σ_8- Tension and the Dark Energy-Dark Matter Interaction Model

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Introduction

The ΛCDM model is the simplest description of dark energy and is consistent with most cosmological observations. With recent observations as the uncertainties in the parameters keep shrinking, we have witnessed some inconsistencies in parameter estimation. The most significant ones are in the estimation of Hubble parameter, which stands at $\sim 4\ \sigma$ level, called the Hubble (H_0) tension, between Planck observations, which assumes ΛCDM as base cosmological model, and other direct local distance ladder measurements. Another significant tension is found in the estimation of $_8$ or S_8 parameter, which shows a disagreement at $\sim 2\ \sigma$ level. This σ_8 tensions is noted between Planck observations and other large scale structure measurements. These tensions can't be explained by systematic errors alone and might be a hint towards new physics beyond ΛCDM. Many models have been proposed in order to resolve the issue, in this work, we assume a Dark Matter-Dark Energy (DM-DE)Interaction model and study if its consistent with cosmological observations.

Dark Matter-Dark Energy Interaction Model

We consider a dark sector interacting model [1] where the interaction term is such that there exists a one-to-one mapping between field theory description and the fluid description of interacting model. The action for the model is given by

$$S = \int d^4x\sqrt{-g}\left(\frac{1}{16\pi G}R - \frac{1}{2}g^{\mu\nu}\nabla_\mu\phi\nabla_\nu\phi - U(\phi) - \frac{1}{2}e^{2\alpha(\phi)}g^{\mu\nu}\nabla_\mu\chi\nabla_\nu\chi - e^{4\alpha(\phi)}V(\chi)\right).$$

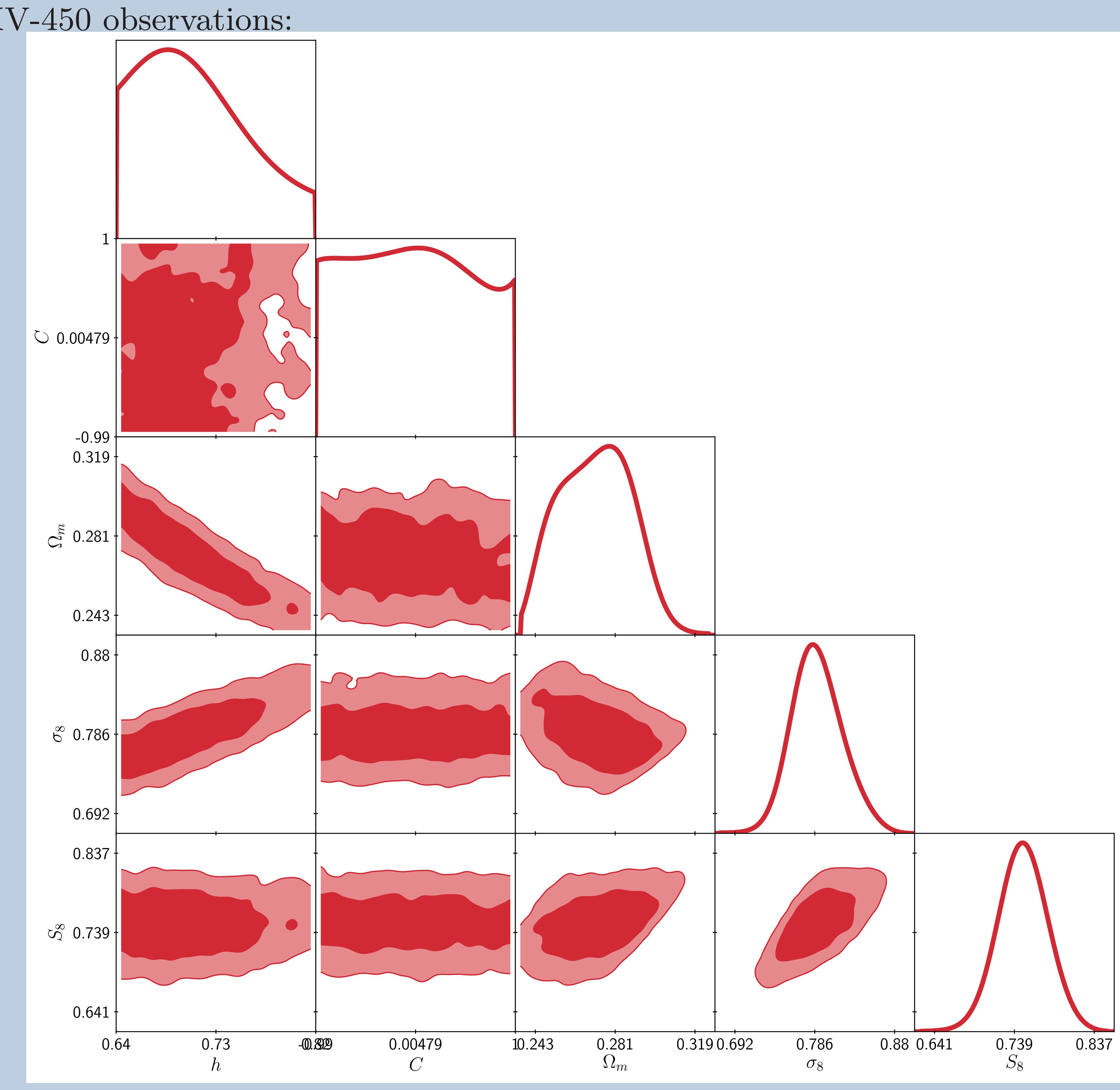
The Einstein's equation in terms of dark energy scalar field and dark matter fluid

