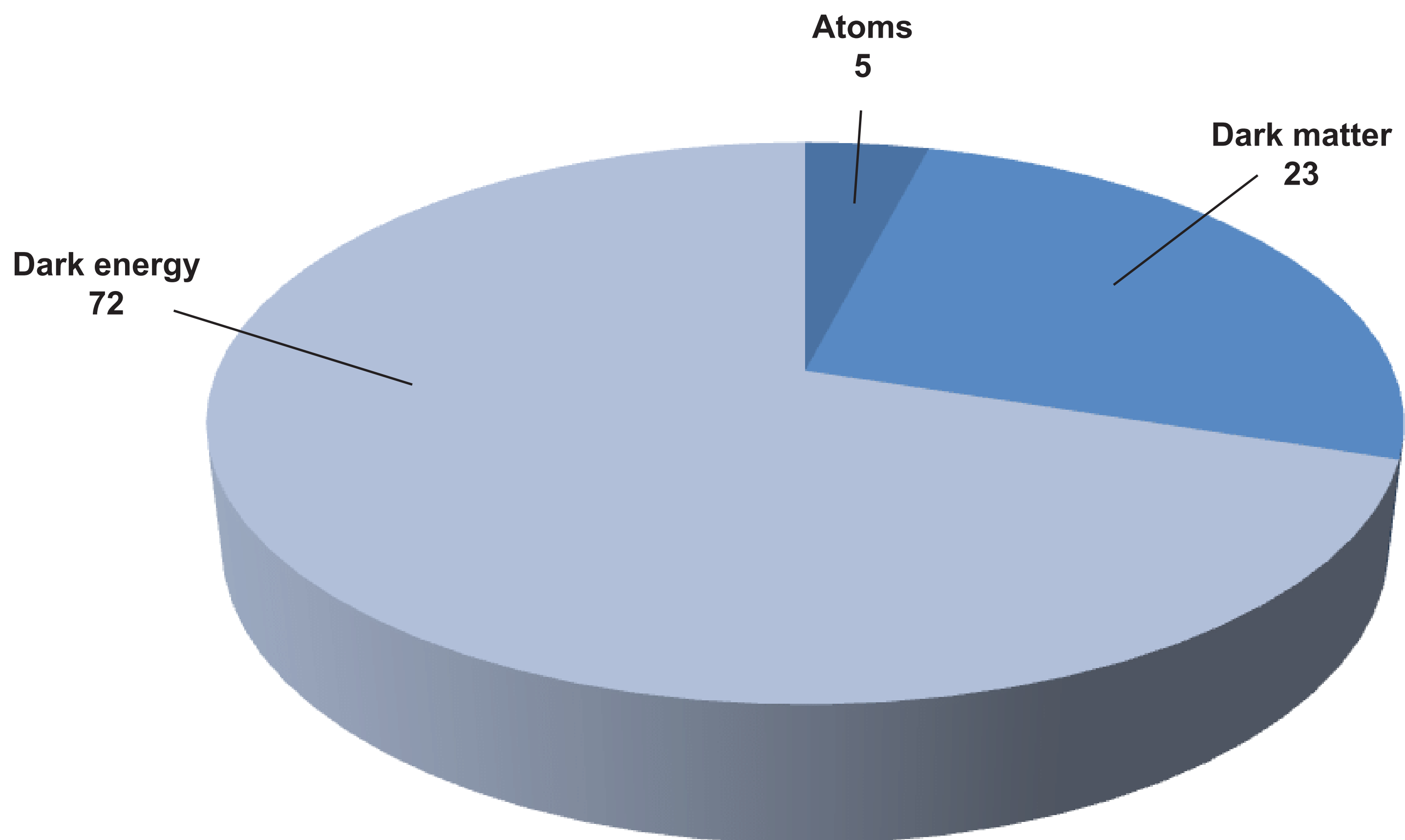


COSMIC PIE

WHAT IS THE UNIVERSE MADE OF?



