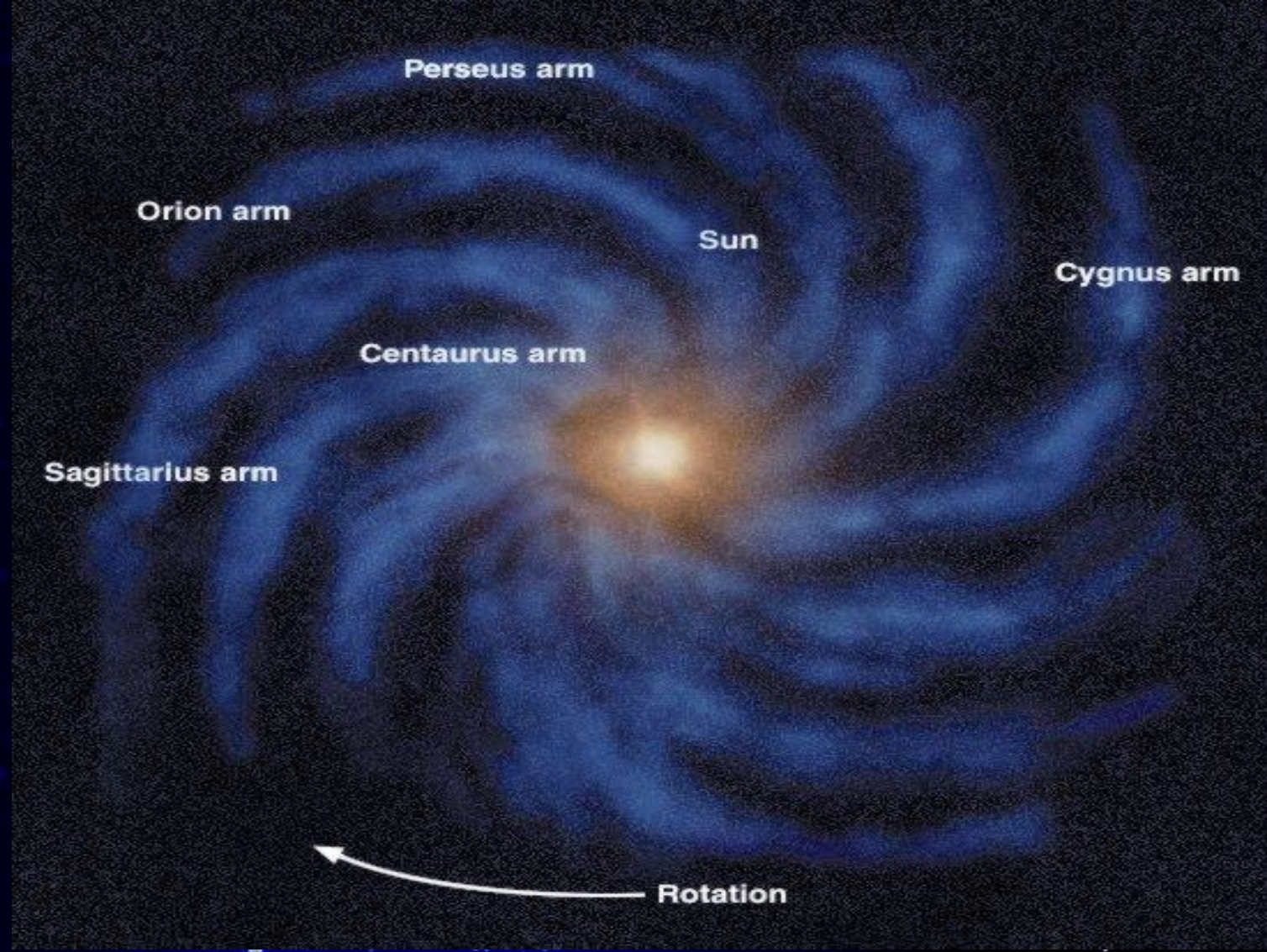


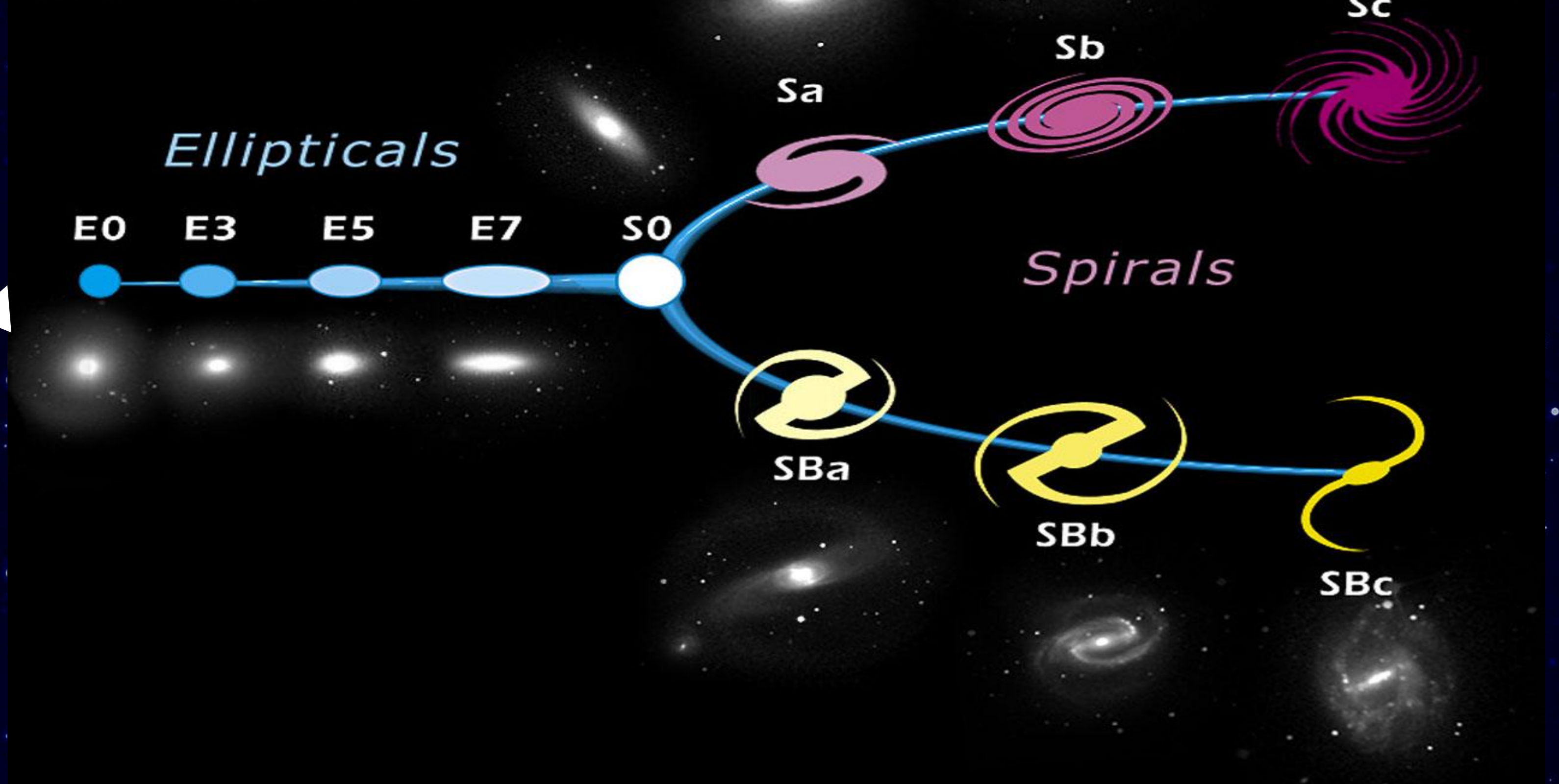
# Galaxies – The “Island Universes”

Galaxies are massive collections of stars. In a galaxy like our own Milky Way (shown below), there can be as many as  $10^{11}$  stars! Other than stars, there is also gas and dust (inter stellar medium), dead star remnants, dark matter and a central super-massive black hole. In the universe, there are estimated to be  $10^{11}$  such galaxies! One can only imagine how big the universe is!

