Cosmological Simulations of spiral galaxies
Dark Matter detection aspects

Indirect Dark Matter searches towards the sun with neutrinos

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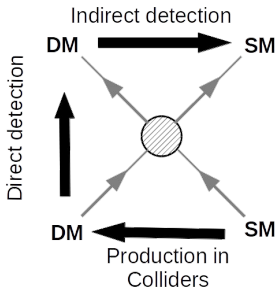
Uncertainties in Dark Matter distribution features

Standard Assumptions:

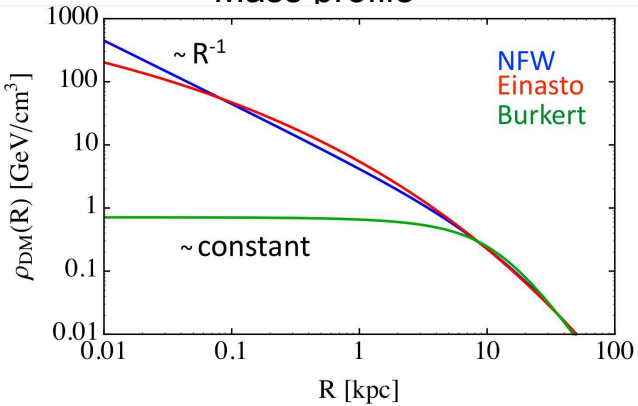
- Mass profile = NFW (DMO motivated)
- Phase space distribution = Maxwellian Distribution

(Solar neighbourhood)
- $\rho_{\odot}$~0.3Gev/cm^3
- v_{esc}~544 km/s
- v_c~220 km/s

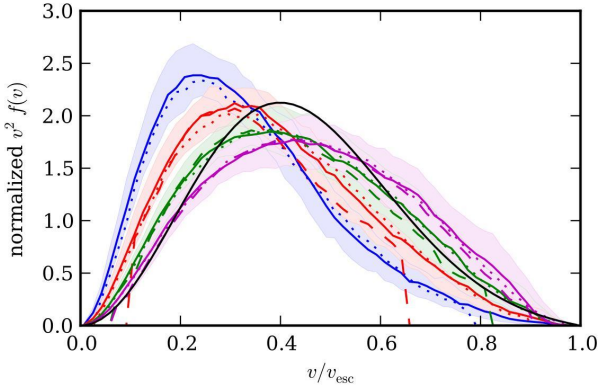


...Often used as input for dark matter detection limits and theoretical predictions but not really agreeing with galactic dynamics and/or cosmological simulations...

Mass profile



Phase space distribution



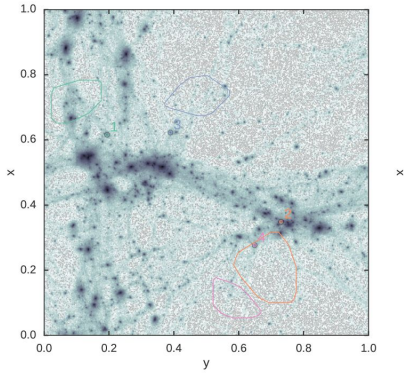
Mao et al.(arxiv:1210.2721)

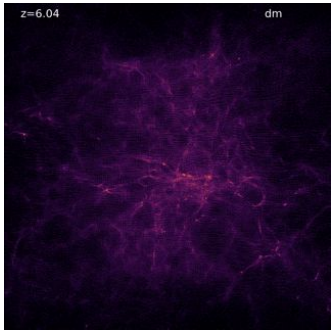
Simulations

1. **Gravity (Poisson-Vlasov equation)**
2. **Hydro or gas dynamics (Euler equations)**

Sub resolution physics

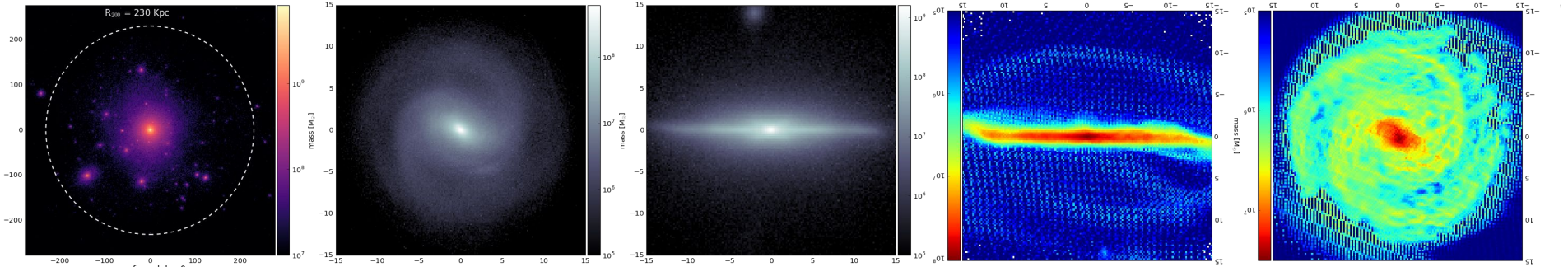
3. **Star formation physics** (State of the art SF-scheme)
4. **Turbulence**
5. **Feedback (SN, UV, AGN)**



