Warm Dark Matter Cosmological Structures
- from Collapse to Caustics and Cores -

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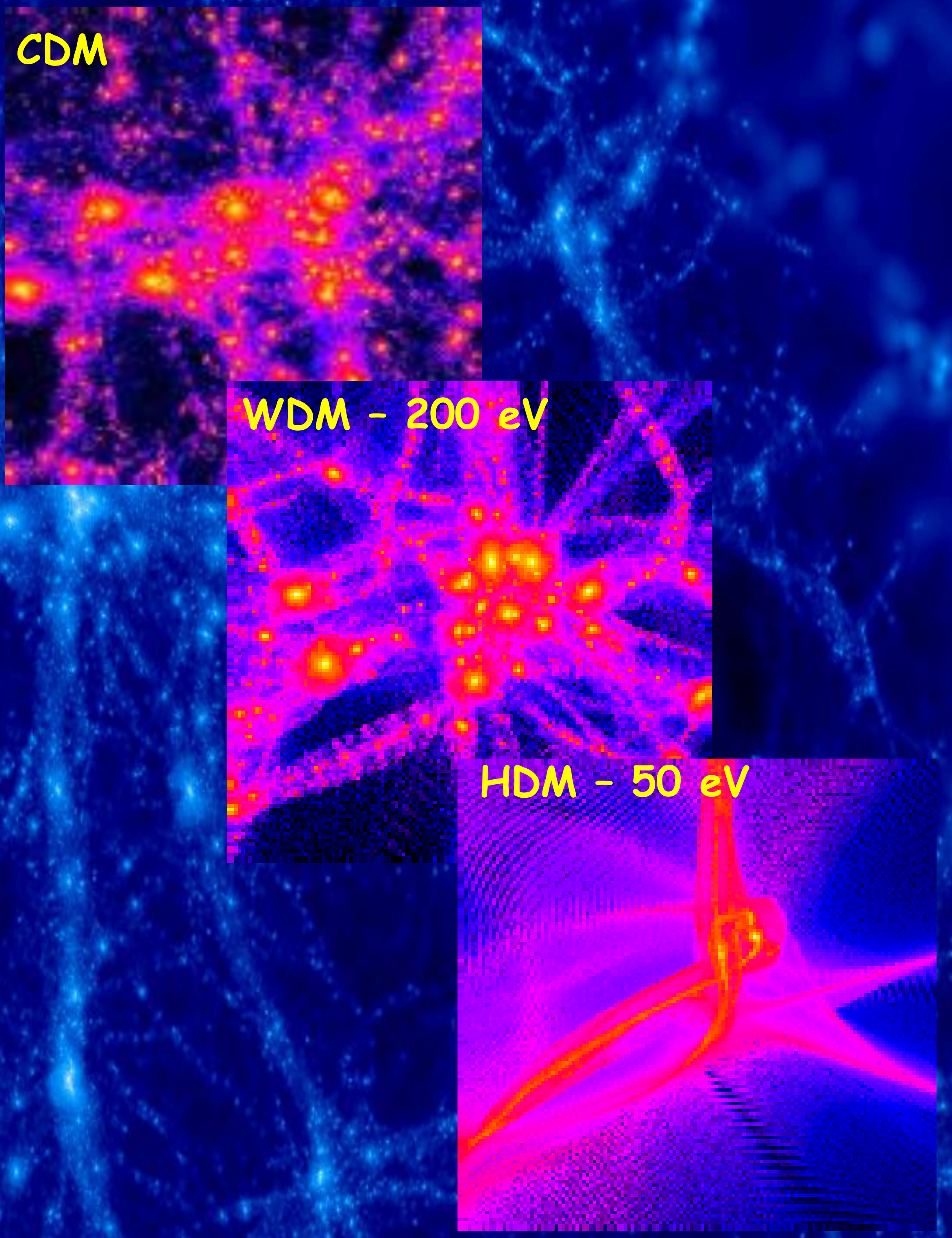
- Cold Dark Matter (CDM) has been successful in explaining many observations on cosmological scales. Still, the missing satellites problem, the cores vs. cusps debate, the high number of observed galaxies that do not suffer mergers, and the pure disk galaxies observed are but a few challenges of the model.
- KeV Warm Dark Matter (WDM) provides the best alternative to CDM since a candidate (e.g. sterile neutrino) may occur naturally within extensions of the standard model of particle physics.
- WDM particles have a non-negligible velocity dispersion, which, along with the free-streaming of particles, dampens the small scale fluctuation spectrum and sets a phase space limit to cosmic structures.
- Since particles in WDM models have different intrinsic properties from the CDM particle candidates, the effect of these properties on structure formation and evolution is expected to be qualitatively different on both large and small scales, possibly explaining some discrepancies between observations and the predictions from CDM simulations.
- To explore these effects, we have performed high resolution cosmological N-body simulation, focusing on a velocity regime where our resolution allows a reliable study.
- The relation between the velocity dispersion and the mass of the particle is strongly dependent on the model assumed for a certain particle (production mechanism, thermalization, etc.), hence the constraints on particle mass from simulation results are weak.

