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Particle Physics & Origin of Mass

Before I start

Link to Tuomas' talk:

DM candidates in Technicolor/composite models

aka

TIMPs (Technicolor Interacting Massive Particle)

Ryttov, Sannino '08 [0809.0713] ← DM from UMT

Foadi, Frandsen, Sannino '08 [0812.3406] ← First? interfering DM

Frandsen, Sannino '09 [0911.1570] ← isotriplet TIMP

EDN, Sannino '11 [1102.3116] ← One zillion effective terms

DIAS
Danish Institute
for Advanced Study

Now I can go to start

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Dark Matter Interference

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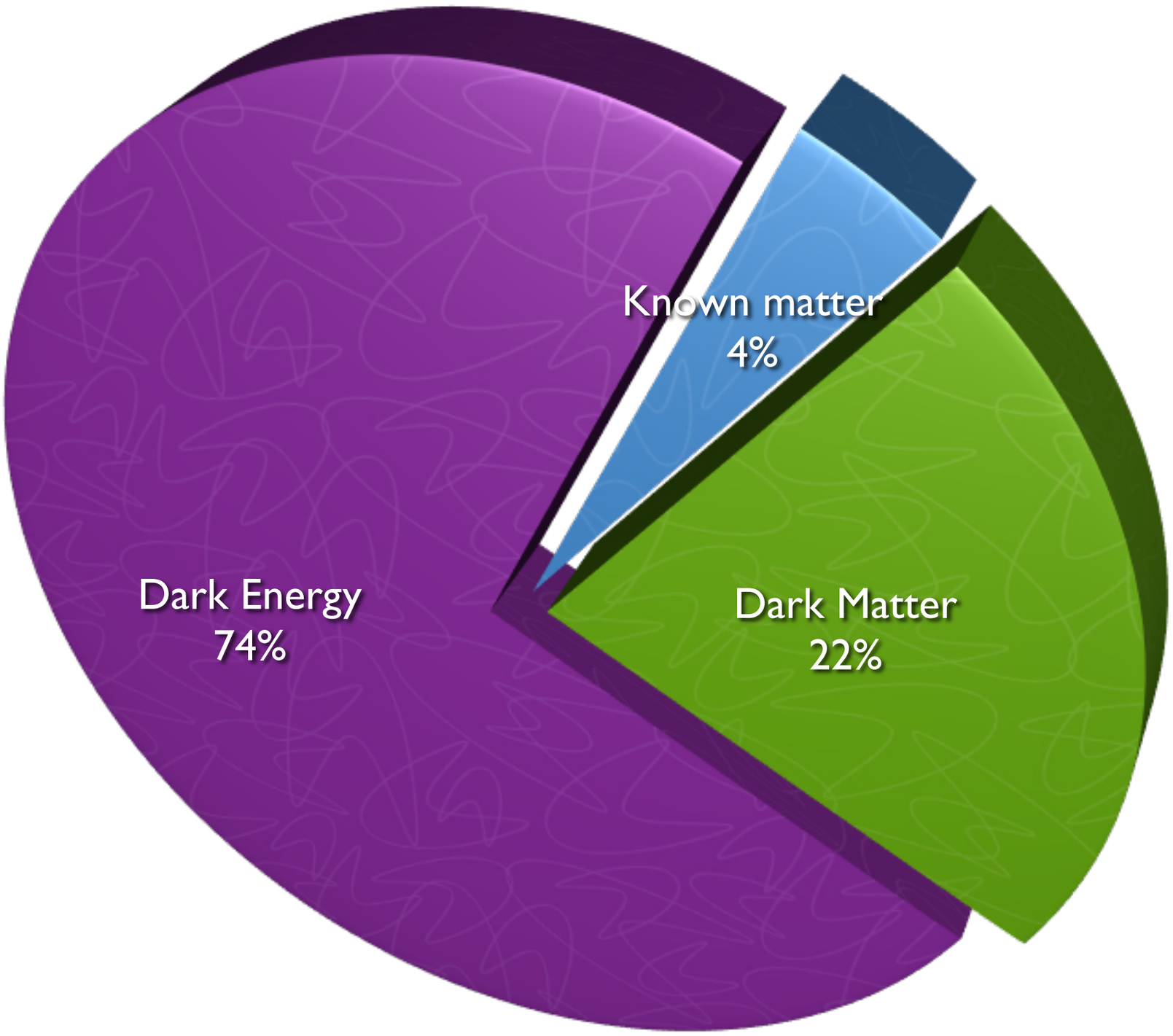
Total energy density



Astrophysical evidences for DM

- galactic rotation curves
- gravitational lensing
- structure formation
- CMB anisotropies
- Bullet Cluster
- ...

