Probing the Dark Matter Particle Spectrum with the Dark Matter Power Spectrum

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KICP: New Views of the Universe
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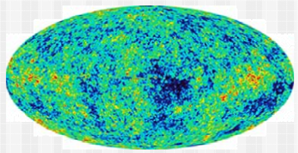
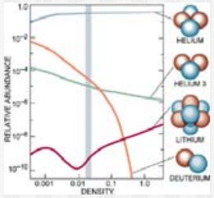
Work in collaboration with Stefano Profumo, Piero Ullio and Marc Kamionkowski think we

What do we know?

$\exists$

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.





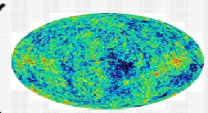
Compelling cosmological evidence that nonbaryonic (non Standard Model) dark matter exists.

$\therefore$

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

$\neq$

Weakly Interacting Dark Matter

- $\Omega_d h^2 \Big($  $\Big) = 0.113$

- Lightest Dark Particle (LDP) stable over cosmological timescales.

- Thermally produced dark matter should have Fermi-scale annihilation cross section. If interacts with SM must be “Weakly Interacting”.

Dark-Sector Couplings to Standard Model Particles

This Talk:

- The point: While we know something about the properties of the LDP the interactions of other (unstable) particles of the dark sector are unknown.

  Can we hope learn something about them?
- Example: a charged Next-Lightest Dark Particle (NLDP) and its impact on the matter power spectrum

A Charged NLDP

- Modified Density Perturbations: GR Perturbation Theory about a smooth FRW Universe
- NLDP Decays: $\phi^{\pm} \longrightarrow \chi + ...$
- Can modify evolution of density perturbations in early Universe.

$$\dot{\delta}_\chi = -\theta_\chi - \frac{1}{2}\dot{h} + \lambda_m \frac{\rho_\phi}{\rho_\chi}\frac{a}{\tau}(\delta_\beta - \delta_\chi)$$

