The 64th Compton Lecture Series

Unsolved Mysteries of the Universe: Looking for Clues in Surprising Places

Brian Odom

http://kicp.uchicago.edu/~odom/compton.htm

Lecture 4: The Search for Dark Matter

Just Waiting to be Found?

- **The evidence is substantial that cold dark matter accounts for most of the mass in the universe.**
- It appears that this cold dark matter is made from different stuff than normal matter, i.e. it is "non-baryonic".
- In some cases, such as with images created by gravitational lensing, we can already "see" the dark matter…
- **However, physicists say that we are still trying to "detect" dark matter, either directly or indirectly.** Why are we not satisfied by watching galaxies rotate or by using gravitational lensing to create images?
    - All evidence thus far comes from the gravitational effects of dark matter. What if our models of gravity are wrong (e.g. MOND)? What if the dark matter is not really particulate like we think?
    - If there really are exotic non-baryonic relics from the big bang, we want to know more about them. We want to answer questions such as:
        1. What is the individual particle mass?
        2. Is there only one type of dark matter WIMP?
        3. What are the various coupling strengths describing non-gravitational interaction with normal matter?
        4. Can we identify the dark matter particles with particles created in future accelerators?
        5. What is the velocity and density distribution of dark matter particles in galactic halos? Around the sun? The earth?
- **For most of the lecture, we will think about the most popular dark matter candidate, the Weakly Interacting Massive Particle (WIMP).**

Indirect Detection

- Just as normal matter clusters into planets, galaxies, galaxy clusters, etc. due to gravitational attraction, we expect WIMPs to cluster in these places as well.
- If WIMPs interact with normal matter via other interactions besides gravity (for example, the weak force) eventually it will slow down and become packed in toward these gravitational centers.
- Once packed and slow, the chances that WIMPs find anti-WIMPs and annihilate increase.
- Depending on the WIMP characteristics, the final annihilation products might be neutrino-antineutrino pairs, electron-positron pairs, etc proton-antiproton pairs. Also, annihilation of positrons or antiprotons on normal matter will produce gamma-ray signals.
- Several experiments search for these possible annihilation products at earth or at satellites. They look for signals from various high-density regions, such as the Milky Way center, the Milky Way halo, the sun, or the center of the earth.
- The upside of this approach is that indirect detection is very promising and has a good chance to find WIMP annihilation signals. The downside is that the models required to interpret the results are complicated.

Direct Detection

- Here, we hope to directly detect WIMP scattering off of normal matter (via some force stronger than gravity), in carefully constructed detectors.
- This is half of a holy grail in the dark matter business. The other half is to produce the same particles in an accelerator.
- The WIMPs are provided by the "WIMP wind", which is created by the motion of our solar system through the dark matter halo. In the most basic halo models, the WIMP wind is blowing at 230 kilometers / second.
- Experiments attempt to see energy deposited as WIMPs collide with nuclei in the detector.