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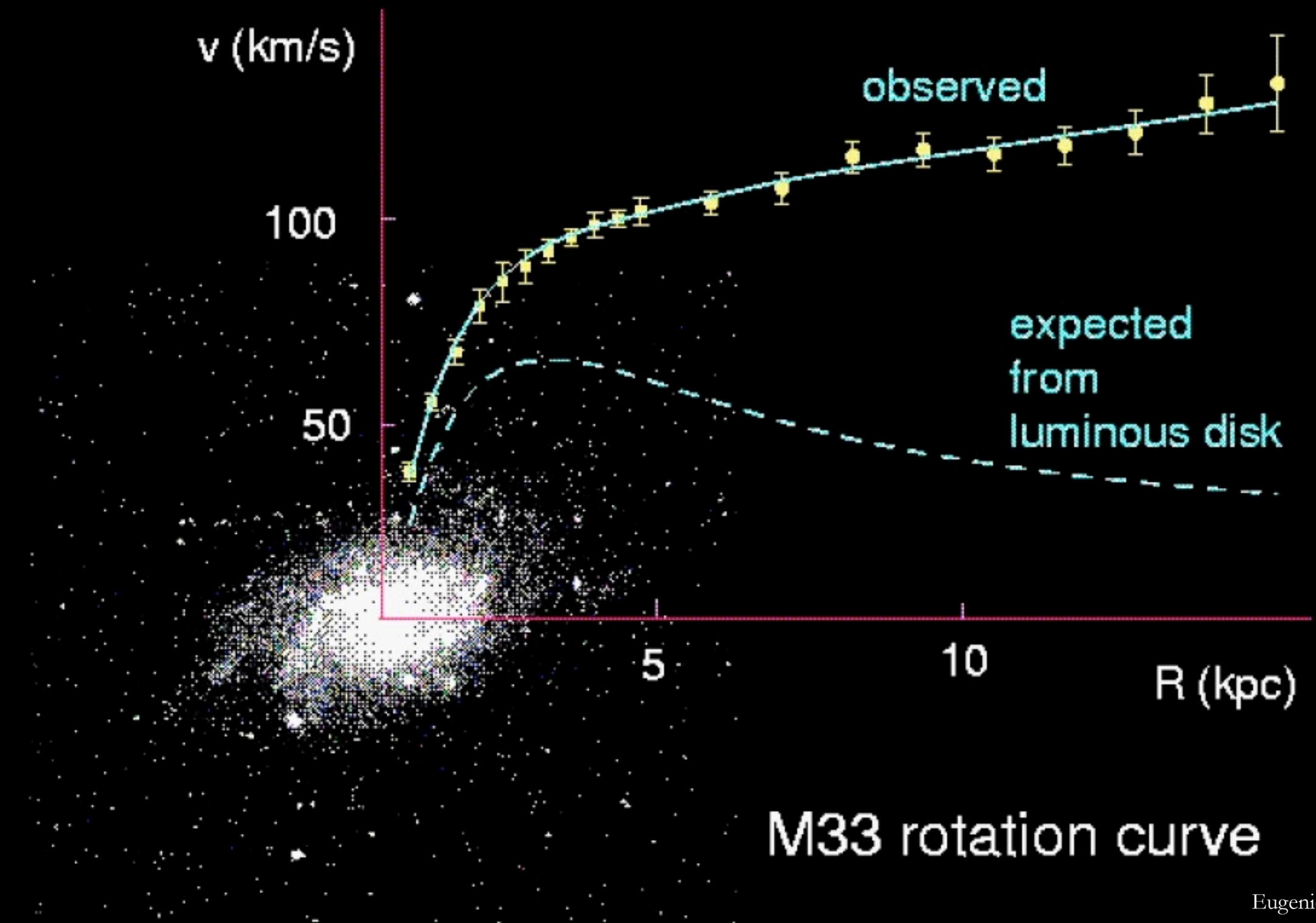
Something missing



