Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *What can the (dark) matter be?*

The apparent need for dark matter can be appreciated by first looking at the solar system where, to stay in orbit around the Sun, Mercury has to move at 48 kilometers a second, while distant Neptune can just move at a leisurely 5 kilometers a second. Strangely though, this principle doesn't seem to apply in the Milky Way or in other galaxies we can observe.

Broadly speaking, you can find stuff in the outer parts of a spiral galaxy that are moving at about the same orbital velocity as stuff that is quite close in to the galactic hub. This is puzzling, particularly since there doesn't seem to be enough gravity in the system to hold onto the rapidly orbiting stuff in the outer parts of the galaxy – which should just fly off into space.

So, we need more gravity to explain how galaxies rotate and stay together – which means we need more mass than we can observe – and so we invoke dark matter.

Dark matter also helps to explain why galaxy clusters stay together and helps to explain large scale gravitational lensing effects, such as can be seen in the Bullet Cluster – which is considered the strongest (although still circumstantial) evidence for dark matter's existence.

The Bullet Cluster is actually the remains of two galaxy clusters that smashed together some time in the past, stripping out a huge amount of intergalactic gas from each of the clusters. But despite losing all that gas, there still remains something massive, but invisible, that produces gravitational lensing across the remains of each post-collision cluster.

Current thinking is that a small component of dark matter is baryonic, meaning stuff that is composed of protons and neutrons. This baryonic dark matter may be in the form of cold gas and dense, non-radiant objects such black holes, neutron stars, brown dwarfs and orphaned planets. These dark, but otherwise familiar, objects are traditionally known as Massive Astrophysical Compact Halo Objects – or MACHOs. The halo word comes from computer modeling which shows how rotating galaxies are able to retain their observed forms if they have a surrounding halo of dark matter – although current thinking also has dark matter distributed throughout the structure of galaxies. And really, the word halo is just there to make a cute-sounding acronym.

In any case, it doesn't seem that there is nearly enough dark baryonic MACHO matter to account for all the circumstantial effects of dark matter – which is thought to represent up to 90% of a galaxy's total mass. Hence, we have come to the conclusion that most dark matter must be non-baryonic, in the form of Weakly Interacting Massive Particles (or WIMPs).

By inference, WIMPS are transparent, non-radiant and non-reflective at all wavelengths of light and they probably don't carry a charge. Neutrinos, which are produced in abundance from the fusion reactions of stars, would fit the bill nicely except they don't have enough mass. The currently most favoured WIMP candidate is a neutralino, a hypothetical particle that has been predicted by supersymmetry theory.

Just to keep it interesting, supersymmetry is itself hypothetical - it builds on the Standard Model of particle physics, but proposes that every elementary particle in the Standard Model (like neutrinos, photons and quarks) has a corresponding super partner – or a sparticle. These sparticles (like neutralinos, photinos and squarks) are hypothesised to have split off from standard particles in the first moments of the big bang. And if it wasn't an exact break, the sparticles could have a lot more mass than their corresponding particles.

So from this long chain of conjectures, it's possible that there might be a neutrino-like sparticle – that is a neutralino, which – unlike a neutrino it would have lots of mass. So this means it would be weakly interactive, transparent, non-radiant, non-reflective but massive thing.

The neutralino would fit the timeframe of when dark matter is thought to have first appeared after the big bang. Dark matter is theorised to have appeared very early and, being weakly interactive, it quickly became cold and static, ultimately becoming a massive scaffolding upon which the large scale structure of all other matter in the universe was built upon.

So all of today's visible matter – that is still very interactive and that glows brightly in the night as it is variously heated, plasma-ised, fused and exploded. All this visible matter was originally gathered together gravitationally, upon a much more massive and invisible skeleton of dark matter.

Now, what I just described is known as the cold dark matter theory where you start with dark matter as something cool and static upon which hot visible matter settles and clumps. There is also an alternative hot dark matter theory that has it that dark matter remained heated and mixed in with all the visible matter in a sort of a big pancake. As the universe expanded, the pancake began to break up into fragments, giving us the large scale structures we see today. Under this scenario, the WIMPs could be standard neutrinos – but this model conflicts with observational data about the early universe and it's kind of fallen out of favour.

There's even a warm dark matter theory which is kind of half-way point between the pancake breaking up story and the tiny little clumps forming bigger clumps story. It all sounds like a bit of a dog's breakfast – but the WIMPs in this scenario are weird hypothetical particles called sterile neutrinos, as well as things called gravitinos.

So as with an awful lot of cosmology – there's perhaps too much theory and not enough data. The scant data that is available best fits the cold dark matter, neutralino-based model – but being a hypothetical model based on a hypothetical particle, maybe you don't want to get too excited just yet.

Wouldn't it be great if we could just find a dark matter particle? Given they apparently make up around 90% of the galaxy, it's reasonable to think there might be a few floating around Earth – or at least passing straight through Earth, given their weakly interacting nature.

So what better place to look for dark matter than down a mine shaft? The second Cryogenic Dark Matter Search Experiment (or CDMS II) runs deep underground in the Soudan iron mine in Minnesota, monitoring for any signs of the elusive dark matter particle using germanium and silicon detectors cooled down to a fraction above absolute zero.

The CDMS II detectors seek ionization and phonon events (the latter being a sort of quantum mechanical vibration). The ionisation and phonon data can be used to distinguish between electron interactions – and nuclear interactions. It is assumed that a dark matter WIMP particle like a neutralino will just ignore electrons, but potentially interact with (that is, bounce off) a nucleus.

Two possible events in nine years have been reported by the University of Florida team, who acknowledge their findings cannot be considered statistically significant, but may at least give some scope and direction to further research. By showing just how difficult it is to directly detect WIMPs – the CDMS II findings indicate the sensitivity of our detectors needs to bumped up a notch.

And so the search continues.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website exploring all the nooks and crannies of the universe, in case someone dropped some loose change there. No ads, no profit, just good science. Bye.