Nuclear dark matter

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Composite dark matter

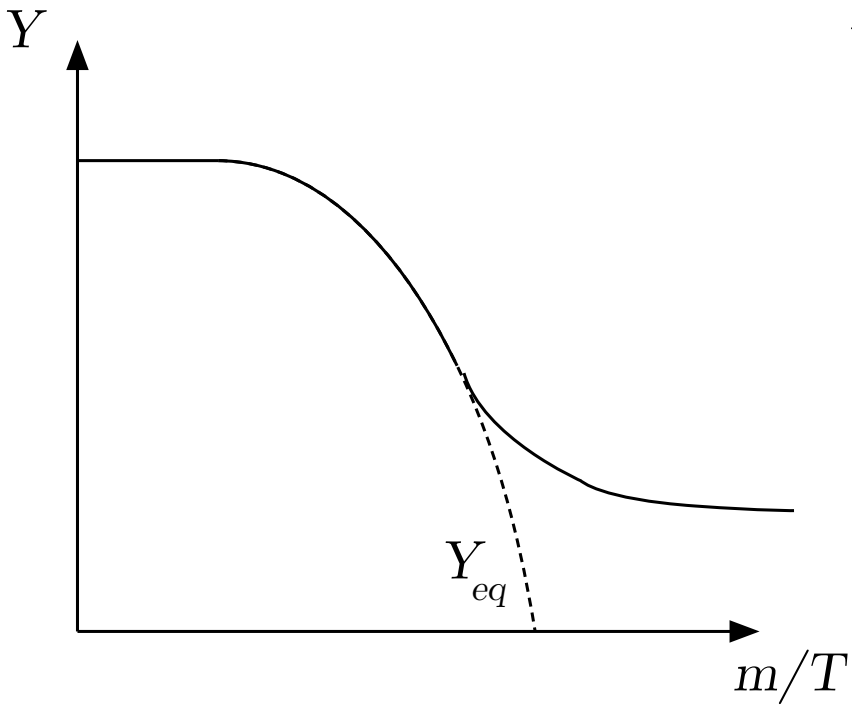
- Dark Matter often assumed to be pointlike particles
- Example of Standard Model: most mass in form of composite states (atoms $\rightarrow$ nuclei $\rightarrow$ nucleons $\rightarrow$ quarks)
- Proposed non-pointlike DM models:
  - 'Dark atoms'
  - WIMPonium
  - Black holes
  - Q-balls
  - ...

Large composite DM states

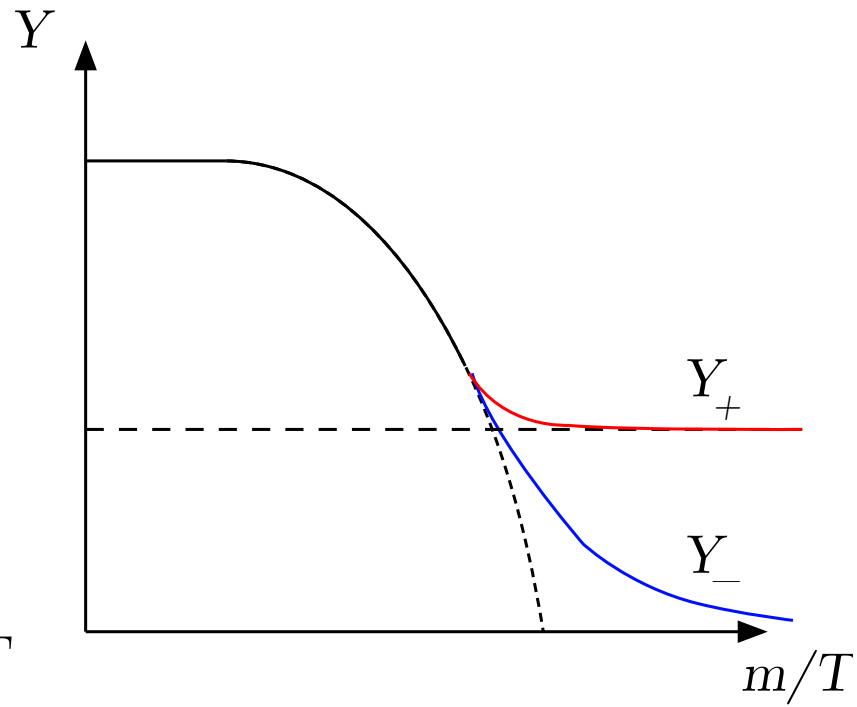
- Interested in models with a large number of stable states, e.g. large values of some quantum number
- Possibilities:
  - Number distribution of DM states
  - Coherent enhancement of interactions with constituents
  - States with large spin
  - Structure on scales $\gg 1/m$ — form factors in scattering, possibility of larger cross sections
  - 'Late-time' ($T \ll m$) synthesis — can achieve very heavy ($\gtrsim 100\,\mathrm{TeV}$) DM from thermal equilibrium
- Q-balls — non-topological solitions of scalar fields — a canonical example

