Is gravitino still a warm dark matter candidate?

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with D. Gorbunov and V. Rubakov

CDM Issues

- Cold Dark Matter Consistent with Bulk of Cosmological Data

BUT

- Some Discrepancies are Observed
  - Missing Satellites:
    CDM Predicts too Many Satellite Dwarf Galaxies
  - Cuspy Galactic Density Profiles
  - Too Low Angular Momenta of Spiral Galaxies
- Possible Hints towards Warm Dark Matter
- WDM: Sizeable Primordial Velocity Dispersions of DM Particles
  - Another way to quantify: Phase space density

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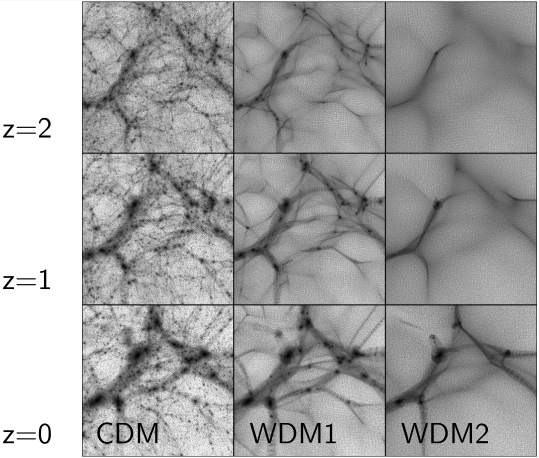

- Simulation of structure formation in CDM and WDM scenarios with various masses of DM particles (P. Bode, J. P. Ostriker and N. Turok, 2001)

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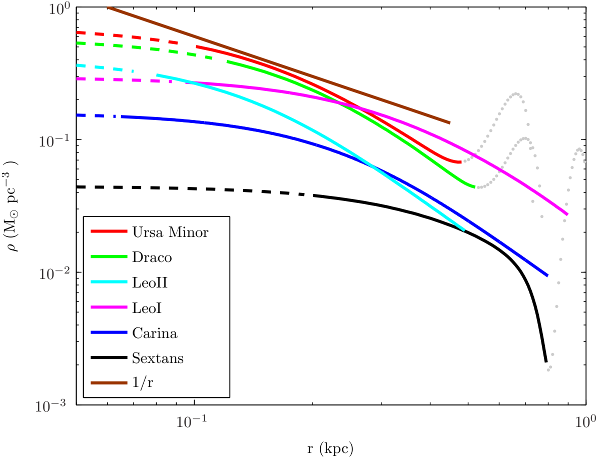

- Derived inner mass distributions for six dSph galaxies (G. Gilmore et al., 2007)

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Phase space density

- Measurable quantity
  $Q = \frac{\rho}{\langle v^2_{radial}\rangle^{3/2}}$ $\qquad Q \approx 5 \cdot 10^{-3} \, \frac{M_\odot/\mathrm{pc}^3}{(\mathrm{km/s})^3}$
- Estimates typical value of halo particles distribution function

$$
\begin{aligned}
Q &\simeq m^4 \cdot \frac{n}{\langle \frac{1}{3} p^2 \rangle^{3/2}} \\
\frac{n}{\langle p^2 \rangle^{3/2}} &= \frac{\left[\int f_{halo}(\mathbf{p},\mathbf{r}) d^3\mathbf{p}\right]^{5/2}}{\left[\int f_{halo}(\mathbf{p},\mathbf{r}) \mathbf{p}^2 d^3\mathbf{p}\right]^{3/2}} \sim f_{halo}(p_*, \mathbf{r})
\end{aligned}
$$

Thus

$$
f_{halo} \simeq \frac{Q}{3^{3/2} m^4}
$$

Warmness Condition

- In course of evolution particles leave dense regions of phase-space
  $\Rightarrow \quad Q \Leftrightarrow f$ decreases by a factor of $\Delta = 10^2 - 10^3$
- But only a fraction of dark matter particles should have high phase space density

$$\nu \simeq \Omega_{\mathrm{dSph}}/\Omega_{\mathrm{DM}} \sim 10^{-5}$$

- WDM: Fraction ν of particles has primordial phase space density

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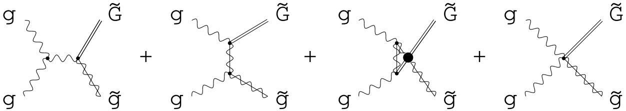
Light gravitinos as Warm Dark Matter

Two production channels

- Scattering processes:

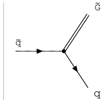


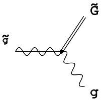
  - Total present mass density:

$$\Omega^{sc}_{\tilde{G}} \approx \sharp\alpha \left(\frac{M}{100\,\mathrm{GeV}}\right)^2 \left(\frac{1\,\mathrm{keV}}{m_{\tilde{G}}}\right) \left(\frac{T_\mathrm{R}}{1\,\mathrm{TeV}}\right)$$

