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Latin American Webinars on Physics

Buscando Materia Oscura con astropartículas y modelos

Roberto A. Lineros

Departamento de Física, Universidad Católica del Norte

V Encuentro de Investigadores Emergentes – 13-14 Diciembre 2018

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Searching for Dark Matter with astroparticles and models

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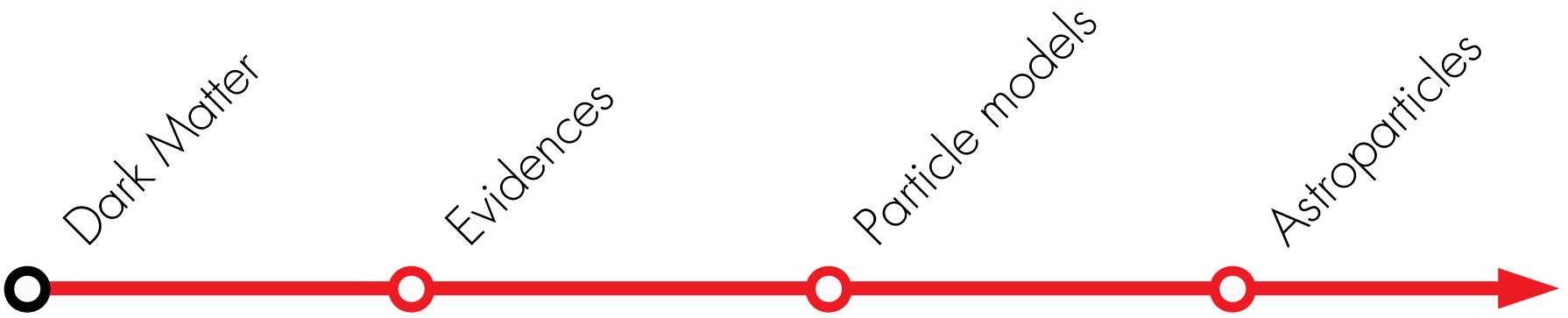
Outline



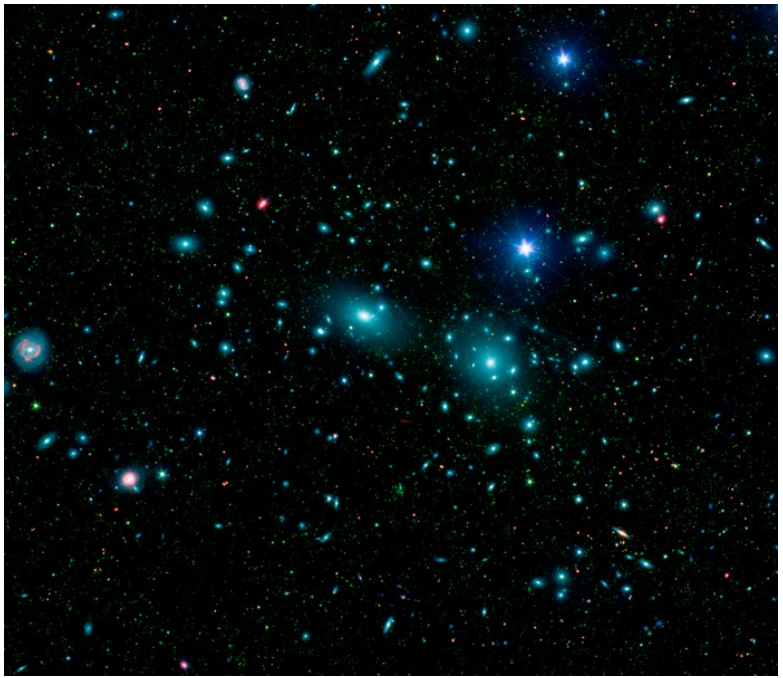
Dark Matter: Evidences

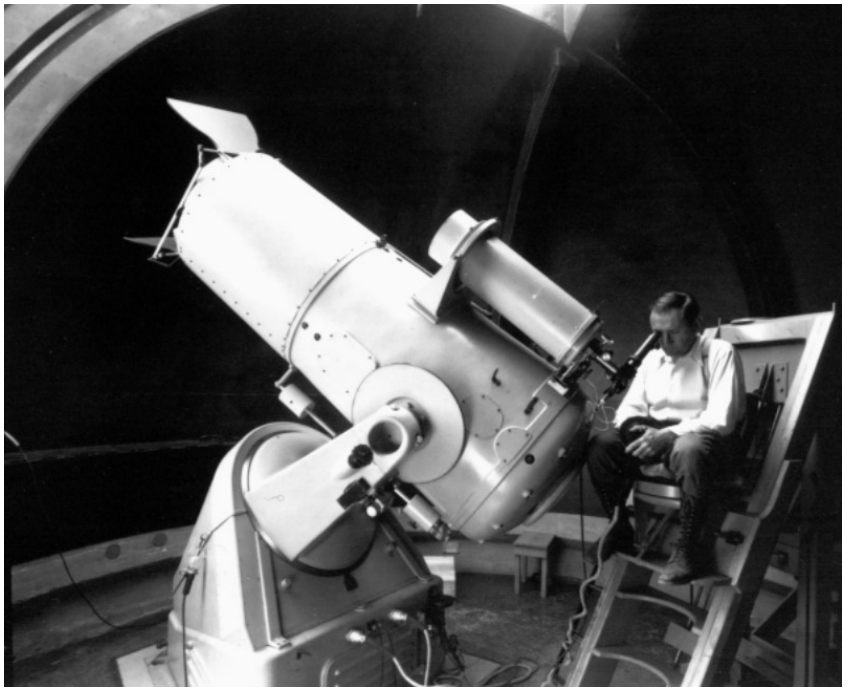
A little of history

1933: Fritz Zwicky postulated dark matter in order to explain Coma cluster dynamics as a bound system

