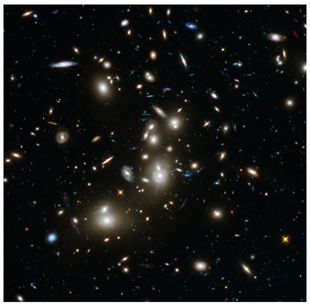
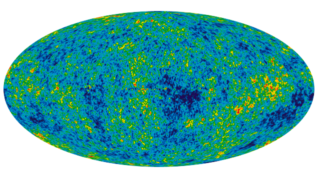
Dark matter

The invisible material


*Galaxy cluster**


*Gravitational lens – galaxies look long and distorted**


Cosmic microwave background (CMB)


*Bullet cluster galactic collision**

*Images courtesy of apod.nasa.gov

Our universe holds everything we know and everything we are still figuring out. For years, physicists around the world have studied our universe to better understand its nature and its future. They have found that we only understand about 4% of the matter and energy in our universe (including stars, planets, and hot gas). The other 96% is invisible to us and 23% of this invisible material is named *dark matter.*

If dark matter is invisible, how do we know it exists?

To answer this, we go back to the 1930s when physicist Fritz Zwicky coined the term *dark matter* while studying galaxy clusters. Galaxy clusters have up to thousands of galaxies (like our Milky Way for example) held together by gravity. When Dr. Zwicky calculated the total visible mass of galaxies in the Coma cluster, he found that it was not enough to create the gravity needed to hold the cluster together (mass causes gravity). He concluded that there must be an invisible material causing the extra gravity: *dark matter.*

Now fast forward to the 1970s when Vera Rubin studied galaxy rotation curves. According to Newton's laws, when objects rotate around a common centre, the ones furthest from the centre move more slowly than those near it. Otherwise, the furthest objects would fly off. Dr. Rubin found that stars in galaxies do not follow this rule. In fact, stars at the outer edges of galaxies move at about the same rate as those near the centre. She concluded that there must be a material causing the extra gravity needed to keep stars from flying off: *dark matter.*

Evidence for dark matter has also been found by studying gravitational lensing. When light travels through our universe, it is pulled and bent by gravity whenever it passes through an area with enough mass. Physicists looking at the light from distant galaxies have found that it bends much more than we would expect when passing through galaxy clusters on its way to Earth. This means that there is much more gravity than we would expect. An invisible material must cause this gravity: *dark matter.*

The cosmic microwave background (CMB) is yet more evidence. We know that the early universe was very hot and contained a smooth expanse of ionized particles. At that time, light was not yet visible. As the universe began to cool, the particles became neutral and light could travel freely. Since this light has been traveling through the universe ever since, we can now measure it from Earth using radio telescopes. Measurements have confirmed that our early universe was smooth and flat. However, we now have a very clumpy universe with dust and rocks, planets and stars. Something must have been present in the early universe to create the gravity that was necessary to start clumping material together: *dark matter.*

More recently, in 2006, studies of the bullet cluster galactic collision (two galaxy clusters colliding) have shown that dark matter exists. Physicists study the location of a galaxy cluster's mass after a collision in two ways: 1) x-ray emission observations and 2) gravitational lensing. When clusters collide, their gas particles become hotter from the energy of the collision. X-ray emission observations show where these hotter particles are located. Gravitational lensing, as explained before, also shows the distribution of mass through studying gravitational effects. Results from x-ray observations and gravitational lensing should match. Physicists found, however, that an extra amount of material is needed to make them match: *dark matter.*

Ok so we know that dark matter exists but what is it?

Nobody knows exactly what dark matter is but physicists today are trying to detect dark matter directly in order to understand it better. A leading candidate for the dark matter particle is a WIMP ("Weakly Interacting Massive Particle") which is a particle predicted by a theory called Super Symmetry. Unfortunately, we do not know how massive WIMPs are and how likely they are to interact with normal matter. In order to increase our chances of detecting dark matter particles, we must get away from the cosmic rays (i.e. noise) at the Earth's surface. 2km underground at SNOLAB, the noise from cosmic rays is significantly reduced so that experiments are more likely to detect a weakly interacting dark matter particle.

These dark matter experiments are currently underway at SNOLAB:

- **PICO** runs two bubble chamber experiments: one filled with 37kg of CF_3I, and another with 3kg of C_3F_8. The goal is to detect a WIMP interacting with these liquids.
- **DEAP-3600** uses 3600 kg of liquid argon. It is approximately 20 times more sensitive than previous dark matter searches for heavier WIMPs.
- **MiniCLEAN** used 500 kg of liquid argon and 92 sensitive photodetectors to look for flashes of light that are produced when WIMPs interact with the argon.
- **DAMIC** ("Dark Matter In CCDs") uses high-tech versions of charged coupled devices – the CCDs found in digital cameras. They are thick and have low intrinsic noise levels, making them ideal for the long exposure times needed to search for WIMPs.
- **SuperCDMS** ("Super Cryogenic Dark Matter Search") uses cryogenic (meaning very low temperature – as low as 10 mK) germanium detectors to search for WIMPs.
- **NEWS-G** (New Experiments with Spheres - Gas) is a spherical proportional counter filled with noble gases that searches for WIMPs with a small sensor put to high voltage to allow for charge collection.