Dark Matter: Candidates and their properties

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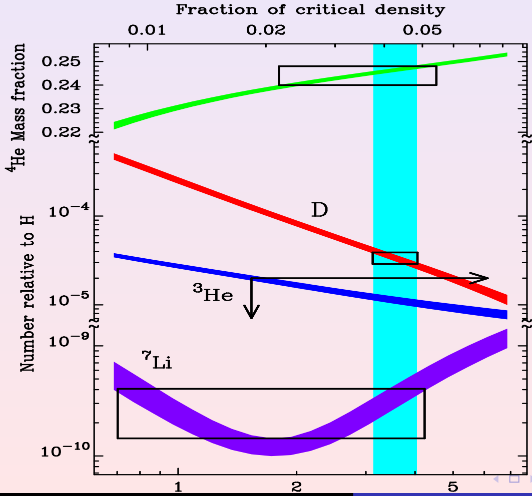

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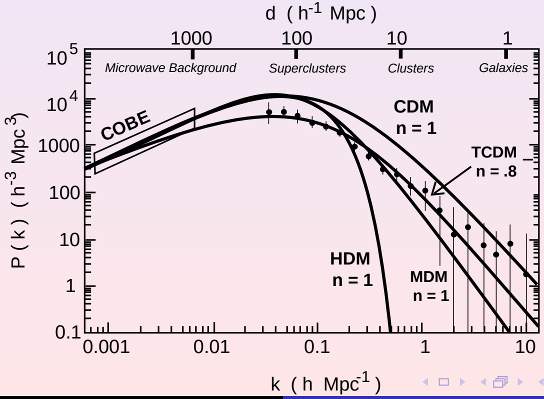
- Large-scale structure requires that DM is
  - dissipation-less
  - "cold", i.e. non-relativistic already for $\gg z_{\rm dec}$



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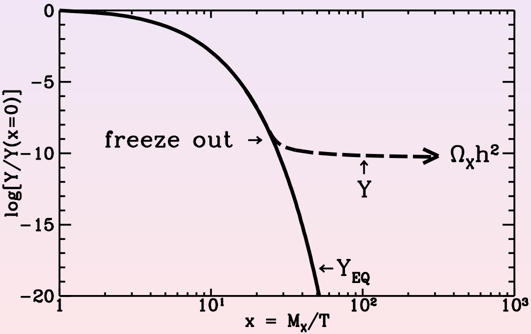
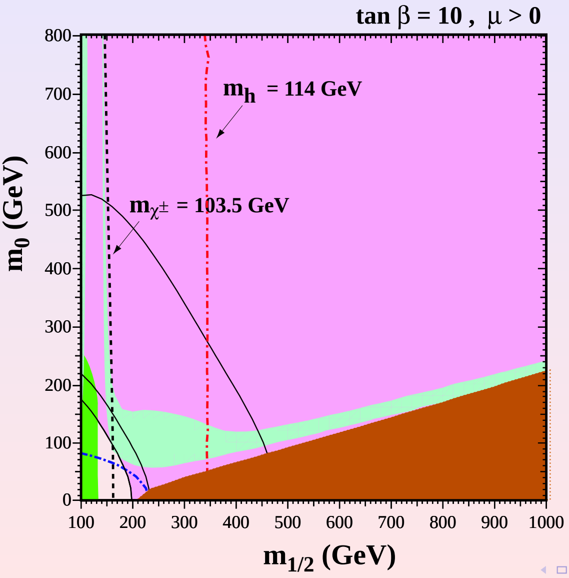
- LSS requires that DM is dissipation-less and "cold"
- thermal production of CDM,



$$\Omega_X h^2 \sim \frac{3 \times 10^{-27} \mathrm{cm}^3/\mathrm{s}}{\langle \sigma v \rangle}$$

suggests weakly interacting DM particle with mass $m \sim m_Z$

Status of neutralino DM (2004):