http://youtu.be/C8ZOgKlsqEA

A little of history





Coma Galaxy Cluster

Virial Theorem

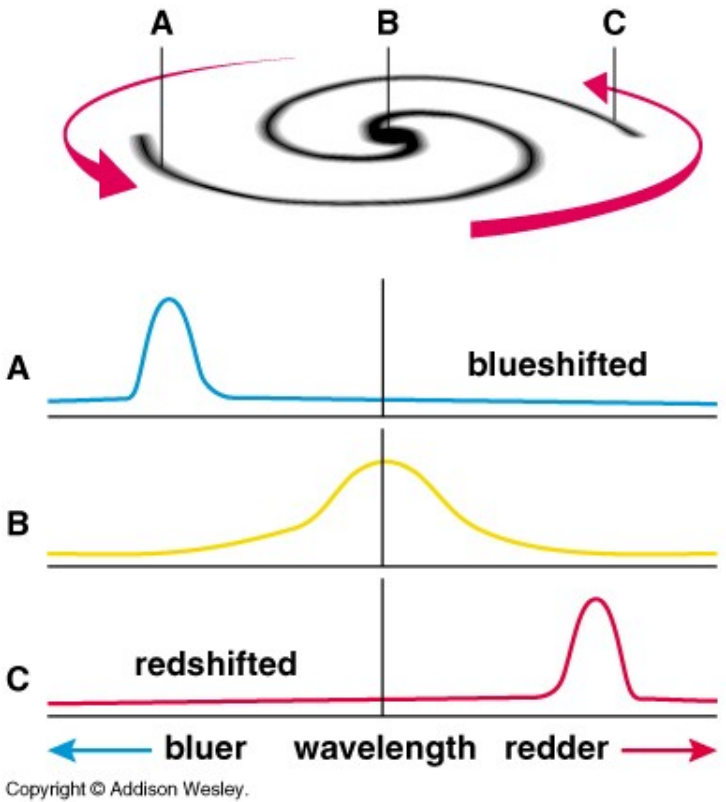
Fritz Zwicky

Dark Matter

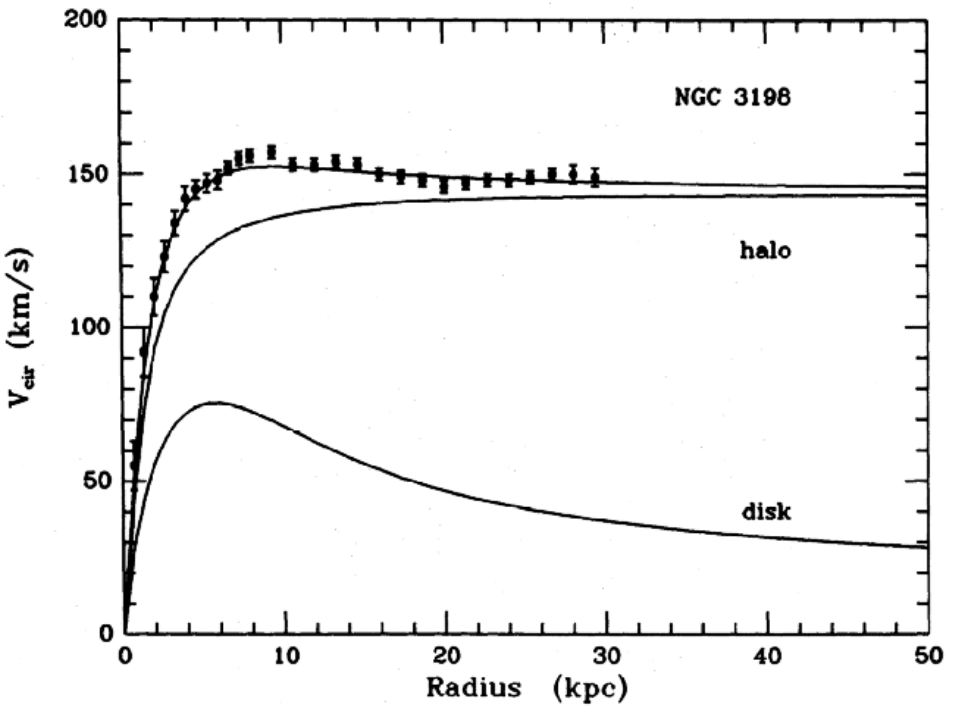
A little of history

60's – 70's Vera Rubin studied rotation curves of many galaxies

A little of history

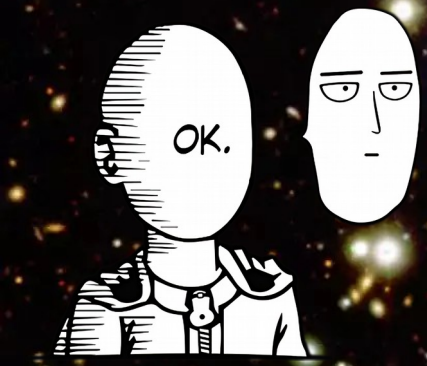


60's – 70's Vera Rubin studied rotation curves of many galaxies

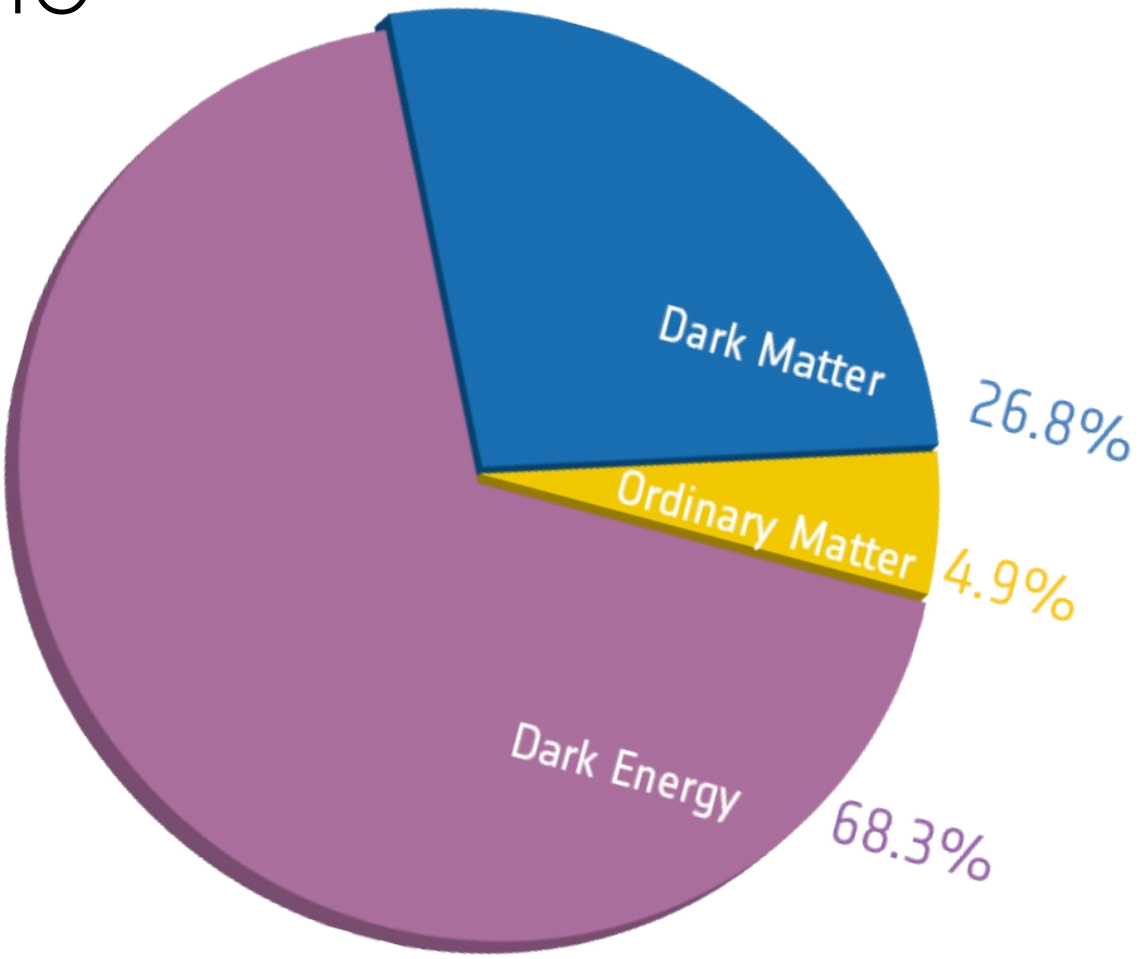


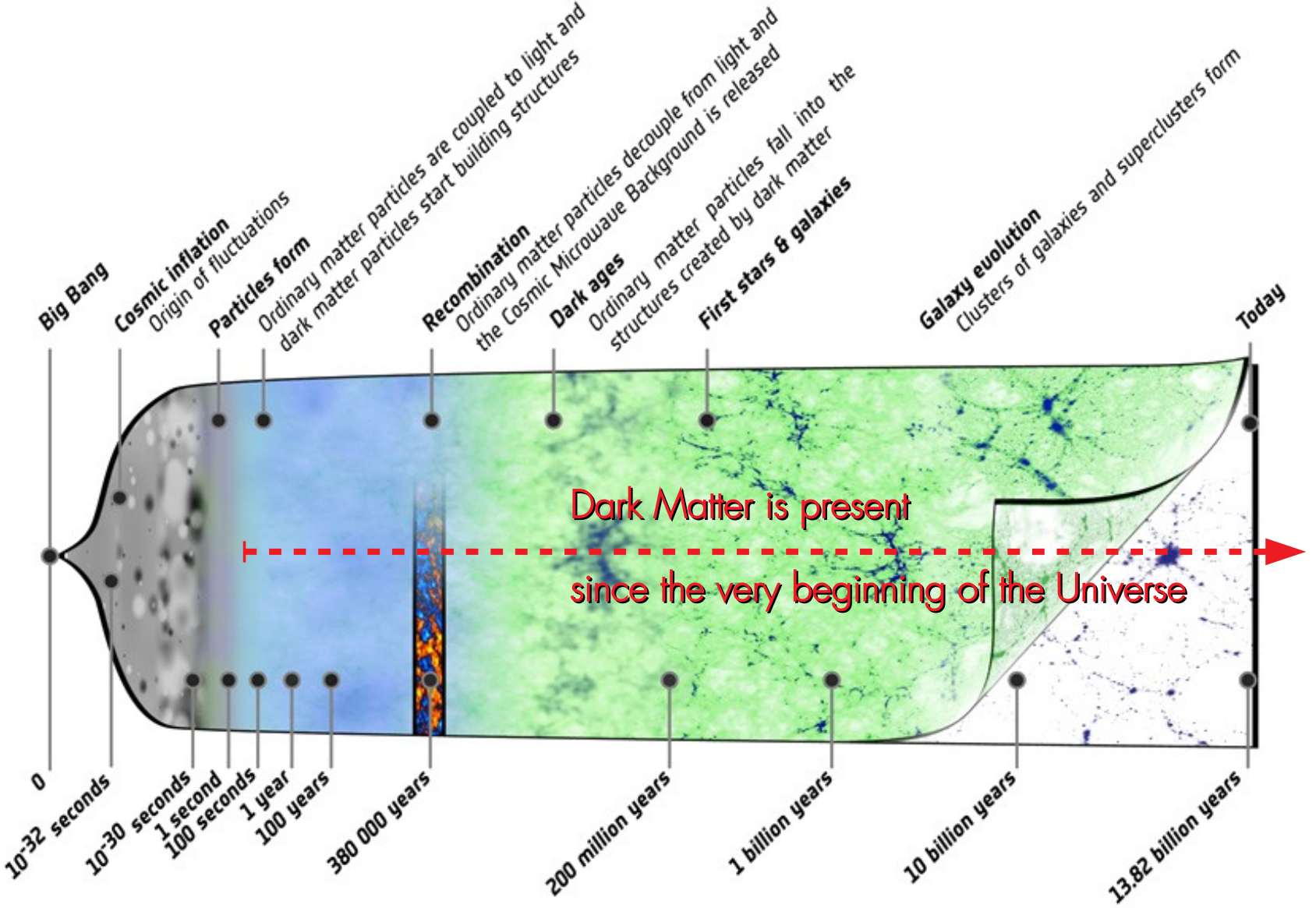
(short story)

Dark Matter is everywhere!