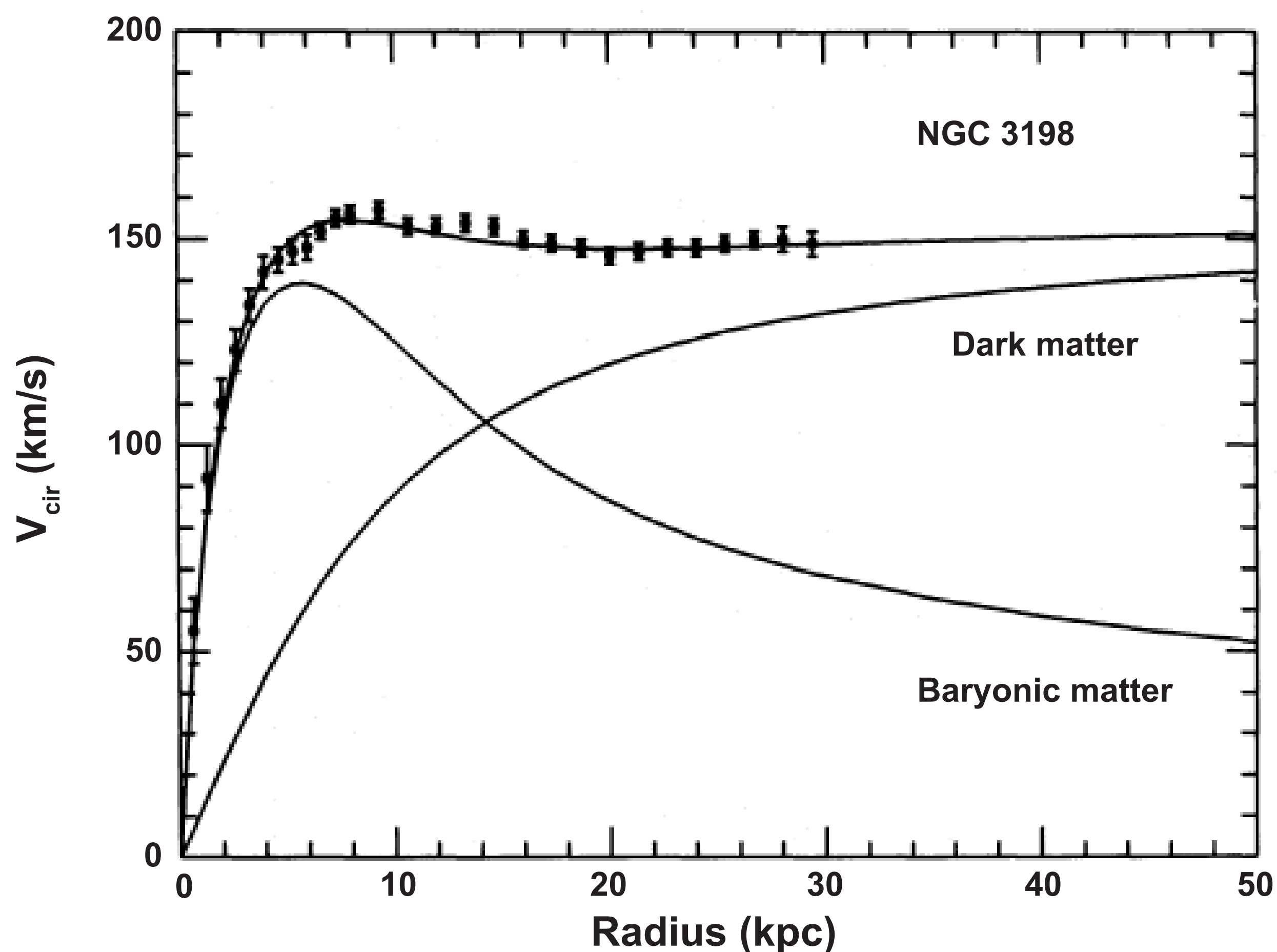
Baryonic matter

Only about 5% of the universe's mass-energy is made of Baryonic matter i.e., atoms, ions and electrons. This is the material that forms stars, planets and the dust and gas found in space. This "normal" matter is in fact everything that we can sense or observe or measure or simulate – our experiential universe.