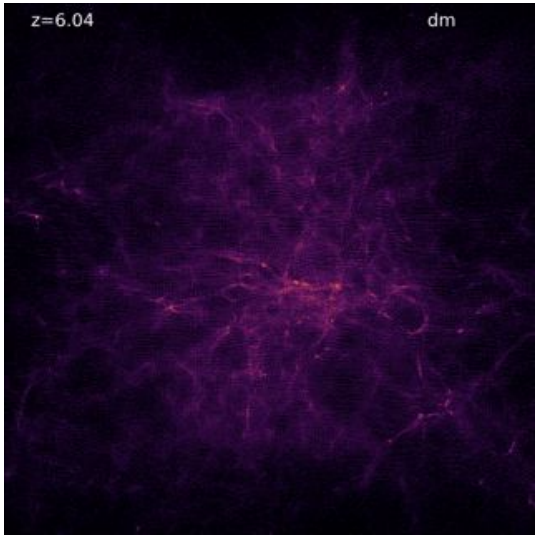


Numerical methods: Particle mesh method, Tree algorithms, parallelization, Adaptative mesh refinement, **Ramses Code**, Zoom-in Technique…

Núñez-Castiñeyra et al. in prep.

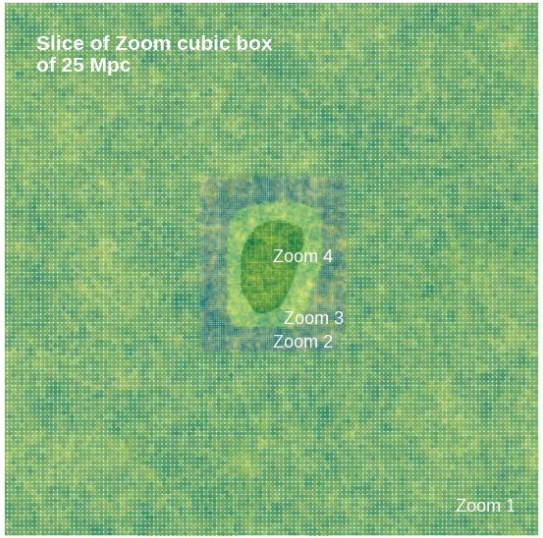


Cosmological Zoom-in hydrodynamical simulations



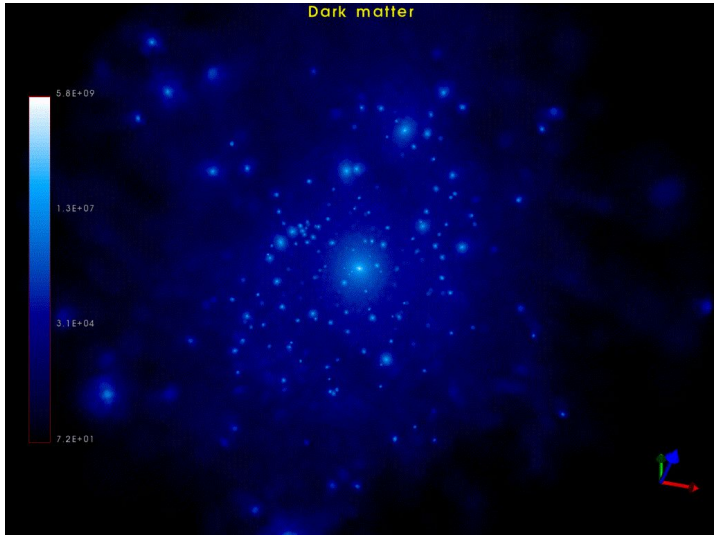
25 Mpc cube
DM Only
Unzoomed
cosmological simulation

(R. Teyssier 2002)