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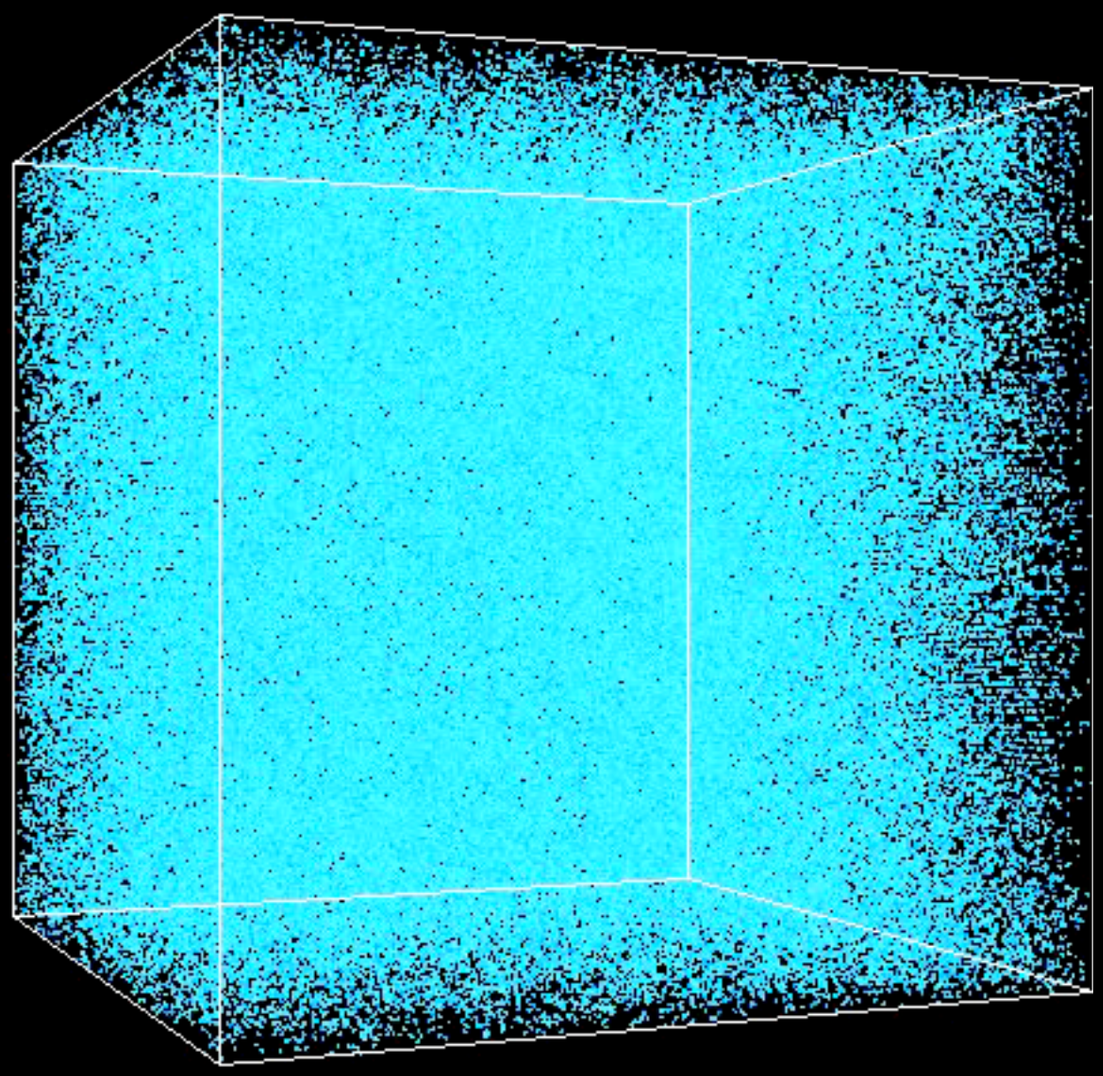
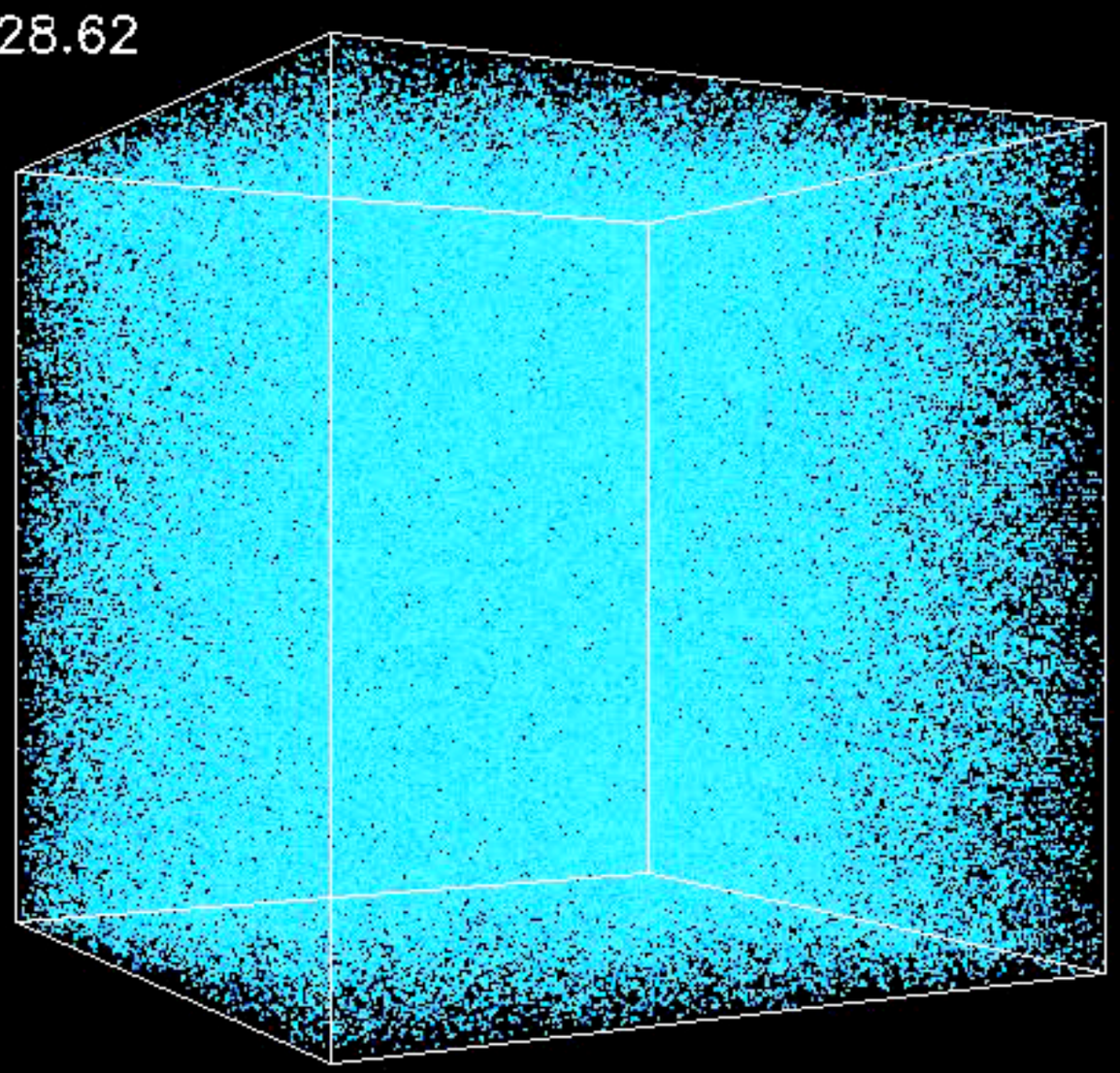
Large structure formation





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Evidences from lensing

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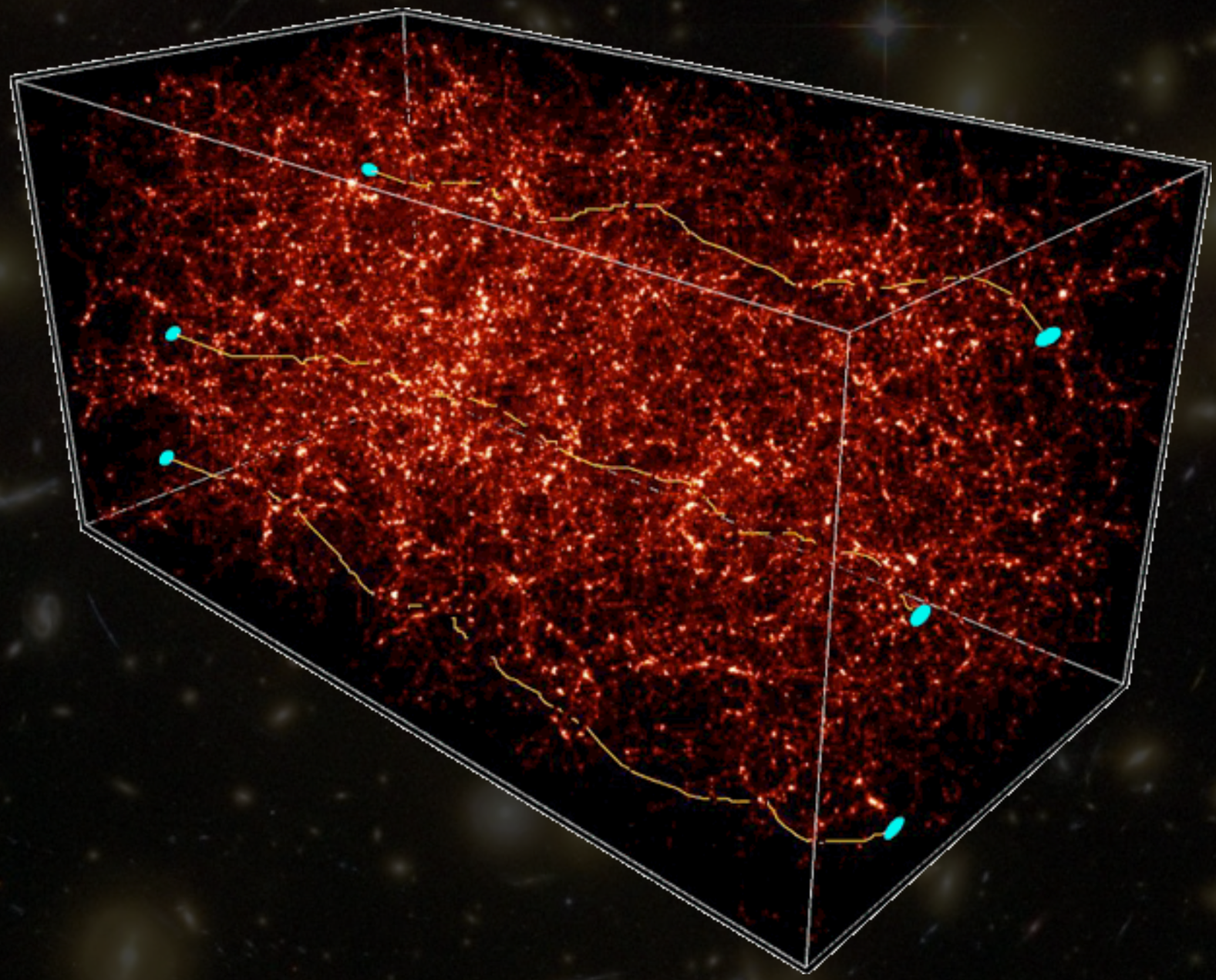
Evidences from lensing



