Previously in KISS DM…

Andrew Benson

History

- Long and meandering path from first suggestion of dark matter to current paradigm (see Joel Primack's talk)
- Current picture, LCDM with no interesting features
- This picture is, so far, very successful
  - No convincing evidence that it's incorrect
  - (Only areas where it seriously questioned involve messy baryonic physics)
- But, this simplicity is most likely a result of lack of constraints
- Good theoretical reasons to believe that dark matter has a richer phenomenology that we may be able to explore

Overview

- Dark Matter – largely unconstrained (like pre-COBE CMB?)
  - Broad Categories
    - Massive objects
    - Particles
      - Thermal
        - WIMPs
        - etc.
      - Non-thermal
        - Axions
        - Gravitinos
        - Etc.
  - Each class needs a separate treatment......

Where to Find Info

- On the Wiki!!!
  - http://kissdm.pbworks.com
  - Request an account if you don't already have one
  - Continuously updated as we figure things out

Workshop Goals

- http://kissdm.pbworks.com/Workshop-goals

1) Can we sensibly work out a way to “evaluate” each benchmark model (whether FOM-like or something else), in a way that will allow us to judge the successfulness of *each* benchmark model?
2) Is there a way to *rule* out a model, or not? How?
3) Can we judge what observation or observations will be the most effective in pushing the evaluation of one or more of the benchmark models? How?

- **Thursday 7/16+ constraints discussion**

	WIMP (SUSY+)	WDM: SuperWIMP	WDM: sterile neutrinos	axions	hidden sector DM	Coupled dark energy DM	Alternative gravity models
Omega_DM	thermal	non-thermal	non-th=> th	non-thermal	thermal		
collisionality	No	No	No	No	Yes		
P(k)	No (modulo baryons)	Yes	Yes	Yes?	Yes		
Q	No (modulo baryons)	Yes	Yes	Yes?	Yes		
BBN	No	Yes	Yes	No	Yes		
Halo properties	No (modulo baryons)	Yes	Yes	Yes?	Yes		
Direct detection	Yes	No	No	Yes	No		
Indirect detection	Yes	No	Yes	Yes	No		

Phase space density constraints

Josh Simon, Louie Strigari, Marla Geha, Ricardo Munoz, Andrew Benson, Priya Natarajan

The quantity $Q=\rho/\sigma^3$ serves as a proxy for the coarse-grained phase space density, and can be derived straightforwardly from observations of the kinematics of galaxies and clusters. Because the coarse-grained phase space density can only decrease with time, phase space density measurements in astrophysical systems provide a lower limit to the primordial phase space density of the dark matter particles. Of course, while astrophysically measured densities are the densities of dark matter particles, astrophysically measured velocities are the velocities of stars or gas (not the dark matter). However, because the dark matter and the baryons are moving in the same gravitational potential, the velocity dispersion of the dark matter particles cannot be much different from that of the stars/gas, so substituting the velocity dispersion of the baryons for that of the dark matter is not a bad approximation.

Current measurements

ultra-faint Milky Way dwarfs (measurements of individual stellar velocities made on scales of ~100 pc):

CVn I: Q = 1.7 +/- 0.5 x 10^-4 [units are always Msun pc^-3 (km/s)^-3]

UMa I: Q = 5.6 +/- 2.9 x 10^-4

Hercules: Q = 7.7 +/- 5.2 x 10^-4

Leo T: Q = 1.9 +/- 1.5 x 10^-3

UMa II: Q = 3.7 +/- 3.1 x 10^-3

CVn II: Q = 5.1 +/- 4.1 x 10^-3

Leo IV: Q = 5.3 +/- 9.9 x 10^-3

Coma Berenices: Q = 2.2 +/- 1.4 x 10^-2 (data for above objects all from Simon & Geha 2007)

Segue 1: Q = 4.5 +/- 5.3 x 10^-2 (data from Geha et al. 2009) low-mass spiral galaxies (measurements made on scales of ~1 kpc):

Q (1.7, 4.4, 1.7, 1.6, 0.5) × 10-6 M pc-3(km s-1)-3

for NGC 2976, NGC 4605, NGC 5949, NGC 5963, and NGC 6689, respectively (calculated by Strigari et al. 2006 using 2D gas velocity fields from Simon et al. 2005)

galaxy clusters: The estimates of the phase space density for clusters and galaxies in clusters have been obtained from gravitational lensing mass models. These were essentially done to rule out versions of MOND that accounted for the extra mass needed on these scales to neutrinos (instead of the conventional dark matter). Details can be found in the paper titled MOND plus classical neutrinos are not enough for cluster lensing (Natarajan & Zhao 2008). Figure 1 in this paper plots the central densities on this range of scales and overplots the phase space density for a couple of neutrino mass ranges.

The central densities for this sample of lensing clusters are: (7.9 X 10^-3; 3.39 X 10^-2; 1.82 X 10^-2; 7.04 X 10^-3; 7.26 X 10^-3; 3.17 X 10^-3) Msun/pc^-3

The corresponding mean densities for the halos that host L* galaxies in these lensing clusters are: (5.22 X 10^-3; 2.62 X 10^-2; 2.38 X 10^-2; 9.75 X 10^-4; 1.6 X 10^-3; 2.8 X 10^-2) Msun/pc^-3

CDM particles, in either vanilla WIMP or axion models, would have primordial phase space densities that are many orders of magnitude larger than any existing or plausible measurements. Observationally determined phase space densities therefore do not provide useful constraints on CDM properties. However, for WDM models and some hidden sector theories (e.g., superWIMPS) the maximum phase space density can in principle be comparable to the observed values, and thus current and future measurements do constrain the available parameter space for the dark matter particle mass. We are not sure how to interpret phase space density measurements for modified gravity theories.

This Week.............

- Program of talks/meetings
  - http://tinyurl.com/darkcal
  - More focus on indirect detection this week
- Expand notes on observational/experimental constraints
- Mathematical framework......?