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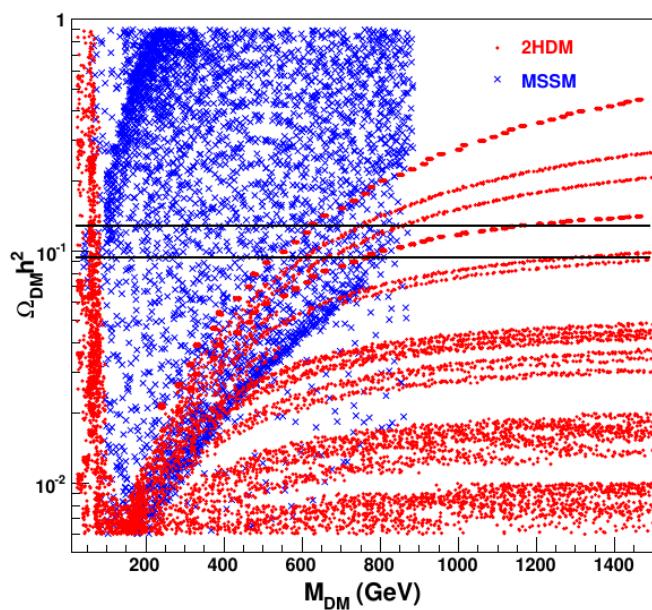
*1<sup>st</sup> IPhU Dark Matter day  
26 november 2021, CPPM*



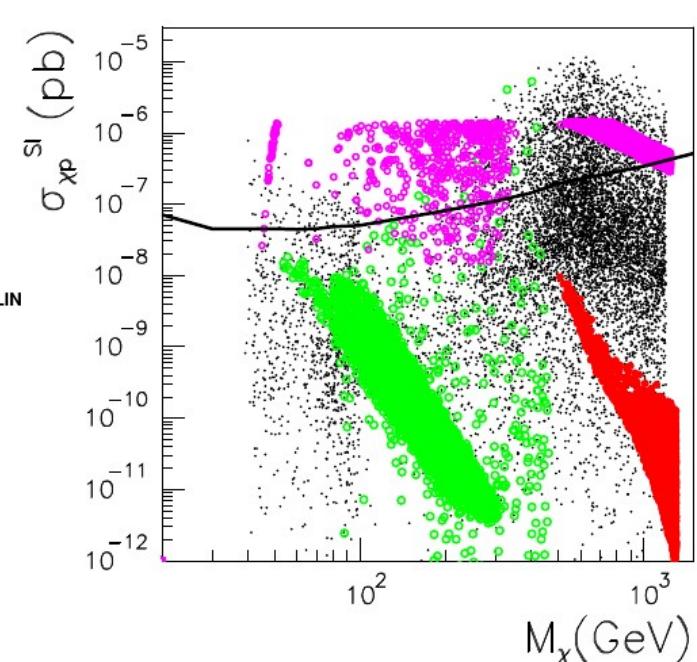
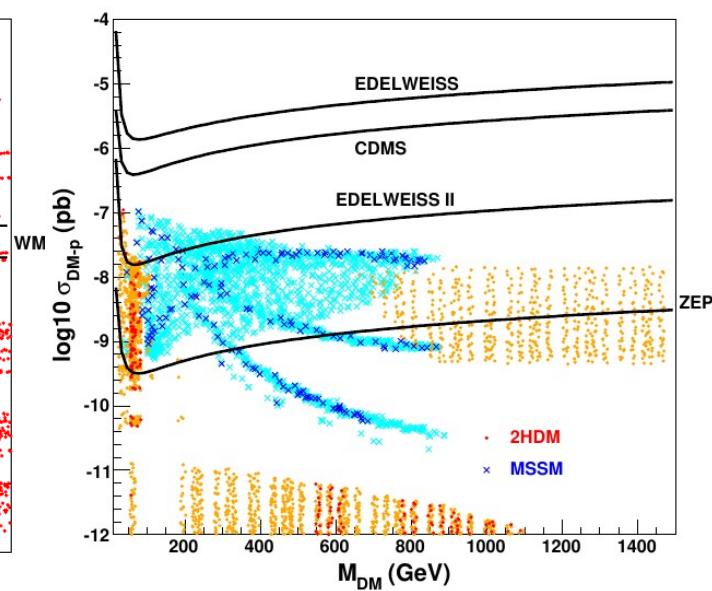
## High Energy Physics – Beyond the Standard Model :