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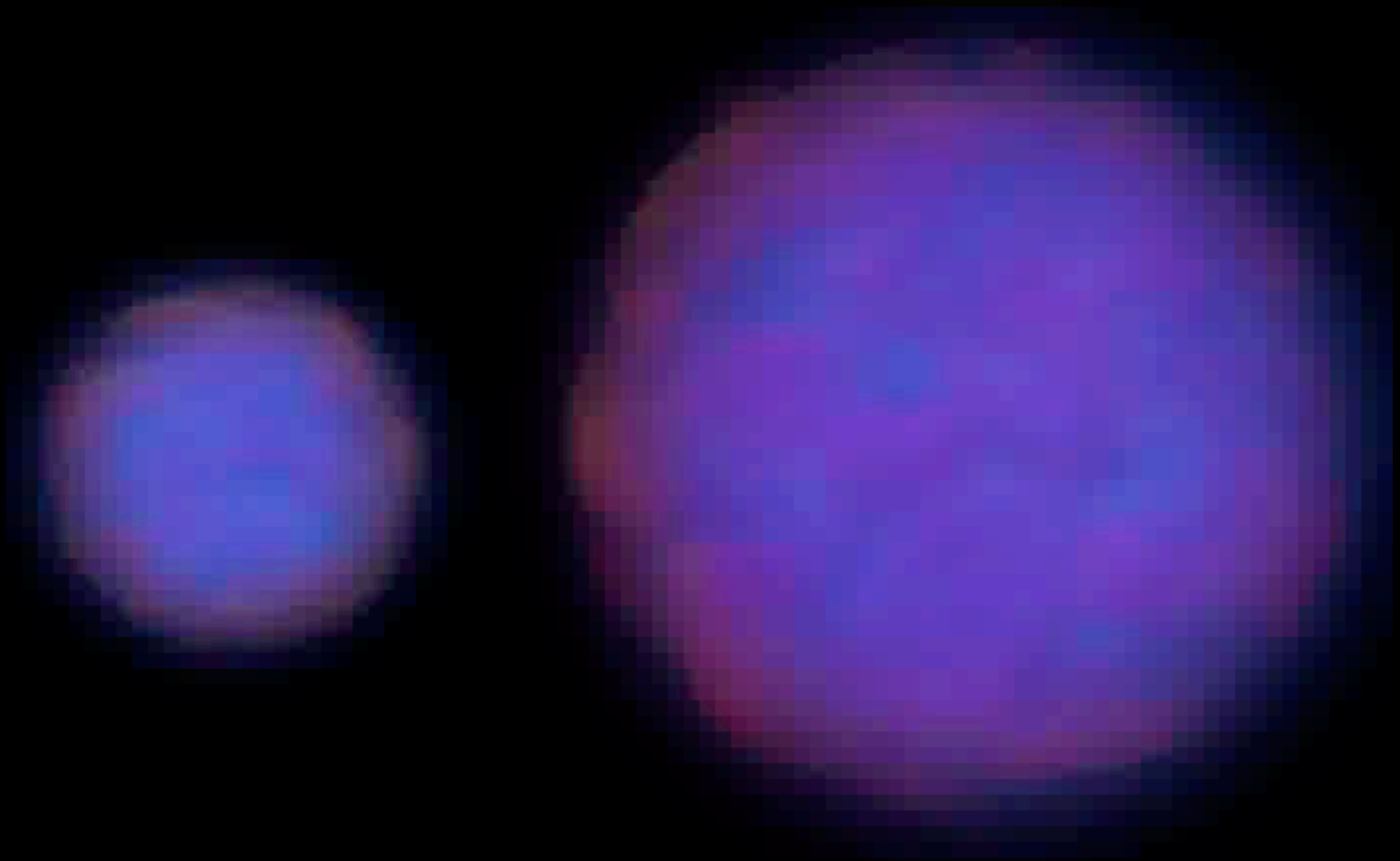
Bullet Cluster



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Bullet Cluster

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DM is not (only)

Black holes, neutron stars, brown dwarfs,
big planets that we don't see
(MAssive Compact Halo Objects: **MACHO**s)

A modification of gravity at large distances
(MOdified Newtonian Dynamics: **MOND**)

Neutrinos (**ν**)