$$G_{\mu\nu} = 16\pi G\left[\nabla_\mu\phi\nabla_\nu\phi - \frac{1}{2}g_{\mu\nu}\nabla^\sigma\phi\nabla_\sigma\phi - g_{\mu\nu}V(\phi) + p_m g_{\mu\nu} + (\rho_m + p_m)u_\mu u_\nu\right]$$

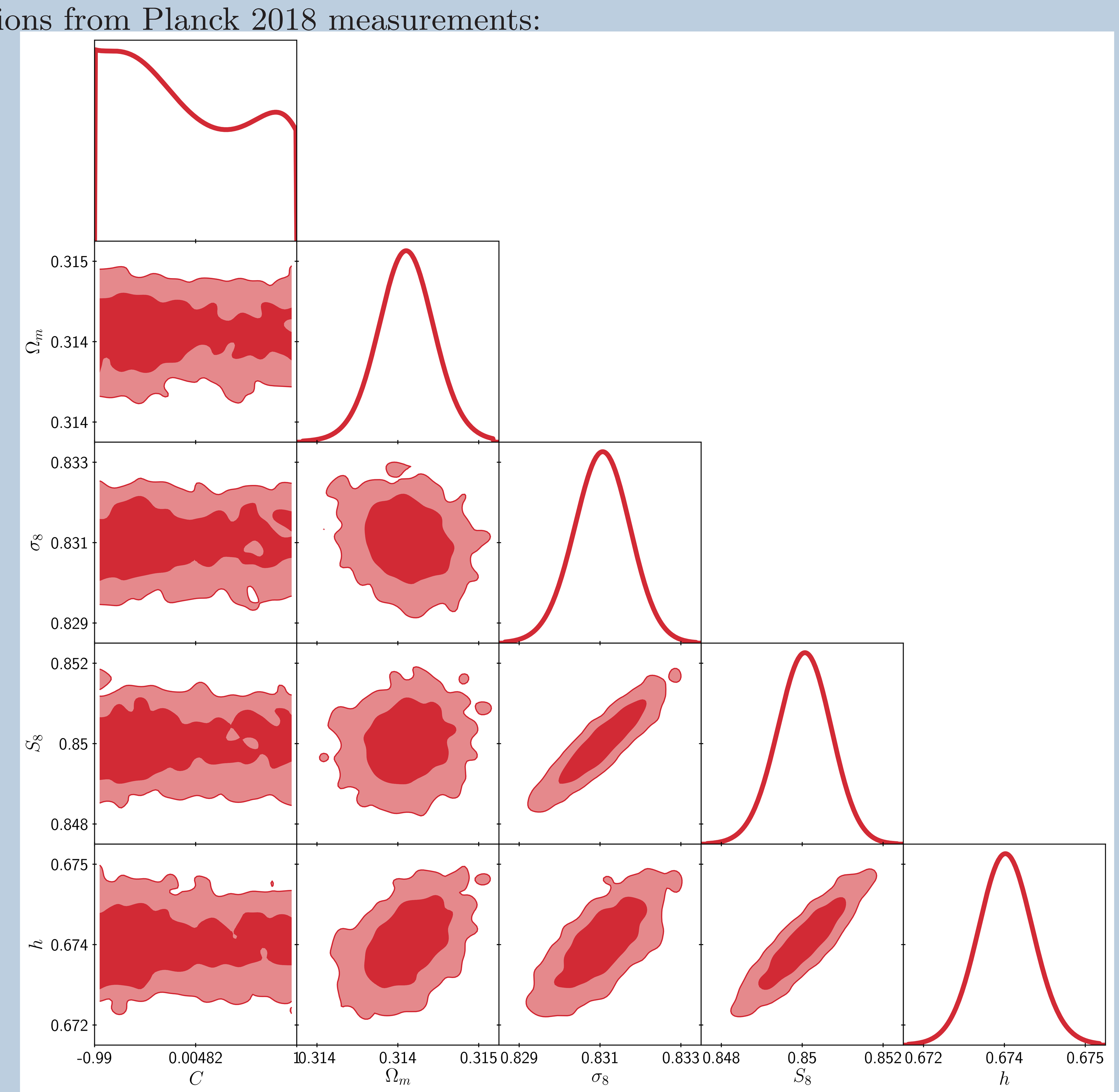
The interaction is given by $\nabla_\mu T^{(m)\mu}_\nu = Q^{(F)}_\nu$ and demanding that the dark sector must have an equivalent field theory and fluid description, we obtain an interaction term $Q^{(F)}_\nu = T^{(m)}\nabla_\nu\alpha(\phi)$. In our work, we consider an interaction term which is linear in field ϕ, $Q = -\alpha_{,\phi}\dot{\phi}\rho_m = -C\dot{\phi}\rho_m$ where $\alpha \sim \phi = C\phi$ and C is the interaction strength, the matter density evolves as, $\rho_m = \rho_{m_0}e^{\alpha(\phi)-\alpha(\phi_0)}a^{-3}$. We consider a quintessence field description of dark energy with potential of the form $U(\phi) \sim \phi^{-n}$. Using the interaction term, we obtain the background evolution equations for the field, density and the modified first order density and velocity perturbation equations.