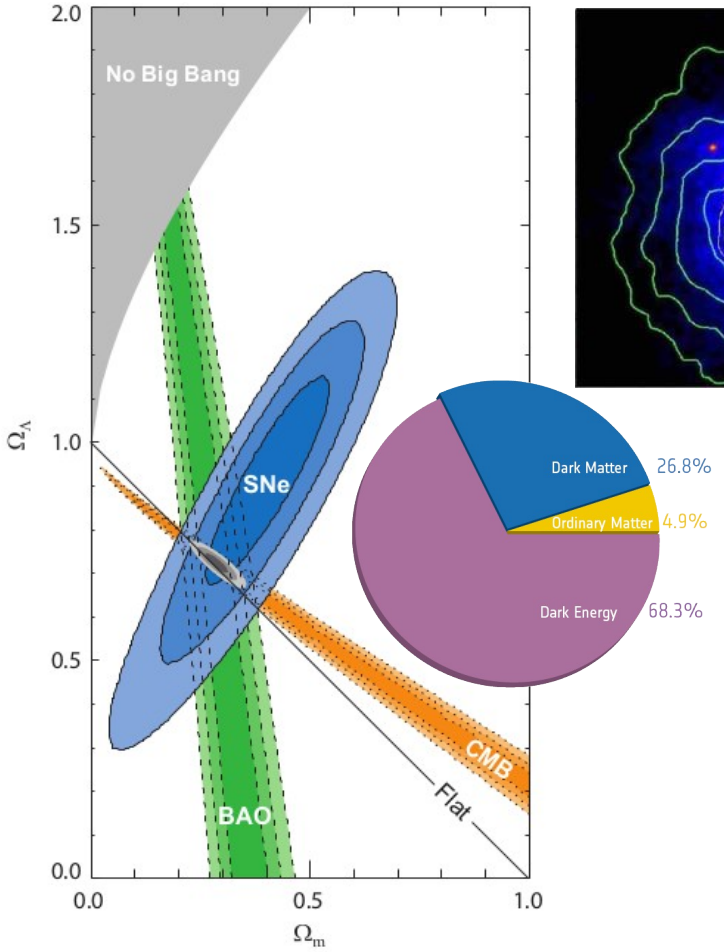


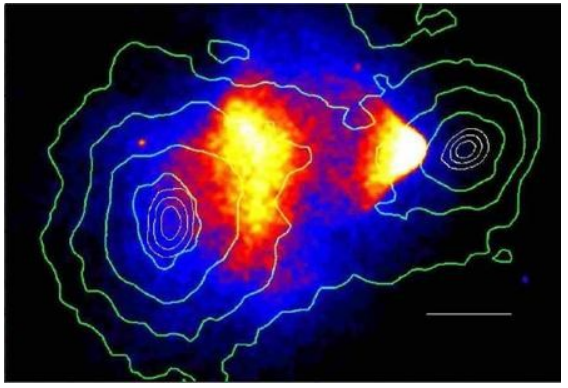
Cosmic pie

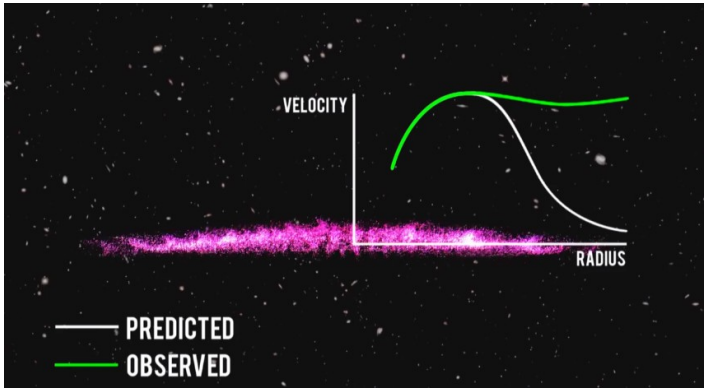



Big Bang
Cosmic inflation
Origin of fluctuations
Particles form
Ordinary matter particles are coupled to light and dark matter particles start building structures
Recombination
Ordinary matter particles decouple from light and the Cosmic Microwave Background is released
Dark ages
Ordinary matter particles fall into the structures created by dark matter
First stars & galaxies
Galaxy evolution
Clusters of galaxies and superclusters form
Today
Dark Matter is present
since the very beginning of the Universe
0
10-32 seconds
10-30 seconds
1 second
100 seconds
1 year
100 years
380 000 years
200 million years
1 billion years
10 billion years
13,82 billion years

Dark Matter







Observations supporting Dark Matter

- Dynamics of clusters and galaxies
- Structure formation
- CMB anisotropies
- Baryon Acoustic Oscillation

$$\Omega_{\mathrm{DM}} h^2 = 0.1196 \pm 0.0031$$

Galactic scales

Rotation curve
Weak lensing
Velocity dispersion of satellite galaxies
Velocity dispersion of dSphs

Galaxy cluster scales

Velocity dispersion of individual galaxies
Strong and weak lensing
Peculiar velocity flows
X-ray emission

Cosmological scales

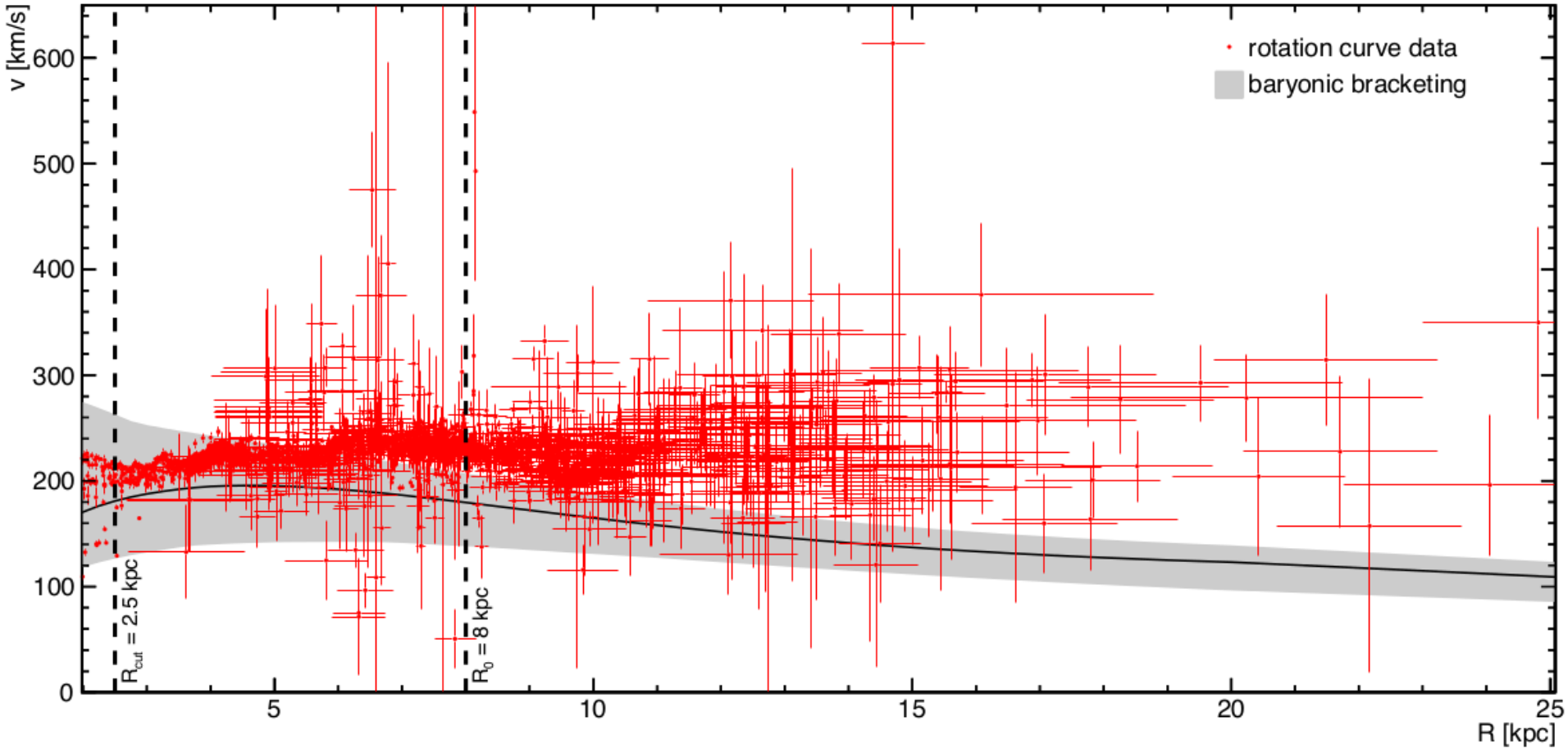
CMB anisotropies
Growth of structure
LSS distribution
BAOs
SZ effect

