The failure of dark-matter cosmology

Towards a new paradigm of structure formation

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The dark-matter concordance cosmology model (CCM) makes strong predictions regarding structure formation in the Universe. Dwarf satellite galaxies (DSGs) in the vicinity of larger galaxies are considered to trace low-mass dark matter (DM) halos in the CCM, also because of the very high mass-to-light ratios implied by the dynamical masses of the DSGs. We test some predictions of the CCM with the DSGs in the Local Group and thereby uncover **five new problems for the CCM.** We also propose a **solution to these problems.**

First problem

Assuming that dark matter (DM) is cold, the CCM predicts many more DM substructures around the Milky Way (MW) than there are DSGs (the so-called missing satellite problem). In order to solve this problem, simulations of structure formation have recently included the impact of stars on the gas in DM halos. Star formation may turn most low-mass DM halos dark by expelling their gas and thereby inhibiting further star formation in them. It can be tested whether the dynamical masses of the DSGs of the MW are consistent with being drawn from the mass function of sub-halos that are still luminous according to the CCM. This is not the case, as is illustrated in Fig. 1.

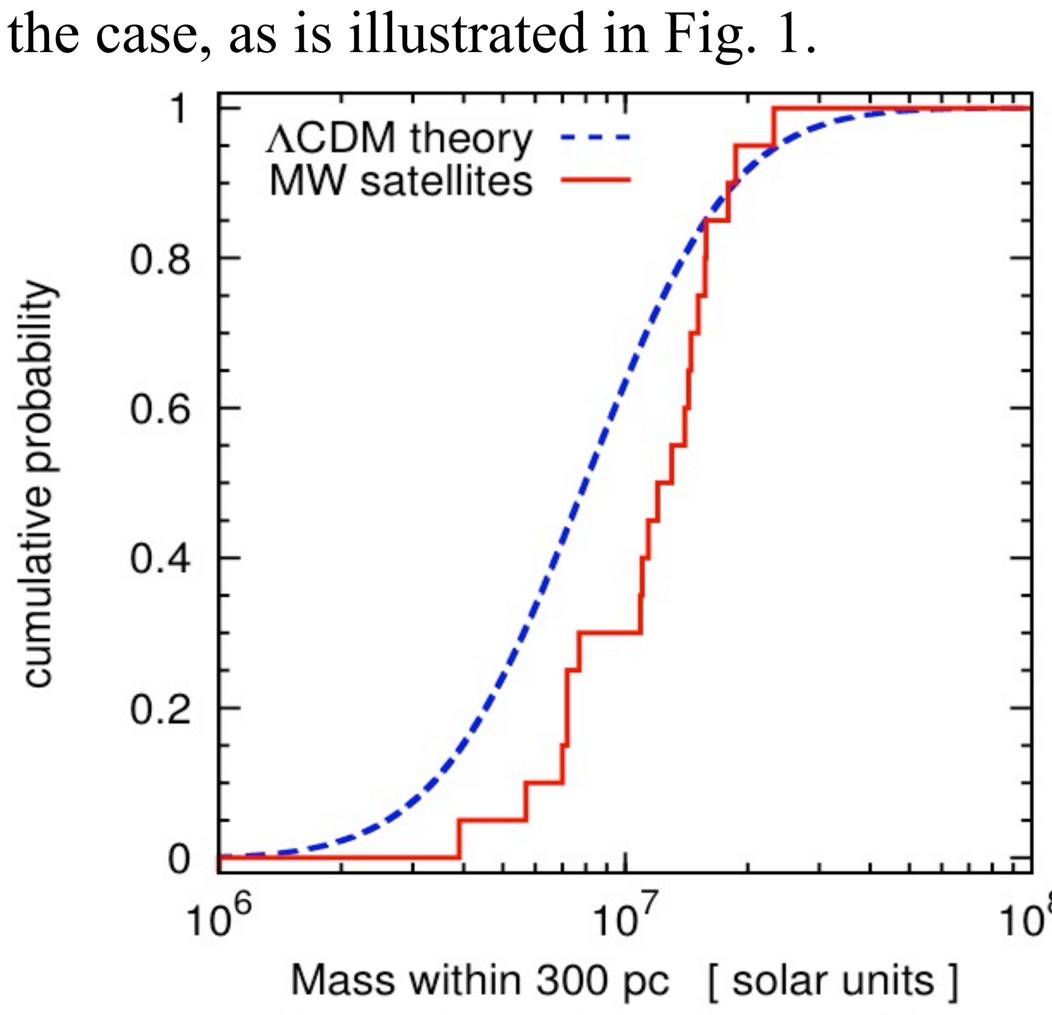

Figure 1: Illustration of the first problem

Second problem

For the simulated DM halos that *do* keep gas, the CCM predicts that the more massive DM halos tend to keep more gas and are thus brighter. Assuming $M \propto L^{\kappa}$, i.e. that the mass of a halo depends on its luminosity to some power, the strength of this relation can be quantified by searching for the best-fitting exponent κ. Various independent, *theoretical* results for κ are shown as dots in Fig. 2. However, observations imply $\kappa = 0$, i.e. that the mass of the DSGs does *not* depend on their luminosity. Thus, *all* theoretical results shown in Fig 2 deviate by at least 3 σ from the observed result, indicated by the shaded area.

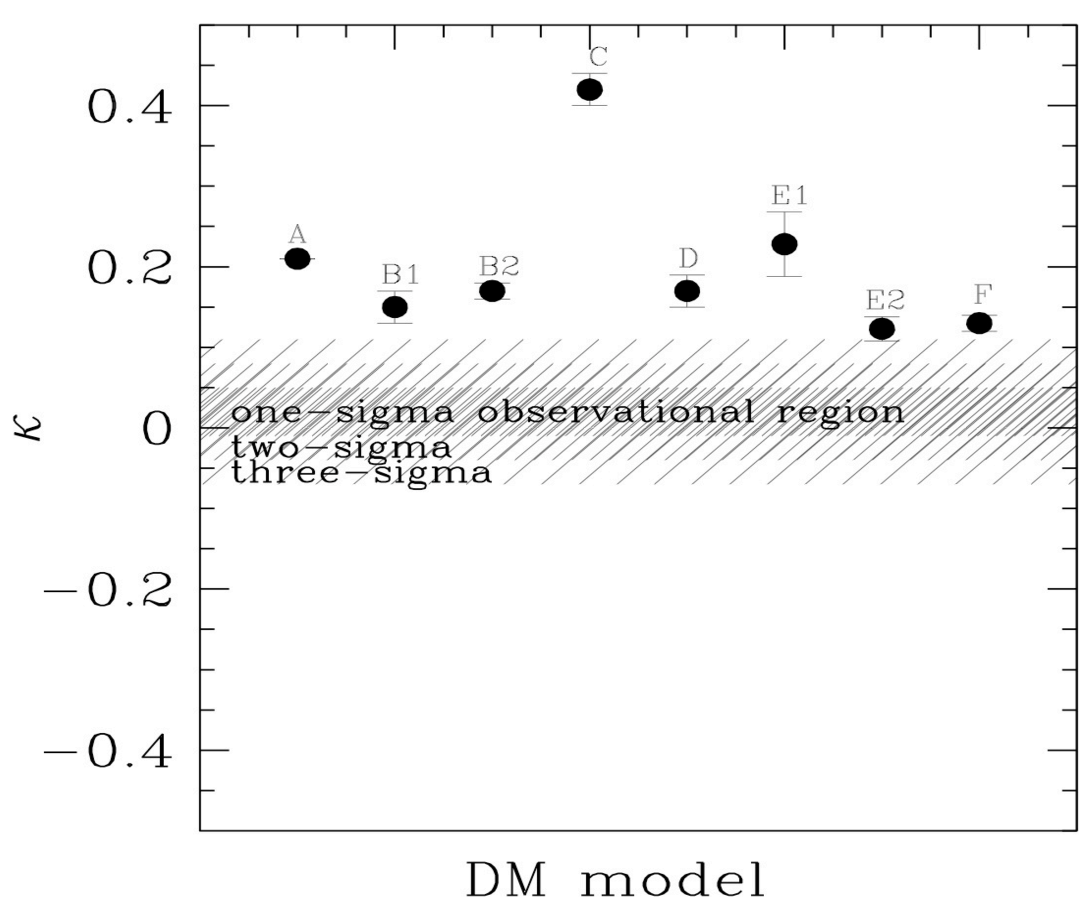

Figure 2: Illustration of the second problem

Third problem

Sub-halos in the CCM are less massive than their host host halo by orders of magnitude and they are located at rather large distances from the dominant galaxy at the centre of the host halo. The sub-halos can therefore hardly have any influence on the internal structure of the dominant galaxy. Nevertheless, there apparently is a correlation between the bulge-mass (i.e. a property of the host galaxy) and the number of satellite galaxies surrounding it (i.e. DM sub-halos according to the CCM). This is illustrated in Fig. 3.