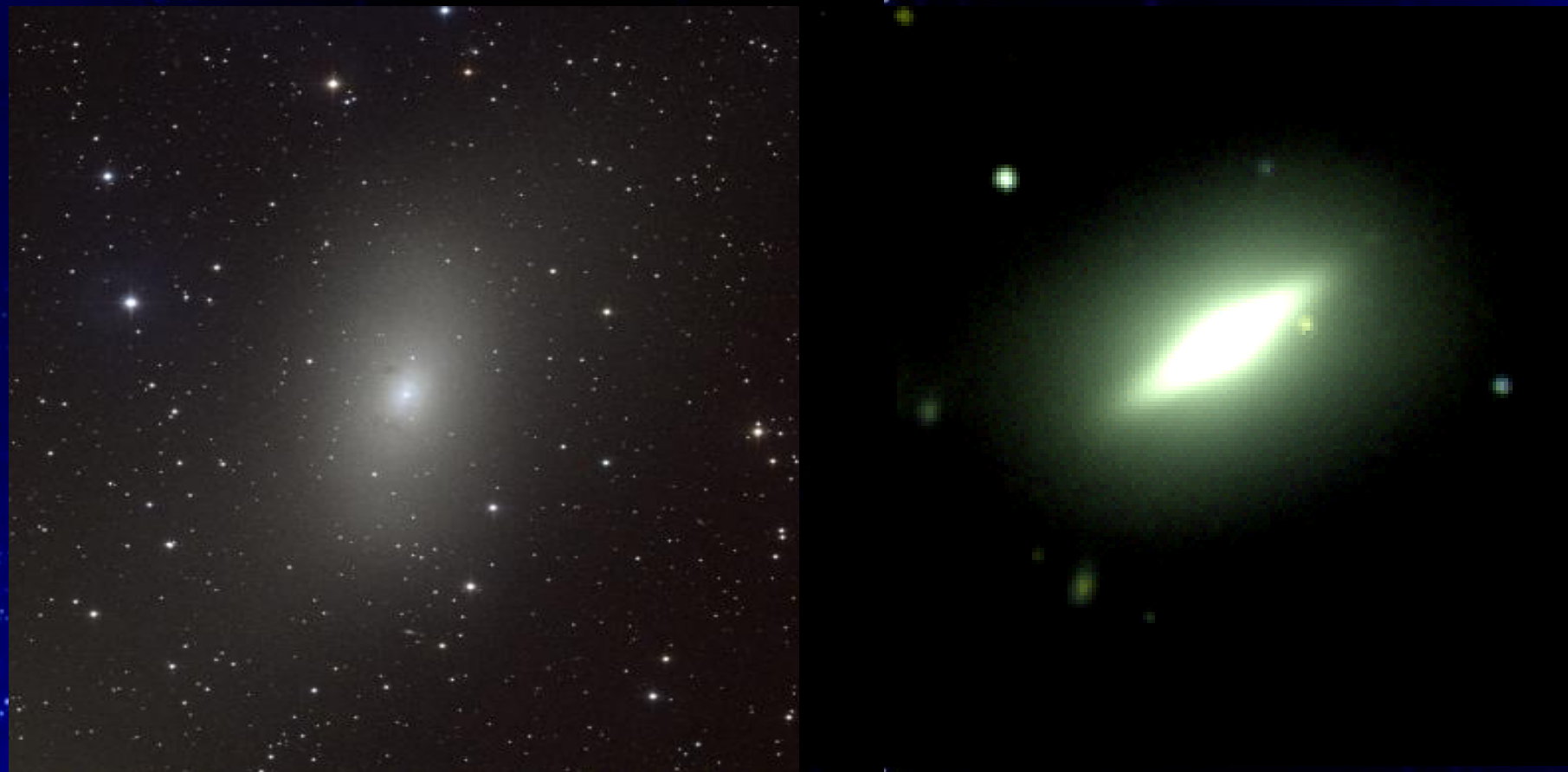


Galaxies were first classified by Edwin Hubble, popularly known as the Hubble Tuning fork diagram. This is shown to the right. Later this scheme was expanded by Sandage and de Vaucouleurs to give due place to galaxies that did not fit in this scheme. (like Irregular galaxies)

## Edwin Hubble's Classification Scheme



**Elliptical** galaxies are smooth and featureless structures. At the center the light is strongly concentrated and fades out towards the outer edges. These contain very old stars, have little dust and hardly any star formation is taking place in them. (The number (in E0, E3, E5, etc.) represents the flatness of the shape 0 – round and 7 – very flat.)