Dark Nuclei

Toy model of Asymmetric Dark Matter, similar to SM nucleons
Similar recent models: [1407.4121, 1406.1171]



Symmetric DM



Asymmetric DM

Dark nucleosynthesis

Chemical equlibrium: $F = E - T\,S$

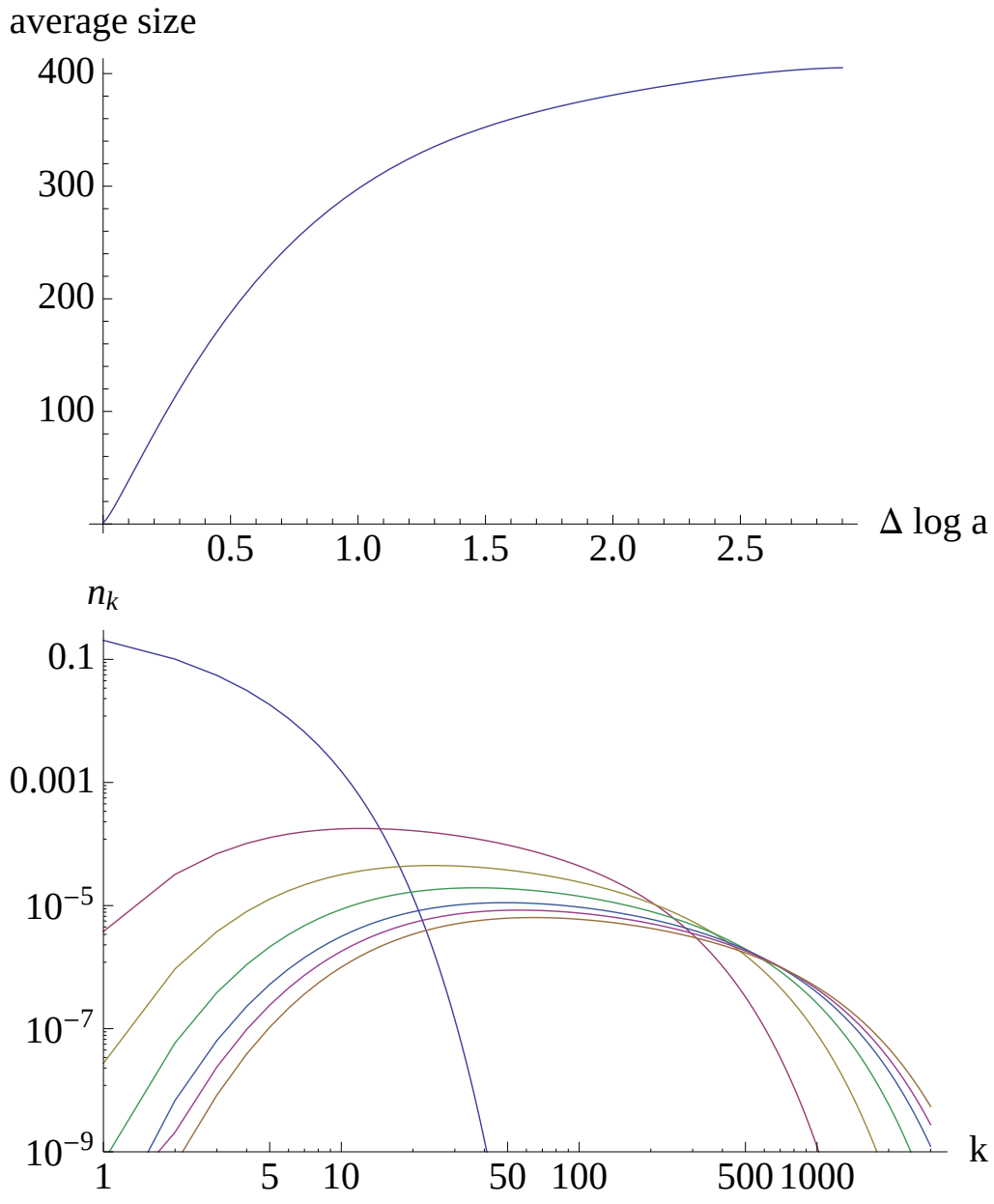
$$\sum_k \tilde{n}_k = n_0 \quad , \quad \tilde{n}_2 = c\tilde{n}_1 \left(\tilde{n}_1 \Lambda^3_{m,T} e^{B/T}\right) \quad , \ldots$$

For $n_0 \Lambda^3_{m,T} e^{B/T} \ll 1$, free nucleons dominate.
For $n_0 \Lambda^3_{m,T} e^{B/T} \gg 1$, neglect dissociation.