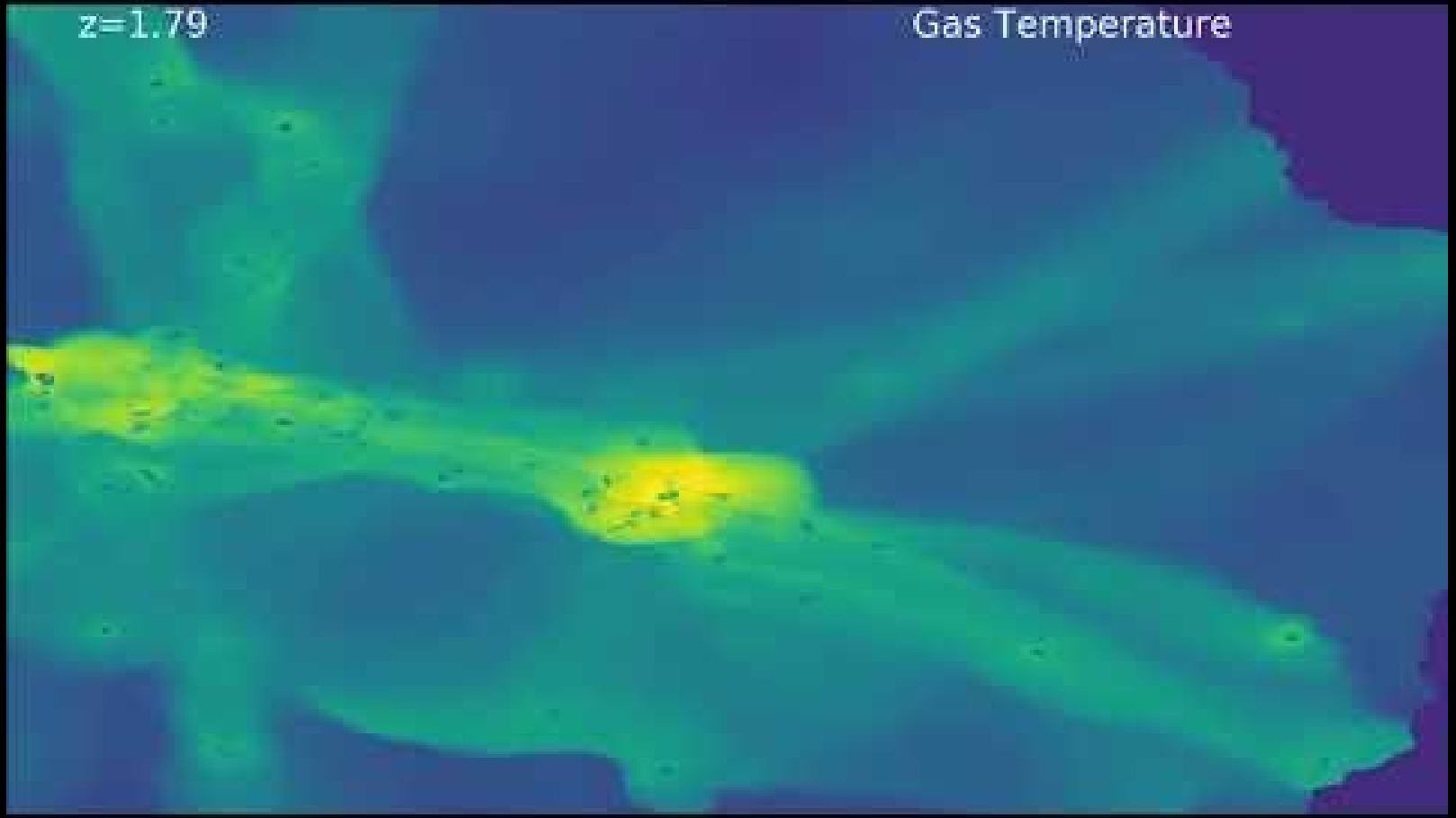


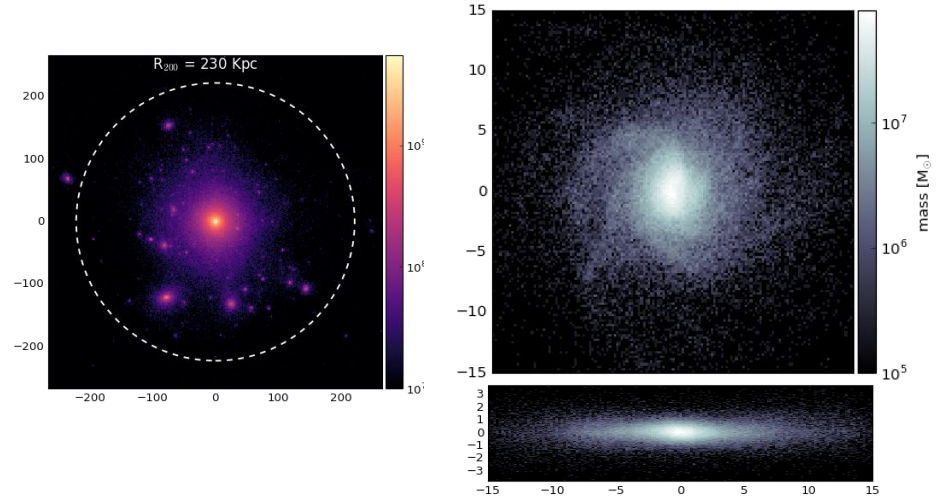
25 Mpc cube,
DM + Baryons
"Zoom in"
cosmological Initial conditions
MUSIC

(Hann & Abel 2011)



~ 200 kpc Rvir ,
DM + Baryons
Zoomed
Final halo and galaxy


z=1.79
Gas Temperature