  - Gravitino mass in keV range $\Rightarrow$ Low reheat temperature

- Decay processes:





Production in decays

- Decay rate:

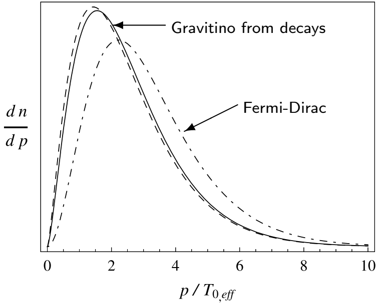
$$\Gamma \simeq \frac{M^5}{6 m_{\tilde{G}}^2 M_{\rm Pl}^2}$$

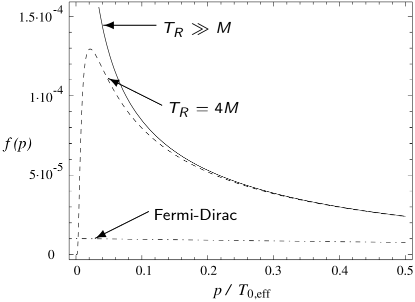
- Total present mass density:

$$\Omega_{\tilde{G}}^{\rm dec} \approx 8{\cdot}10^{-4} \left(g_b + \frac{15}{16} g_f \right) \left(\frac{g_{\rm MSSM}}{g_*} \right)^{3/2} \left(\frac{1\,\mathrm{keV}}{m_{\tilde{G}}} \right) \left(\frac{M}{100\,\mathrm{GeV}} \right)^3$$

  - Largest contribution comes from heaviest superparticles
  - Superparticles mass in 100 GeV range

Gravitino from decays spectrum

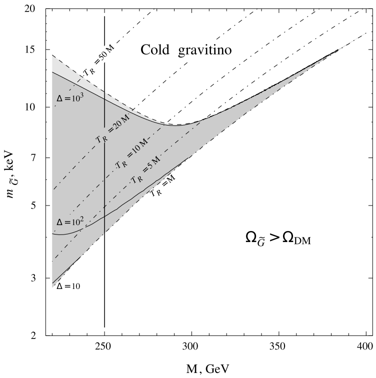




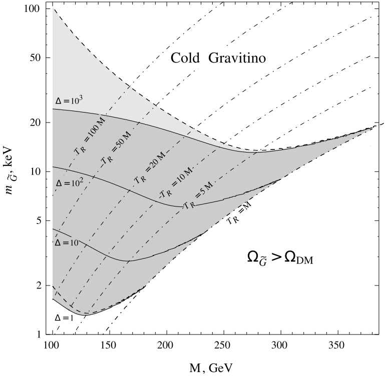
- Feature at low reheat temperature
- Gravitino from decays are "colder" than thermal:
  - Mean momentum is lower
  - Phase space density is higher

Two scenarios are considered

$M \sim M_{\tilde{q}}, M_{\tilde{g}}$



$T_R \gg M_{\tilde{q}}, M_{\tilde{g}};\ M \sim M_{\tilde{\chi}}, M_{\tilde{\ell}}$



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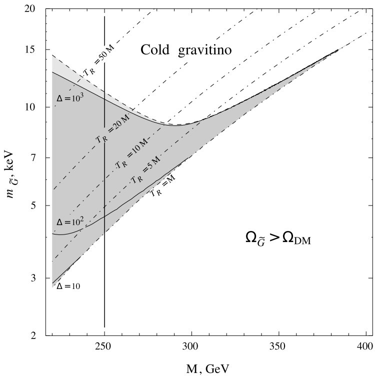

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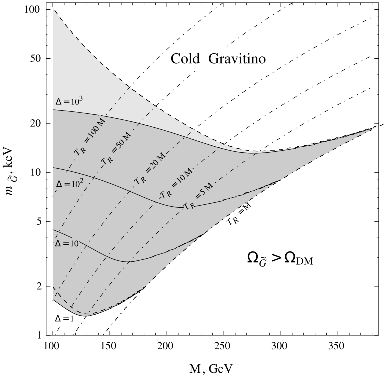

Allowed region is too small

Results and Conclusion

We find that gravitino is warm dark matter provided that

- its mass is in range

$$1\,\text{keV} \lesssim m_{\tilde{G}} \lesssim 25\ \text{keV}$$

- T_R is at most in the TeV range
- superparticles whose mass M is below the reheat temperature obeys

$$M \lesssim 350\ \text{GeV}$$

- Gravitino as warm dark matter candidate will soon be either ruled out or supported by the LHC experiments.

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