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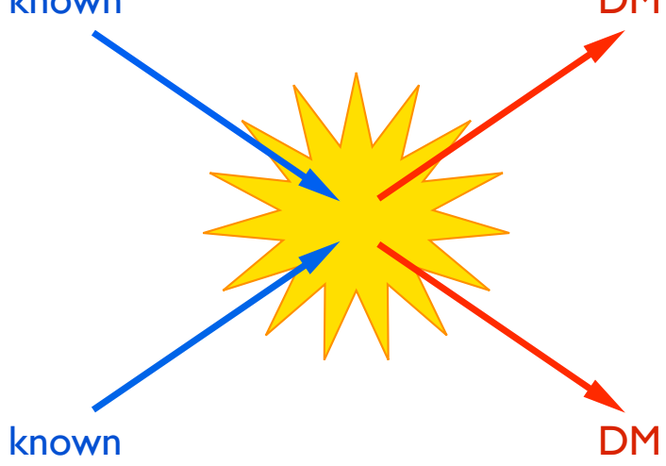
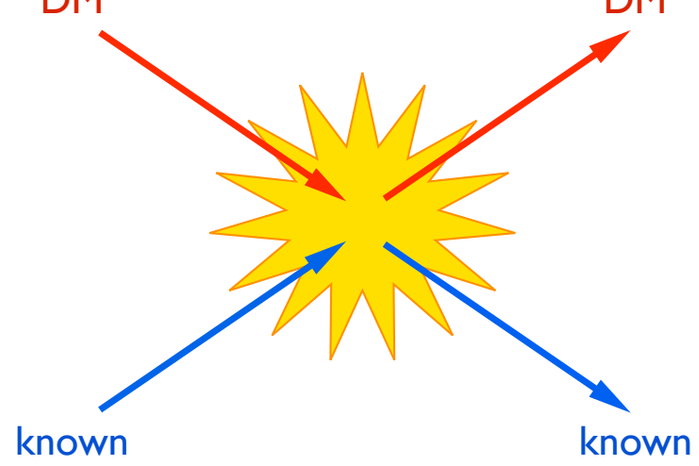
Detection strategies

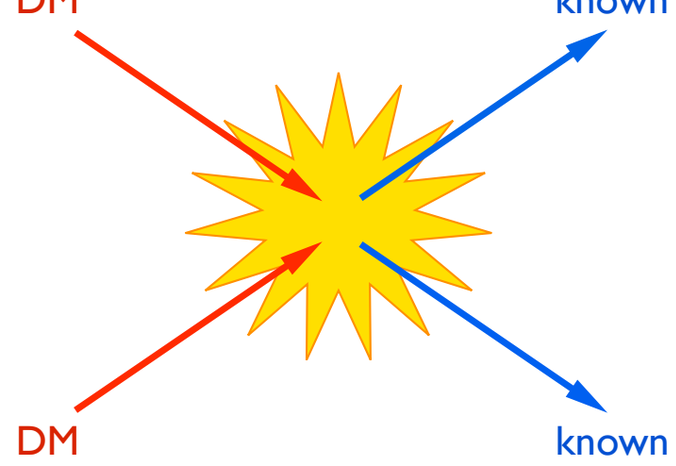
Collider



Direct



Indirect



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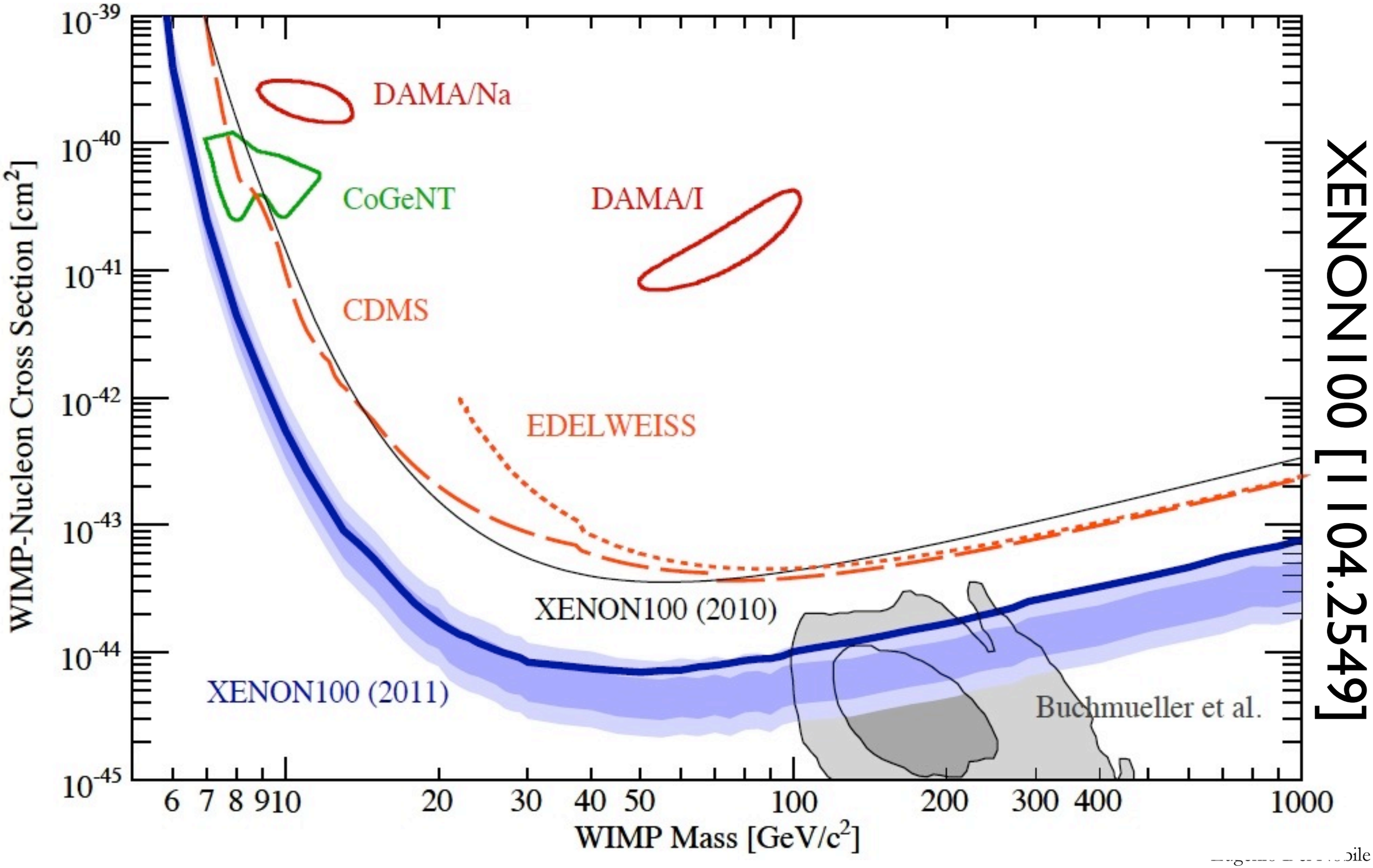
Direct detection plot