Continuity Equation

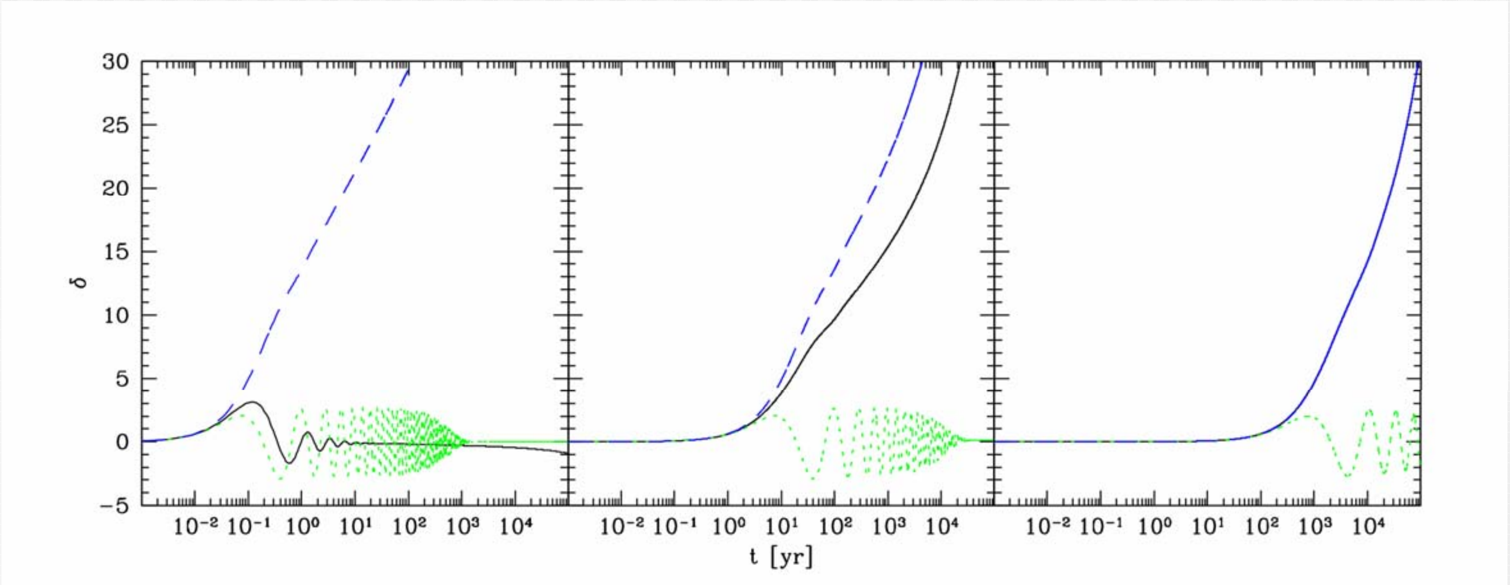
Gravity

Decay

Effect of Charged NLDP?

- Before Decay: The NDLP couples to the photon-baryon fluid! NLDP perturbation modes that enter the horizon oscillate rather than grow. These modes source the LDP modes and thus suppress growth of dark-matter perturbations.
- After Decay: Dark-Matter modes that enter the horizon grow under the influence of gravity, as in the standard case.

Effect of Charged NLDP?



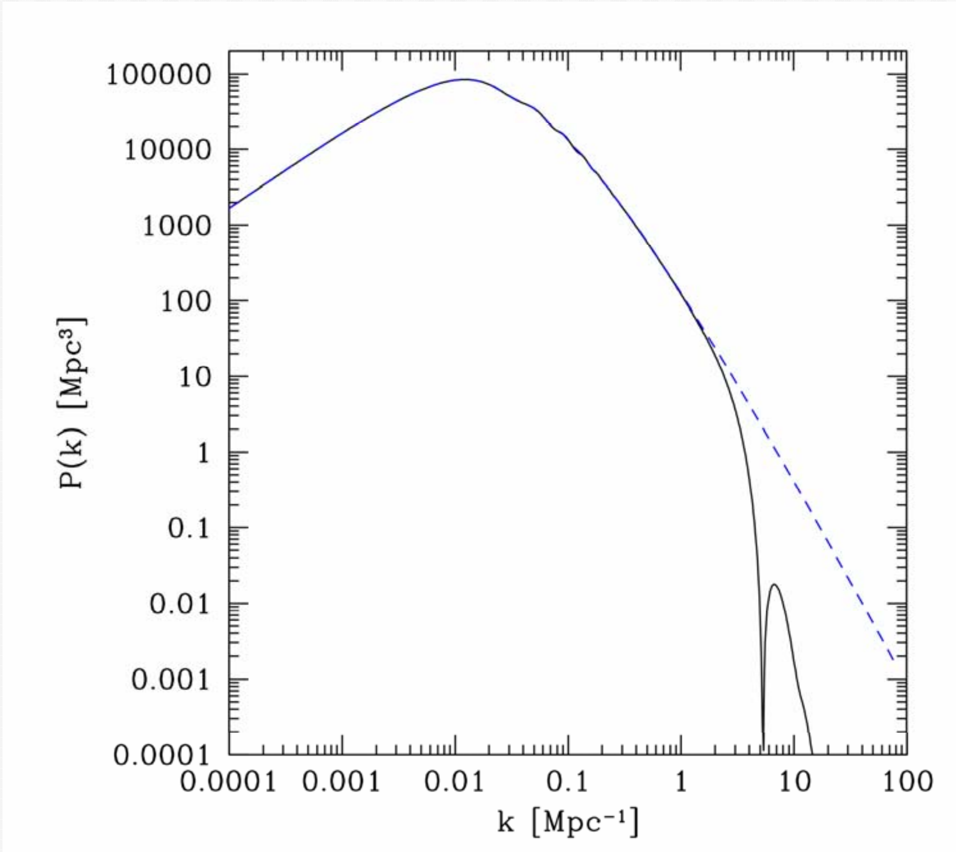
k= 30 Mpc^{-1} 3 Mpc^{-1} 0.3 Mpc^{-1}

Dark Matter (Standard Case)
Dark Matter (w/Charged NLDP)

