# Evolution of perturbations and cosmological constraints in decaying dark matter models with arbitrary decay mass products

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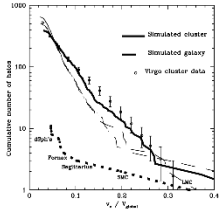
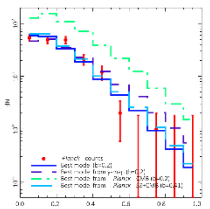
## Introduction

Numerous kinds of observations agree with ΛCDM predictions. However some discrepancies between observations and ΛCDM model predictions on small scale have been pointed out (e.g. missing halo problem, core cusp problem).
In order to rescue this problem, some mechanisms that suppress small scale structure formation may be required [1]
In addition, Planck collaboration reported that $\sigma_8$ estimated from $C_l^{\rm TT}$ is higher than that from cluster number counts from SZ effect by more 2σ CL. Decaying dark matter (DDM) is a possible candidate.



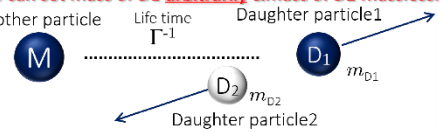

accumulated # of galaxies obs. vs simulation (ΛCDM[2])



The cluster number counts from Planck SZ and ΛCDM prediction[3].

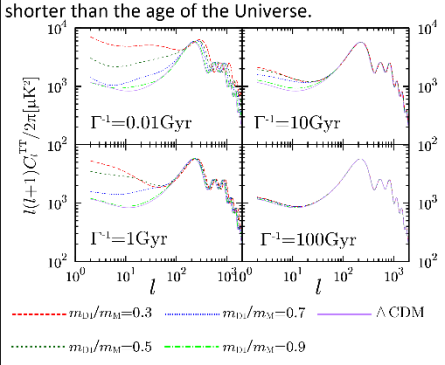
## Model

We consider the dark matter which decays into two particles well after the cosmological recombination epoch. In our study,
we can set mass of D1 arbitrarily &mass of D2 massless.




## The effect on CMB

Due to dark matter decays, gravitational potential becomes shallower than that in the ΛCDM model and the correlation of temperature fluctuation is enhanced at large scales. This effect should be observed as additional latetime Integrated Sachs-Walfe effect(ISW).
In addition, because of the history of cosmic expansion is changed by dark matter decaying, the acoustic peak of $C_l^{\rm TT}$ is shifted in the case the lifetime of DDM is much shorter than the age of the Universe.

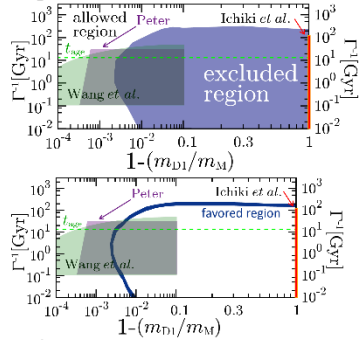



## Result

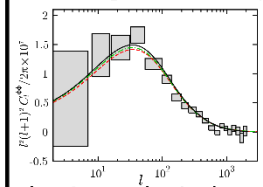
Matter density fluctuation amplitude at $8h_0^{-1}$Mpc, $\sigma_8$ can be calculated from $P(k)$. Sánchez *et al.* (2012)[4] has obtained $\sigma_8$ observationally and reported as

$\sigma_8 = 0.80 \pm 0.02$ .

From this observational constraint on $\sigma_8$, we obtain the following constraint at 2σ CL.



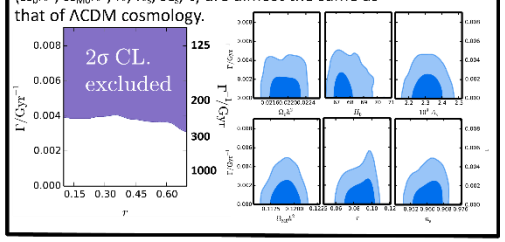

We also found that DDM which decays into relativistic 2 particles can explain the difference of $\sigma_8$ estimated from Planck $C_l^{\rm TT}$ & SZ catalog (blue shaded region). Such a DDM is not ruled out from the observational CMB lensing data and seveal previous constraints.




Here we compare the calculated CMB lensing power spectrum of our DDM models with observational data from Planck.

### The Cosmological Parameter estimation with DDM parameters by MCMC

The lifetime of DDM $\Gamma^{-1}$ should be larger than 250 Gyr. regardless of the mass ratio $r=m_{D1}/m_M$.
It is due to the restriction of the additional ISW effect by Planck.
Besides, the center values of other six parameters ($\Omega_b h^2$, $\Omega_{M0} h^2$, $h$, $n_s$, $A_s$, $\tau$) are almost the same as that of ΛCDM cosmology.




Main references
1. J.P. Ostriker, P. Steinhardt, 2003, *Science*, 300, 1909 [arXiv:astro-ph/0306402]
2. Ben Moore et al. (1999), *Astrophysical Journal Letters*, [astro-ph/9907411]
3. Planck Collaboration(2014), *A&A*, [1303.5062〜1303.5080]
4. A.G. Sánchez *et al.*, 2012, *MNRAS*, 425, 415 [arXiv:1203.6616]

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I investigate a (possible) nature of dark matter particles, which changes spontaneously other two particles.
It is called decaying dark matter (DDM).

It is based on the linear order cosmological perturbation and Boltzmann equation of DDM particles.

In this poster, we show a constraint on parameter of DDM such as the lifetime.

Our model can reconcile the discrepancy of the Planck anomaly about the amplitude of the density fluctuation $\sigma_8$.