Direct detection rate

$$R \equiv \frac{\mathrm{d}N}{\mathrm{d}t\,\mathrm{d}m_{\mathrm{T}}} = \frac{\mathrm{d}N_{\mathrm{T}}}{\mathrm{d}m_{\mathrm{T}}} n v \sigma(v)$$

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Direct detection rate

$$R \equiv \frac{\mathrm{d}N}{\mathrm{d}t\,\mathrm{d}m_{\mathrm{T}}} = \frac{\mathrm{d}N_{\mathrm{T}}}{\mathrm{d}m_{\mathrm{T}}} n v \sigma(v)$$

DM density distribution $\mathrm{d}n = n_0 f(\vec{v}, \vec{v}_{\mathrm{E}}) \mathrm{d}^3 v$

Elastic kinematics: $E_{\mathrm{R}} = E\, r\, (1 - \cos\theta)/2$ $\qquad r \equiv 4 \frac{\mu_A^2}{M_{\mathrm{DM}} m_A}$

$$R = \frac{\mathrm{d}N_{\mathrm{T}}}{\mathrm{d}m_{\mathrm{T}}} n_0 \int_0^\infty \mathrm{d}E_{\mathrm{R}} \int_{v_{\mathrm{min}}(E_{\mathrm{R}})}^{v_{\mathrm{esc}}} \mathrm{d}^3 v\, v\, f(\vec{v}, \vec{v}_{\mathrm{E}}) \frac{\mathrm{d}\sigma}{\mathrm{d}E_{\mathrm{R}}}$$

$$v_{\mathrm{min}} = \sqrt{m_A E_{\mathrm{R}} / 2\mu_A^2}$$

Cross section

$$\frac{\mathrm{d}\sigma}{\mathrm{d}E_\mathrm{R}}(E_\mathrm{R}) \longrightarrow F^2(E_\mathrm{R})\frac{\mathrm{d}\sigma_0}{\mathrm{d}E_\mathrm{R}} = F^2(E_\mathrm{R})\,\sigma_0\frac{m_A}{2\mu_A^2 v^2}$$

$$\sigma_0 \equiv \int_0^{Er} \frac{\mathrm{d}\sigma_0}{\mathrm{d}E_\mathrm{R}}\mathrm{d}E_\mathrm{R} = Er\frac{\mathrm{d}\sigma_0}{\mathrm{d}E_\mathrm{R}}$$

$$\mathcal{M} = M_\mathrm{DM} m_A [Z f_p + (A-Z) f_n]$$

$$\sigma_0 = \frac{\mu_A^2}{16\pi}|Z f_p + (A-Z) f_n|^2 F^2(E_\mathrm{R})$$

$$= \frac{\mu_A^2}{\mu_p^2}\sigma_p |Z + (A-Z) f_n/f_p|^2 F^2(E_\mathrm{R}) \qquad \sigma_p = \frac{\mu_p^2}{16\pi}|f_p|^2$$

Finally

Define $$I_A \equiv \frac{\mathrm{d}N_\mathrm{T}}{\mathrm{d}m_\mathrm{T}} n_0 \int \mathrm{d}E_\mathrm{R}\, F^2(E_\mathrm{R}) \int_{v_\mathrm{min}}^{v_\mathrm{esc}} \mathrm{d}^3 v \frac{m_A}{2\mu_A^2 v} f(\vec{v}, \vec{v}_\mathrm{E})$$

Then $$R = \sum_{\{A\}} \eta_A I_A \frac{\sigma_0}{F^2(E_\mathrm{R})} = \sum_{\{A\}} \eta_A I_A \frac{\mu_A^2}{\mu_p^2} \sigma_p |Z + (A-Z) f_n/f_p|^2$$

$$= \sum_{\{A\}} \eta_A I_A \frac{\mu_A^2}{\mu_p^2} \sigma_p^\mathrm{exp} A^2$$

Therefore $$\sigma_p = \sigma_p^\mathrm{exp} \frac{\sum_{\{A\}} \eta_A \cancel{I_A} \frac{\mu_A^2}{\mu_p^2} A^2}{\sum_{\{A\}} \eta_A \cancel{I_A} \frac{\mu_A^2}{\mu_p^2} |Z + (A-Z) f_n/f_p|^2}$$