Charged Matter (Baryons+NLDP)

$$\tau = 3.5 \text{ yr}$$

$$f_\phi = 1$$



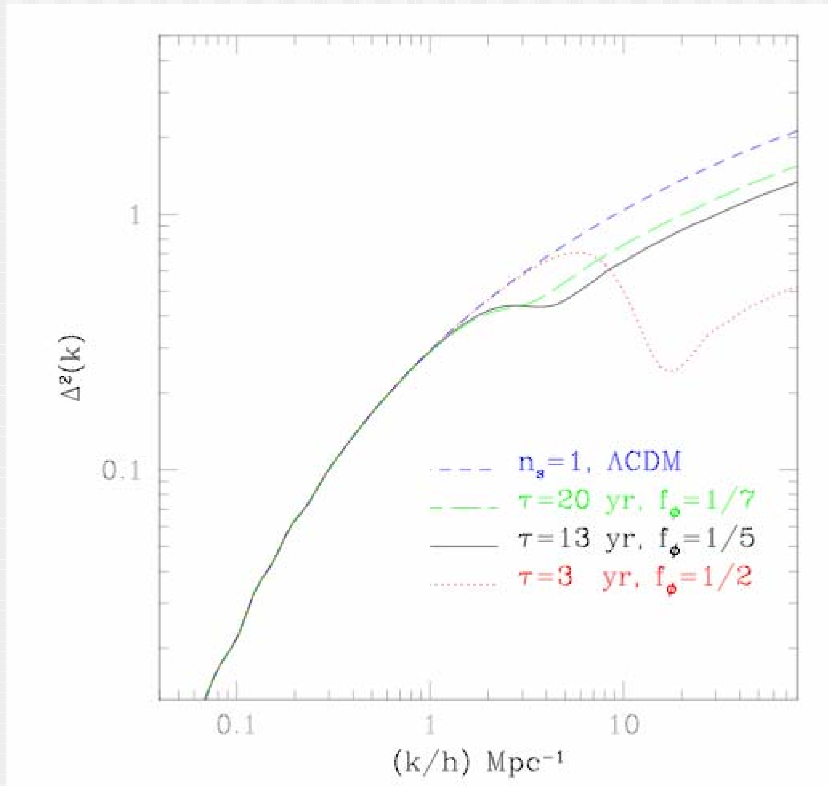
KS and Marc Kamionkowski

Phys. Rev. Lett. **92**, 171302 (2004)

$f_\phi < 1$

$$\Delta^2(k) = k^3 P(k)/2\pi^2$$

Suppression by a factor $(1 - f_\phi)^2$ in the linear power spectrum.



Particle Theory Models? $f_\phi = 1$

- Long lifetime? Very Weak coupling?

  SuperWIMPS

  $$\tilde{e} \longrightarrow \tilde{G} + e$$

  J. Feng et al. (2003) (See talk by F. Takayama on Monday!)

  $$e^1 \longrightarrow G^1 + e$$

- Gravitational Decay can get lead to cosmologically interesting lifetimes.

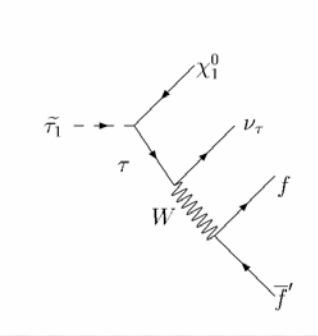
- May solve the small-scale structure problem with charged-decay for lifetimes of order years.

  Or if substructure is found constrain these models!