Constraints

Results from KV-450 observations:



CMB observations from Planck 2018 measurements:



Summary and Conclusions

We study the evolution of universe and to check the consistency of the model, cosmological observations in the analysis are incorporated and constraints on model parameters are obtained. The observations used are: KiDSViking-450 measurements and Planck 2018 CMB measurements. The preliminary results are shown in the figures and the best fit values are given in the following table:

Parameters	KV450	Planck 2018
C	-0.808	-0.02917
Ω_m	0.268	0.314
σ_8	0.798	0.831
S_8	0.772	0.850
h	0.712	0.6735

- For KV450 and Planck 2018 observations, considering the interaction between DM-DE shows an increase in Ω_m, where as the value of σ_8 decreases slightly, resulting in a higher value of S_8 when compared to the non-interacting scenarios. The σ_8 tension is not removed completely but is not as severe as in the case of ΛCDM model.
- The KV450 observations constrains H_0 to a lower value of $H_0 = 71.2\ km\ s^{-1}\ Mpc^{-1}$, which is consistent with the H_0 value obtained by using low-z observations [2]. For Planck data constrains on H_0 doesn't change much when considered with non-interacting scenarios and are $H_0 = 67.3\ km\ s^{-1}\ Mpc^{-1}$.
- Both the KV450 observations as well as Planck observations are unable to constrain the interaction parameters in the range $C \in [-1, 1]$.

References

1. Joseph P Johnson, and S. Shankaranarayanan, "Cosmological perturbations in the interacting dark sector: Mapping fields and fluids", Phys. Rev. D 103, 023510 (2021).
2. Joseph P Johnson, Archana Sangwan, and S. Shankaranarayanan, "Observational constraints and predictions of the interacting dark sector with field-fluid mapping", JCAP 01 (2022) 01, 024.