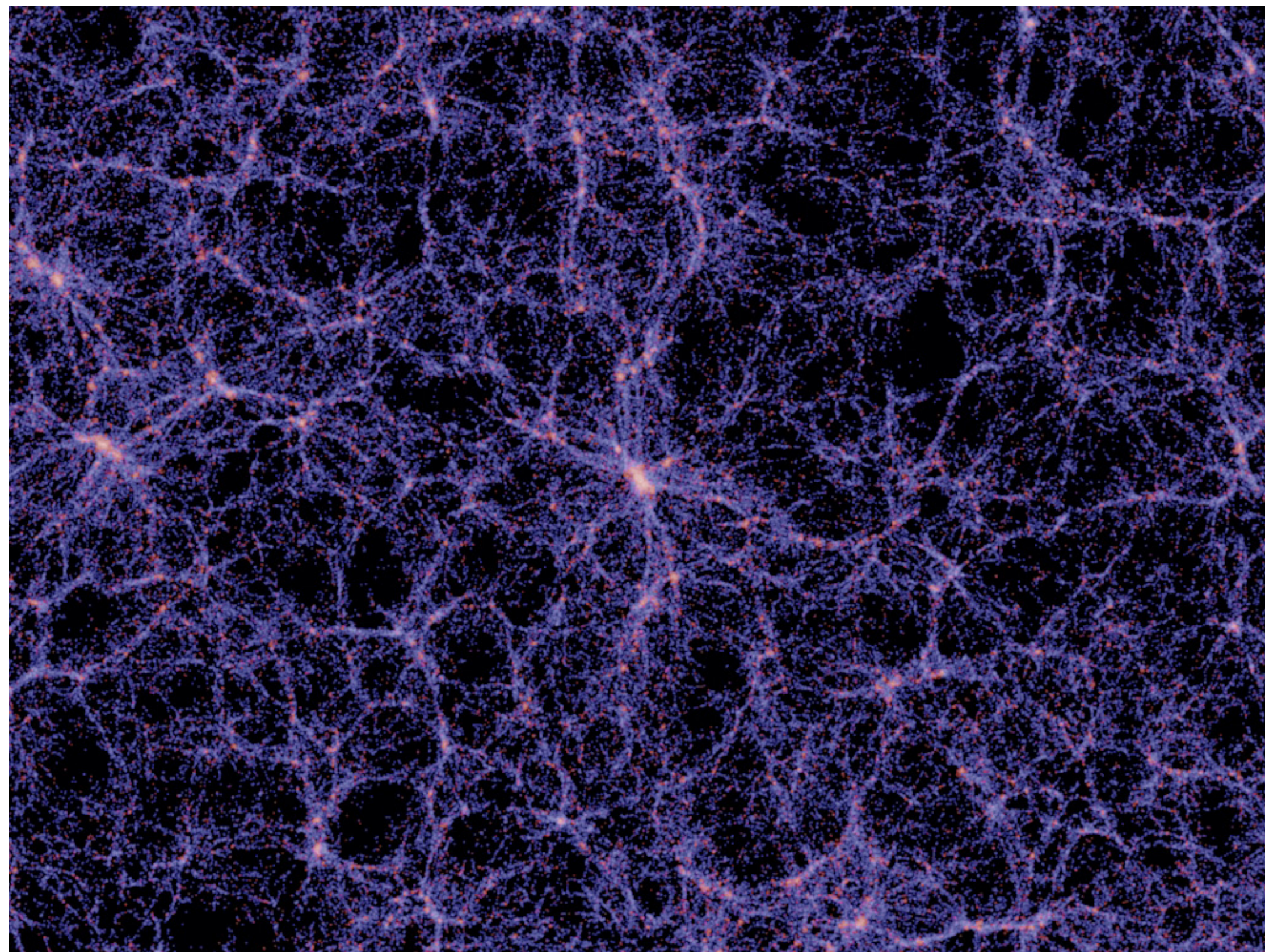
Dark matter

Dark matter makes up the rest of the matter in the universe, forming about 20 to 25% of the mass-energy in the universe. Like ordinary (Baryonic) matter, it has mass, but is invisible because it does not interact with the electromagnetic field and therefore does not absorb or emit electromagnetic radiation. Its presence is only detected from the effects of its gravity. Its existence was first detected by Vera Ruben using a sensitive spectrograph to measure the rotational speed of stars in the outer edges of the spiral galaxy M33. The results of her influential paper in 1980 showed that galaxy masses increase linearly with radius well beyond the location of most stars.