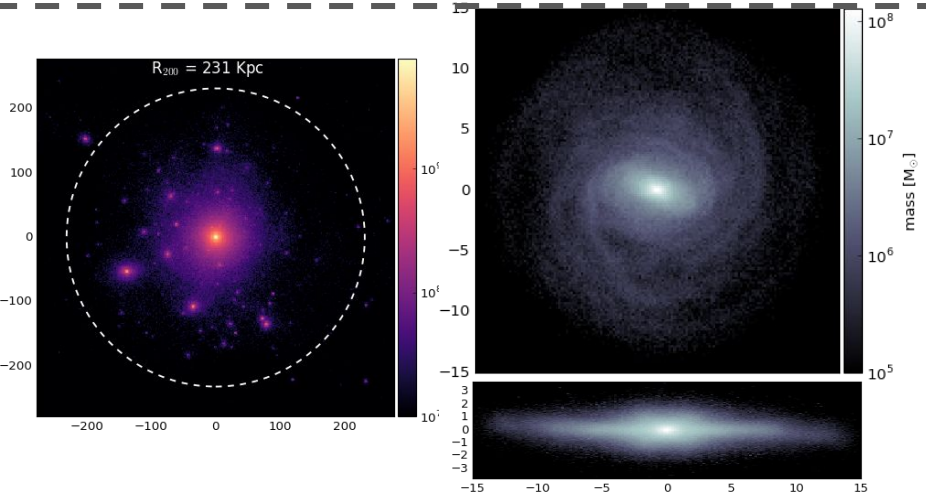
Probing star formation schemes

Classic star formation:

- Local gas density
- Gas temperature

based on observations constrains (the Schmidt law)

Two different star formation schemes



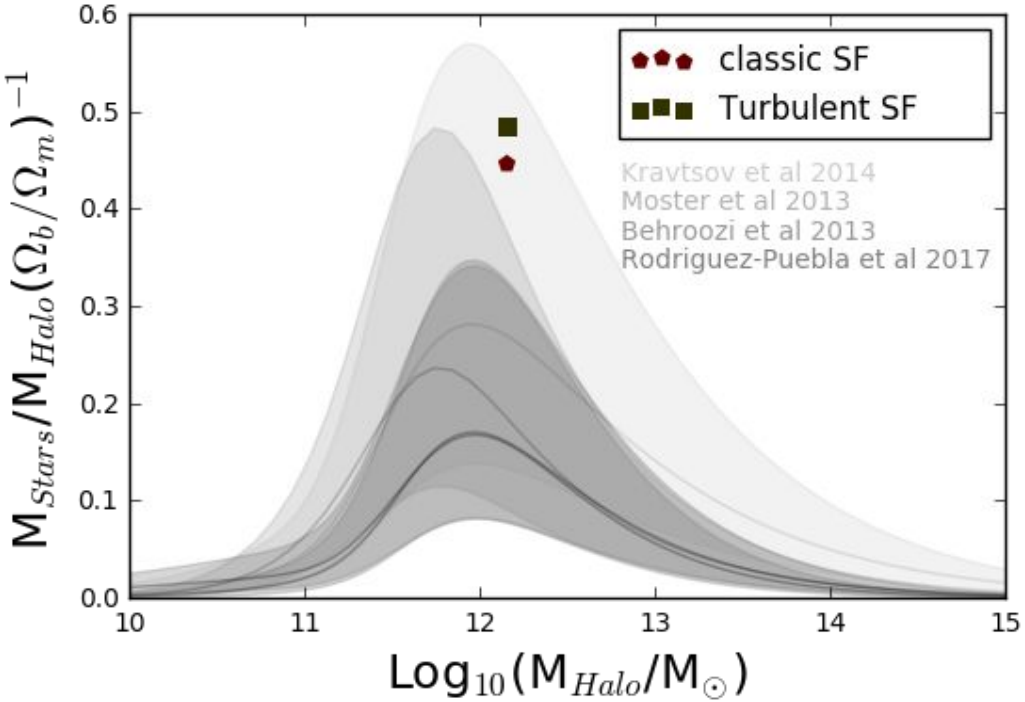
Turbulent star formation:

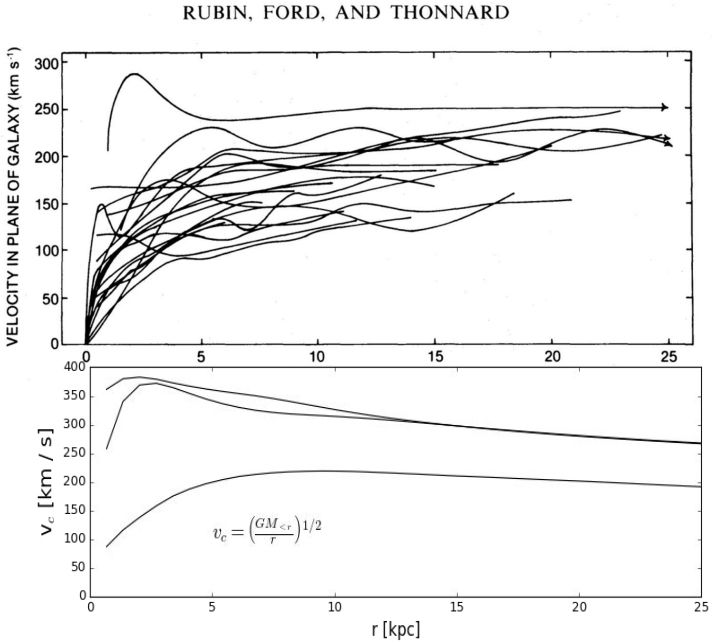
- Local gas density
- Gas Temperature
- Local gas turbulence

based on Federrath et al. 2010 work on turbulence in molecular clouds

Núñez-Castiñeyra et al. in prep.

Test SF against observations





High uncertainties in observations

Same M_* and M_{halo} do not imply same galaxy morphology.

Dark Matter profiles

Different SF ↔ different galaxy morphology↔ different DM profile

Compression, feedback ⟶ core/cusp

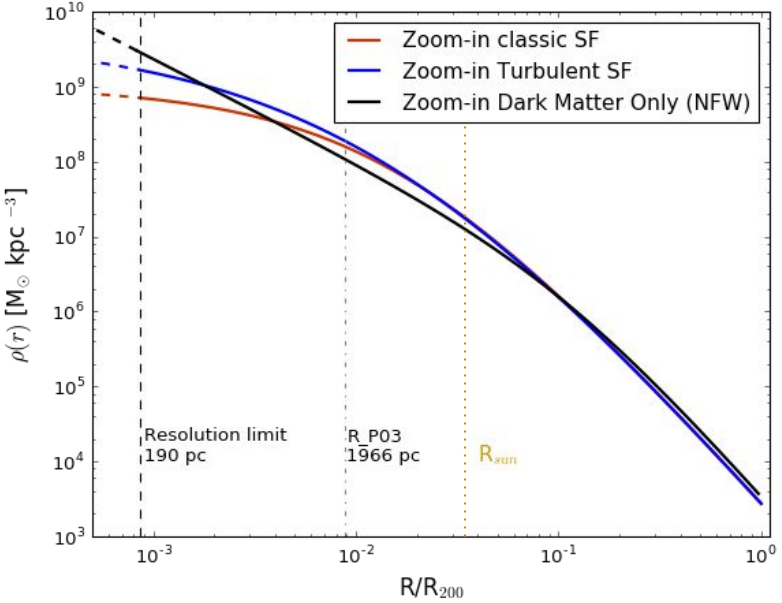
- Resulting Numerical galaxies will depend on hydrodynamics but specially on subgrid physics
- DM profile depend on subgrid physics (star formation, SN feedback)

No definite answers in SF scheme and SN feedback (hot topic in Galaxy evolution community) meaning no definitive answer on DM mass profile from simulations.

$$\rho(r) = \frac{\rho_0}{\left(\frac{r}{r_s}\right)^{\gamma}\left(1+\left(\frac{r}{r_s}\right)^{\alpha}\right)^{\frac{\beta-\gamma}{\alpha}}}$$

$$\Phi^{source}_{\gamma,\nu,\bar{p},(e^+)} \propto \rho^2_{DM}$$

Detection:
strong consequence on the flux.