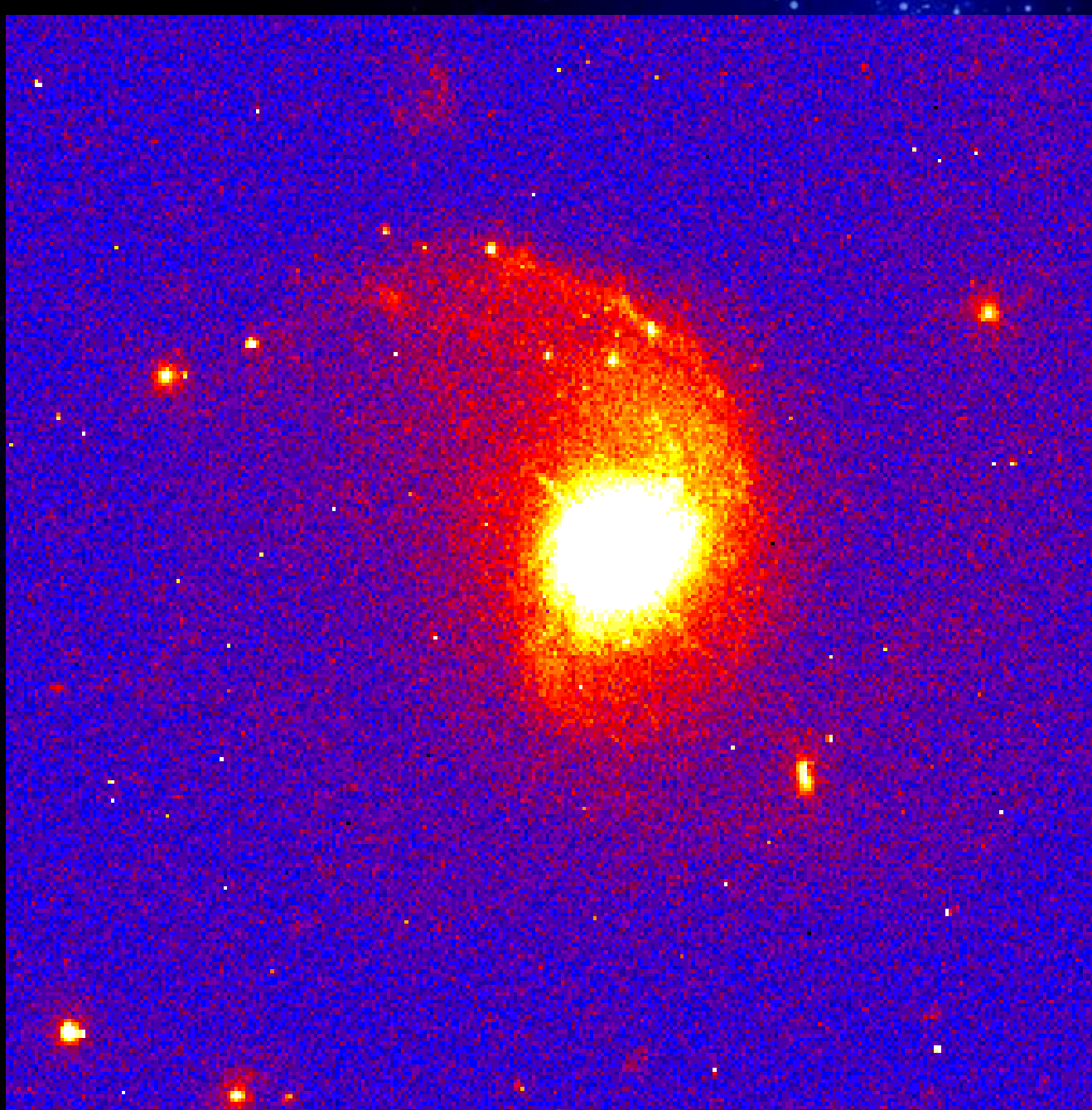


In between spirals and ellipticals are the “**lenticulars**”. They are neither as featureless as ellipticals nor feature-rich as the spirals. S0s have a large featureless bulge similar to the ellipticals but also have a prominent disk, with no spiral arms. SB0s are like S0s but have a bar at the center. (S0 – lenticular without bar, SB0 – lenticular with a bar.)



**Spiral galaxies**, beautiful to look at, are also very interesting objects. They have a