Distribution of Dark matter in NGC 3198



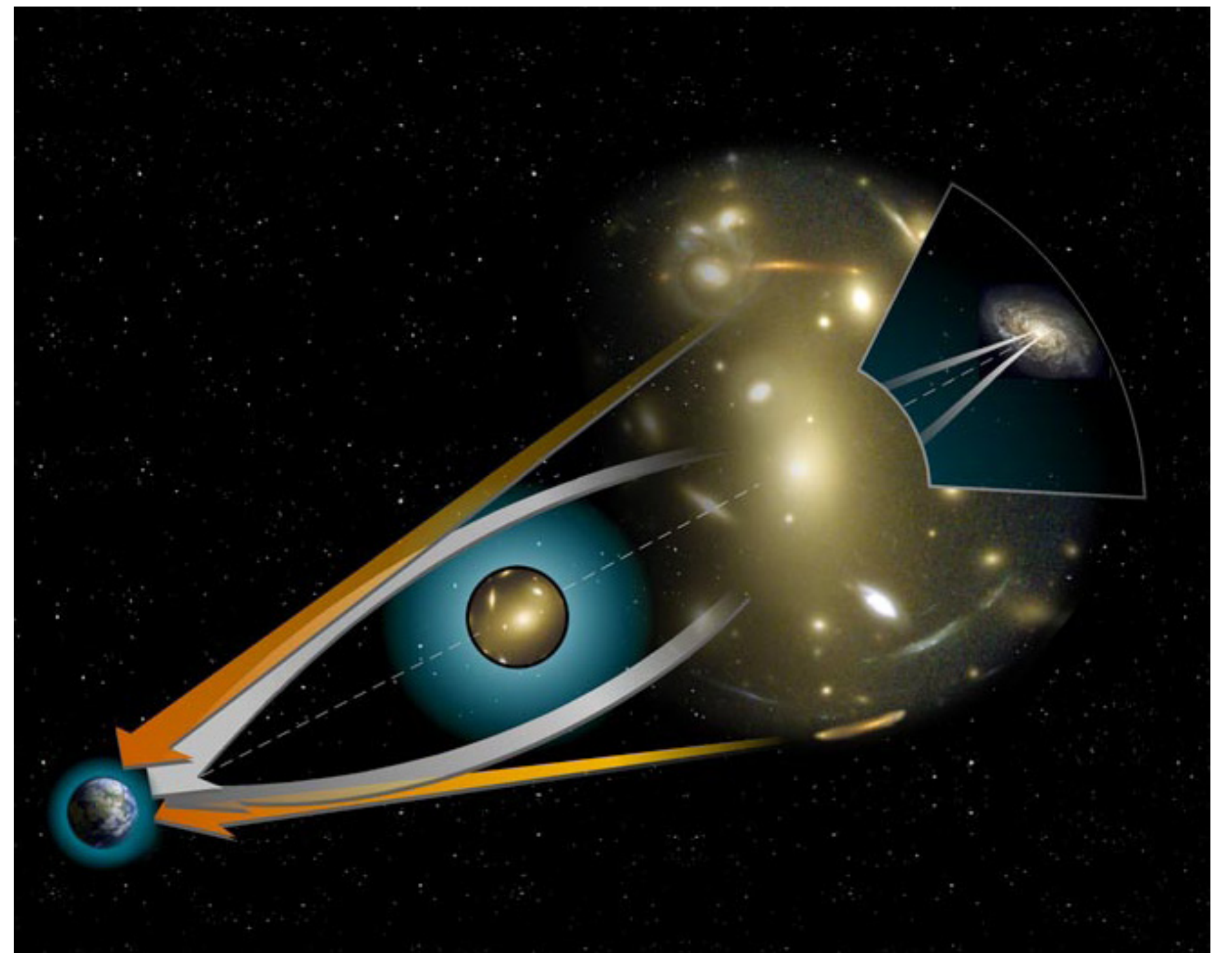
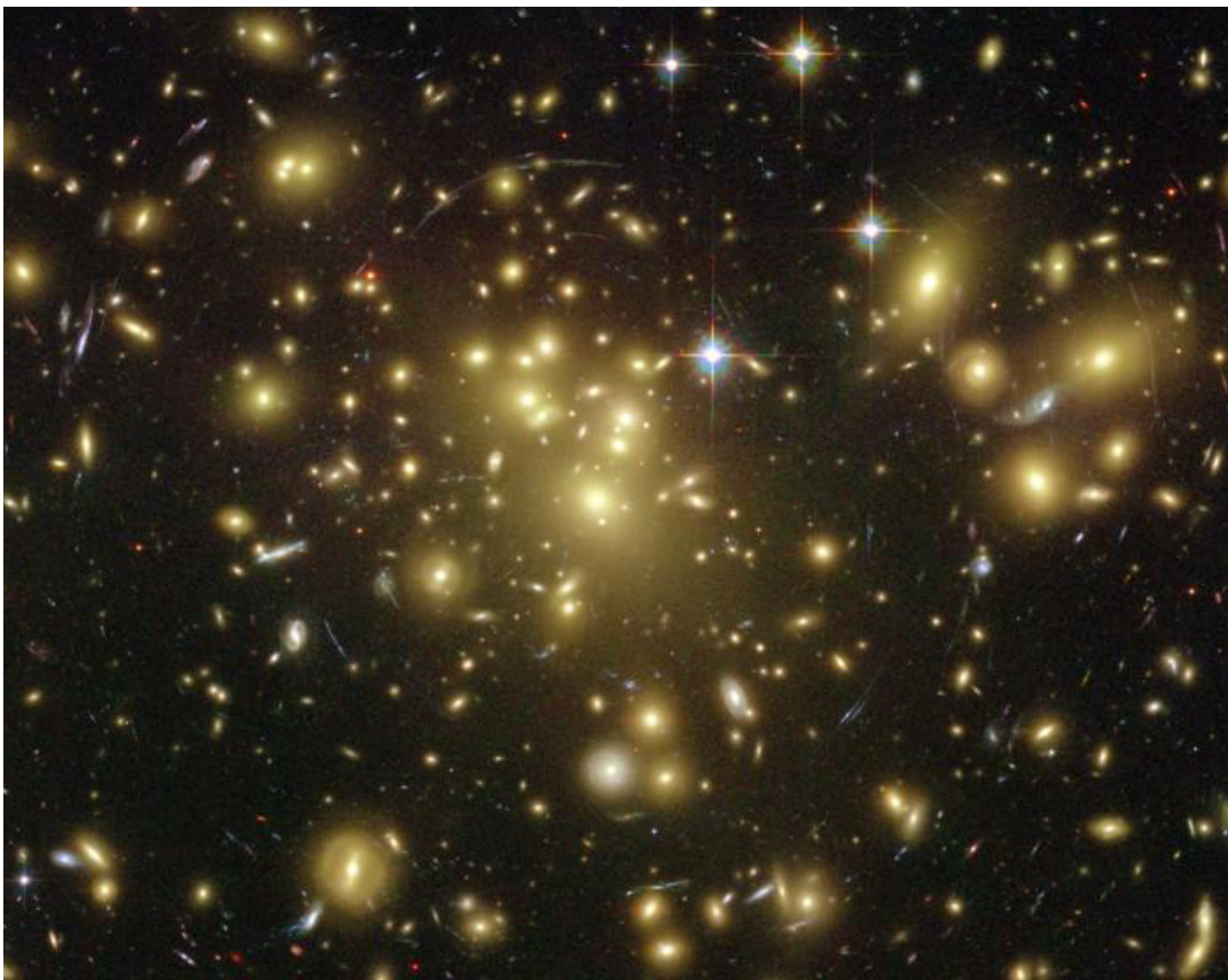
It is also the matter which forms a structure called the 'cosmic web'. The cosmic web is a universe-wide three-dimensional net-like structure that forms the scaffolding on which matter builds galaxies, stars and planets.



'cosmic web'

The Gravitational Lensing of galaxy clusters is both an observational proof of the existence of Dark matter and a method of estimating its abundance. The lensing amount enables the total mass of the lensing object to be calculated, from which the visible Baryonic matter can be subtracted to derive the Dark matter amount.

Gravitational Lensing



The composition of Dark matter remains one of the key questions in cosmology.

Dark energy

The remaining 70 to 75% of the universe's mass-energy is made up of even more mysterious Dark energy, which is invisible and has no mass but is a powerful force. It opposes the inward-pulling gravity of matter and Dark matter and is the force that is making the universe expand. Dark energy is what makes galaxies move away from one another.

Dark energy was discovered by two independent and competing groups in 1998 from an analysis of the recession speeds of distant Type 1a Supernovae, which act as standard candles to determine their distance from Earth. These supernovae all explode with the same intrinsic brightness or luminosity, which implies that their *apparent* luminosity enables one to calculate their actual distance. The expansion of the Universe (see the Big Bang tablet) has been decreasing for the *Matter Dominated* era until about 8 billion years after the Big Bang. Since then Dark energy has become dominant and the expansion rate of the Universe has accelerated.