Dark matter cosmological spectra and the beginnings of structure formation

A team of researchers from the Observatoire de Paris, Pierre and Marie Curie University and Milano-Biccoca University calculated for the first time the full spectra of the cosmological fluctuations for the different types of dark matter and obtained their explicit mathematical formulas in terms of the mass the dark matter particle and other fundamental cosmological parameters. These spectra provide the initial data for the formation of structure in the universe, they can trace the physical and cosmological parameters in the different schemes and evolution (linear and nonlinear) of the cosmic structures and galaxies. These theoretical results are relevant to compare with observations of distant galaxies (at high redshift), and has implications for young star formation. They are recently published in the journal The Physical Review .

Context 81% of the matter in the universe is composed of dark matter : it is different from the ordinary visible matter formed by atoms , it is not visible and mainly manifests through the action of gravitation, it is an essential component of galaxies in particular of dwarf galaxies . As a result , dark matter and gravity play a decisive role in the formation and structure of galaxies, large and small structures. Candidates for dark matter are essentially of three types: (i) Cold, consisting of very heavy particles, very slow (their speed is almost zero), so they are almost frozen. (ii) Hot, formed by particles of very small mass with very high speeds close to the speed of light , but the cosmological observations of large scale structures and galaxies have shown from many years that hot dark matter alone is unable to form structures like galaxies and so it is not more considered. (iii) Warm, formed by particles with mass in the intermediate energy scales (thousand times the electron volt) with corresponding speeds producing structures in the galactic scales. For larger scales, warm dark matter yields the same results as cold dark matter and is consistent with the galactic and cosmological observations. As a consequence, warm dark matter reproduces the small and large scale structures and the observations of CMB (cosmic microwave background) anisotropies.

This work The evolution of the primordial fluctuations during the different periods of expansion of the universe leads to the formation of structures as observed today. The team succeeded to solve mathematically this evolution from the big bang to the present day and obtained for the first time the precise cosmological spectra for the warm dark matter, their properties, and their comparison with the cold dark matter. These spectra provide the initial data for the structure formation of the universe, they can trace the physical and cosmological parameters in different regimes of cosmic structures: the linear regime (when the fluctuations are small) and non- linear regime (when the structures are formed , and they give the following results :

(I) Non-linear structures of warm dark matter began to form later than in the case of cold dark matter, and it is clear that reducing the mass of the dark matter particle delays the onset of the non-linear regime, and thus the formation of structures.

(II) The non-linear regime of structure formation begins earlier for smaller objects than for large objects, so a scheme of hierarchical structure formation is also present for warm dark matter.

(III) The effect of removing small-scale substructure in warm dark matter compared to cold matter increases with the spectral red shift, and the structures formed with warm dark matter reproduce the observations at all scales : small , intermediate and large cosmological scales.

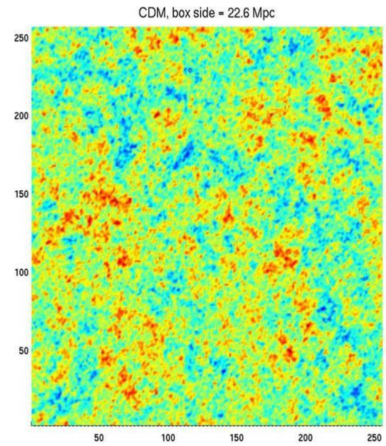

Fig.1: *Cold dark matter primordial fluctuations: They produce the observed large scale cosmic structures but they result in too many small structures that are not observed (this is the problem of cold dark matter overabundance of substructures or " satellites" cold dark matter problem) .*

Credit for all images : C. Destri , H.J. de Vega and N.G. Sanchez .

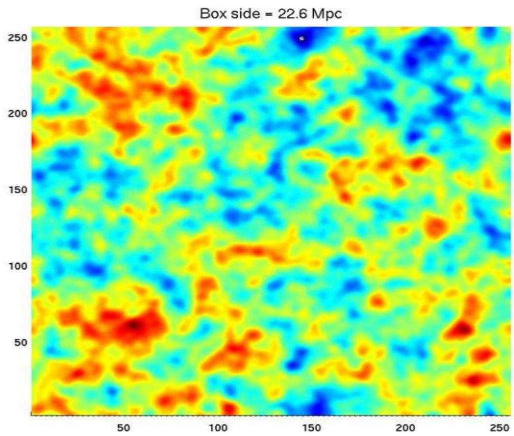

Fig. 2: *Warm dark matter primordial fluctuations: They produce the observed large structures and also the correct number of small structures that are erased with respect of those of the cold dark matter. The reason for this removal effect of small structures being in the mass (and speed) of the warm dark matter particles : they naturally produce characteristic lengths and masses in the scale of the galaxies and not in the* smaller scales .

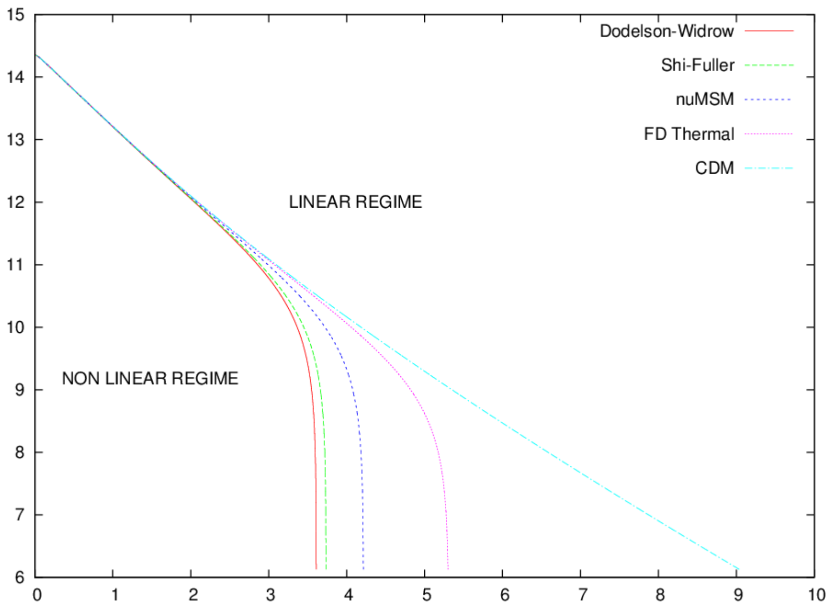

Fig. 3: Linear and nonlinear regimes for different types of warm dark matter; cold dark matter is shown by the light blue line. The diagram shows in vertical the logarithm of [0.7 M / Sun] , where M is the mass of galaxies, versus the redshifts z in the horizontal line . For large masses , cold and warm dark matter yield similar results. They differ most for the small structures and for z > 4 , hence the importance of observations to redshifts z > 4.

Implications of high current interest: These theoretical predictions are highly topical for comparison with observations of distant structures (large redshift), especially for galaxies at redshifts 4 < z <12 , and they have also implications for the formation of young stars: the action of warm dark matter on ordinary visible matter leads to the formation of filaments with stellar and proto -stellar cores through the process of fragmentation. Precisely, the results of recent observations of the Herschel satellite point to the formation of stars through filaments with such characteristics. In addition, by desintegration, warm dark matter can also stimulate the production of molecular hydrogen and accelerate the formation of stars at very high redshift , which is another interesting consequence of this cosmological work.

Reference:

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Warm dark matter primordial spectra and the onset of structure formation at redshift z
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