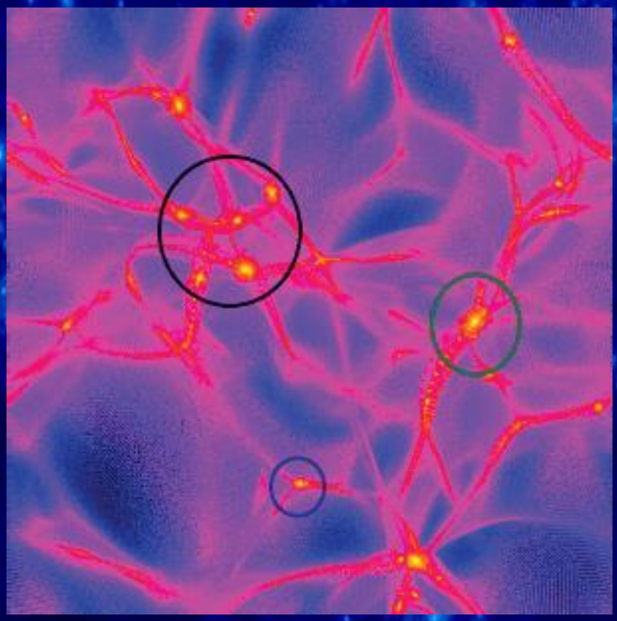


Mass	Bode et al.	Pierpaoli et al.	Paduroiu et al.	Boyarsky et al.	Boyarsky et al.
	$v_0 \times 3.571$			TR	NRP
keV/c^2	km/s	km/s	km/s	km/s	km/s
0.2	0.366	0.4032	1.113	0.29	0.785
1.0	0.0429	0.0225	0.223	0.034	0.157
3.5	0.00806	0.0230	0.0636	0.0064	0.00448

Correspondence between particle mass and rms velocity dispersion at redshift zero for different particle models.

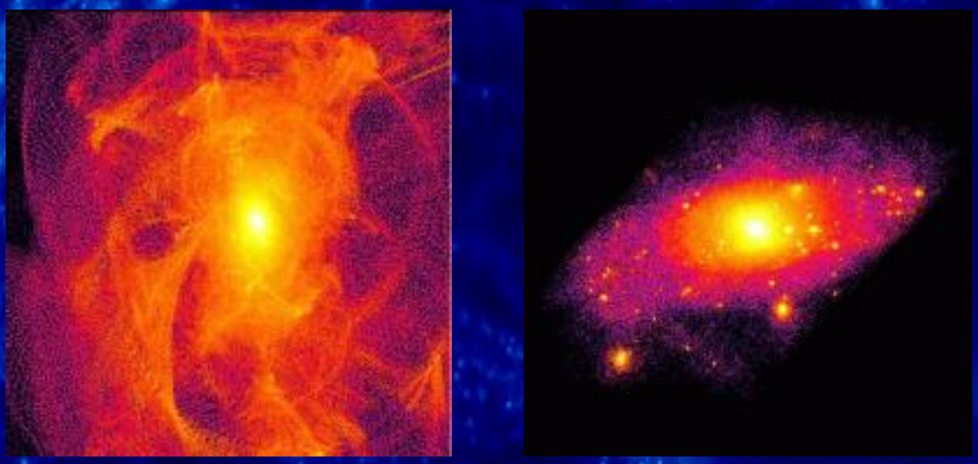
Structure Formation

- In the WDM case, the structure formation is more complex, a hybrid mechanism where both long-range and short-range effects are present, from long distance to nearest neighbours, from top-down to bottom-up.
- Big halos form 'top-down' at the intersection of large filaments and grow by accreting matter (green circle); small halos form 'top-down' and then merge into bigger ones (black circle); in low density regions small halos form later and do not suffer mergers (blue circle).
- The exact recipe for structure formation seems to depend only on the morphology and architecture of the environment.



Caustics and Shells

The internal structure of WDM halos differs from that of CDM halos. WDM halos contain caustics and shells much more visible than the CDM ones. A thin slice of a WDM halo formed 'top-down' is displayed on the left and a CDM one on the right.



Cores

The finite initial fine grained phase space density (PSD) represents a maximum of the coarse grained PSD, resulting in PSD profiles of WDM halos that are similar to CDM profiles in the outer regions, but turn over to a constant value towards the center, giving a constant density core. In order to explain the cores of order of several kpc observed in dwarf galaxies, one needs, however, a particle that is too light to form the galaxy in the first place – a Catch 22.
The quantum effects of warm dark matter particles and the baryonic processes may play an important role.

Structure formation HD movies available on youtube (simply search 'warm dark matter'): https://www.youtube.com/playlist?list=PLnGS4wkStJ1aqi3M9hTDaUzuZ-vs-Qg6i

References

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