smaller
kpc

larger
Gpc

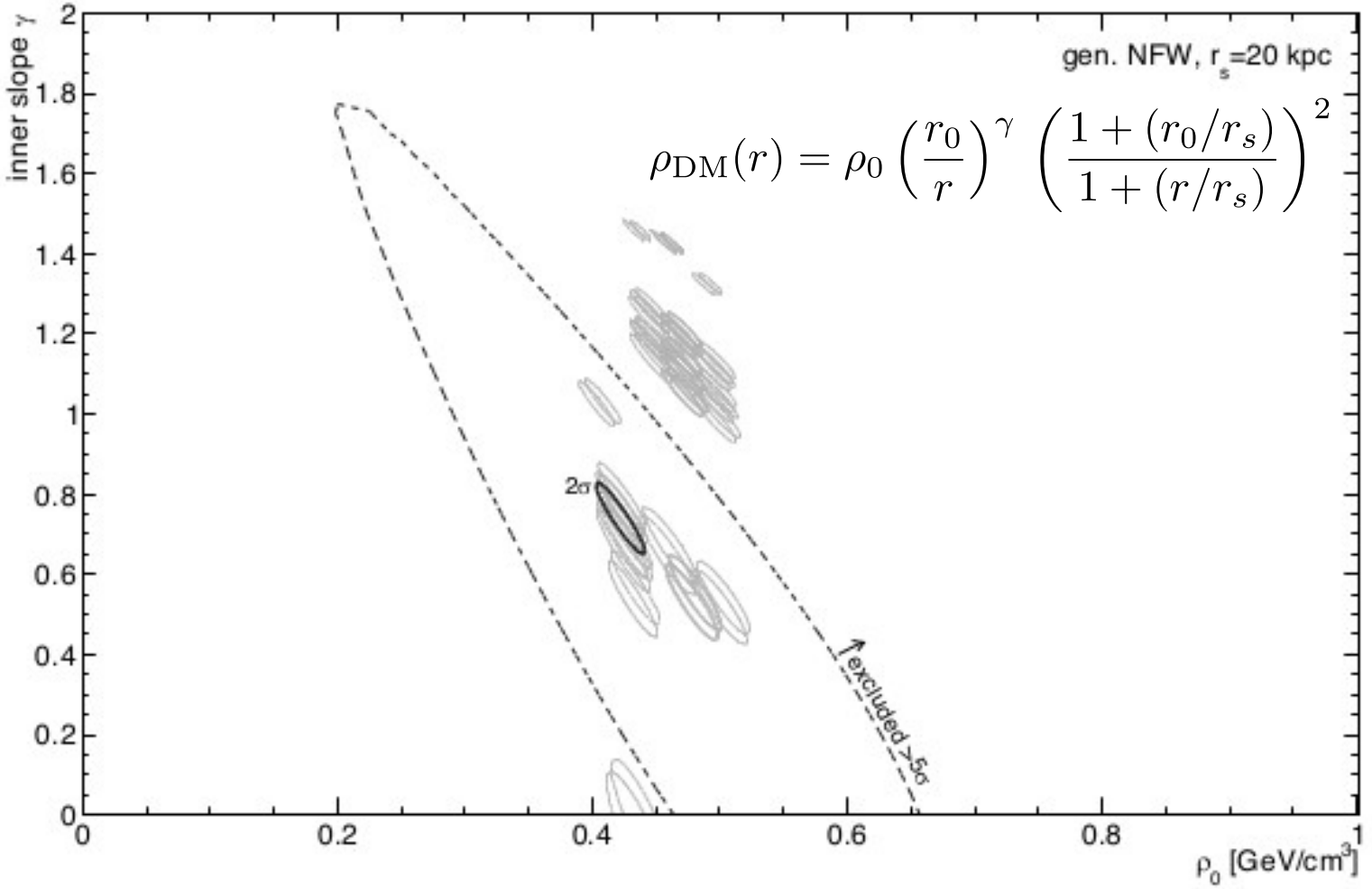
Galactic scales

M. Pato et al JCAP 1512 (2015)



Galactic scale

M. Pato et al JCAP 1512 (2015)

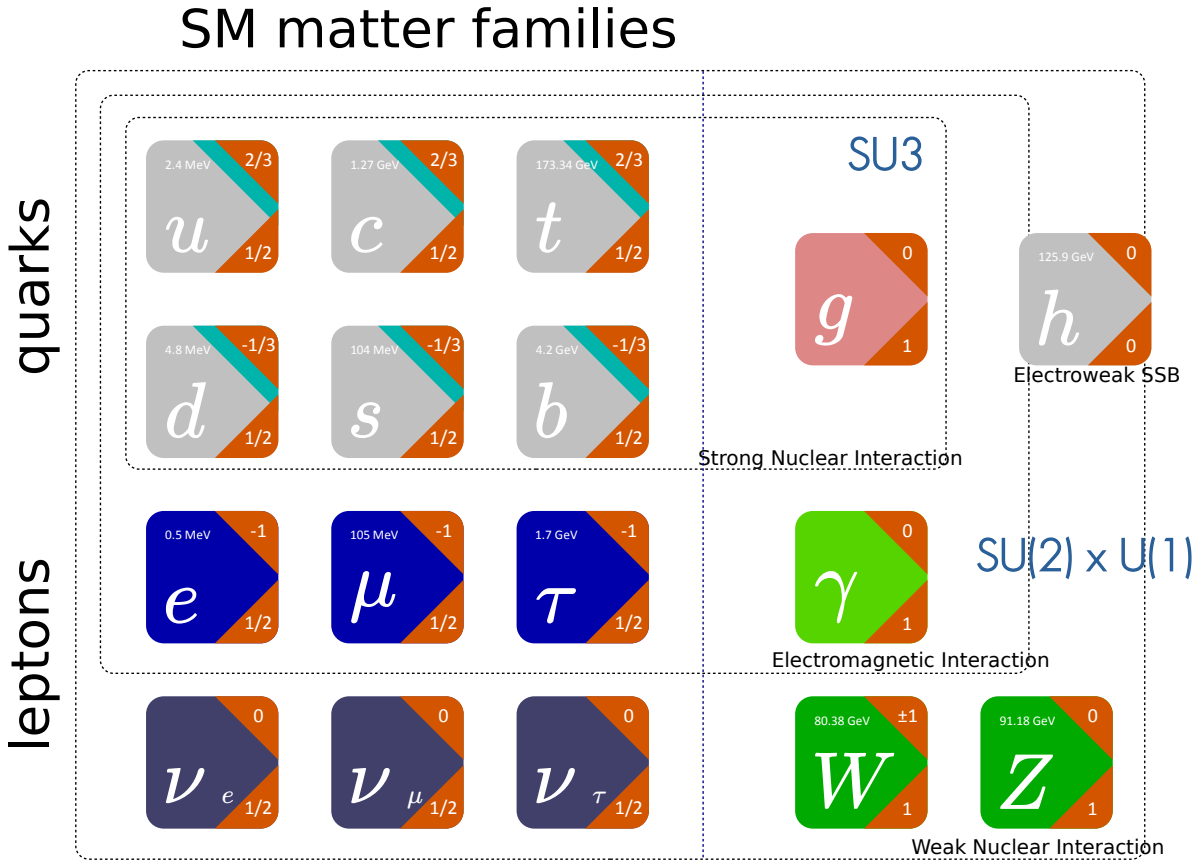


$$\rho_{\rm DM}(r) = \rho_0 \left(\frac{r_0}{r}\right)^{\gamma} \left(\frac{1+(r_0/r_s)}{1+(r/r_s)}\right)^2$$

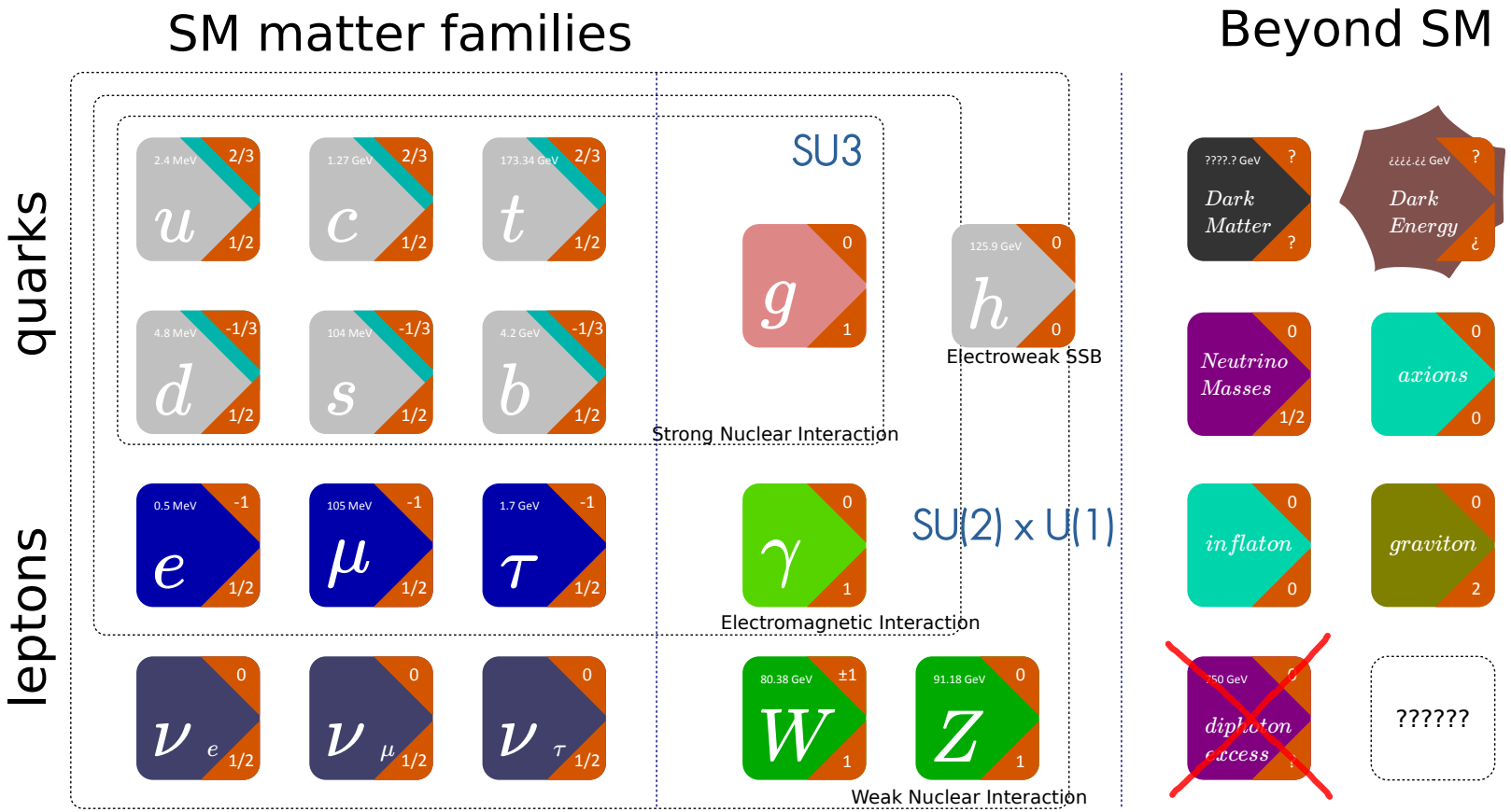
a small sample of

Dark Matter Candidates

The Standard Model (so far)



The Standard Model (so far)



Dark Matter particle properties

Massive

Non baryonic

Electrically neutral

Stable

Dark Matter particle properties

Massive

Non baryonic

Electrically neutral

Stable

Dark Matter particle properties

Massive (*)

