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Extract of Euclid section

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5.6 Euclid: a Dark Energy mission

In response to the first Call for Missions for the Cosmic Visions plan, two dark-energy-related missions were proposed: the dark universe explorer (DUNE) and the spectroscopic all-sky cosmology explorer (SPACE). The two concepts have been merged, and a mission that combines measurements of weak gravitational lensing and baryonic acoustic oscillations is currently being studied. This mission is called Euclid.

Introduction

Several independent observations indicate that the cosmological expansion began to accelerate when the Universe was around half its present age. This conclusion assumes the correctness of General Relativity, and requires that the Universe must contain a new component known as dark energy. As a surprising consequence, the dark energy must contribute to 70% of the total matter density of the Universe, reducing the amount of baryonic matter to only 4%. The remaining 26% is locked up in dark matter, which, just as dark energy, has no explanation in standard physical theory. Like the accelerated expansion which took place during the early epoch of our Universe, commonly known as 'inflation', the present acceleration leaves imprints in the Universe. This is because the growth of structures in the Universe is sensitive to the details of the acceleration process. The equation of state of dark energy can thus be constrained from observations of the expansion history of the Universe throughout its visible epoch since the decoupling of the microwave background.

Euclid is an ESA mission to map the geometry of the dark Universe. The mission will investigate the distance-redshift relation and the evolution of cosmic structures by measuring shapes and redshifts of galaxies and clusters of galaxies. The statistical study of structures in a large volume of the Universe requires a survey of the entire extragalactic sky. Euclid will address several fundamental cosmological questions. Is dark energy merely a cosmological constant, as first discussed by Einstein, or is it a new kind of field that evolves dynamically with the expansion of the Universe? Alternatively, the dark energy may be a manifestation of a breakdown of General Relativity and deviations from the law of gravity. The mission can address other important dark energy issues such as galaxy cluster statistics, the integrated Sachs Wolfe effect, and the growth of structures. Euclid's legacy can be used to investigate all areas in modern cosmology, in particular the nature of dark matter and extra-galactic astronomy.

Scientific goals

Euclid will measure the distance-redshift relation and the growth of structure by optimising its observing strategy on two complementary dark energy probing methods. The baryonic acoustic oscillations (BAO) method relies on the distribution of baryonic matter, i.e. galaxies, to infer the redshift-distance relation. The characteristic scale length of structure which can be accurately determined from the cosmic microwave background is used as a standard rod. By measuring the angular size of this characteristic scale-length as a function of redshift, the effect of the dark energy can be inferred.

The other method is based on weak gravitational lensing (WL) whereby the distribution of mass along the line of sight distorts the apparent shapes and orientation of galaxies. The matter distribution and hence cosmological structure is obtained from the inferred gravitational field causing the weak lensing.

The combined results of the two methods provide very strong constraints on the dark energy equation of state. Observing from space provides a well-controlled environment and avoids sources of systematic errors caused by the Earth's atmosphere and thermal variations, which seriously limit similar observations from ground.

The survey will produce a visible image of the entire extra-galactic sky (20 000 deg^2) at a spatial resolution of ~0.3 arcsec, and near-infrared (NIR) images in one or more bands of the same area. It will also yield medium resolution (R~400) spectra of about a third of all galaxies brighter than 22 mag in the same survey area.

The mission

Euclid will measure shapes and redshifts of galaxies out to redshifts ~2, or equivalently to a look-back time of 10 billion years, thus covering the entire period over which dark energy played a significant role in accelerating the expansion.

The baseline mission carries a telescope with a primary mirror of 1.2 m diameter. The rest of the payload consists of three scientific instruments: a CCD based optical imaging channel, an NIR imaging photometry channel, and an NIR spectrometric channel. The optical channel is used to measure the shapes of galaxies at the diffraction limit of 0.2–0.4 arcsec in one single wide visual band (R+I+Z) spanning the wavelength range of 550–920 nm. The NIR photometric channel contains up to three NIR bands (Y, J, H), employing NIR detector arrays with 0.3 arcsec pixels. The NIR spectroscopic channel operates in the wavelength range 0.8–1.7 micron at a spectral resolution $\lambda/\Delta\lambda \sim 400$.

The mission will survey 20 000 deg^2 of the extragalactic sky in the visible down to 24.5 mag where the average density of galaxies reaches 40 per square arcminute. The redshift determination is based on two independent measurement principles. For all galaxies, the so-called photometric redshift ('photo-z') is obtained from the broad band visual and near-IR measurements. Ground-based observations in other visible bands will be employed to increase the accuracy in the photo-z determination. For the ~10^8 sub-sample of galaxies brighter than AB magnitude 22, accurate redshifts are also measured directly from the NIR spectroscopic channel.

Status of the mission

A quick feasibility study, due to finish end-May, is being carried out by ESA, leading to a very preliminary design for the mission and its payload. This preliminary design will then be used by industry for a more thorough assessment lasting about a year. The report of this assessment study will be presented to the scientific community in late 2009.