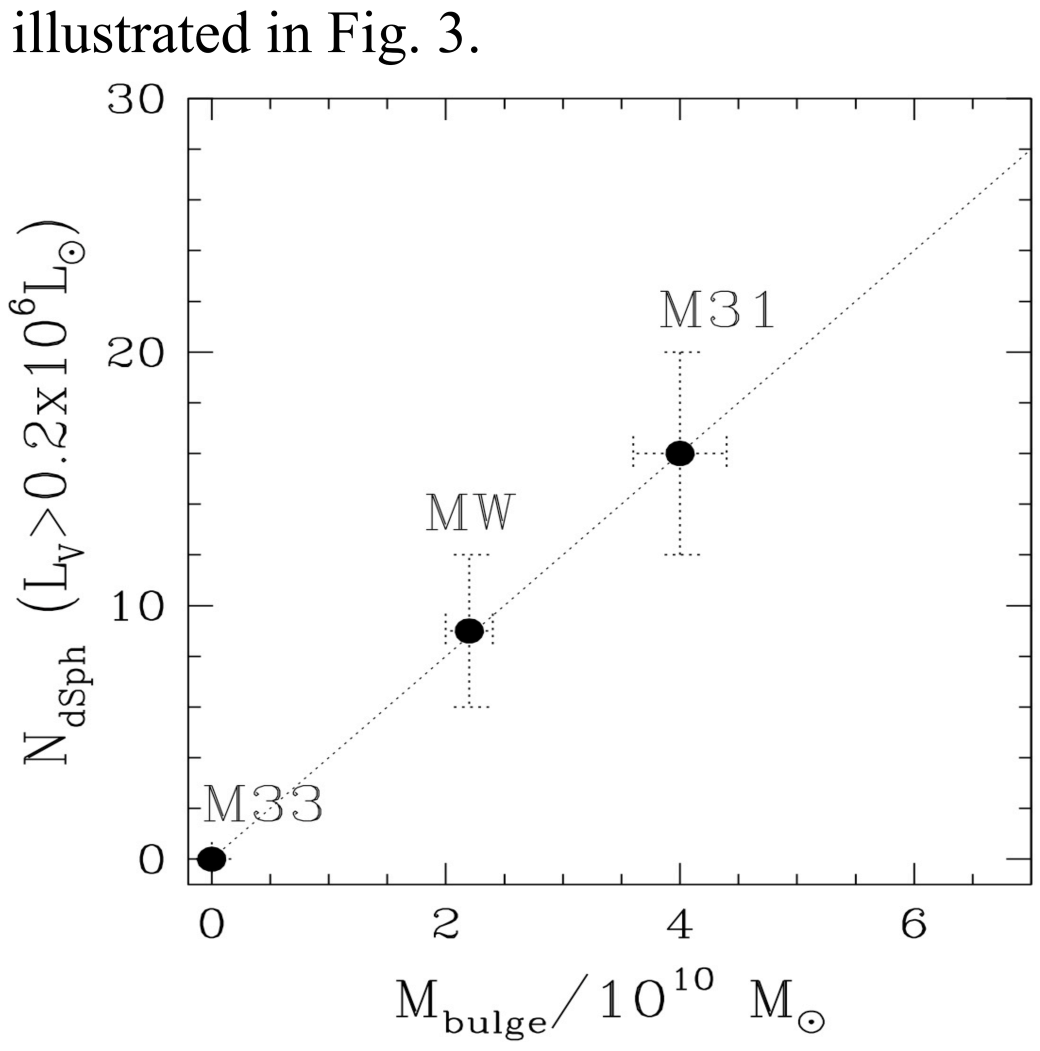

Figure 3: Illustration of the third problem

Fourth problem

The CCM predicts a spherical distribution of DM sub-halos within their host halo, since infalling small halos would come from every direction. It is well established, however, that the 11 brightest DSGs of the MW are distributed such that they define a disk, which in itself already poses a challenge to the CCM. In the past years, 13 additional faint DSGs have been discovered. We have shown that these 13 newly discovered DSGs define essentially the same disk as the 11 brighter DSGs. This is shown in Fig. 4. Seen from the proper angle, almost all DSGs are within the disk defined by the dashed lines. In contrast, about half of the DSGs lie outside a disk of equal thickness if the viewing angle is changed by 90 degrees.

