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Can blue-tilted primordial power spectrum save the small scale crisis in MW? – From the perspective of Zoom-In simulation for MW host size dark matter halo [1]



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1. Motivation

The standard cosmology model includes a single-field slow-roll inflation model that specifies the initial condition of the very early universe, and the lambda cold dark matter model which governs the later evolution of our universe. It has achieved **great success on large scales** over the past several decades.

However, a small scale crisis has existed for the past several decades, one problem of which is called **Missing Satellites Problem (MSP)**: the observation of MW satellite galaxies is not enough compared to the theoretical simulation result of the standard cosmology model. (See Figure 1)

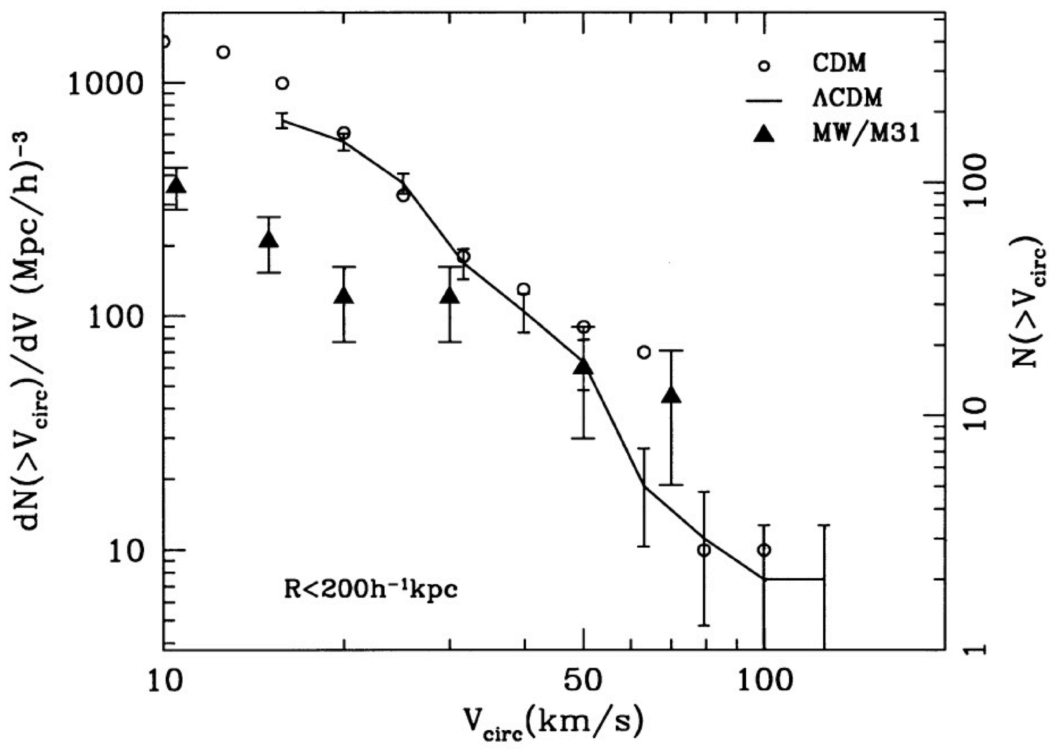

Figure 1: Missing Satellites Problem: figure 4 of [2].

Recently, the Missing Satellites Problem has been believed to be solved by considering reionization and completeness check. On the contrary, a **Too-Many-Satellites** problem appeared if considering the central baryonic disk in the Milky Way. (See Figure 2)