Parameters Simulation	log(ρ) log($M_\odot$kpc^3)	r_s (kpc)	α	β	γ
DMO	6.56	24.9	1.0	3.0	1.0
Classic SF	8.93	3.42	0.8	3.1	0.03
Turbulent SF	9.51	2.85	0.6	3.1	0.06

Local Dark Matter

Phase space distribution

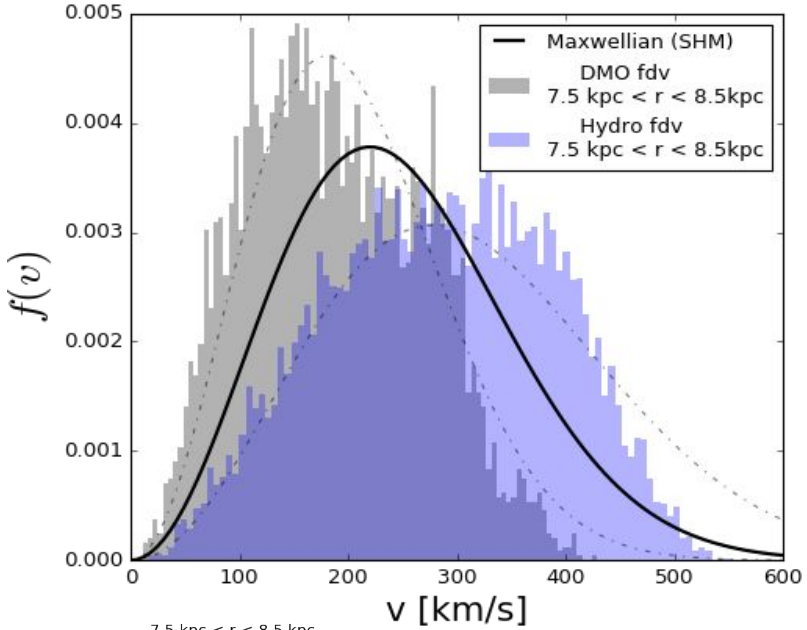
what is the shape of the f(v) in the solar neighbourhood

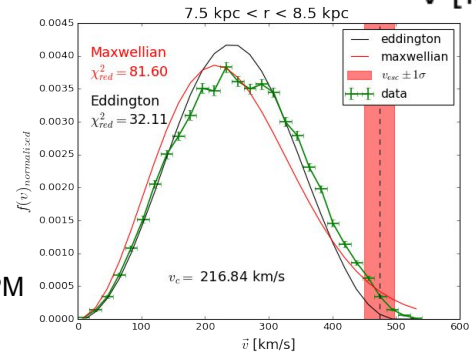
Solution of isothermal assumption for the DM halo

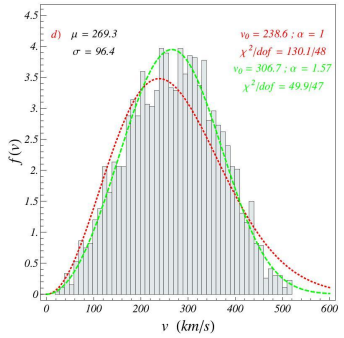
Test agreement with simulations (Mao, Tsallis distributions) and galactic dynamics (Eddington inversion)

Dark disc disfavoured by recent hydro simulations.

