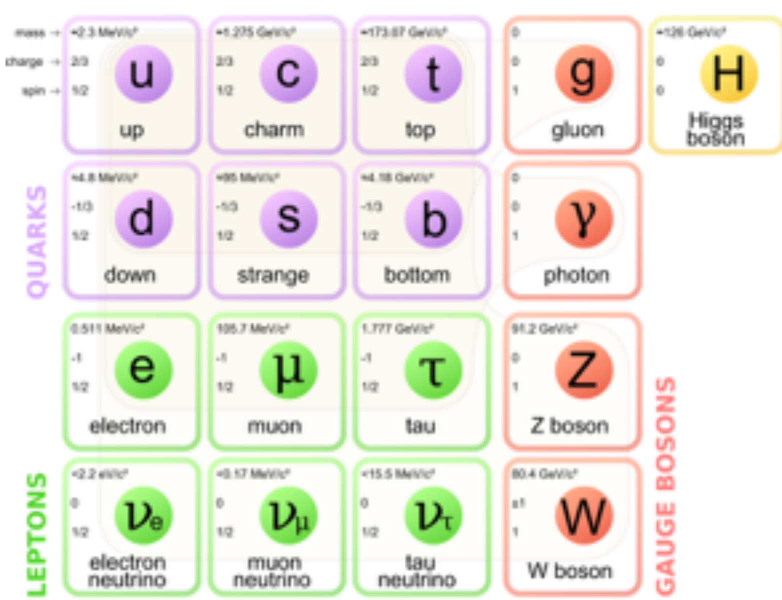
THE UNIVERSITY OF CHICAGO

Particle Dark Matter

What Could the Dark Matter Be? - Dark matter must have three key properties. The dark matter particle must be:

- **Dark -** it doesn't interact with photons much.
- **Stable -** it can't decay into other particles often and it exists with the same density in both the early universe and today.
- **Cold -** the particles can't be moving very quickly, since the dark matter must be able to collapse to form structure.

What Standard Model Particles Could Produce the Dark Matter? - None! There is no known particle that has all three properties listed above. Particles like protons and electrons are charged and interact with light. Neutrons aren't charged (though they interact with light too often to be dark matter), but they aren't stable. Neutrinos are stable and dark, but they are not cold.

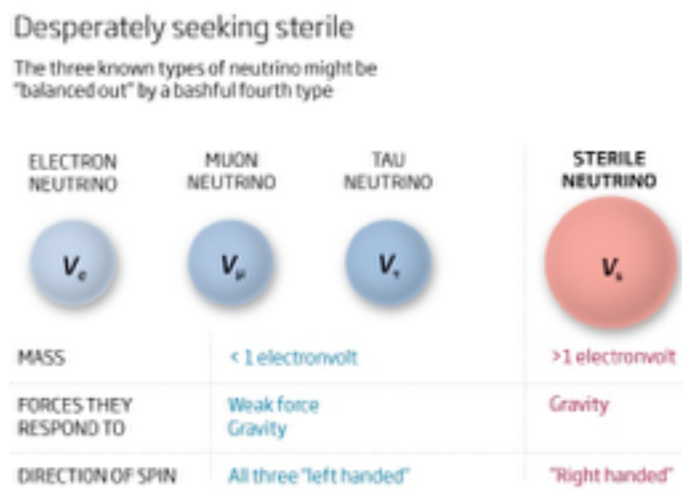


The known elementary particles consist of quarks (charged and colored), leptons (charged leptons, uncharged leptons, not colored), and bosons (force carrying particles). The stable charged particles (electron, up and down quarks) and the charged forced carrier (photon) produce nearly every interaction in our everyday experience.

What Do We Need to Explain Dark Matter? - Some extension to the standard model. We know that the standard model of physics is incomplete, and there are several extensions to the standard model which are theoretically motivated (and produce a dark matter candidate). Three prime candidates are:

- **Axions:** Originally proposed in the 1970s to explain why the strong nuclear interaction has been observed to follow something called "CP" symmetry. The axion particle is a well motivated extension of the standard model, and is cold, dark, and stable. These three properties make the axion a great candidate to be the dark matter particle.

- **Sterile Neutrinos:** Explains why all the neutrinos in the standard model are left handed (have a spin that points in the opposite direction of their momentum). All other standard model particles can have spins that point in the same direction, or the opposite direction of their momentum. A sterile (right handed) neutrino will be very heavy, and thus will be cold, dark, and stable.



- **Weakly Interacting Massive Particle:** A product of supersymmetry. Supersymmetry explains why gravity is much weaker than the other fundamental forces of nature. The lightest supersymmetric particle is stable by design, heavy (cold), and might be neutral.