Light Gravitinos at Colliders and Implications for Cosmology
(\textit{arXiv:1004.4213; PRD 82, 015012 (2010)})

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Supersymmetry and Supergravity

SUSY fixes problems in the SM
Spontaneously-broken SUSY = supergravity

Gravitino $\tilde{G}$ is superpartner of graviton

Standard particles

- Quarks
- Leptons
- Force particles

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TASC - Light Gravitinos
Supersymmetry and Supergravity

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Light Gravitinos: Overview

**Light gravitinos** \((\text{eV} \lesssim m_{\tilde{G}} \lesssim \text{MeV})\)

- Arise in supergravity theories without flavor violation
- Are the LSP, and hence are a dark matter candidate
- Have “stronger-than-gravitational” interactions \(\propto \frac{1}{M_{\text{pl}}} \frac{1}{m_{\tilde{G}}}\)
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Cosmology (Viel et al. 2005, Boyarsky et al. 2009)

- Canonical: After reheating, light \tilde{G} are thermally produced
- Then at \( t \lesssim \text{ns} \), \tilde{G} freeze out as relativistic thermal relics
- Abundance and small-scale structure constraints on \( m_{\tilde{G}} \)
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Collider Signals

- Pair-produce SUSY particles; SUSY $\rightarrow$ SM + $\tilde{G}$ signals
- Before decaying, SUSY particles travel a distance

$$c\tau_{\text{SUSY}} \sim 10 \text{ m} \left(\frac{m_{\tilde{G}}}{\text{keV}}\right)^2 \sim \text{detector sizes!}$$

- Location of decay signals in detector depends on $m_{\tilde{G}}$
Collider Signals: Scenario I

Since $c\tau_{\text{SUSY}} \propto m_{\tilde{G}}^2$: For very light $m_{\tilde{G}}$, SUSY decays occur promptly.

Example: $\tilde{\chi}^0 \rightarrow \gamma + \tilde{G} \Rightarrow \text{PROMPT DI-PHOTONS}$
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Hundreds of events at LHC7 for $m_{\tilde{G}} \lesssim 10\text{s of eV}$. 
Collider Signals: Scenario II

Since $c\tau_{\text{SUSY}} \propto m_{\tilde{G}}^2$; For intermediate $m_{\tilde{G}}$, SUSY decays occur within the detector.

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Collider Signals: Scenario II

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Example: $\tilde{\tau}^\pm \rightarrow \tau^\pm + \tilde{G} \Rightarrow \text{KINKED CHARGED TRACKS}$

Hundreds of events at LHC7 for 10s of eV $\lesssim m_{\tilde{G}} \lesssim$ keV.
Collider Signals: Scenario III

Since $c\tau_{\text{SUSY}} \propto m_{\tilde{G}}^2$: For heavier $m_{\tilde{G}}$, SUSY decays occur outside the detector.

Example: $\tilde{\tau}^\pm \rightarrow \tau^\pm + \tilde{G} \Rightarrow \text{METASTABLE CHARGED TRACKS}$

Hundreds of events at LHC7 for keV $\lesssim m_{\tilde{G}}$. 

Samuel Lee (Caltech)
Collider Signals: Scenarios I-III

<table>
<thead>
<tr>
<th>Scenario</th>
<th>I</th>
<th>II</th>
<th>III</th>
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<tbody>
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<tr>
<td>Event rates</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
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3 DISTINCT COLLIDER+COSMOLOGY SCENARIOS, CATEGORIZED BY COINCIDENT $m_{\tilde{G}}$ RANGES!

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### Collider Signals + Cosmology

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SMOKING-GUN LIGHT-GRAVITINO COLLIDER SIGNALS MAY REQUIRE NEW EARLY-UNIVERSE ($t \lesssim$ ns) PHYSICS TO BE CONSISTENT WITH ASTROPHYSICAL CONSTRAINTS!