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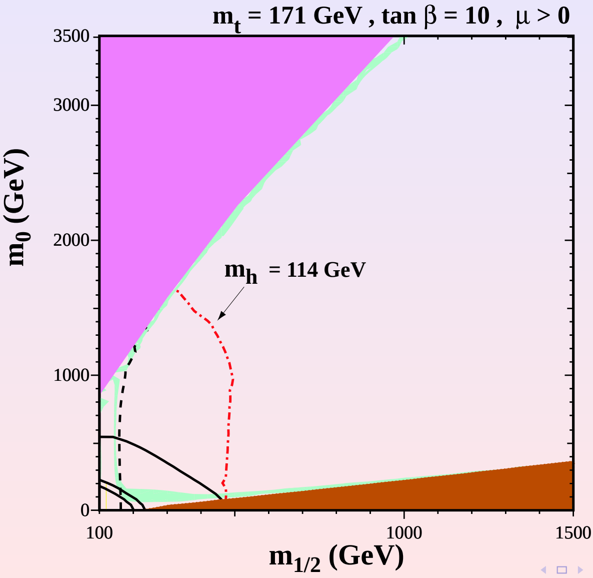

Indirect detection claims:

[*Elsässer, Mannheim '04*]

- Signal from
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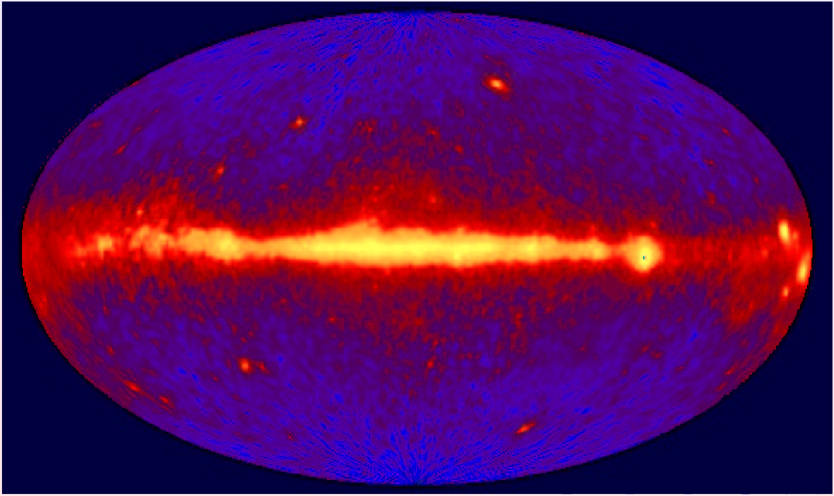

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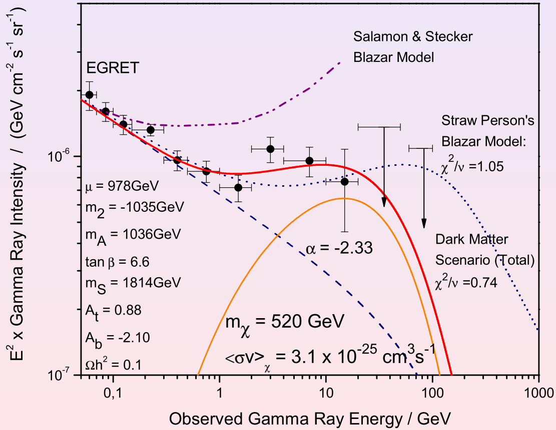

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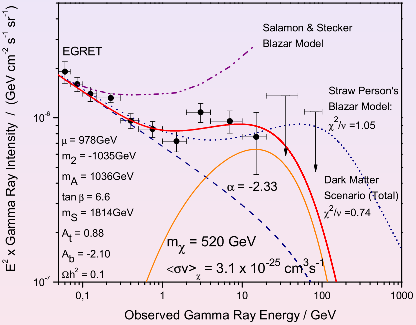

problems:

- assumes γ absorption, not developement of el.-mag. cascade
- needs large enhancement $\sim 10^6$ (clumpiness)
- should lead to strong Galactic signal

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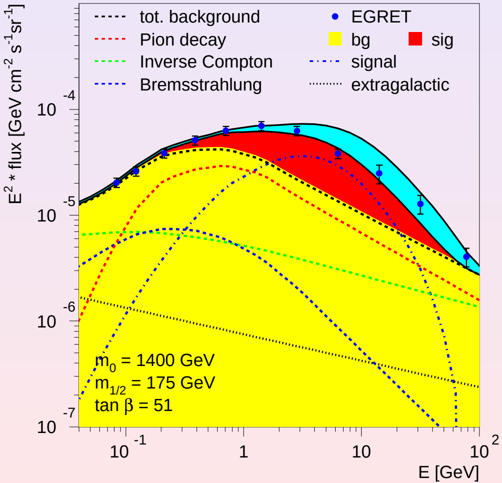