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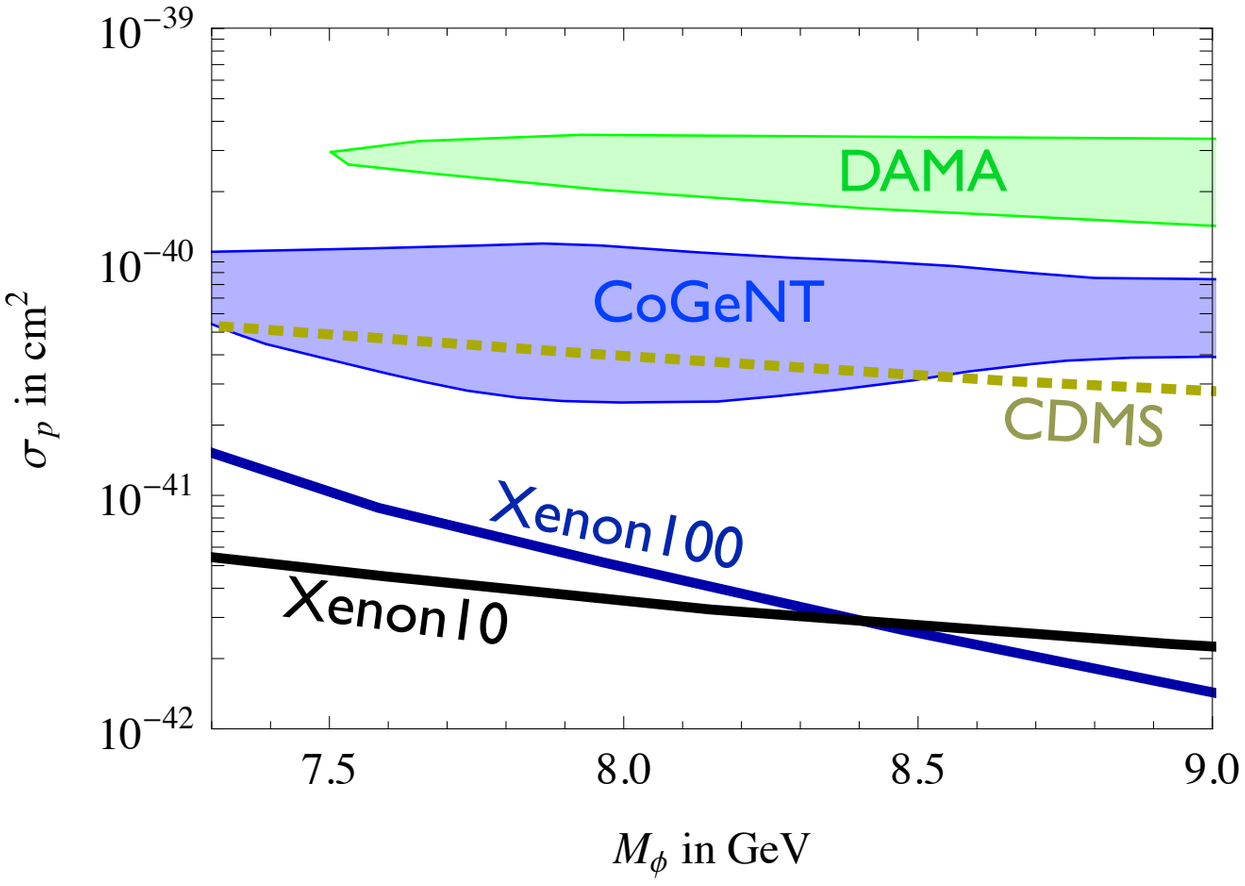
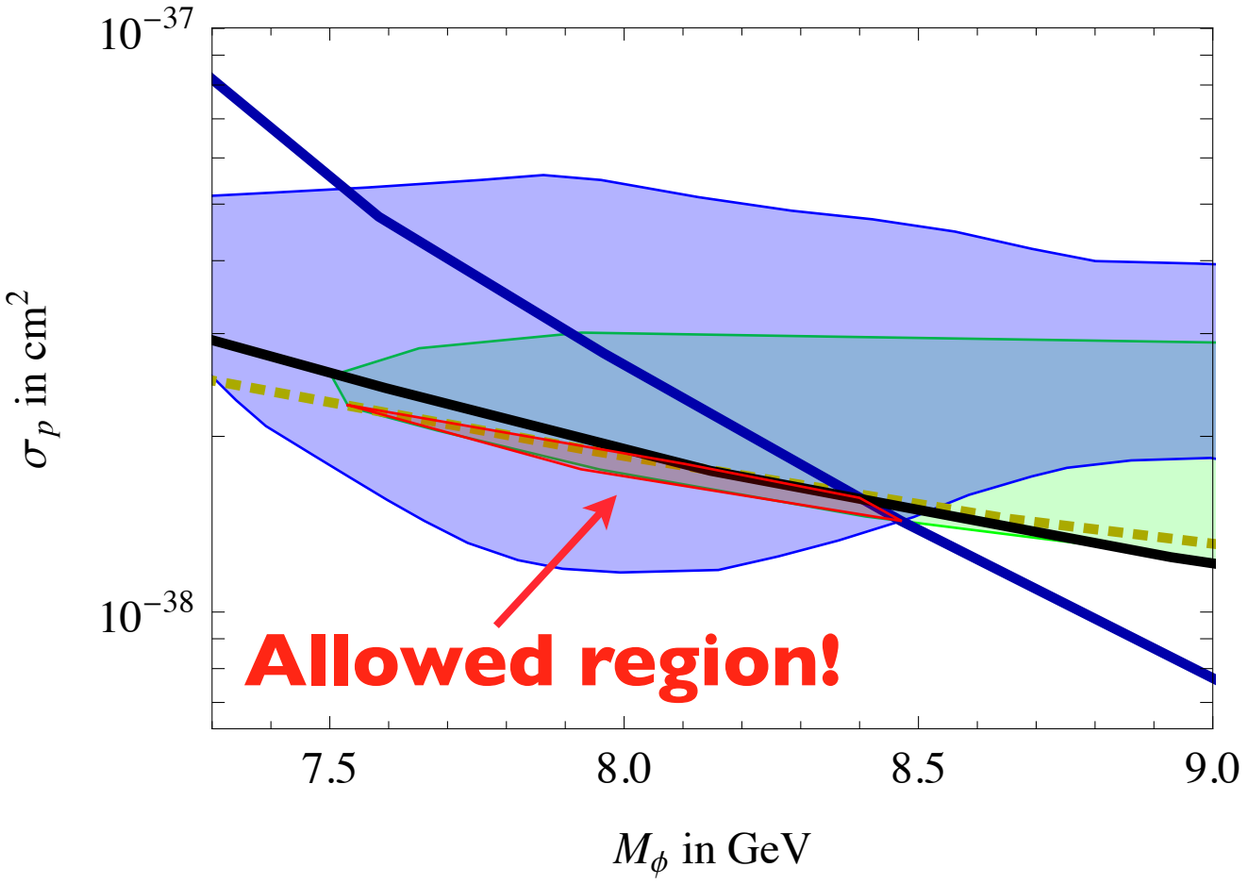
Then plot again

Feng, Kumar, Marfatia, Sanford '11 [1102.4331]