- DM WIMP candidates: SUSY models (GUT, string inspired), Inert Doublet model, Right-handed Neutrino, Xtradim ...
- cosmological abundance
- Dark matter direct and indirect detection (neutrino, gamma, CR).

MUED, LHM, RHNM, IDM



arXiv:hep-ph/0612275



arXiv:0810.1362

*Astrophysical hypothesis of those studies ? NFW profile, Maxwellian velocity distribution*

## *Astro-Cosmo*

*Dark matter distribution features ?*

*Clumps-substructures:*

*Mas spectrum*

*Concentration*

*Spatial distribution*

*Streams*

*Phase space :*

*Maxwellian velocity distribution ?*

*Density profile:*

*Cusp/core*

*Baryons ?*

*Compression ?*

*Stellar formation/feedback*

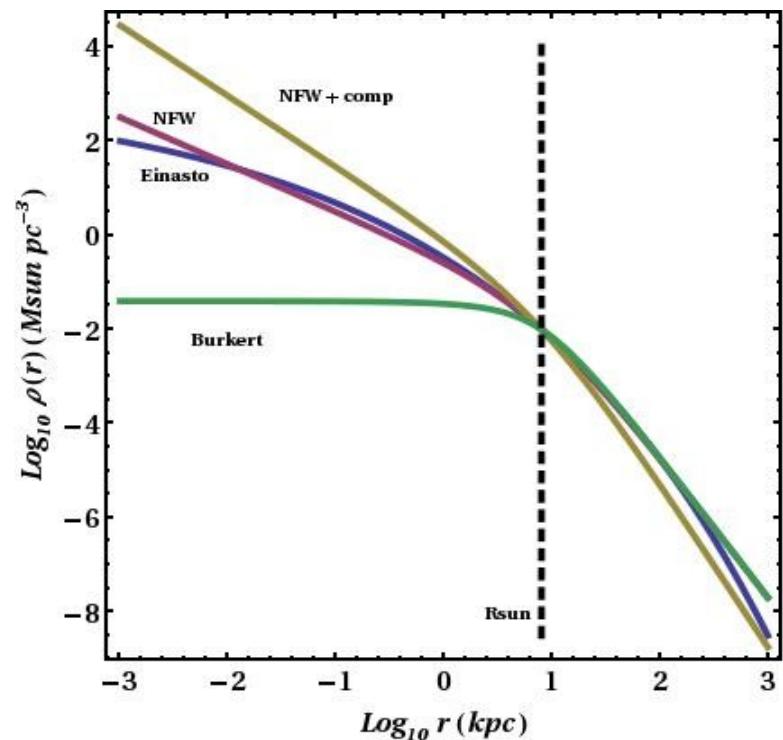
*Steepening-Flattening ?*

## Astro-Cosmo

- *Dark matter density profiles*
- *Adiabatic compression*
- *Geometry: triaxial halo*