central concentration of stars, an outer disk which rotates and a beautiful spiral structure made of stars. Unlike ellipticals, there is a lot of dust present in these galaxies and new stars are forming in them, especially in the spiral arms. Some of these even have a bar at their center. (S – spiral, SB – spiral with a bar. The letters a, b and c are used to represent the tightness of the spiral arms.)

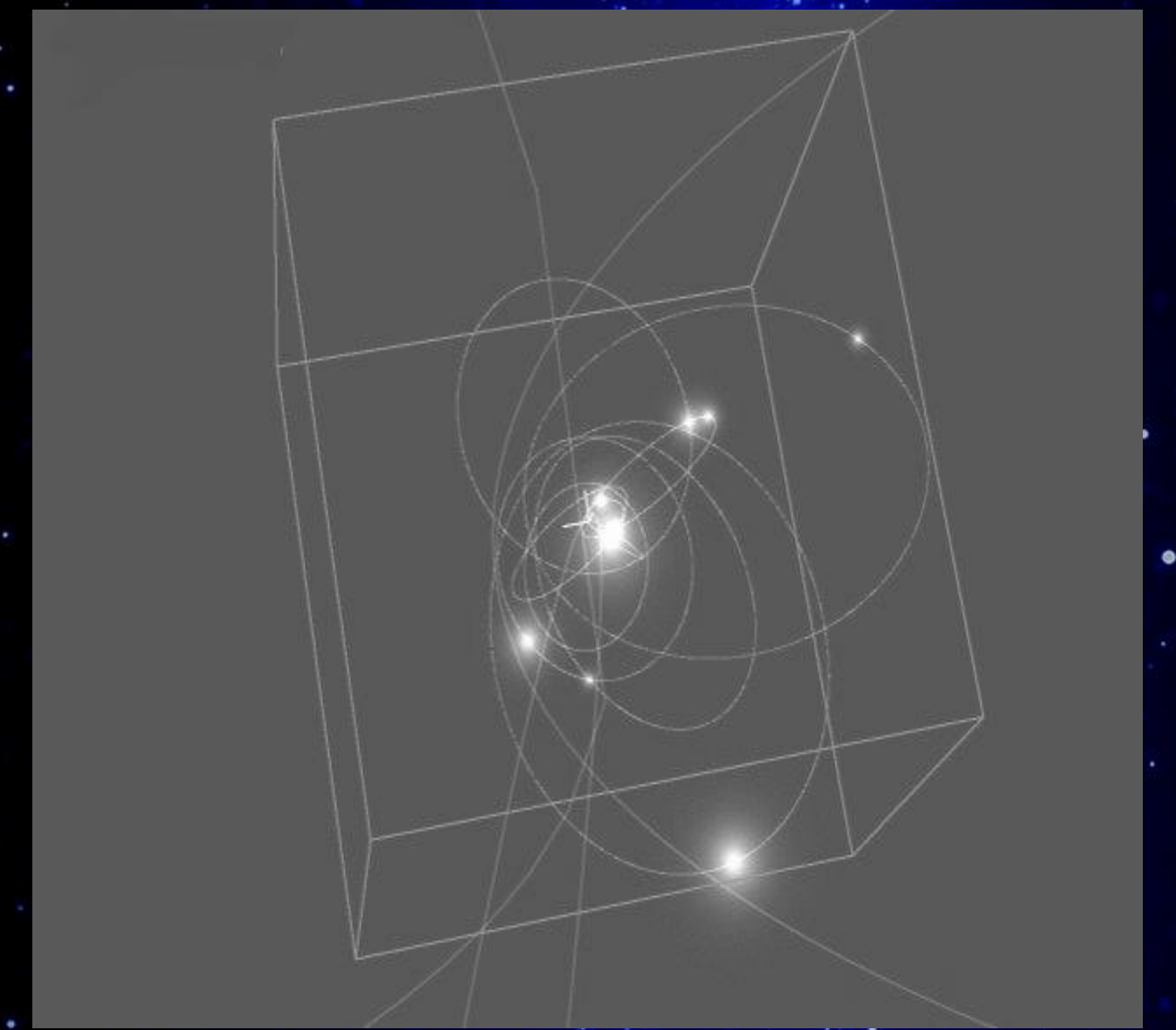
## Galaxies are not just a passive collection of stars!