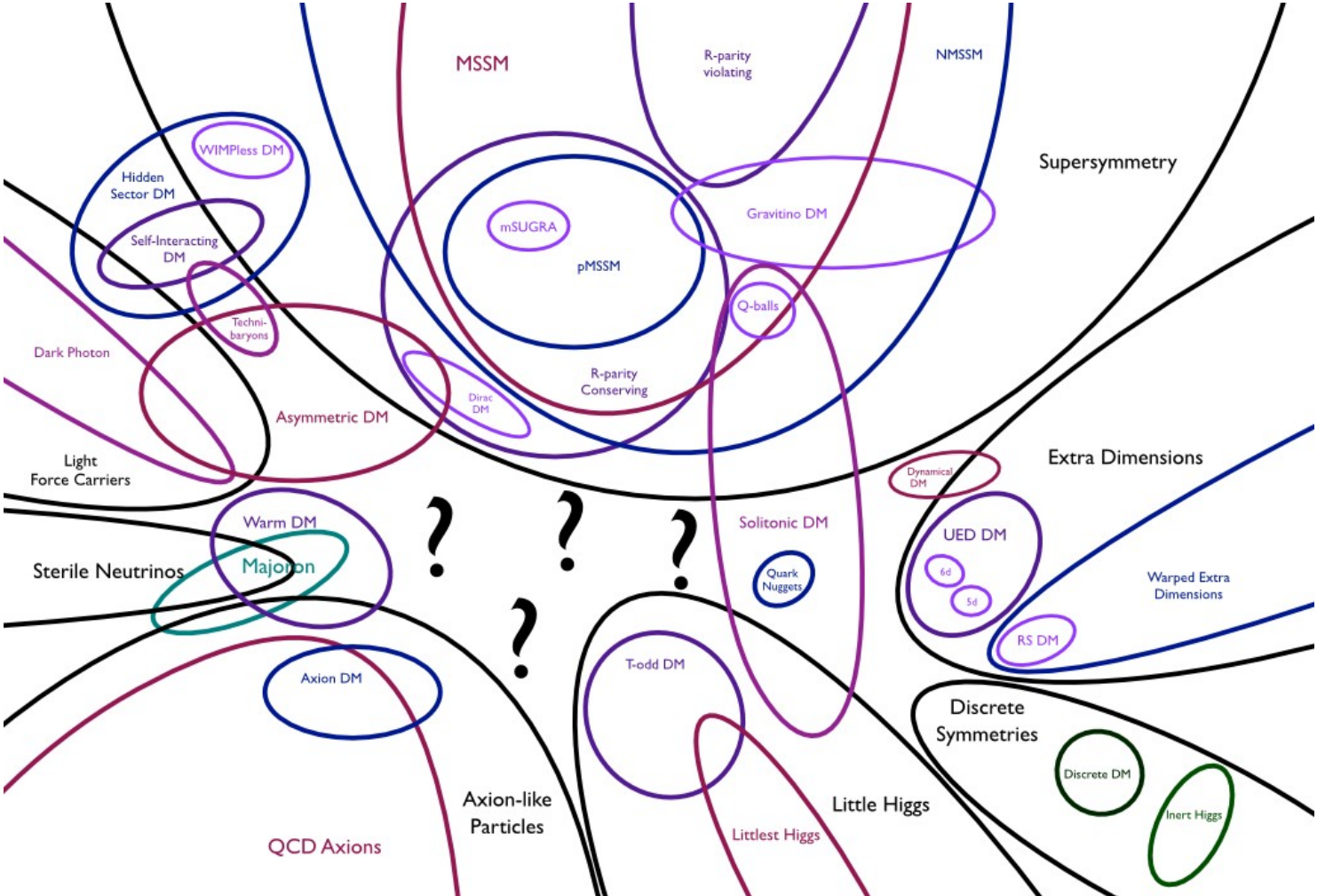
Non baryonic

Electrically neutral (**)

Stable (***)

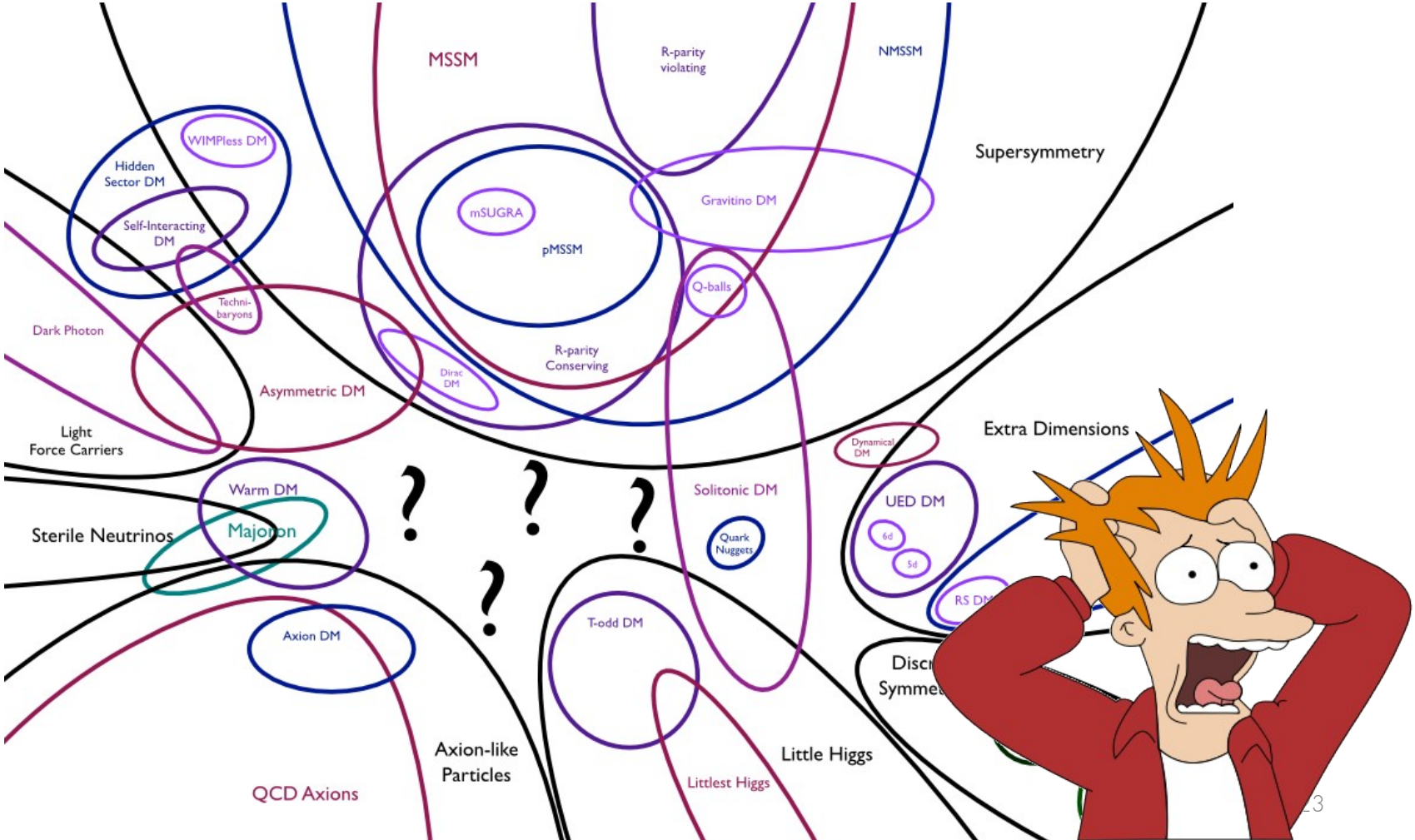
(*) Its mass can go from 10^{-22} eV to 10^{9} GeV
(**) Except Milicharged DM or CHAMPs
(***) DM lifetime larger than 10^{27} seconds (Universe = 10^{17} seconds)