Aggregation equation:

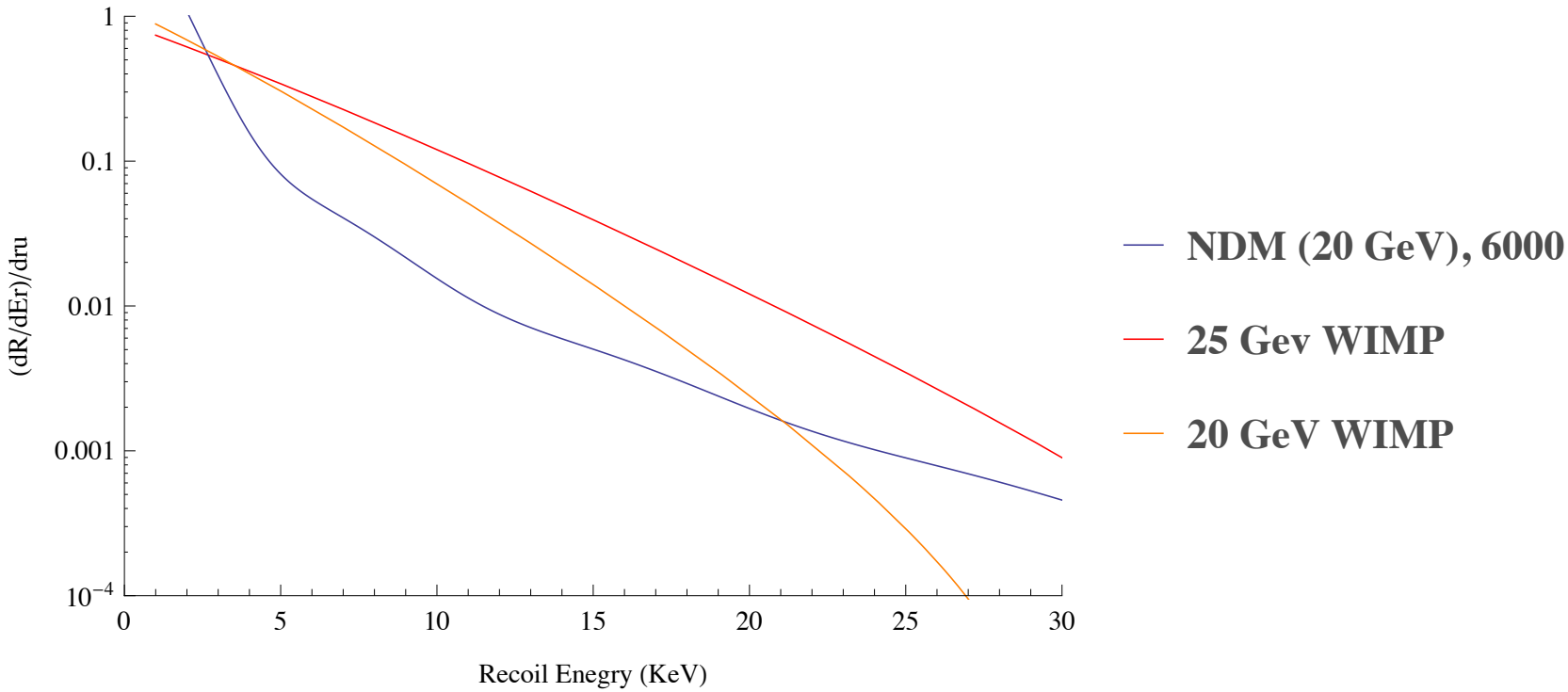
$$\frac{dn_k}{dt} + 3Hn_k = -\sum_j \langle \sigma v \rangle_{j,k} n_j n_k + \frac{1}{2} \sum_{j<k} \langle \sigma v \rangle_{k-j,j} n_{k-j} n_j$$

Number distribution



Direct detection form factors

[hep-ph/0203179] — if $R_{\rm DM} > (\Delta p)^{-1}$, probe DM form factor
Sharp boundary $\Rightarrow$ spherical Bessel function FF



Summary

- Composite dark matter is an interesting possibility
- We investigated some toy models of asymmetric, strongly self-interacting DM, similar to Standard Model nucleons
- Have parameter space where 'dark nucleosynthesis' can build up large composite states
- Possibility of direct detection signatures
- Haven't discussed:
  - Composite cross sections
  - Cosmological energy injection constraints
  - Capture in stars
  - Indirect detection signals