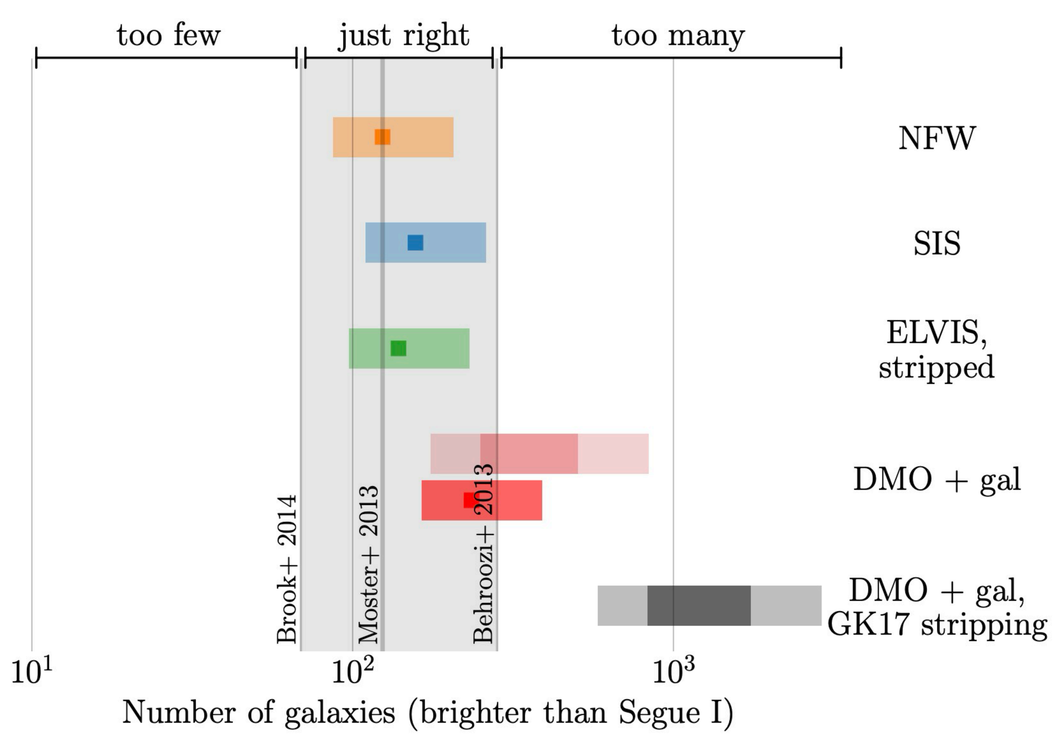

Figure 2: Missing Satellites Problem has been solved and Too Many Satellite Problem has been proposed: figure 2 of [3].

2. Theoretical Model

To solve the above mentioned too-many-satellites problem, in this paper, we gave a small scale enhancement to the early universe model while keeping the LCDM model unchanged.

2.1 Blue tilted primordial power spectrum

Standard single-field slowroll inflationary model[4, 5] is believed to generate a power-law form primordial power spectrum:

$$P_i(k) \propto k^{n_s} \quad (1)$$

where n_s is close to 1 from CMB measurements.

To get enhancement in small scale structure, a *blue tilted* primordial power spectrum[6, 7, 8] for the early universe density perturbation has been proposed with m_s to be larger than n_s:

$$P_i(k) \propto k^{n_s} (k \le k_p), \quad (2)$$

$$\propto k^{n_s} \cdot \left(\frac{k}{k_p}\right)^{m_s - n_s} (k > k_p) \quad (3)$$

The parameters of the chosen models are shown in Table 1:

Model	Related parameters
PL	Standard Inflation, equivalent to $m_s = n_s$
BT_deep	$k_p = 3.51$ Mpc^{-1}, $m_s = 1.5$
BT_soft	$k_p = 0.702$ Mpc^{-1}, $m_s = 1.5$

Table 1: The parameters of chosen models.

