2009 GGI Workshop Program

New Horizons For Modern Cosmology

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Motivation

Cosmology is offering us a new laboratory where standard and exotic fundamental theories can be tested on scales not otherwise accessible.

The success of the standard cosmological model has many puzzling consequences and raises several key questions which are far from being answered. For example, the observation of dark energy demonstrates that our well established theories of particles and gravity are incomplete if not incorrect. What makes up the dark side of the universe? What created the primordial fluctuations? Is gravity purely geometry as envisaged by Einstein, or is there more to it (such as scalar partners and extra dimensions)? An unprecedented experimental effort is currently being devoted to address these grand-challengs questions in cosmology. This is an intrinsically inter-disciplinary issue, and the range of opportunities afforded by the wealth of high precision data that will become available means that it will inevitably be at the forefront of research in astrophysics and fundamental physics in the coming decades. We aim to bringing together scientists at the forefront of the field both on the experimental side and the theoretical side to discuss these issues.

Workshop topics

We aim at gathering in the Galileo Institute a large number of leading scientists in the field of Cosmology and Astro-Particle Physics. More precisely,we aim to discuss four main topics:

Dark Energy. Our goal will be to firstly evaluate, with the help of experimentalists and experts in the field of data-analysis, the evidence for Dark Energy from the cosmological data and the agreement between the different datasets. We will then discuss the several proposed alternatives and the statistical tools needed for discriminating among them. In particular we plan to undertake a comprehensive study of scalar field models exploring their dynamical behavior and their effect on the growth of dark matter perturbations. Using SN-Ia, BAO, CMB and Weak Lensing data, new constraints on the generic scalar field potential parameters will be presented, along with the reconstructed dark energy equation of state. A major goal of the meeting will be to identify the most promising dataset or data set combination and analysis techniques for future data and forecasts their performance in discriminating among dark energy models. The unavoidable links between dynamical dark energy and varying fundamental constants will also be explored.

Dark Matter. Several key questions on dark matter will be discussed: Does the dark matter match the appropriate relic density? Is it *cold* or *hot* ? Is it neutral? Is it consistent with Big Bang Nucleosynthesis ? Is it compatible with constraints on self-interactions? Is it consistent with *direct* DM searches? Is it compatible with gamma-ray constraints? Is it compatible with other astrophysical bounds? Can it be probed experimentally? What is the mass of neutrino and how many neutrinos or relativistic particles do we have in our universe ?
More specifically, several talks will review the current status of cosmological and astrophysical evidence for dark matter. In particular, we will focus on new lensing observations, galaxy clustering, X-rays, gamma-rays, antimatter with space-borne detectors and direct DM detection in low background underground experiments. We plan to address the main theoretical extensions of the standard model which allow to explain dark matter and the corresponding predictions for future searches. Special attention will be given on the requirements

for collider tests of dark matter candidates at LHC. Constraints on neutrino physics can be obtained from cosmological data. During the workshop, we aim to summarize the latest bounds on neutrino physics and discuss future experiments sensitive to neutrino masses into the sub-eV range. We will discuss what systematic effects degrade the constraints on neutrino properties from cosmological observations and how these systematics can be controlled.

Inflation. The recent data have been an extraordinary success for inflation. However several points have to be still clarified. What is the physical mechanism that produces inflation ? What is the amount of gravity waves produced by inflation and is it detectable ? How well are Isocurvature modes constrained ? Is there any evidence for non gaussianity in the current data and how to disentangle the cosmological signal from systematics ? How to interpret the current anomalies in the WMAP data (low quadrupole, cold spot) and what is their statistical significance. We plan several review talks and round tables on the current status of inflation. After evaluating the ability of current CMB data to reliably constrain the form of the primordial power spectrum, we plan to identify more exotic power spectra that yield equally good (or better) fits to the data. We will address the implications of recent indications for a red spectrum of primordial density perturbations for the future detection of inflationary gravitational waves. In particular, we will evaluate the ability for a IGW detection from future ground based and balloon-borne experiments and from the proposed satellite missions of the ESA Cosmic Vision and NASA Inflation Probe programs. Finally, we plan round tables, reviews and specialized talks on primordial non-Gaussianities. Non-Gaussianity emerges as a key observable to discriminate among competing scenarios for the generation of cosmological perturbations and is one of the primary targets of present and future Cosmic Microwave Background satellite missions. A major goal of the workshop will be to provide a detailed presentation of the state-of-the-art of the subject of non-Gaussianity, both from the theoretical and the observational point of view.

Gravity. We will discuss most of the proposed current alternatives to dark energy and dark matter as DGP, TeVeS and $f(R)$, based on modifications of general relativity and/or Friedmann-Robertson-Walker metric. We will focus the discussion on the key cosmological observables able to disentangle modified gravity and dark energy. For example, an important prediction of the standard cosmological model based on GR is a fixed relationship between the gravitational potentials responsible for gravitational lensing and the matter overdensity. Alternative theories of gravity often make different predictions for this relationship. A main goal of the workshop will be to identify the measurements which can test the lensing/matter relationship.

Workshop format

We envisage that the standard, continuous activity of the workshop will be a set of $3-4$ weekly talks which should discuss cutting-edge research problems of the various fields. All the participants will be expected to give a talk, preferably during the initial period of their stay, so that their interests are known to the other participants and areas of common interest can be readily identified and subsequently explored. Occasionally talks may be given by 'non-residents' that are unable to stay for extended periods but still can schedule a short trip. In addition we will organize a series of 'cross-boundary' review lectures. These can be thought of as graduate-level lectures, useful for PhD students, though with an explicit interdisciplinary focus: they should be specifically aimed at participants who are not experts on the relevant topic, and may not have encountered it at all. For example theorists should learn about key observational and experimental issues, and vice- versa. Depending on the topic, these can be individual lectures or series of a few lectures, and we'd expect to have an average of 4 such lectures per week. We believe that this kind of activity can have a great impact in a cross-disciplinary program like the one we propose: in addition to its intrinsic pedagogic value it will encourage further interactions among the participants, and obviously it will be extremely useful for the younger participants. In this respect, we expect review lectures from at least five experimentalists leaders in the field of CMB, Weak Lensing, BAO, Galaxy Clusters and Supernovae research to illustrate each week the most recent results and perspectives in the field.
Finally, we plan an afternoon round table discussion at the end of each week where all the main topics of the week will be discussed and summarized.