Particle Theory Models? $f_\phi < 1$

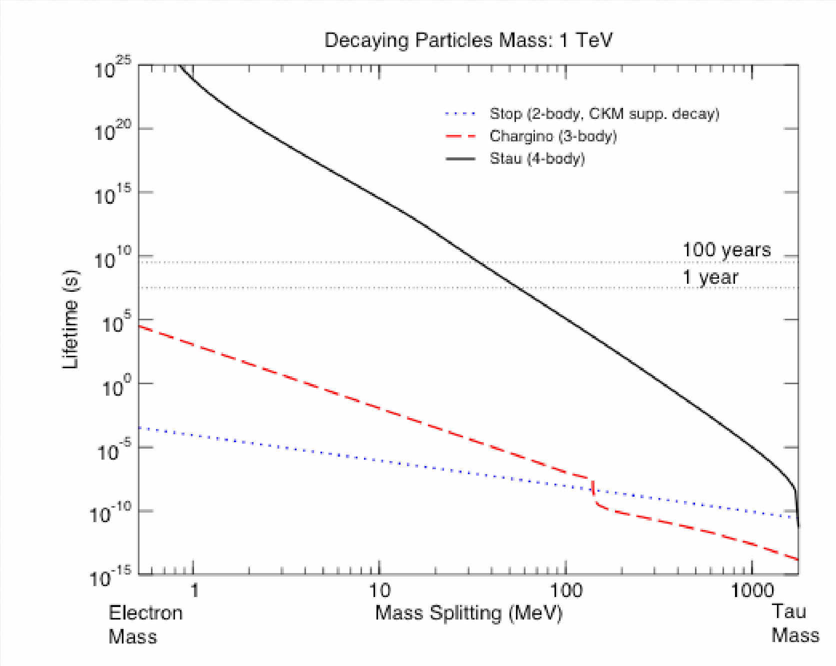
- Supersymmetric Dark Matter Models with the LDP=neutralino and NLDP=stau. $\tilde{\tau} \longrightarrow \chi + ...$
- The stau coannihilation region ($m_{\chi_1^0} \simeq m_{\tilde{\tau}_1}$) of the MSSM can give the observed WMAP relic abundance.
- If $\Delta m < m_\tau$ The stau is long-lived because it decays via 4-body processes

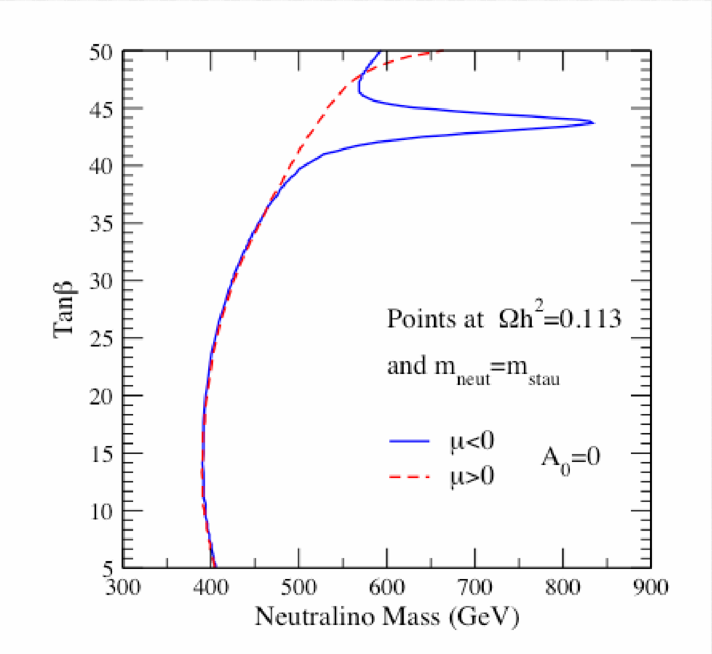
$$\tau^{(4)} \propto (\Delta m)^{-8}$$



Stefano Profumo, KS, Piero Ullio and Marc Kamionkowski
Phys. Rev. D **71**, 023518 (2005)

Particle Theory Models? $f_\phi < 1$





Only the stau can play the role of a quasistable charged particle (with cosmologically interesting lifetimes) in the MSSM.

Other Signatures

- Production of neutralinos at the LHC if they are Bino-like.
- Production and trapping of long-lived staus at the LHC of ILC.
- Direct Detection of neutralinos possible.
- Indirect detection is unlikely.
- Might observe these effects with the high-redshift Cosmic 21-cm Power Spectrum

Summary

- The properties of dark-sector particles are not known.
- Example: A charged NLDP could have interesting effects on the matter power spectrum.
- Stau is a good candidate in the MSSM.
- Direct Detection. LHC/ILC.

  21-cm fluctuations.