The matter power spectra for them are in Figure 3:

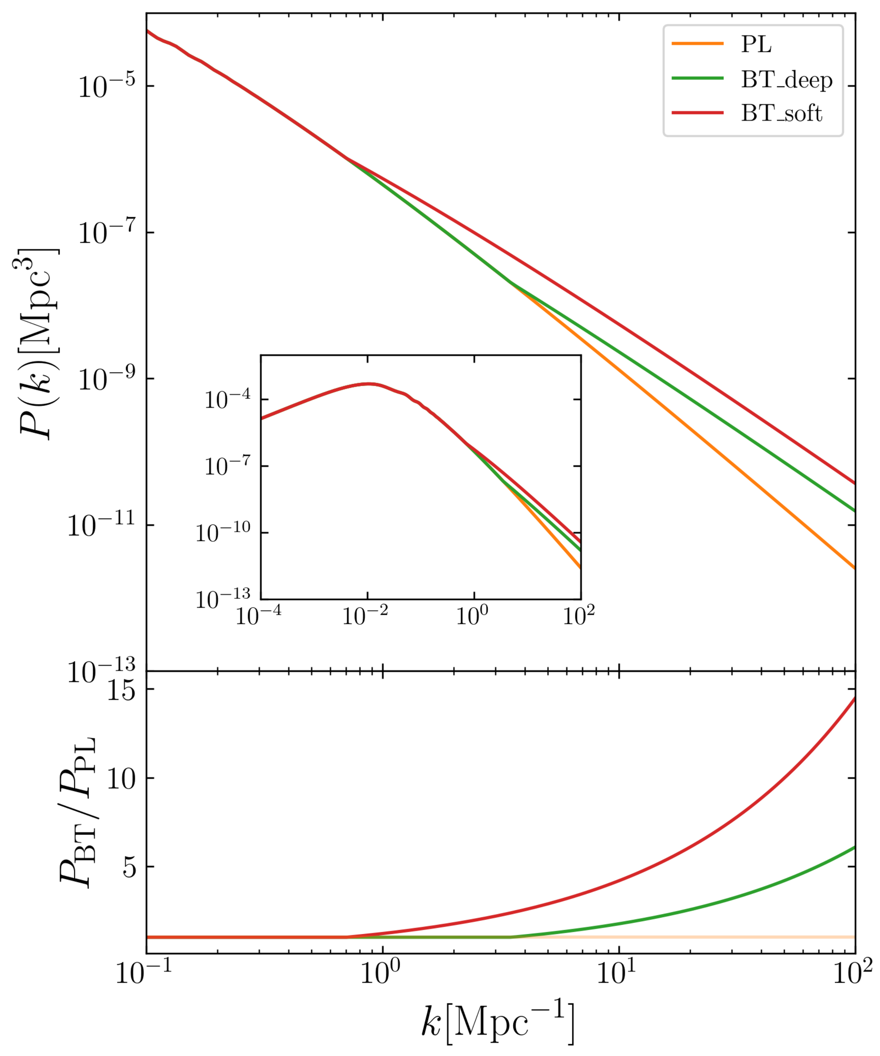

Figure 3: The power spectrum for matter density perturbation at z=1089.

3. Numerical Setup

The main simulation steps could be seen in Figure 7, where the corresponding cosmological stages are also shown:

1. We used the public code MUSIC - *multi-scale cosmological initial conditions*[9] which could help to fit with the CMB parameters, to generate the initial condition for our cosmological simulations with the power-law and blue-tilted primordial power models respectively.
2. We carried out zoom-in **dark matter only** simulations via the publicly available cosmological simulation code SWIFT[10].
3. We identified halos and subhalos from the cosmological snapshot by HBT-HERONS[11], and calculated the spherical overdensity properties by SOAP[12].