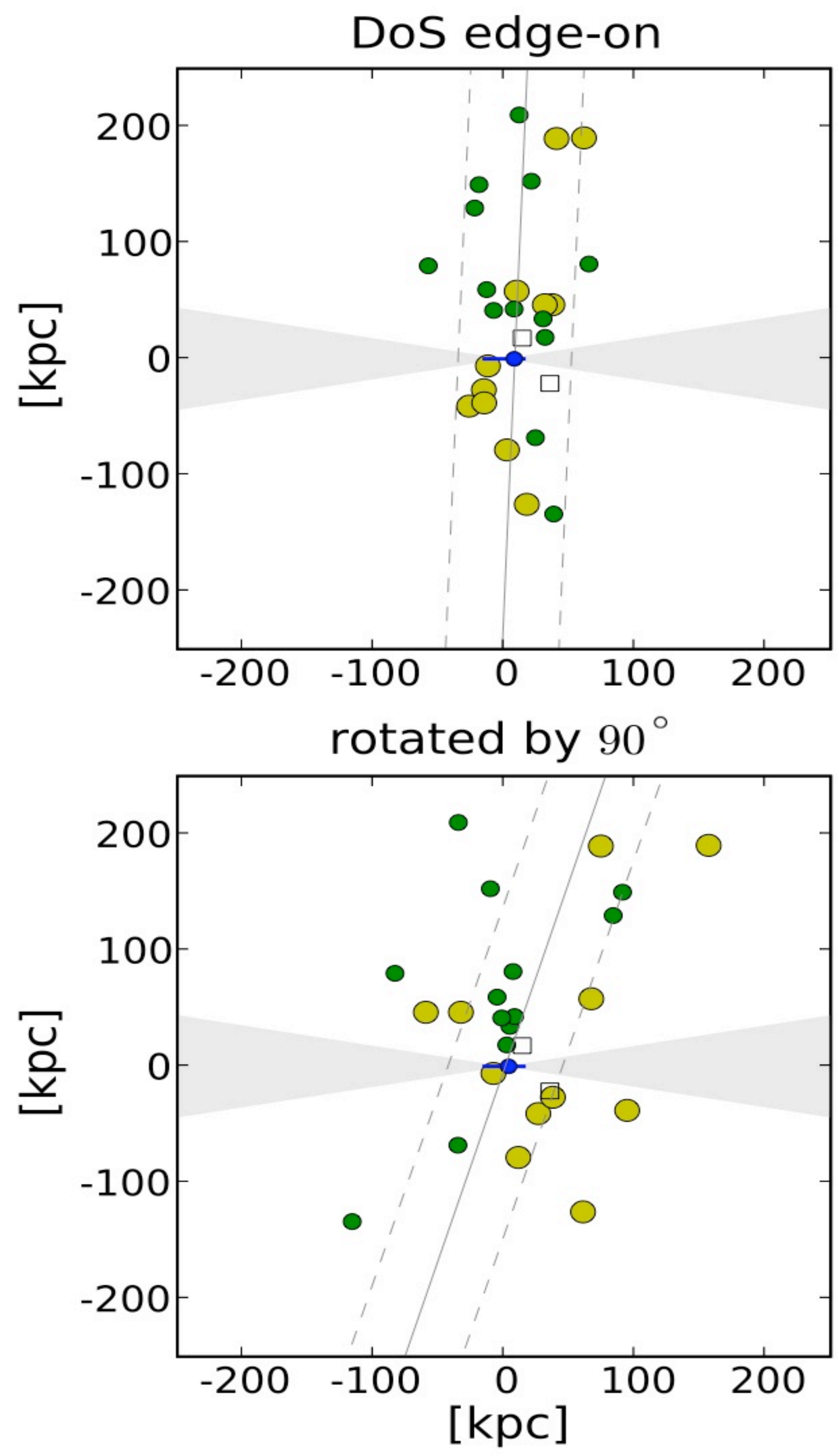

Figure 4: Illustration of the fourth problem

Fifth problem

According to the CCM, the Local group is dominated by two DM-halos of similar size, of which one contains the MW and the other the Andromeda galaxy. The CCM also predicts that the dominant galaxies in DM-halos in this mass range would have vastly different properties. Thus, the Andromeda galaxy being similar to the MW by its stellar mass, structure and satellite population is a highly improbable situation within the CCM.

The solution?

The five problems presented here can be resolved by assuming that **DSGs were created by interactions between galaxies.** Note that also the CCM predicts that many DSGs are formed that way. Obviously, those galaxies do not trace primordial DM-halos and the missing satellite problem (mentioned in problem 1) thereby becomes disastrous. The conclusion from the problems listed here is that the CCM, being based on the validity of general relativity and thus requiring a large amount of (cold or warm) DM, dramatically fails to explain the observed Universe on galaxy scales. This strongly implies that **general relativity has to be modified in the limit of weak gravitational fields, so that the assumption of (cold or warm) DM can be avoided.**

Further reading

Kroupa et al. (2010, A&A in press, arXiv-id: 1006.1647) and references therein