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Project Acronym: DEMO (Dark Energy Models and Observations)
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The goal of the DEMO project was to give a significant contribution in cosmology by investigating Coupled Dark Energy (CDE) and modified gravity models in view of current experiments like Planck and LHC and future experiments like Euclid.
The starting point was the Dark Universe: it appears that baryonic matter (the ordinary atoms we are used to) contributes only to the 4% of the total energy density content of the Universe; about 23% is thought to be composed by non luminous particles interacting at most weakly with ordinary matter (Cold Dark Matter, CDM) and still clustering under the effect of gravitational attraction. The remaining 73% is generically referred to as Dark Energy, a non-luminous component that, unlike CDM, acts against gravity: effectively, Dark Energy behaves as a fluid with negative pressure that speeds up the expansion of the universe.
The simplest known explanation for Dark Energy is the Cosmological Constant (**Λ**CDM) model. It consists of a homogeneous contribution to the energy density that does not vary with time, first introduced by Einstein in 1917 in order to find a static description of the Universe.

During the two years of my Marie Curie Fellowship I published 12 papers on refereed international Journals on the topics of Dark Energy, Dark Matter and comparison with data. Among them there are works on theoretical models as well as works on comparison with data. Concerning theoretical models, I summarize here my results.

- Coupled dark energy: since most models in which General Relativity is modified include a fifth force, I tested the case of coupled dark energy, in which the fifth force is parametrized by a constant $\beta$ (the parameter that appear in the figure attached and that measures the strength of the interaction). I implemented a numerical code that allows to test a coupling between dark energy and dark matter; I compared expectations on the cosmic microwave background spectrum with the first new cosmological data that became available in 2013 from the Planck Collaboration. I showed that despite the cosmological constant model is still compatible with the data, the small difference in the estimation of the Hubble expansion parameter and direct measurements from Baryonic Acoustic Oscillations (BAO) or the Hubble Space Telescope (HST) and Supernovae, can actually favor a non zero coupling. In particular, a value of $\beta$ different from zero would indicate deviations from the standard model. As shown in the Fig.1 and Fig.2 and described in detail in [1, 3], data are still fully compatible with non zero values of $\beta$, with a tension of 2.2 or 3.6 standard deviations from a zero value, depending on the datasets.
- Early dark energy: I showed in [2] for the first time that the amount of dark energy at early times depends on the epoch at which dark energy starts to become relevant. While constraints are quite tight if dark energy is present at all times since decoupling (380.000 yrs after the Big Bang), larger amounts of dark energy are allowed at later times, up to about 8%.

- I have been working on Dark Matter models (including a framework beyond the standard gravitational attraction [6]) showing the possibility of a scenario in which the non standard interaction makes dark matter and dark energy behave as two aspects of the same fluid.

- With regard to observations, being in Geneva has allowed me to contribute more significantly than before to the ESA Planck collaboration (http://sci.esa.int/planck/) and in particular to the analysis of Dark Energy models from the Cosmic Microwave Background (CMB) as well as on the comparison with Supernovae. During my fellowship, Planck has released the first cosmological results, observing the CMB with a resolution better than ever before, which was largely advertised also in all main international newspapers. The cosmology parameter paper in particular [5] is now a renowned paper with almost 1500 citations one year after publication. Being able to contribute to such an achievement has clearly helped me to integrate more in the CMB scientific community and actually present my results to the collaboration and beyond (papers [1,4] were for example advertised in the NOVA blog of the Science TV show from Pbs: http://www.pbs.org/wgbh/nova/blogs/physics/2014/01/will-we-ever-know-the-true-nature-of-dark-energy/. A complete list of dissemination activities is attached separately).

- I became Editor in Chief and author of the Theory Review [4] for the Euclid Mission that illustrates Dark Energy and Dark Matter models along with a collection of forecasts and cosmological results expected for the satellite. The Review is meant to be updated every two years as the experiment moves on towards launch in 2020 and beyond. This activity also gave me the chance to build up an Editorial Board that worked efficiently in a joint coordinated effort devoted to the Review.

- Working in Geneva has also given me the opportunity to get into contact with the particle physics community. I have extended my expertise and interests and I am now also working on testing Dark Matter models in indirect detection experiments like AMS-02, in collaboration with Prof. A.Riotto (University of Geneva) and Prof. A. De Simone (who was visiting CERN at the time of my fellowship).

Without the Marie Curie Fellowship and in particular the constant support and collaboration from the scientist in charge Dr. M. Kunz, the achievements above would have never been possible.

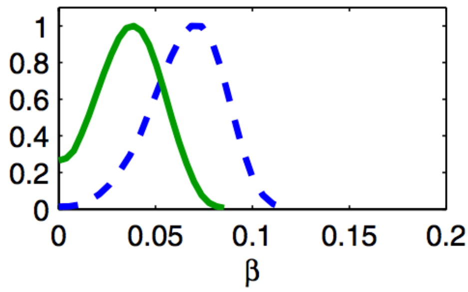


Fig.1 Likelihoods for the cosmological parameters for coupled dark energy models. We compare runs from Planck + BAO (green, lighter) and Planck + HST (blue, darker). This is interesting and still represents, to my knowledge, the strongest result in favor of a model beyond the cosmological standard one. β gives the strength of the fifth force and a value different from zero would indicate deviation from the cosmological constant model.

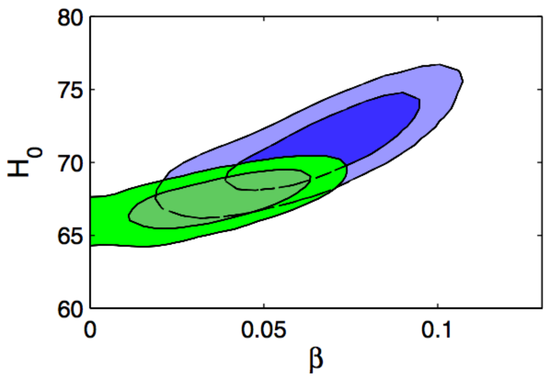


Fig.2 Confidence contours for the Hubble expansion $H_0$ and the coupling β for coupled quintessence models. We compare Planck + BAO (green, light left contours) and Planck + HST (blue, dark right contours). 1 and 2 standard deviation contours are shown.