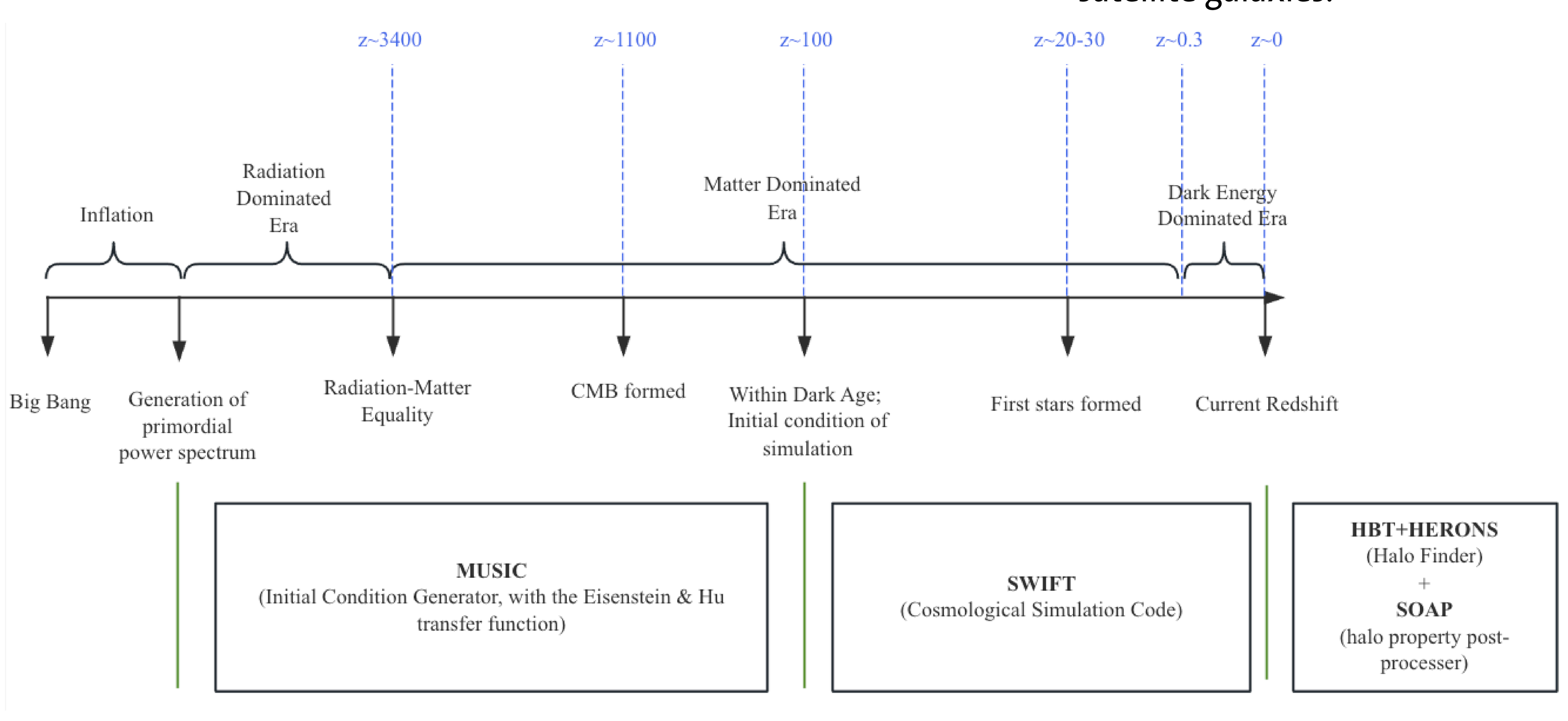

Figure 7: The conceptual flow and the corresponding cosmological history.

4. Result

We show more satellite galaxies from two ways: projection maps(Figure 4) and the subhalo mass(Figure 5)/Vmax(Figure 6) functions, both of which have suggested we could generate more satellite galaxies.