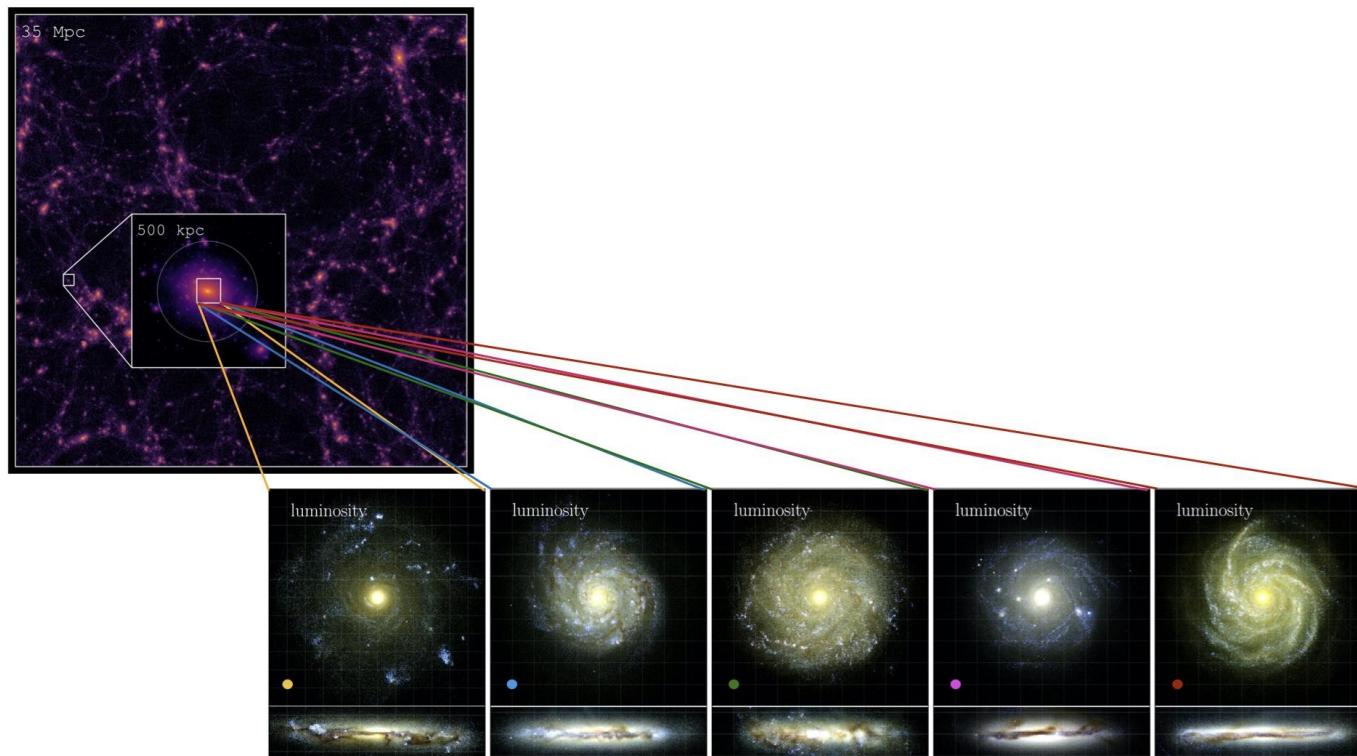
arXiv:astro-ph/0504631

arXiv:hep-ph/0506204



## Astro-Cosmo

- *Dark matter density profiles*
- *Adiabatic compression*
- *Geometry: triaxial halo*
- *Cosmological simulations (Zoom-in)* arXiv:1405.4318  
arXiv:2004.06008



# Astro-Cosmo

- *Dark matter density profiles*
- *Adiabatic compression*
- *Geometry: triaxial halo*
- *Cosmological simulations (Zoom-in)*
- *Connecting cosmo simulations with astroparticles and dark matter detection*