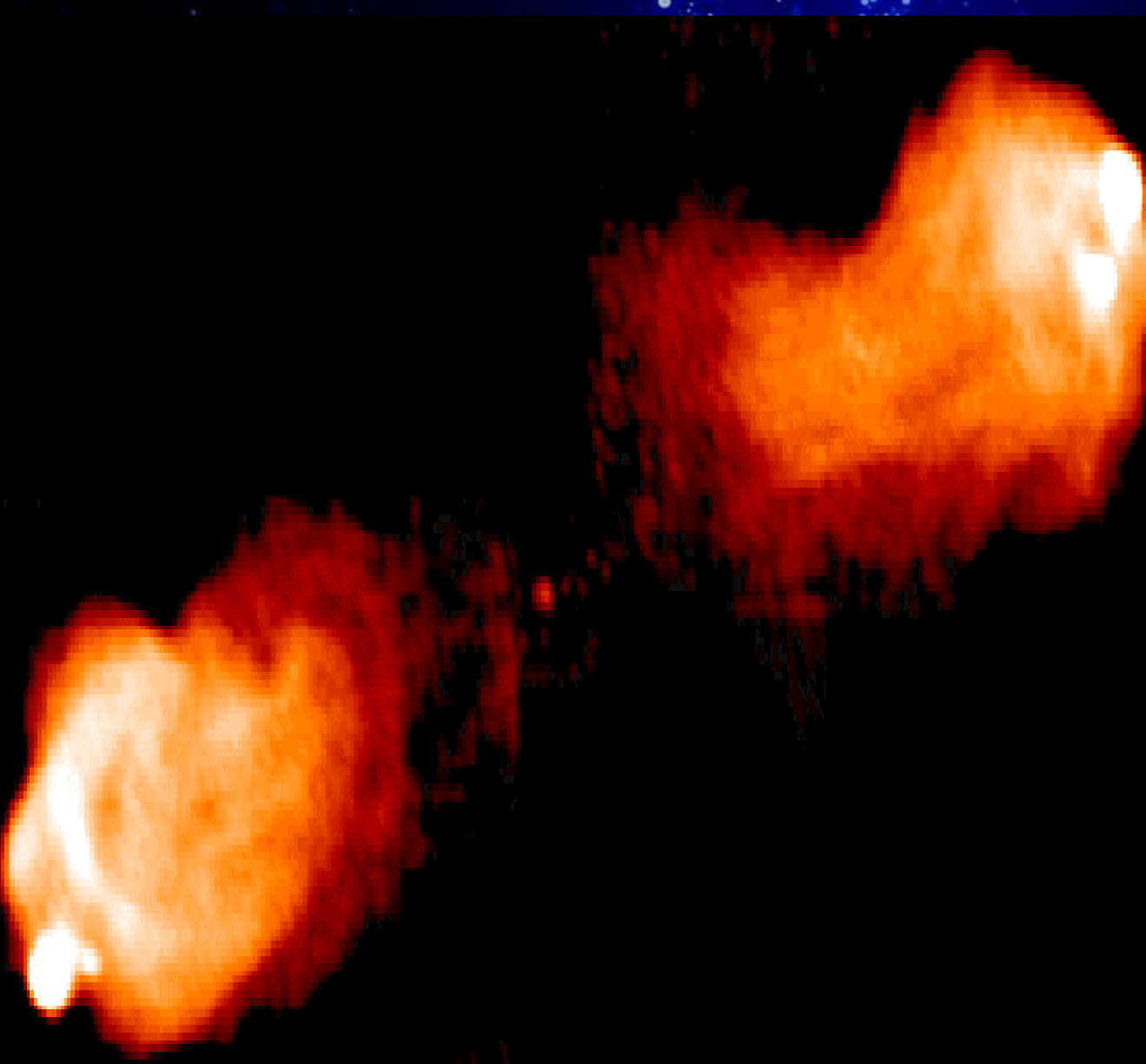
A false color image of a Quasar in X-Ray wavelength.

