SHORT TERM SCIENTIFIC MISSION (STSM)
SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA18108
STSM title: Modified models in cosmology
STSM start and end date: 13/01/2020 to 24/01/2020
Grantee name: Denitsa Staicova

PURPOSE OF THE STSM:

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(max.200 words)
The purpose of this STSM was to discuss the generalisation of the multimeasure model to include the contribution of matter fields to the evolution of the Universe. The multimeasure model aims to unify the dark sector of the universe and its numerical study has proven it capable to describe the main stages of the evolution of the Universe – the early inflation, the matter domination and the exit to the current stage of accelerated expansion. This is done trough the introduction of an additional non-Riemannian measure into the action. The new non-Riemannian volume forms add only purely-gauge degrees of freedom to the theory, but when coupled to scalar fields they lead to the description of the dark sector as a dark fluid, with a hidden symmetry and a dynamically generated cosmological constant.
Additional goal of the STSM was to consider the possibility of a collaboration with Dr. Diego Rubiera-Garcia in the study of cosmological solutions with matter fields.
The long-term goal is to establish contact between the cosmological group at the Institute of Particle and Cosmos Physics, at the Complutense University of Madrid and the theoretical cosmological group at the Institute for Nuclear Research and Nuclear Energy in Sofia, Bulgaria.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

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(max.500 words)
The planned work was divided into two parts:
The first part was aimed at studying the particular cases of the multimeasure model so that we can decrease the number of parameters of the model. In the general case, the multimeasure model has 12 parameters, which makes the proper study of the parameter space very hard and it make the numerical work with it very computationally demanding. Thus we have studied the case b0=0, p_u=0 and we found solutions having the desired properties – an evolution with 3 stages. This case corresponds to the removal of the non-linear coupling between the kinetic terms of the two scalars in the generalised k-essence action of the model. A particularly interesting feature of the full model is the inflaton "climbing-up the effective potential". Such behavior is against the notion of the inflation being generated by the inflaton rolling down the slope (i.e. due to the exchange of potential for kinetic energy) but instead pointed to it being generated by the interaction between the two fields. The numerical results show that in the special case, this feature is not observed. Additional problem of the model was that in the full parameter-space, it seems that it's not capable of producing the needed number of e-folds – instead of above 65 e-folds, we obtain only 23. While this problem could have a numerical origin related to the closeness to the initial singularity, it also seems to be connected with the existence of a dark charge in the model. In the special case, the dark charge is eliminated and thus the number of e-folds is not limited. This leads to the improvement of the model and enables us to start our work on the matter-fields in a simplified version of the model.
The second part of the STSM was the discussion of other interesting cosmological models with the host, Dr. Diego

Rubiera-Garcia. As a possible such model, we discussed a model with a disformal coupling of the fields. In those theories the Einstein frame and the Jordan frame are related instead of with a conformal transformation, with a disformal one, including the derivatives of the scalar field. Such models have been studied in numerous works – for example their effect on the evolution of the energy density and the possibility to create theories without the Ostrogradski instability. These models give us an opportunity to study how the interaction between the fields affect the dynamics of the universe. This may give us clues on the "climbing up the slope" phenomenon, which seems to stem from the interaction between the two fields. During the STSM, the equations of the disformal theory have been studied and some details have been clarified with Dr. Diego Rubiera-Garcia. The next step will be to study analytically and numerically some specific cases for the parameters of the disformal theory.
Finally, as part of the STSM, the grantee gave a seminar to the group at the Department of Theoretical physics, where the multimeasure model was presented.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

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- The case b0=0 (p_u>0 and p_u→ 0) has been studied and a Universe with the needed EOS has been obtained.
- As part of the discussions with the group, the question of the speed of sound was raised. Upon examination, it has been found that the model has an instability with respect to the speed of sound (cs^2 becomes negative during inflation)
- As a consequence, the cases with very large alpha (I.e very steep slope of the effective potential) and very small f2 (i.e. very high effective potential) for b0>0 have been studied in detail and according to the obtained results, the instability continues to exist even in the limit cases. This problem needs to be further examined and the results will be published in a future article.
- The equations of the disformal theories have been studied with the help of Maple and they've been put into the proper form for numerical work for the future examination according to a plan discussed with the host.

FUTURE COLLABORATIONS (if applicable)

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A possible collaboration with Dr. Diego Rubiera-Garcia was discussed related to the study of the disformal theories. Also, it has been discussed the possibility to invite members of the group to visit the *Institute for Nuclear Research and Nuclear Energy in Sofia, Bulgaria.*