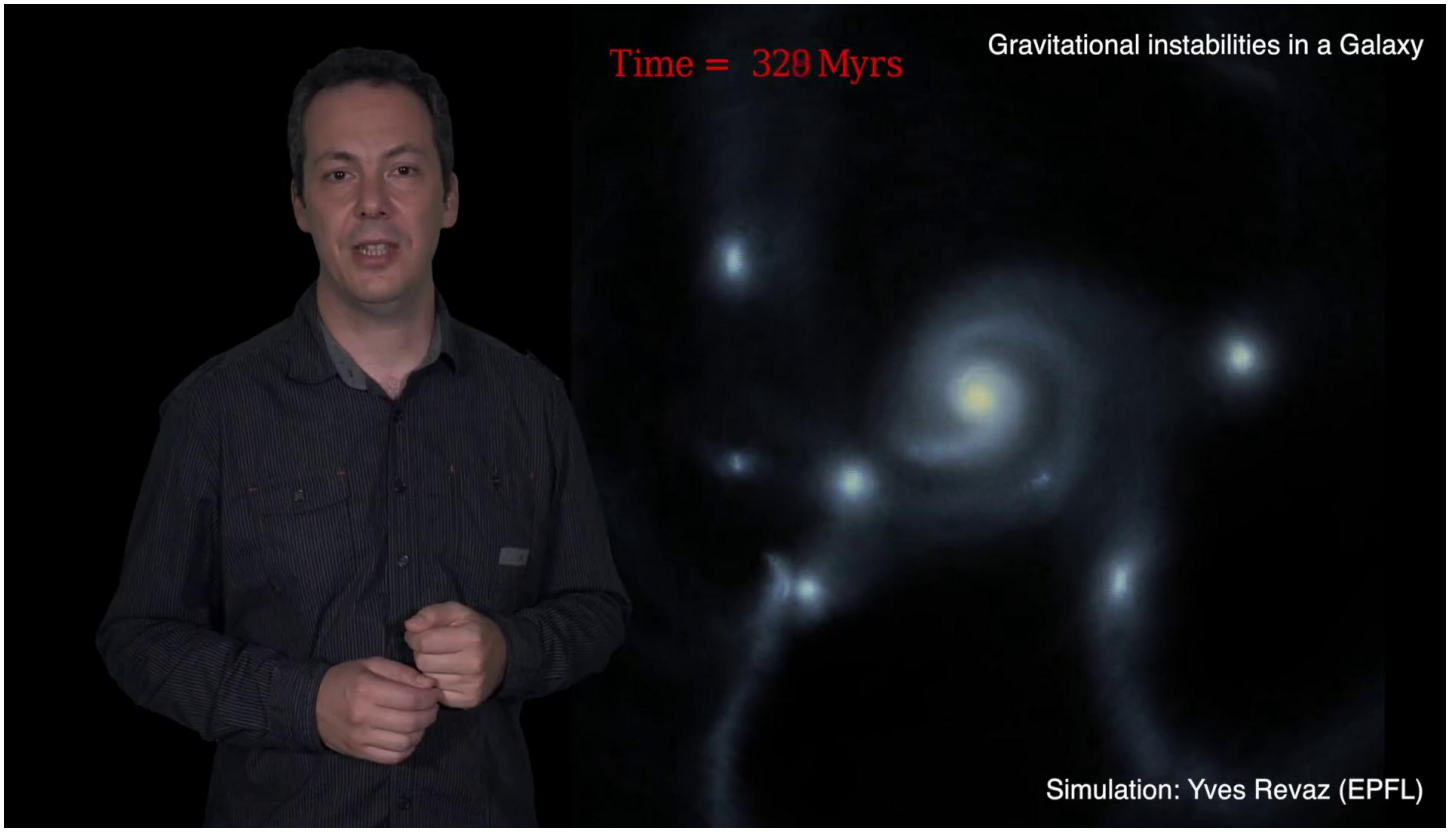



Lets see now the extreme case of galaxy interactions. In this simulation, a spiral galaxy is attracted into a potential well materialized by the red point in the centre of the image. The galaxy dives into the potential well and the disk stars from all sides of the bulge are dragged out then scattered. Only the bulge survives the interaction. This video illustrates well how a galaxy, here a spiral one, is destroyed by the tidal forces caused by the potential well, and how the final product of the interactions participates in the formation of, in this case, a compact elliptical galaxy from a bulge of a spiral galaxy. This phenomenon is relatively fast, it takes place in the simulation in about 1.5 billion years - a little less than 10 percent of the age of the Universe.

Notes

Summary

2m 59s




A galaxy does not have to interact with other galaxies in order to be destroyed. In the regions (locally) dynamically colder than others, matter may collapse and form small nodules which develop gravitational instabilities that might result in the destruction of the galaxy. It may occur even if a galaxy is completely isolated, as shown in this simulation, where the initial conditions are those of an isolated disk of matter. This condition does not prevent the galaxy from being disrupted due to the gravitational instability.

Notes

Summary

3m 57s