**Quasars/AGNs:** These are objects that are not exactly stars but are producing immense amount of energy from a central point like source, and appear like stars by outshining the galaxies in which they reside. AGNs are quasars in whom the galaxy and central source can be seen separately. They are believed to be super-massive black holes accreting nearby stars but a lot remains unexplained about them.

**Central Black Holes:** As a support to the presence of the black holes, astronomers have noted the motion of stars around the center of our galaxy as shown. From the orbits traced by the stars one can infer that there is a dark massive object sitting at the center whose mass is confined to a very small volume. It is most likely to be a super-massive black hole.



A computer-generated depiction of the tracks traced by stars at the center of our galaxy – The Milky Way



The above is a false color image of the radio galaxy Cygnus A in Radio Wavelength.

**Radio Galaxies:** We have also observed using radio telescopes certain galaxies with giant emission lobes as shown in this figure. These are again thought to be jets coming out from the central black hole. These jets are huge extending to the order of Mpc i.e. size bigger than the galaxy itself! It is still an unsolved question as to how such powerful emissions can be generated.

**Galaxy Clusters:** Galaxies are a collection of stars. We have also found collections of galaxies, called as galaxy clusters. One can study these clusters to see how galaxies evolve and how their evolution is governed by the environment around them. Since clusters also contain a significant portion of dark matter, the study of these clusters also allows us the study of dark matter distributions since its gravitational effects are the only things that allow us to detect it. In between galaxies lies lot of hot (1-100 million °C) gas as well, called inter-cluster medium.