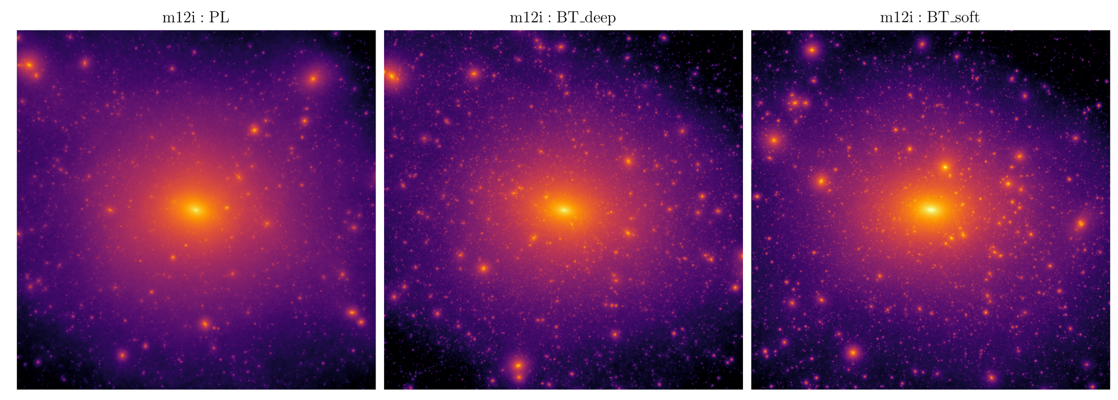

Figure 4: The comparison between dark matter mass projection maps with power law and blue tilted(deep/soft) primordial power spectrum for m12i. Both images are squares with a side length of 400 kpc.

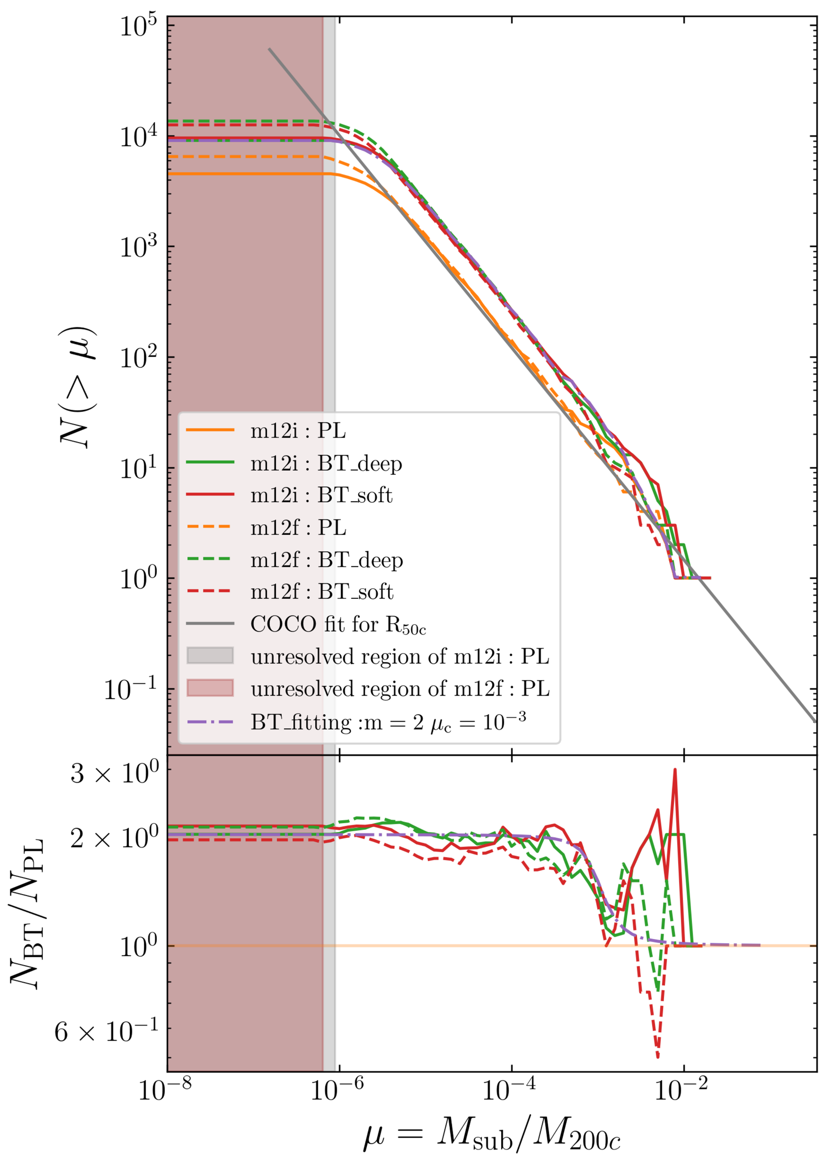

Figure 5: The inverse cumulative subhalo scaled mass functions.