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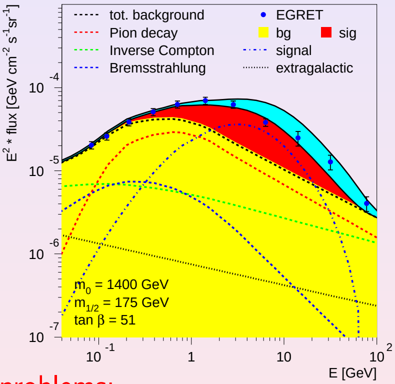

problems:

- assumes perfect modelling of astrophysical backgrounds
- if global CR parameters are allowed to deviate from local ones, good fit without DM

Non-thermal DM: Axions

- Strong CP problem:

$$\mathcal{L} = -\frac{\alpha_s}{8\pi} \underbrace{\left(\theta - \arg\det M_q\right)}_{\bar{\theta} < 10^{-9}} G\tilde{G}$$

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- axions are "like" pions, thus

$$m_a = m_\pi \frac{f_\pi}{f_a} \sim 0.6\text{eV}\ \frac{10^7\text{GeV}}{f_a}$$

i.e. light axions decouple

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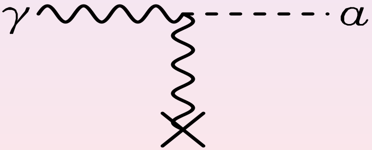
- Primakoff effect:



Cosmological Production of Axions

- light axions, $m_a \lesssim 1$ eV, were never in thermal equilibrium,
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- axionic strings form during the PQ phase transition and emit axions later on.

Stellar evolution limits:

- virial theorem:

$$\langle E_{kin} \rangle = -\frac{1}{2} \langle E_{grav} \rangle$$

$\Rightarrow$ star has negative specific heat
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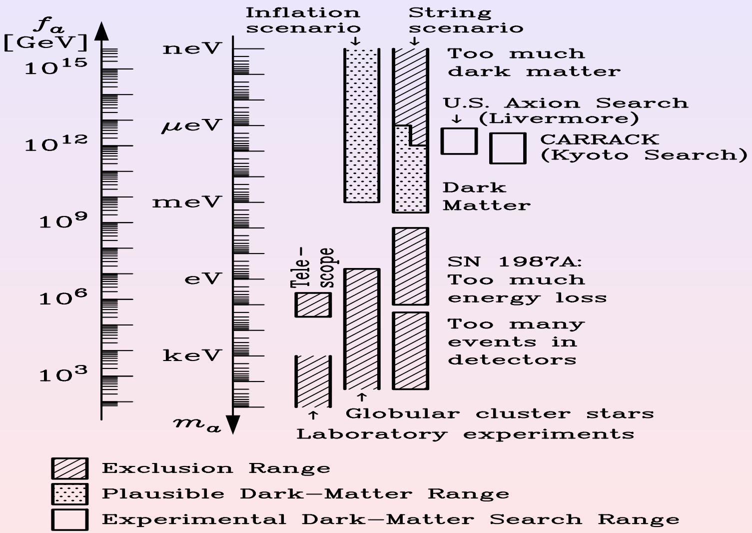
- reduction of stellar lifetime:

$$\frac{\delta\tau}{\tau} \sim \frac{L_a}{L_\gamma} \lesssim 1$$

  $\Rightarrow$ upper limit on $g_{a\gamma}$, m_a; lower limit on f_a

Summary of axion limits:



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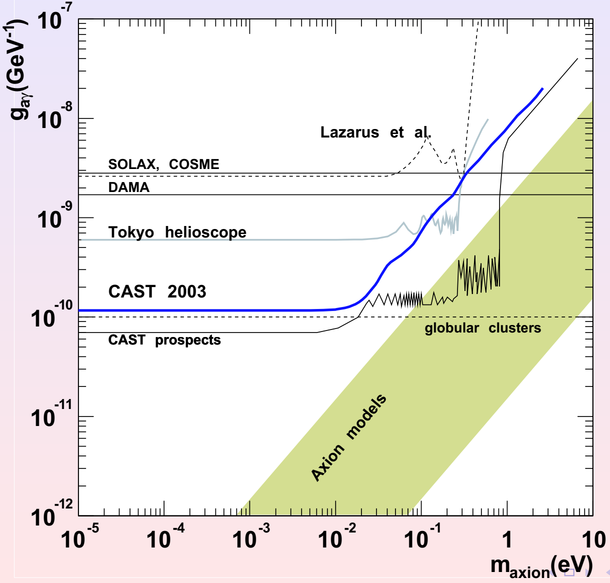