*Indirect detection*

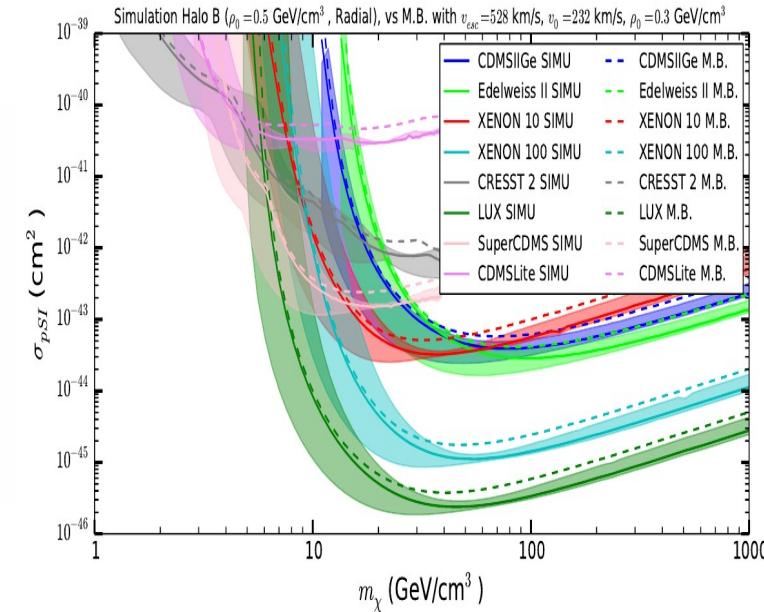
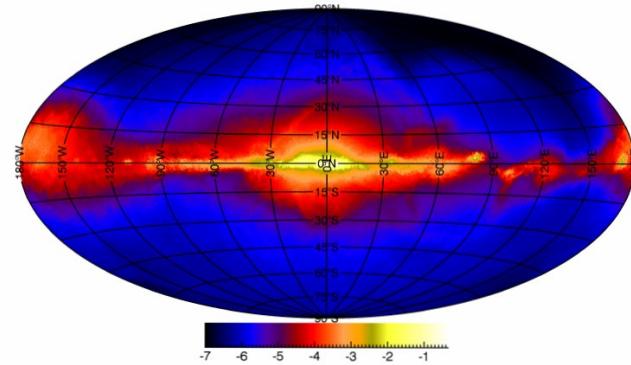
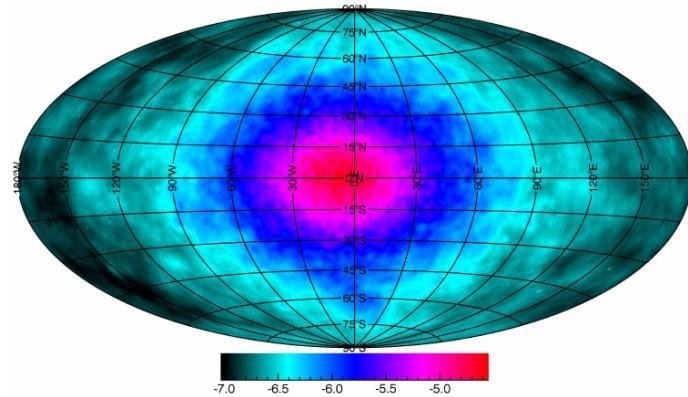
[arXiv:1204.4121](https://arxiv.org/abs/1204.4121)

[arXiv:0808.0332](https://arxiv.org/abs/0808.0332)

[arXiv:0801.4673](https://arxiv.org/abs/0801.4673)

*Direct detection*

[arXiv:0909.2028](https://arxiv.org/abs/0909.2028)



## Astro-Cosmo

- *Dark matter density profiles*
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*Indirect detection*

*direct detection*

- *Phase space distribution beyond the Maxwellian distribution of the Standard Halo Model*