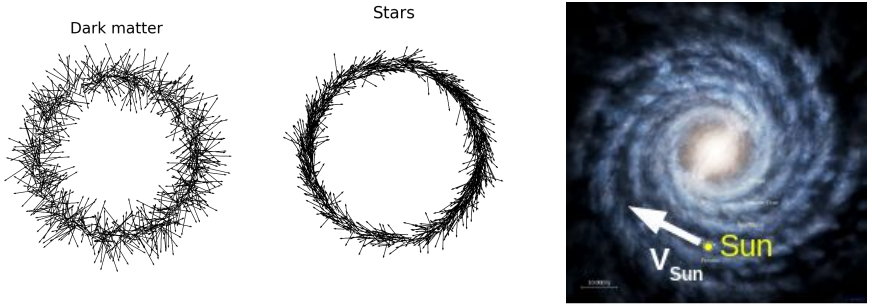
Work in progress for eddington inversion in collaboration with LUPM







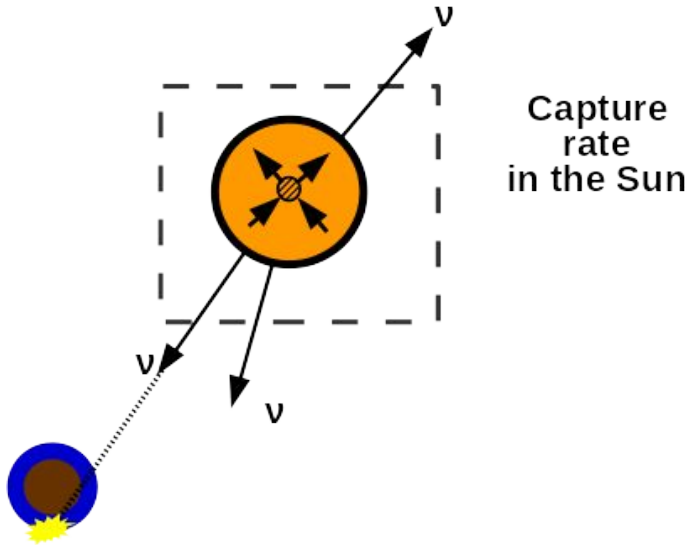
Application:
DM capture by the Sun



$$\frac{dC}{dV} = \frac{\rho}{M_\chi} \int_0^{u_m} du \frac{f(u)}{u} w\Omega(w)$$

Astrophysics and Particle Physics come together

(A. Gould 1987)
(Garani & Palomares-Ruiz 2017)



Application:
DM capture by the Sun

OBJ

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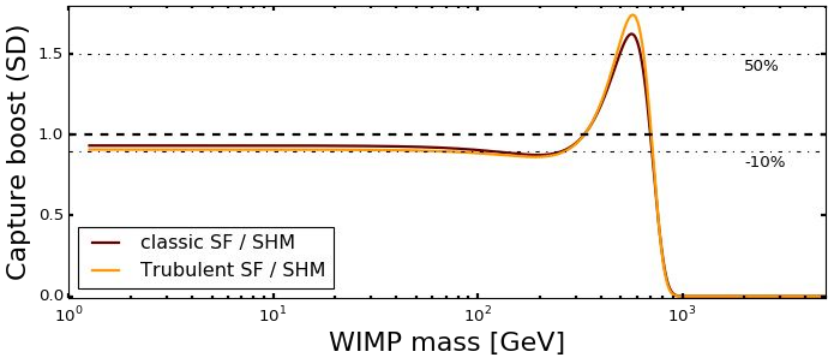
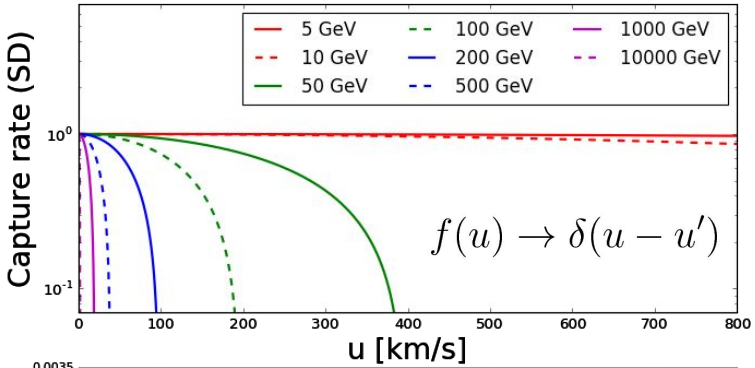
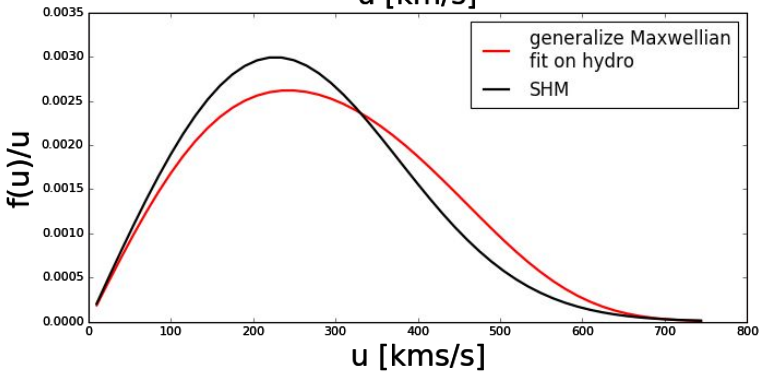
Astrophysics and Particle Physics come together