Some candidates



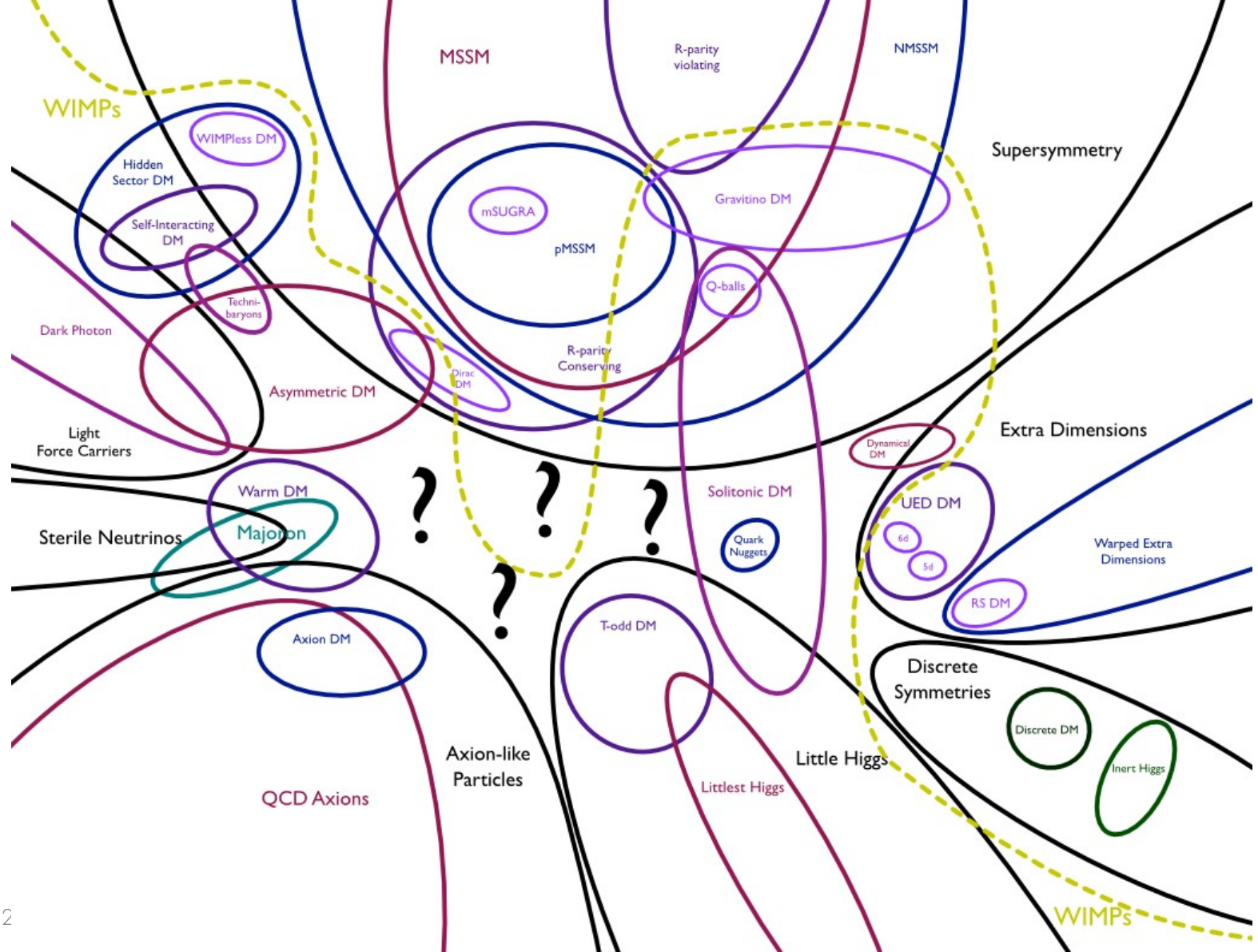
Adapted from 1401.6085

Some candidates

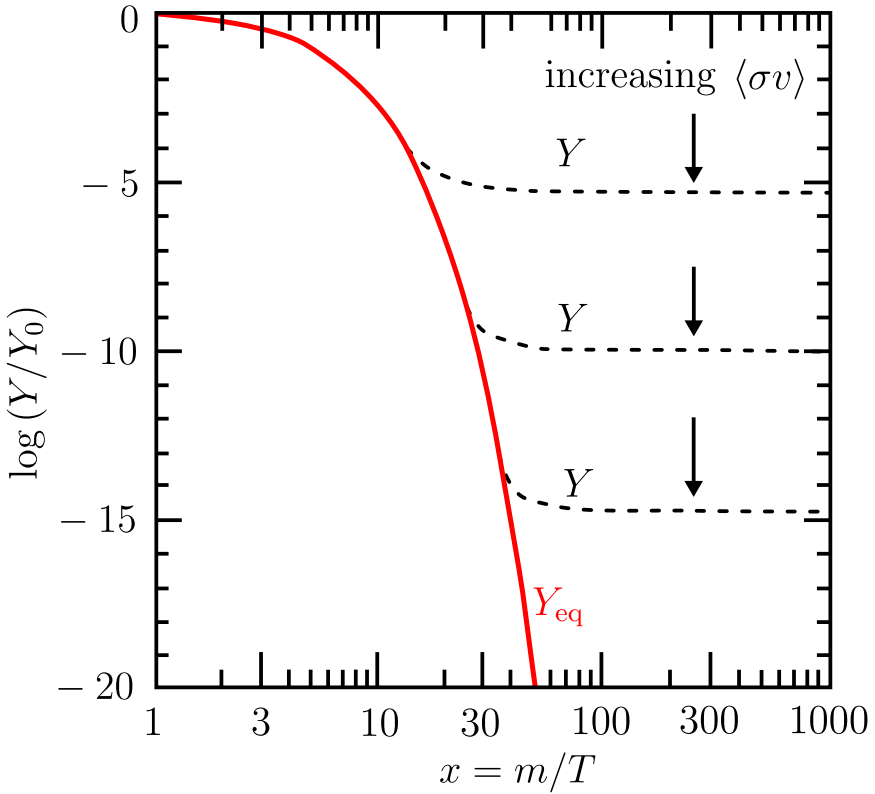


Adapted from 1401.6085


WIMPs
Weakly Interactive Massive Particles


MSSM
R-parity violating
NMSSM
WIMPs
WIMPless DM
Hidden Sector DM
Self-Interacting DM
Supersymmetry
Gravitino DM
mSUGRA
pMSSM
Q-balls
Techni-baryons
Dark Photon
R-parity Conserving
Dirac DM
Asymmetric DM
Light Force Carriers
Extra Dimensions
Dynamical DM
Warm DM
Majoron
Sterile Neutrinos
Solitonic DM
UED DM
6d
5d
Quark Nuggets
Warped Extra Dimensions
RS DM
T-odd DM
Axion DM
Discrete Symmetries
Discrete DM
Inert Higgs
Axion-like Particles
Little Higgs
Littlest Higgs
QCD Axions
WIMPs

WIMPs



Big Bang Thermal relic

Correct relic abundance for

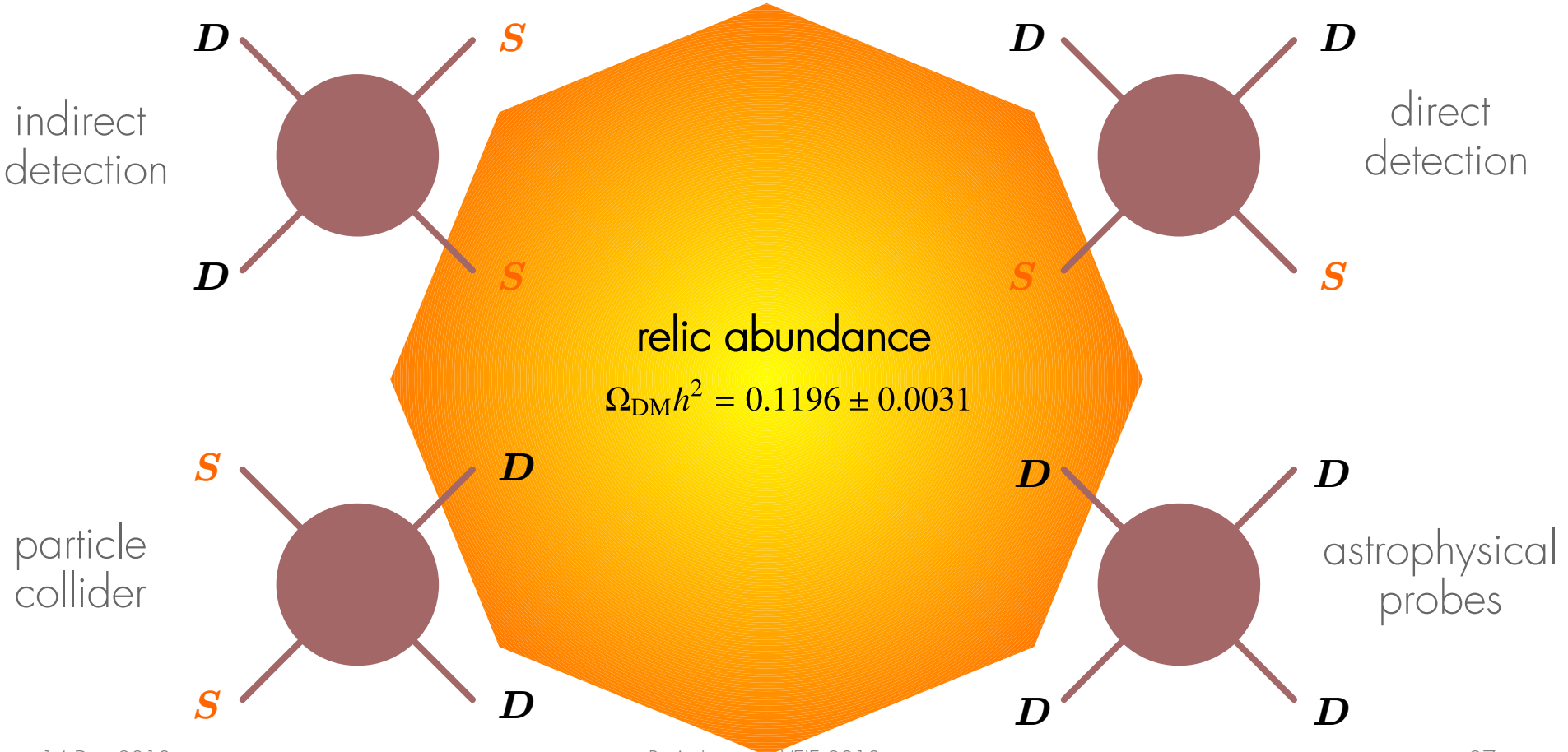
<σv> ~ 1 pb · c

Mass in GeV-TeV range

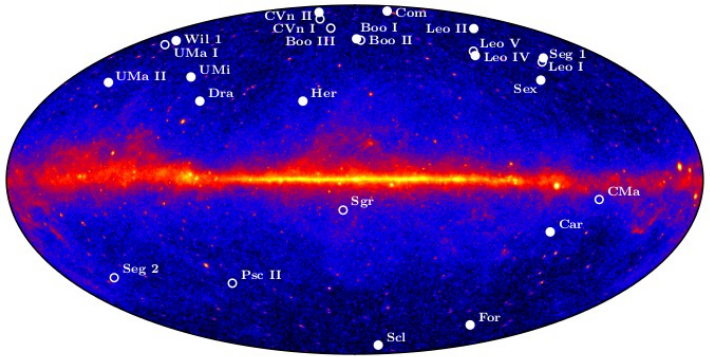
For WIMPs:

$$\Omega_{\rm DM} h^2 \simeq 0.1 \, \frac{3 \times 10^{-26}\,{\rm cm}^3/{\rm s}}{\langle \sigma v \rangle_{\rm f.o.}} \qquad T_{\rm DM}^{\rm f.o.} \simeq \frac{1}{20} m_{\rm DM}$$

Dark Matter Searches



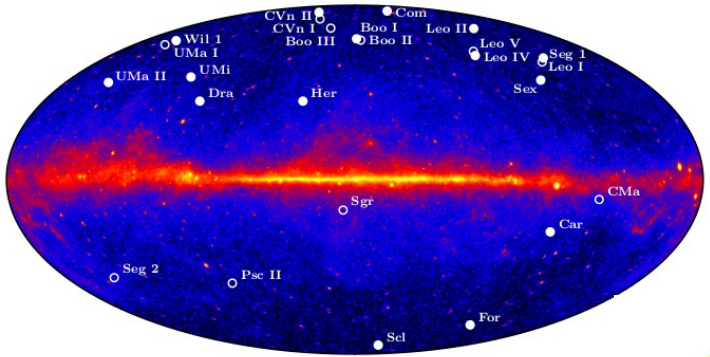
Dark Matter Searches

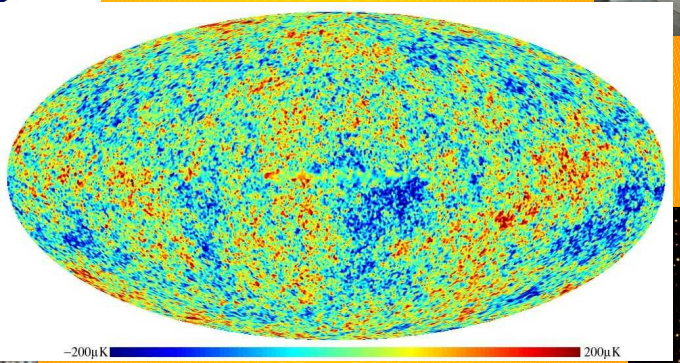


relic abundance

$$\Omega_{\mathrm{DM}} h^2 = 0.1196 \pm 0.0031$$

Dark Matter Searches





Some extra details:

Búsqueda de Materia Oscura con astropartículas 1/4

https://youtu.be/DHc8Z2b1W5M

Búsqueda de Materia Oscura con astropartículas 2/4

https://youtu.be/Gpi4vlQM348

http://twitter.com/DMHunters

Búsqueda de Materia Oscura con astropartículas 3/4

https://youtu.be/Mxt33mN7sgU

Búsqueda de Materia Oscura con astropartículas 4/4

https://youtu.be/y-dpl_FulQY

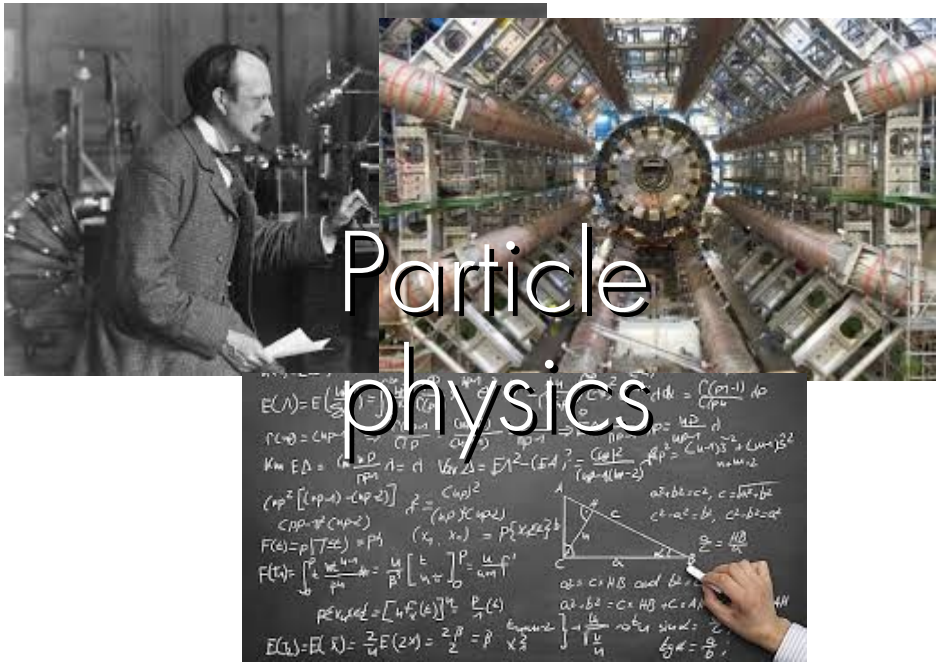
lawphysics

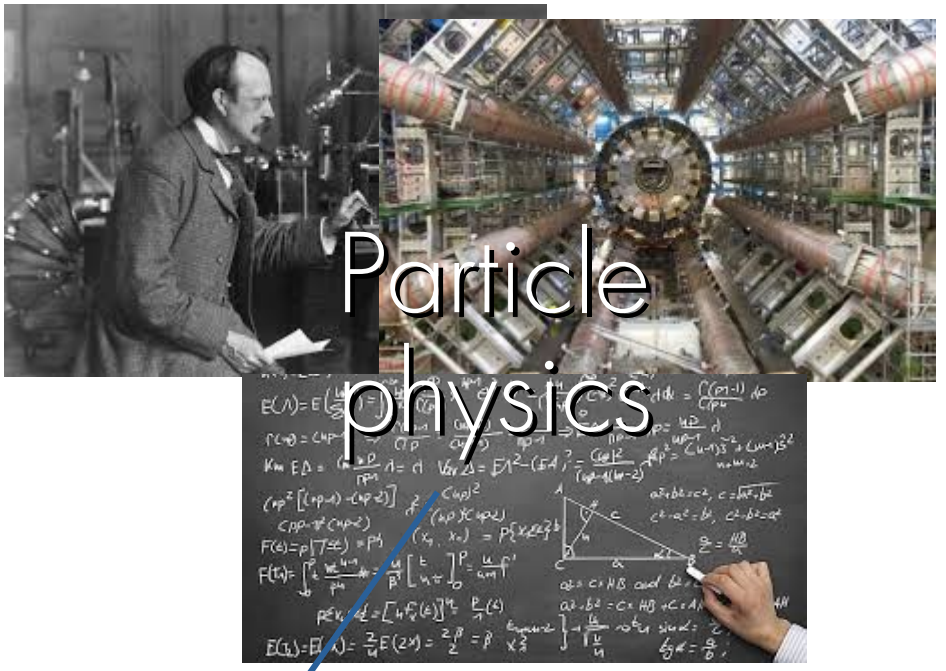
Latin American Webinars on Physics

http://youtube.com/lawphysics

Searches with Astroparticles


Astronomy
Astrophysics


Particle
physics



Astroparticle physics

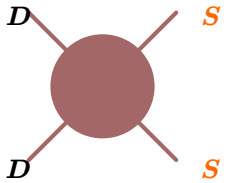
Astroparticles

What we observe:

- Cosmic-rays: electrons, positrons, (anti)protons, heavy nuclei
- Electromagnetic radiation: gamma-rays, x-rays, radio waves
- Neutrinos
- Gravitational waves

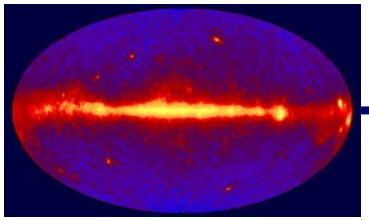
Multimessengers & multiwavelength

Multimessenger signal

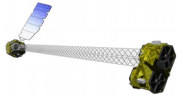


Process

Cosmic-rays
Gamma-rays
Neutrinos

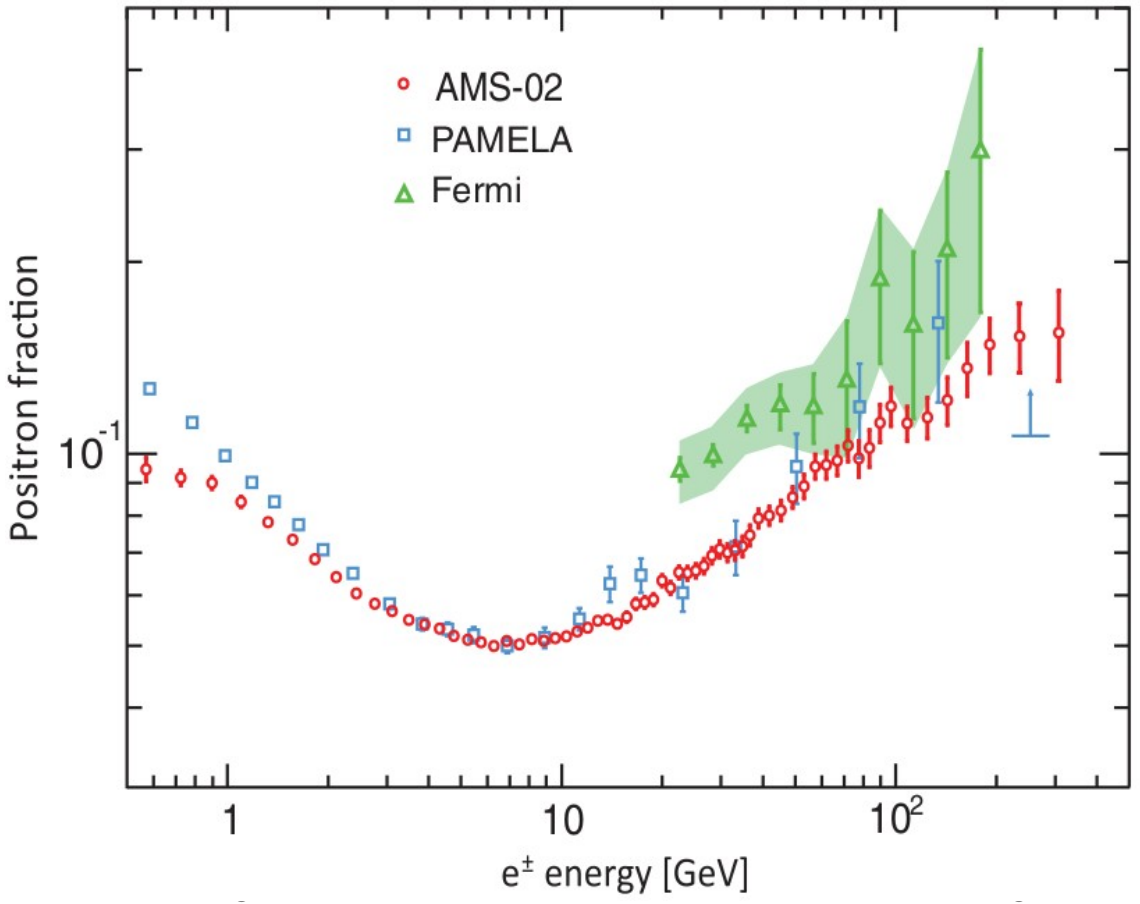


Process'



Cosmic-rays
Gamma-rays
Neutrinos

Searches in CRs: AMS' positron fraction



Transport equation

$$\frac{\partial \psi}{\partial t} + \nabla \cdot \left(-K_0 \epsilon^{\delta} \nabla \psi + \mathbf{V}_c \psi \right) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\rm src}$$