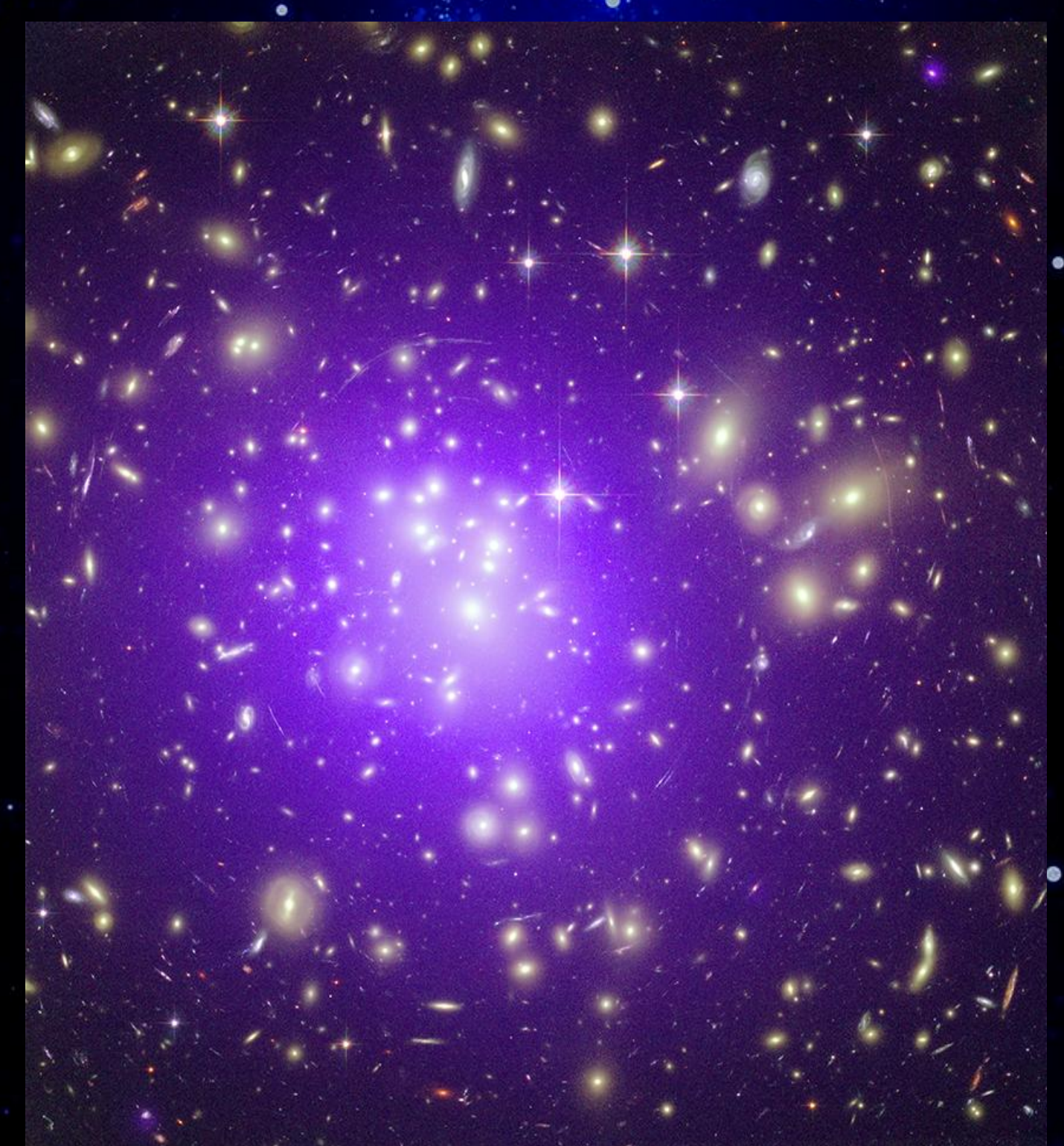


Image of the Abell Cluster 1689



This picture shows galaxies interacting with each other. This interaction takes a very long time compared to the human time scales. It is believed that elliptical galaxies have formed from such interactions.

This galaxy (NGC 4826) is full of violent activity with gas rotating opposite to that of stars. This is thought to be a galaxy formed by interactions like the one on left but not yet settled down.