*Direct detection*

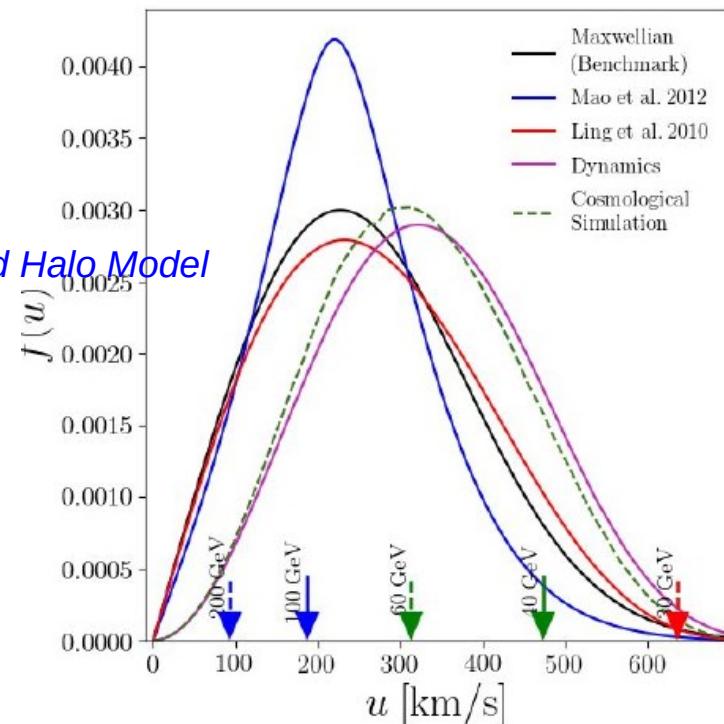
*Capture in the Sun*

*Comparison with dynamical models (Eddington inversion)*

arXiv:1906.11674

arXiv:2005.03955

arXiv:2106.01314



## Astro-Cosmo



- *Semi-analytic Dark Matter halo modelling*

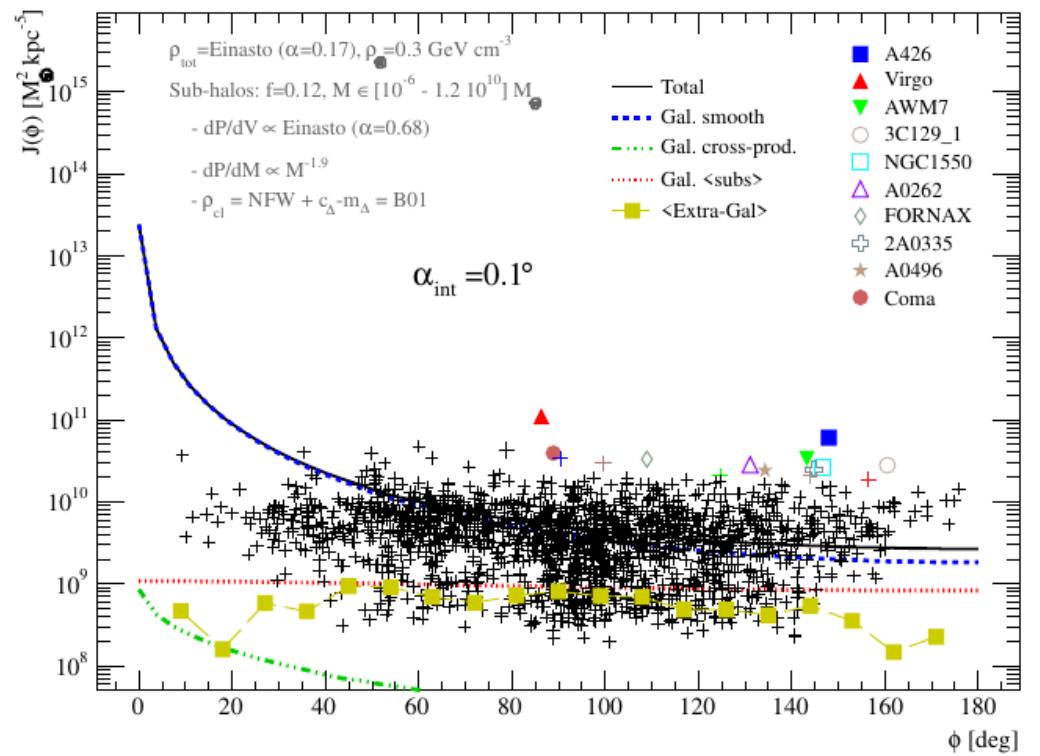
*CLUMPY package* arXiv:1506.07628

$$\frac{d^3N}{dVdMdc} = N_{\text{tot}} \frac{d\mathcal{P}_V}{dV}(r) \cdot \frac{d\mathcal{P}_M}{dM}(M) \cdot \frac{d\mathcal{P}_c}{dc}(M, c)$$

