

Stauino $\tilde{\nu}_L$

Is a WIMP and stable if it is the LSP.

Problematic coupling to Z-boson:

$\tilde{\nu}_L$ $\cdots \cdots \tilde{\nu}_L$ Would be observable as
recoils in baryonic matter.



$\tilde{\nu}_R$ could work as DM in models beyond the MSSM.

Gravitino

Gravitino is a spin- $3/2$ supersymmetric partner of graviton in supergravity models. If LSP then it can be DM, but not a WIMP due to super-weak interactions (gravitational strength).

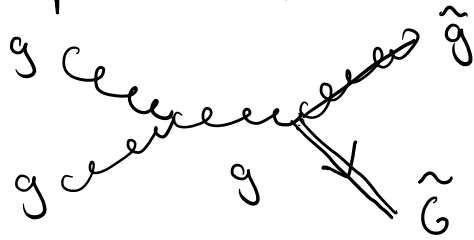
Two ways to produce it:

1) By decay of the NLSP we get

$$\Omega_{\tilde{G}} = \frac{m_{\tilde{G}}}{m_{NLSP}} \Omega_{NLSP}$$

Problematic because $NLSP \rightarrow \tilde{G}$ decay would inject energy into BBN ruining BBN.

- 2) Could be produced in reheating period after inflation.
One important process is



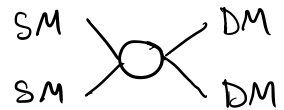
The reverse process $\tilde{g}\tilde{g} \rightarrow gg$ is not efficient as $\tilde{g}$ density is small (never in equilibrium). This is called freeze-in.
This has the magic formula

$$\Omega_{\tilde{g}} h^2 \approx 0.5 \left(\frac{T_R}{10^{10} \text{ GeV}} \right) \left(\frac{100 \text{ GeV}}{m_{\tilde{g}}} \right) \left(\frac{m_{\tilde{g}}}{1 \text{ TeV}} \right)^2$$

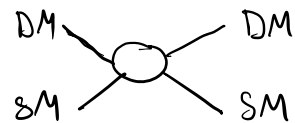
where T_R is the reheating temperature.

How to find DM?

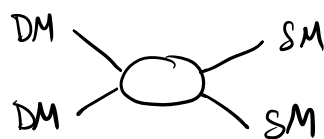
1) Direct production (at collider)



2) Direct detection (DD)



3) Indirect detection (ID)



Direct detection (DD)

Rare scatters with recoil of nuclei.

Need to shield experiment from cosmic rays and natural radioactivity.

Rate of scatters with recoil energy E_r is

$$\frac{dN}{dE_r} = \frac{\sigma g_{DM}}{2\mu^2 m_X} |F(q)|^2 \int_{v_{min}}^{v_{esc}} \frac{f(\vec{v})}{v} d^3v$$

σ is scattering cross section of DM χ off nucleus

g_{DM} is DM halo density (density at Earth)

μ is reduced mass

$F(q)$ is a nuclear form factor dependent on scattering momentum $q = \sqrt{2ME_r}$

$f(\vec{v})$ is velocity distribution of DM

$v_{min} = \sqrt{\frac{ME_r}{2\mu^2}}$ is minimal velocity to give E_r

v_{esc} is escape velocity of DM

Two main strategies:

- 1) Reduce background and go big (XENON, PANDAS)
- 2) Look for annual modulation in signal (DAMA)

Indirect detection (ID)

Looking for annihilation products in $\chi\chi \rightarrow \text{SM SM}$ or decay products $\chi \rightarrow \text{SM SM}$. Can only use stable SM particles: ~~proton~~, ~~electron~~, photon, neutrinos, positrons, antiprotons, antineutrons ($\bar{p}\bar{n}$).

Photons

Sharp spectrum ^{from} $\chi\chi \rightarrow \gamma\gamma, \gamma\chi$

Continuous spectrum from bremsstrahlung and π^0 decays

Photons point back to source, we can look in regions with large ρ_{DM} .

DM annihilation in our galaxy gives photon flux

$$\frac{d\Phi}{dE d\Omega} = \frac{1}{8\pi m_\chi^2} \frac{dN_\gamma}{dE} \langle \sigma v \rangle \int_{\text{los.}} \rho_{\text{DM}}^2(l) dl$$

$N_\gamma(E)$ is the number of photons with energy E in an annihilation event.