$f_n = f_p$



$f_n / f_p \sim -0.7$



$$M_{\rm DM} \simeq 8 \text{ GeV} \qquad \sigma_p \simeq 2 \times 10^{-38} \text{ cm}^2$$

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Isospin violating DM

Z boson exchange gives $f_n / f_p \sim -10$

Higgs exchange gives $f_n / f_p \sim 1$

photon exchange gives $f_n / f_p \sim 0$

Therefore consider multiple mediators exchange

DM Interference

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~ Models I

Foadi, Frandsen, Sannino '08 [0812.3406]
EDN, Kouvaris, Sanninino '11 [1105.5431]

ϕ a SM-singlet scalar composite DM field

ϕ can be naturally light being a PNGB, and is protected by a new global U(1) symmetry, e.g. in UMT (Ryttov, Sannino '08 [0809.0713])

$$\mathcal{L}_{\rm int} = -d_H H^\dagger H \phi^* \phi + i \frac{d_B}{\Lambda^2} e\, \phi^* \overleftrightarrow{\partial_\mu} \phi\, \partial_\nu F^{\mu\nu}$$

$$\frac{d_B}{\Lambda^2} \sim 3 \times 10^{-4}\ \mathrm{GeV}^{-2} \qquad \frac{d_H}{m_H^2} \sim 5 \times 10^{-4}\ \mathrm{GeV}^{-2}$$

Therefore if $\Lambda, m_H \sim \mathcal{O}(100\ \mathrm{GeV})$, d_B and d_H are natural

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~ Models II

Other possibilities are, with fermionic DM:

(EDN, Kouvaris, Sannino, Virkajärvi '11 [1111.1902])

- Z - Higgs interference ← Excluded by LEP
- Z' - Higgs interference ← Works for light Higgs (~ 50 GeV)
- Z - Z' interference ← Basically only Z'
- two Higgs doublets interference ← It doesn't spoil Baryogenesis

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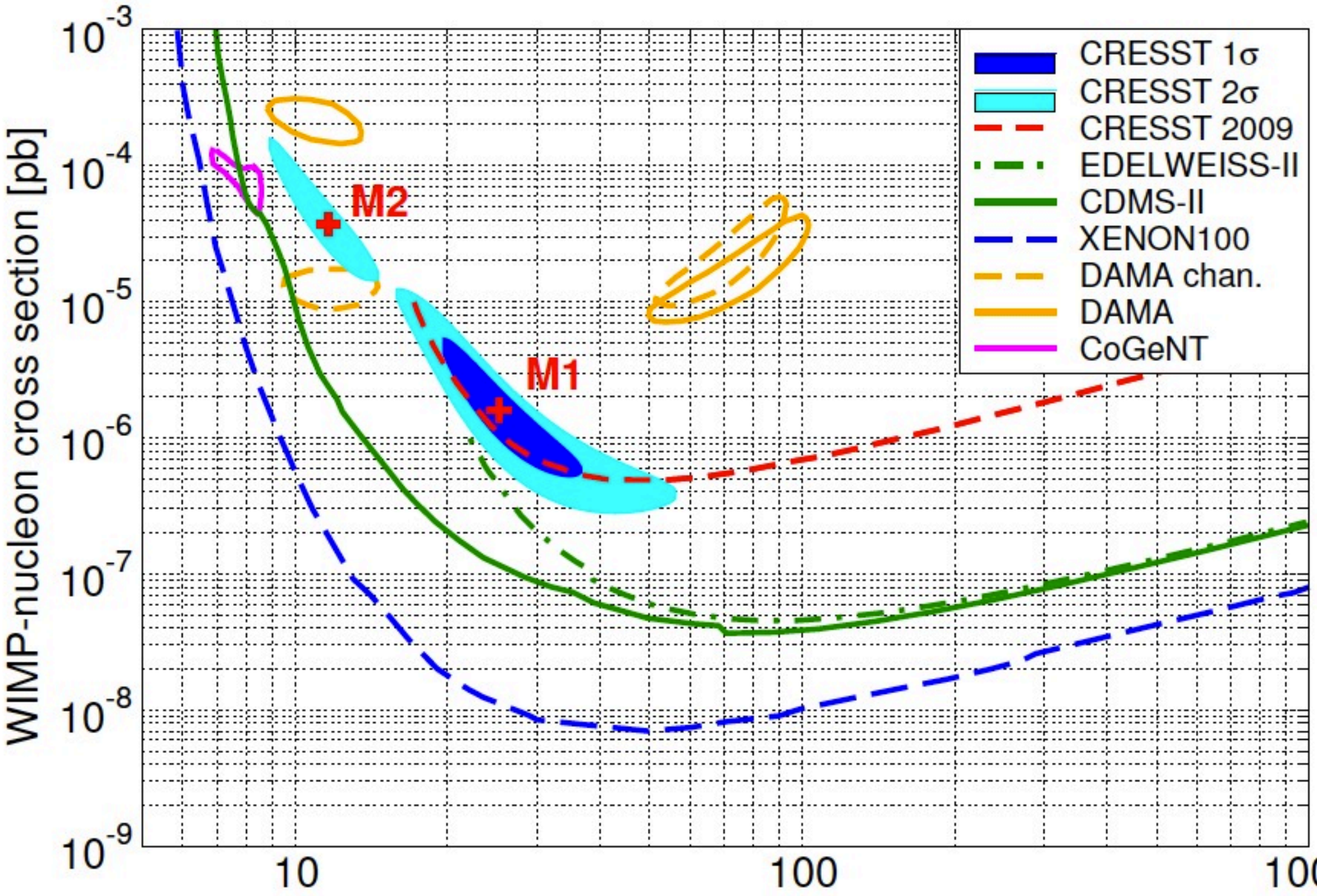
Also CRESST!



:-(

CoGeNT

DAMA

Xenon10

CDMS

CRESST

$f_n / f_p \sim -0.7$

Xenon100

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Conclusions

The experimental assumption of equal DM interaction with protons and neutrons is an assumption

DM Interference is a mechanism to get the right amount of isospin violation

Isospin violating DM is nice, but can't accommodate all the experimental results so far

Maybe what experiments see is not DM, or maybe we just need to discover some other mechanisms to find/fit it.