Cosmology with dark matter from late decays

Collaborators: James Bullock, Manoj Kaplinghat

Louie Strigari
SUSY 2006
Irvine, CA
June 13, 2006
Dark Matter Candidates

- Cold Dark Matter (CDM)
- Warm Dark Matter (WDM)
- Non-thermal Dark Matter
  - sterile neutrinos
  - DDM -> DM + SM particle

\[ \Omega_{\text{LSP}} / \Omega_{\text{NLSP}} \approx m_{\text{NLSP}} / m_{\text{LSP}} \]

Dark matter \( \Omega_{\text{dm}} \approx 0.27 \)
CDM: missing satellites

Klypin et al. 99; Moore et al. 99
Rotation curves of low-mass galaxies

CDM prediction
\[ \rho \sim \frac{1}{r} \]

Isothermal core
\[ \rho \sim \text{constant} \]

Options:
- Problem with interpretation/systematics: CDM is ok
- Cores are really there and CDM is in trouble.

Recent analysis: Simon et al. [2005], Kuzio de Naray et al. [2006]
Modifying the power spectrum with dark matter

WDM

from decays

Power Spectrum

Abazajian 2006

Kaplinghat 2005
Cembranos et al. 2005

Lyalpha
Lyman-alpha power spectrum

Viel et al 2006
For a fermionic particle, the primordial phase-space density freezes with a maximum:

\[ f_{\text{max}} = 0.5h_{\text{pl}}^{-3} \]

For a collisionless particle, this maximum cannot be exceeded.
phase space density

\( Q \equiv \frac{\rho}{\sigma^3} \)  

[Hogan & Dalcanton 2000]

**cold dark matter**

\[ Q_{\text{CDM}} \approx 7 \times 10^{14} \left( \frac{m_{\text{cdm}}}{100\text{GeV}} \right)^{3/2} M_{\text{sun}} pc^{-3} (\text{km/s})^{-3} \]

**warm dark matter**

\[ Q_{\text{max}} \approx 5 \times 10^{-4} \left( \frac{m}{\text{keV}} \right)^4 M_{\text{sun}} pc^{-3} (\text{km/s})^{-3} \]

**dark matter from decays**

\[ Q \approx 10^{-6} \left( \frac{10^{-3}}{\Delta m/m_{DM}} \right)^3 \left( \frac{z_{\text{decay}}}{1000} \right)^3 M_{\text{sun}} pc^{-3} (\text{km/s})^{-3} \]
dwarf spheroidal galaxies

Data from Walker et al. (2005)

Fornax

Radius from galaxy center [kpc]

Velocity dispersion [km/s]

Radius from galaxy center [kpc]

\[ r_{\text{core}} = 1 \text{ kpc} \]

\[ \sigma_p \text{ [km s}^{-1}] \]

\[ v_{\text{max}} = 140 \text{ km/s} \]

\[ v_{\text{max}} = 30 \text{ km/s} \]

\[ r_{\text{core}} = 0.15 \text{ kpc} \]

NFW
Can we describe cores with warm dark matter?

Yes, but they are unobservable.
Meta-Cold Dark Matter

Dark matter today is born from the (non-relativistic) decay of a neutral NLSP at \( z \sim 1000 \)

\[ NLSP \rightarrow \text{meta-CDM} + \text{SM particle} \]

\[ \Omega_{\text{LSP}}/\Omega_{\text{NLSP}} \approx m_{\text{NLSP}}/m_{\text{LSP}} \]

Dark matter is born late, so it is both ‘heavy’ and ‘warm’

[Strigari, Kaplinghat, Bullock 2006]
mCDM Power Spectrum

Consistent with recent measurements from Ly-alpha [Seljak et al 06, Viel et al 06]

For late decays, characteristic scale in power spectrum depends on the \textit{lifetime} and \textit{Q}.
Constraints on Meta-CDM

- 300 pc core radii in LSB mass galaxies
- Neutrinos produced in decays:
  - Future CMB experiments
  - Low-energy neutrino background
- Final state hard gammas
Summary

- If cores are real, not consistent with CDM

- Meta-CDM: Cores in low-mass galaxies and consistent with small scale power spectrum

- Numerous probes for late-decaying dark matter