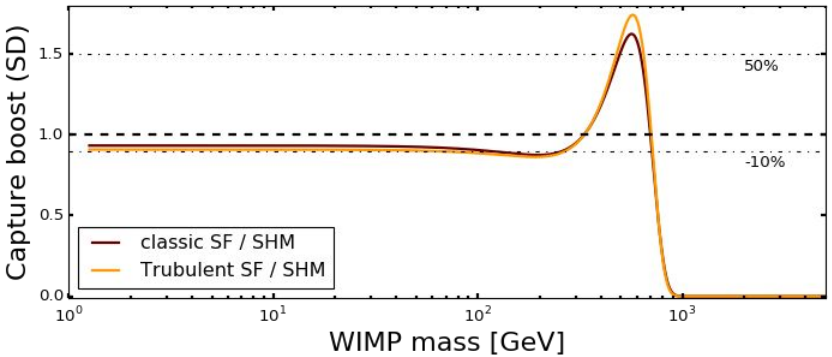
Capture in Sun: Low velocity part
Direct Detection: High velocity tail

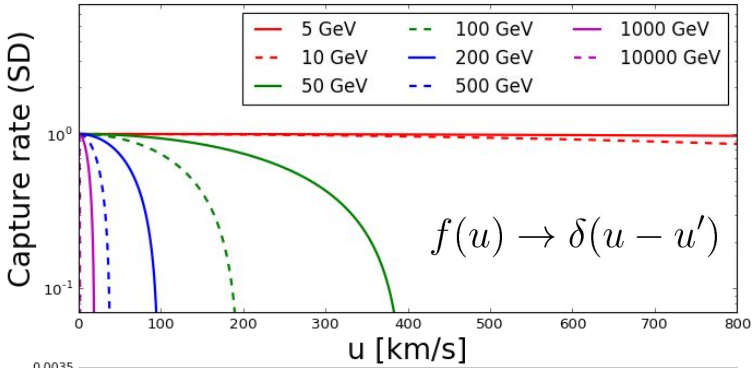
Application:
DM capture by the Sun

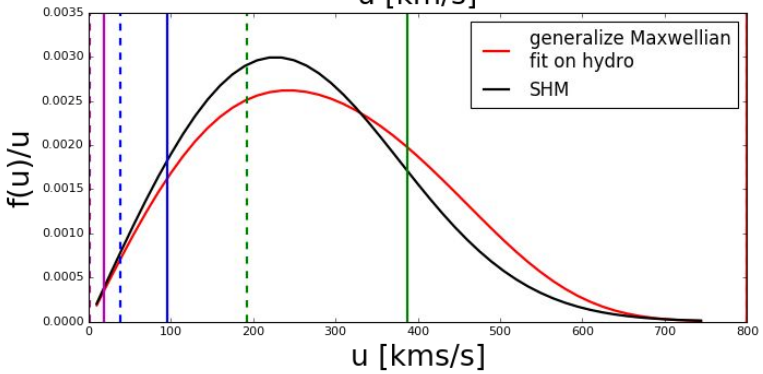
OBJ

$$\frac{dC}{dV} = \frac{\rho}{M_\chi} \int_0^{u_m} du \frac{f(u)}{u} w\Omega(w)$$

Astrophysics and Particle Physics come together







Capture in Sun: Low velocity part
Direct Detection: High velocity tail

Conclusions

- No definite answers in SF scheme and SN feedback (hot topic in Galaxy evolution community) meaning no definitive answer on DM mass profile from simulations.

- DM velocity distributions are influenced by Baryons-DM interactions and galactic morphology.
- 10% effect on DM capture by the sun with f(v) extracted from simulations. Similar effect is expected on DM Direct Detection.

Publications in prep.

Perspectives:

- Apply to ANTARES Sensitivity and Direct Detection
- Estimate gamma emissions from numerical galaxies (DM+background)

Thanks

Back up

Ramses (Adaptative Mesh Refinement)

Solve gas dynamics in eulerian way.