- *Dark matter at cluster scale and beyond*

- *Gamma emission of MCXC cluster catalog*

arXiv:1203.1165 arXiv:1203.1164



- *Minkowski Functionnals (Katarina Kraljic and Carlo Schimd @LAM)*

*PhD: G.Bonnet (2022)*

*DEUS simulation*

## *Collaboration in IPhU :*

- *Collaboration with ANTARES/KM3NeT (V.Bertin@CPPM)*  
*PhD : Ziad Charif (2012), Alexis Dumas (2014), A. Nunez-Castineyra (2019) OCEVU*  
*Postdoc: Guillaume Lambard*  
*Sun, Earth, Galactic Center, Dsphs*
- *Collaboration with direct detection group @CPPM (P.Barrillon, F.Hubaut, P.Pralavorio, I.Wingerter-Seez)  
DarkSide*  
*PhD: Marie Van Uffelen (2024). IphU*
- *Collaboration with L.Lellouch@CPT OCEVU,IPhU*  
*Lattice QCD → Quark content of nucleons*  
*Direct dark matter searches*  
*Capture in the Sun*



*Dark matter in a nutshell*

- *Cold Dark Matter works well in cosmology, CMB, structure formation*

*WIMPs, WDM, SIDM Fuzzy DM, FIMPs ...*

*PBHS*

*MOND*

*Early universe mechanism production : freeze-out, freeze in ... ? PBHs ?*

*Nature of DM, smallest scales ?*

- *Dark Matter in galaxies :*

*Success Rotation curves*

*Issues: Rotation curves – core/cusp – diversity (driven by surface density of the baryons)*

*Satellites – To-big-to-fail – phase space correlation (plane)*

*Bar, Bulge/stellar halo*

*Among solutions :*

*Baryonic physics in cosmological simulations ? Star formation, Feedback (SN,AGN ..)*

*More complex dark matter at least at small/galactic scales ?*

## Solving the $S_8$ tension alone

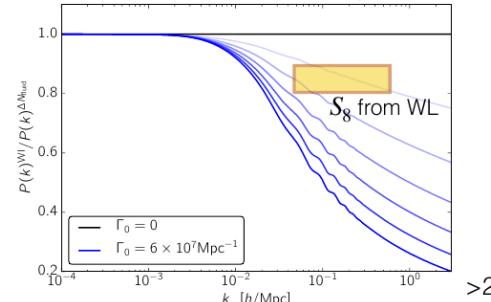
Works well:

- Many Modified Gravity (MG) models (e.g.  $f(R)$ )
- Feebly interacting DM (with relativistic particles: photons or DR; collisional damping) (Buen-Abad et al. 1708.09406; Becker et al. 2010.04074)
- Cold + Warm DM (small fraction of  $\sim$ keV DM) (Boyarsky et al. 0812.0010)
- Long-lived CDM decaying into massless + massive but lighter particle; possible connection with Xenon-1T (Abellan et al. 2008.09615)
- Cannibal DM (inelastic scattering  $3 \rightarrow 2$  causing slow transition from radiation-like to matter-like (Heimersheim et al. 2008.08486)
- Connection with small-scale CDM crisis...
- Testable with Lyman- $\alpha$  (should avoid exponential cut-off)

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Cosmological tensions and Dark Matter - J. Lesgourges

: DM-related



Works better:

## Solving the $H_0$ tension alone

1. Increase  $N_{\text{eff}}$  after BBN and compensate with new ingredients in the Dark Sector
2. Get the same with a scalar field dominating just before recombination (Early Dark Energy)
3. Shift the time of recombination (variation of fundamental constants, inhomogeneous recombination from e.g. small-scale primordial magnetic fields)

## Solving both tensions?

Currently, no known and studied models convincingly solving both tensions!