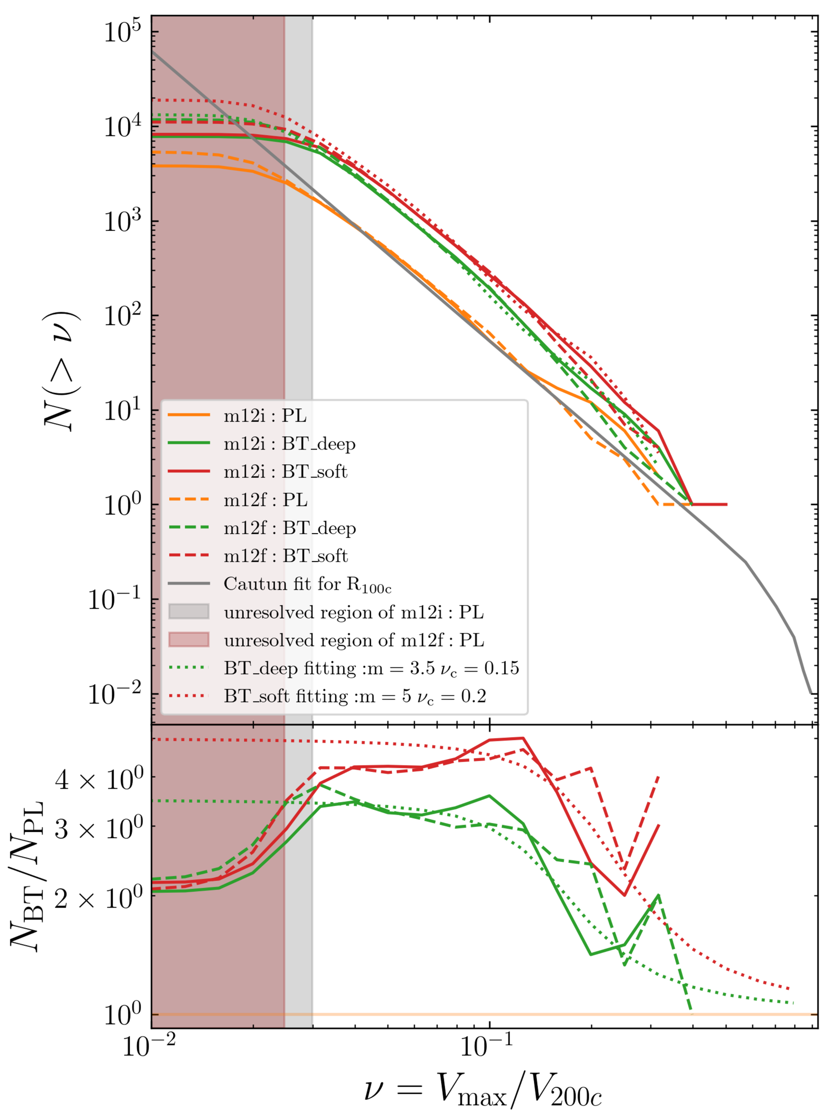

Figure 6: The inverse cumulative subhalo scaled Vmax functions.

5. Future

1. At small scales, the baryonic physics could make a significant difference. So We are working on considering **the potential of baryonic disk** for our dark matter only simulations at low redshift, in order to be able to compare with the satellites counts in Milky Way.
2. Besides, our another ongoing project is to use BT model to explain the **over-concentrated subhalo events in strong lensing** detection!

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