Origin of Dark Matter

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There’s still no viable alternative to Dark Matter
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CMB anisotropies (WMAP 5 yr) imply
\[ \Omega_{DM} h^2 = 0.1099 \pm 0.0062 \]
Dunkley et al., arXiv:0803.0586 [astro-ph]

Was \[ \Omega_{DM} h^2 = 0.105^{+0.007}_{-0.013} \]
Spergel et al., astro-ph/0603449
Network activities: Making DM

Let $\chi$ be a generic DM particle, $n_\chi$ its number density (unit: GeV$^3$). Assume $\chi = \bar{\chi}$, i.e. $\chi\chi \leftrightarrow$ SM particles is possible, but single production of $\chi$ is forbidden by some symmetry.
Network activities: Making DM

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Evolution of $n_\chi$ determined by Boltzmann equation; in standard cosmology:

$$\frac{dn_\chi}{dt} + 3H n_\chi = -\langle \sigma_{\text{ann}} v \rangle \left( n_\chi^2 - n_{\chi, \text{eq}}^2 \right)$$

$H = \dot{R}/R$ : Hubble parameter
$\langle \ldots \rangle$ : Thermal averaging
$\sigma_{\text{ann}} = \sigma(\chi\chi \rightarrow \text{SM particles})$
$v$ : relative velocity between $\chi$’s in their cms
$n_{\chi, \text{eq}}$ : $\chi$ density in full equilibrium
Neutralino DM

Two papers investigated neutralino DM in SUGRA scenarios with non–universal boundary conditions:

- **Finetuning in NUHM**: “Finetuning” decreases if several contributions to $\sigma_{\text{ann}}$ happen to be comparable (which is not generic). [Ellis, King, Roberts, arXiv:0711.2741 [hep-ph]]
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Decreasing $H(T \lesssim T_F)$ in ST gravity: Need several “matter sectors” with different CFs to decrease $H$; increasing $H$ is easier. Catena, Fornengo, Masiero, Pietroni, Schelke, arXiv:0712.3173 [hep-ph].
DM Candidates

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- Type-II seesaw and singlet scalar DM: Can also incorporate TeV scale leptogenesis, with TeV–ish doubly charged Higgses. $S \rightarrow e^+e^-$ can be significant if $m_S \sim 3$ MeV. McDonald, Sahu, Sarkar, arXiv:0711.4820 [hep-ph].
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- 10–point test: $\Omega_\chi h^2$; cold; neutral; BBN; stellar evolution; self–interactions; direct searches; $\gamma$ rays; other astrophysics; testable. Taoso, Bertone, Masiero, arXiv:0711.4996 [astro-ph].
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**DM Candidates (cont.’d)**

- **Gravitinos:** Production through $WW$ fusion. Ferrantelli, arXiv:0712.2171 [hep-ph].

- **Flaxino $\tilde{F}$:** Is the (lightest) axino in multi–field, flat direction axion models, with $f_a \sim 10^{10}$ GeV: $\tilde{\tau}_1 \rightarrow \tau + \tilde{F}$ is sufficiently fast, but detectable. Chun, H.B. Kim, Kohri, Lyth, arXiv:0801.4108 [hep-ph].
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- **$Z_2$ singlino**: OK if it interacts with Higgses through scalar $S$ with $m_S \lesssim 10$ TeV; applicable to NMSSM; does not need $R$–parity. McDonald, Sahu, arXiv:0802.3847 [hep-ph].
Constraining DM properties with INTEGRAL/SPI: No evidence for strong angular variation of flux in X–ray lines between 20 keV and 7 MeV; constrains e.g. “sterile” $\nu$. Boyarsky, Malyshev, Neronov, Ruchayskiy, arXiv:0710.4922 [astro-ph].
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- **DM caustics and indirect detection:** Caustics relevant only for quite extreme NFW–type distributions. Mohayee, Salati, arXiv:0801.3271 [astro-ph].
Constraining DM properties with INTEGRAL/SPI: No evidence for strong angular variation of flux in $X$–ray lines between 20 keV and 7 MeV; constrains e.g. “sterile” $\nu$. Boyarsky, Malyshev, Neronov, Ruchayskiy, arXiv:0710.4922 [astro-ph].


DM detection (cont.’d)

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- **Solar \( \nu \) background to direct WIMP detection:** Relevant only for \( \sigma_{\chi p} < 10^{-10} \) pb, \( Q \lesssim 5 \) keV.  
Outside developments: Experiment

- Direct detection sensitivity improving quickly: Xenon, CDMS–II, COUPP, KIMS, …
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- PAMELA preliminary data confirm HEAT excess; Phys. Rev. (sensibly) refuses to publish theory papers on this until data are official.
Summary and Conclusions

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bullet We’re still pretty sure that non–baryonic Dark Matter exists
bullet We still don’t know what it’s made of
bullet Experiment may give clues soon: LHC, GLAST, PAMELA, Xenon–100, . . .