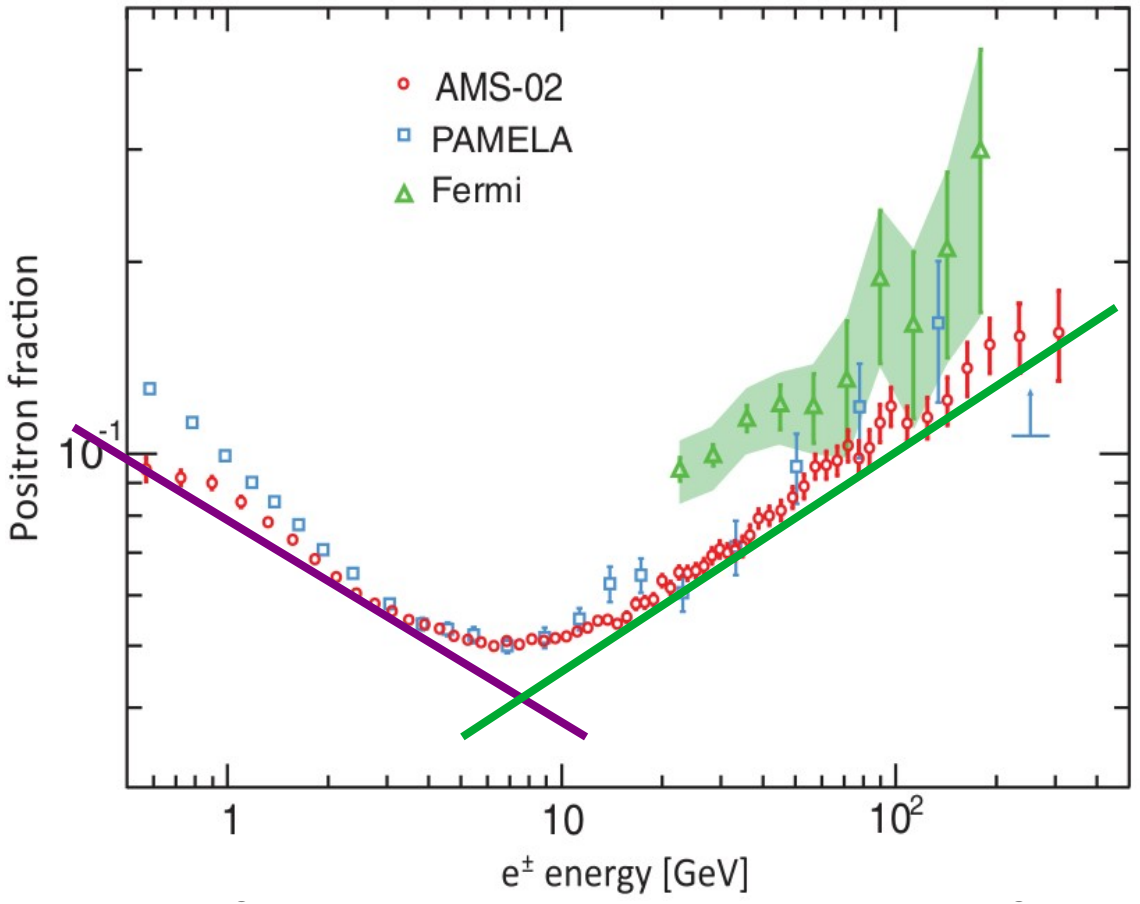
Sources

$$q_{e^\pm}(\mathbf{x}, E_e) = 4\pi \; n_{\rm ISM}(\mathbf{x}) \int dE_{\rm CR} \Phi_{\rm CR}\left(\mathbf{x}, E_{\rm CR}\right) \frac{d\sigma}{dE_e}(E_{\rm CR}, E_e)$$

$$\mathcal{Q}(E) = \mathcal{Q}_0 \epsilon^{-\gamma} \exp\left\{ -\frac{E}{E_c} \right\}$$

$$Q(x, E) = \langle \sigma v \rangle \left(\frac{\rho}{m_\chi} \right)^2 \frac{dn}{dE}(E)$$

Searches in CRs: AMS' positron fraction



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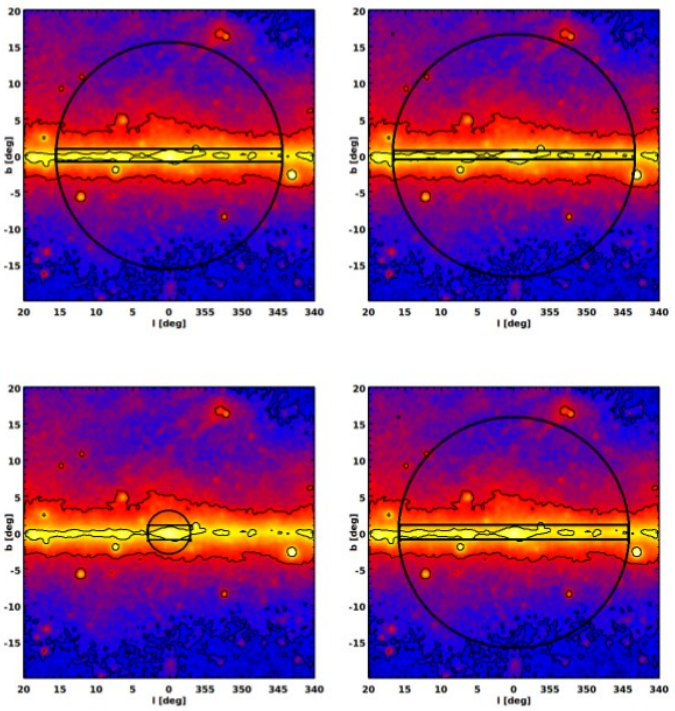
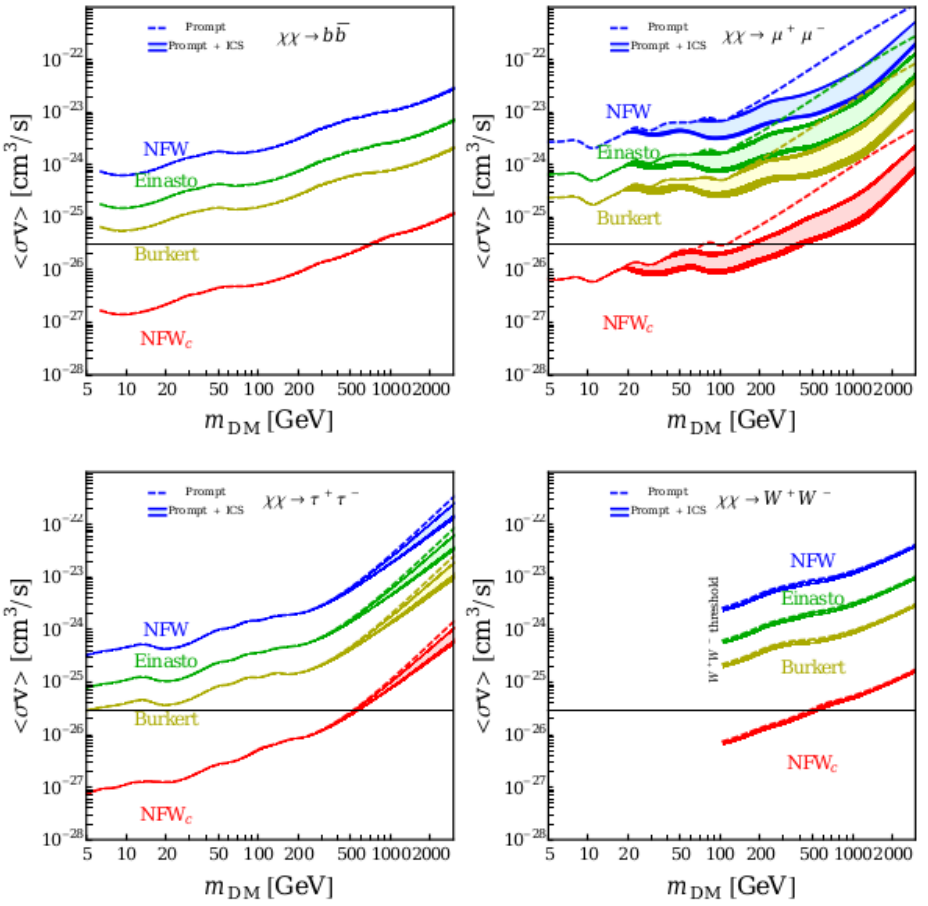
Searches in gamma rays

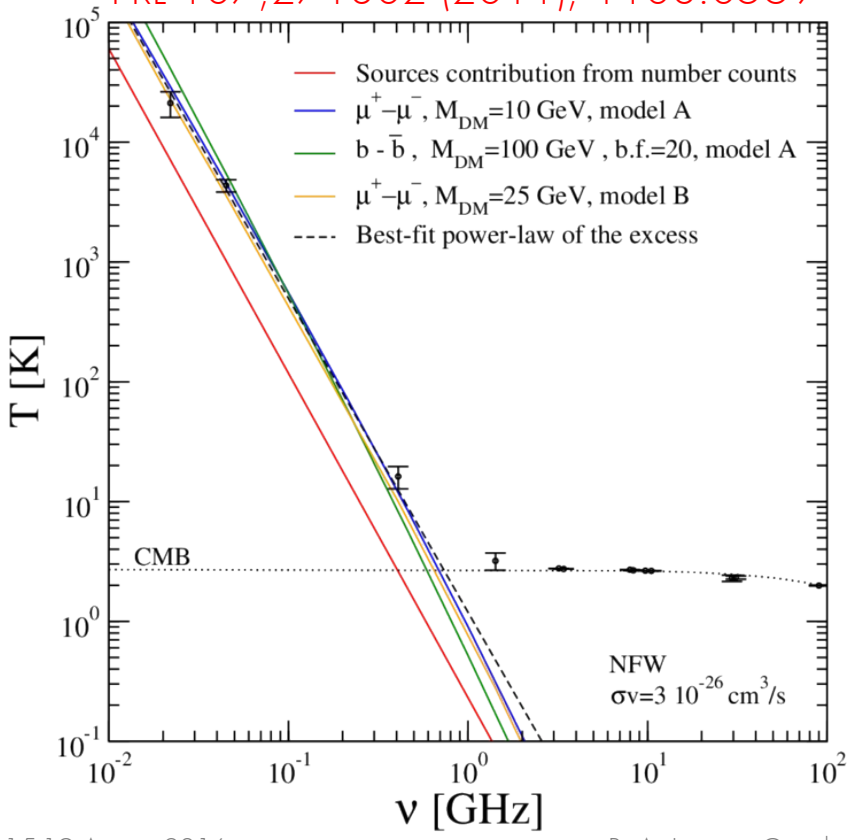




G. Gómez-Vargas et al.
JCAP10(2013)029. arXiv:1308.3515

Searches in Radio: ARCADE 2 anomaly

PRL 107,271302 (2011), 1108.0569



DM can provide the missing signal

However, it is not unique

Alternative explanations

> Faint quasars
> Radio-quite AGNs
> Star forming galaxies
> Unresolved galactic sources(?)

More details:
Gervasi et al. 0803.4138
Singal et al. 0909.1997

Final words

Dark Matter and **Astroparticles** is a fast growing research area

DM searches need a strong feedback between astrophysicists and particle physicists

Chile is entering to DM quest thanks future observatories and underground labs


Thanks!