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- In inflationary cosmology

$$\Omega_X h^2 = \left(\frac{M_X}{10^{12}\text{GeV}}\right)^2 \frac{T_{RH}}{10^9\text{GeV}}$$

independent of details of particle physics, for any $M_X \lesssim H_I$

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lifetime:

- $\tau \ll T_0$ or
- metastable or stable due to some (gauged) R symmetry

Lifetime of superheavy matter:

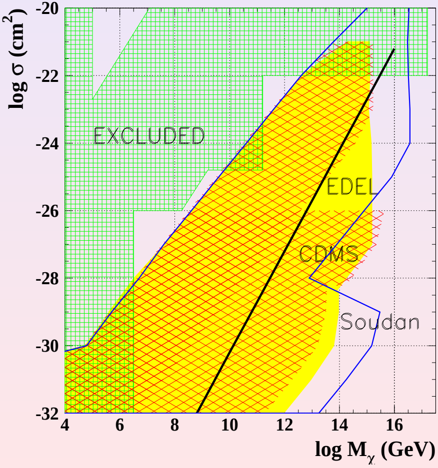
- for SHDM, even gravitational interactions $d = 5$ result in cosmological short lifetimes, $\tau_X \ll t_0$.

three possibilities:

- (global) symmetry,
  perhaps broken by wormhole effects, $\tau_X \propto \exp(S)$ or by instanton effects, $\tau_X \propto \exp(4\pi^2/g^2)$
- discrete symmetries forbid operators with $d < 9$
- crypton, i.e. fractionally charged and confined particle of superstring theories

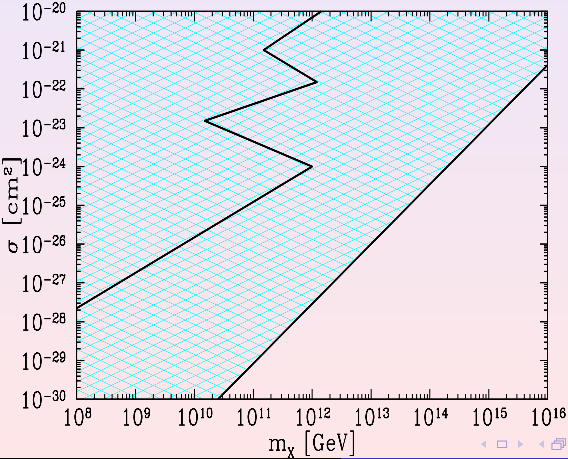
Detection of superheavy matter:

- direct detection: density $1/M_X$, recoil energy is constant
  $\Rightarrow$ large σ_{XN} required



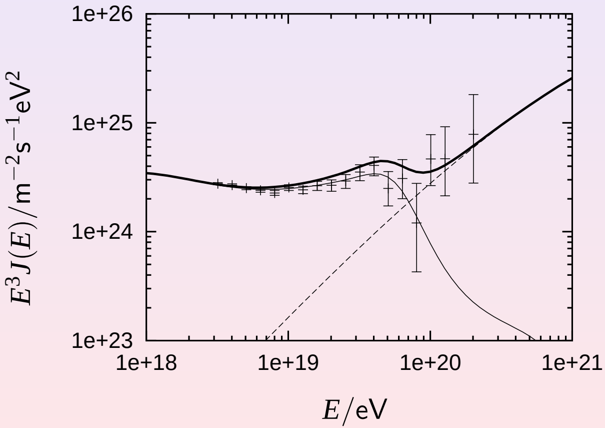
Detection of superheavy matter:

- indirect detection via neutrinos from the Sun: signal should compete with usual fluxes
  $\Rightarrow \langle\sigma v\rangle \sim 10^{-26}$ cm^2 needed



Detection of superheavy matter:

- UHECR above the GZK cutoff via nucleon, photon secondaries



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- various candidates with these properties: neutralino, gravitino, axion, axiono, SHDM, ...
- only a combination of accelerator, direct and indirect searches can identify the DM particle
- even in the best-case scenario (SUSY at LHC), confirmation of LSP as DM by (in-) direct searches necessary