Newsletter Interview

EUCLID AND THE GEOMETRY OF THE UNIVERSE

On 31 July, slightly less than a month after its launch, after a journey that brought it to its operational destination at the Lagrange Point L2 at 1.5 million kilometres from Earth, the European Space Agency Euclid space telescope, dedicated to studying the geometry and expansion of the universe, provided the first evocative images. The outcome of an international collaboration, Euclid involves a fundamental contribution from Italy, through the Italian Space Agency (ASI), the Italian National Institute for Astrophysics (INAF), and INFN. Alongside France, our country is in fact leading the scientific consortium, which is composed of more than 2,000 researchers responsible for creating the telescope and doing the scientific analyses based on the observations that Euclid will perform in the next six years. The observations will concern a large number of galaxies, corresponding to approximately one third of the sky, and will serve to map their distance and distribution and, in doing so, contribute to understanding how dark energy and dark matter have influenced the evolution of the universe.

The mission is mainly dedicated to investigating big open questions in contemporary cosmology, such as the nature of dark energy and dark matter, which alone represent almost 95% of the universe. However, Euclid also promises to influence a vast number of research areas with its results. It may provide essential information in the fields of particle physics and fundamental physics, in particular for studying gravity, excluding possible candidates for dark matter or identifying any gravitational phenomena that do not agree with the predictions of Albert Einstein's General Theory of Relativity. The INFN contribution was engaged at the forefront of creating and integrating the telescope and will collaborate on data analysis and provide computing resources as well. It is represented by a numerous group of researchers, coordinated by Luca Stanco, researcher of the INFN Padova Division.

Where did the idea for a space telescope that studies the evolution of the universe and its dark component come from?

The idea for a mission for studying the dark component of the universe can, in some ways, be traced back to the discoveries made in 1998 by the Hubble space telescope, whose observations revealed how the escape velocity of a particular class of supernova, used as references due to their continuous luminosity, increased over the life of the universe. This incredible discovery, which was totally unexpected since it went against all the cosmological knowledge of the time, was compatible with the presence of an extremely widespread component of unknown energy. This energy should represent approximately 70% of the whole universe and justify the accelerated expansion of the latter. The scientific community needed about ten years to metabolise this hypothesis, but it was confirmed by additional evidence. It was really the reflections and attempts to investigate

the distribution and nature of this dark component of the universe that led to setting up two space projects, named DUNE, Dark Universe Explorer, and SPACE, which were created and promoted by French and Italian research groups respectively.

How did you arrive at Euclid? And how did Italy and INFN become part of it?

At the end of 2010, thanks to a call launched as part of the Horizon 2020 programme, it was possible to incorporate the two proposals: DUNE and SPACE. These merged into a single, more extended mission, formalised and selected in 2012 by the European Space Agency, which was given the name Euclid. The name does not come from an acronym but was chosen to pay homage to the founding father of geometry, the Greek mathematician Euclid, with the main mission and purpose of understanding the reasons behind the geometry of the universe. In the following decade, the project then took form mainly through the principal contributions provided by the two promoter nations, France and Italy, initially represented by the Italian Space Agency, since this is the coordination body of our country's space activities. INFN, whose mission of studying the fundamental components of the universe overlaps the one of Euclid, thus became part of the Euclid scientific consortium, which had been founded in the meantime in strong synergy with INAF, in 2015.

What are the characteristics of Euclid and what is its objective?

Euclid is a space telescope able to make measurements both in the visible spectrum, thanks to one of the tools it is equipped with, VIS, and in the near-infrared spectrum, via the NISP detector. Both instruments, which receive light in these different wavelengths thanks to an enormous quantity of pixels, 600 million for VIS and 63 million for NISP, will need to measure the geometry of the universe. This will be done using an approach that we could define as "brute force" because, in the next six years, Euclid will map an enormous quantity of galaxies, providing an accurate description of approximately a third of the structure of the whole universe. In this way, the mission will be able to contribute to shining light on the causes that have determined the geometry of the universe, supplementing the current cosmological model, and making it more accurate, through new information on the nature of dark energy. According to current models, dark energy could consist of a quantum field of a new type, or it could depend on changes in the gravitational field as described by the general theory of relativity, or, again, be associated with the value of the cosmology constant, which determines the rate of expansion of the universe, the actual value of which is still in doubt today, depending on the different measurement techniques used to calculate it. By measuring billions of galaxies, Euclid could give indications about the possible origin of dark energy, whose presence obviously cannot be analysed by neglecting dark matter, the other dark component of the universe, because it is equally involved in the evolution and structure of the universe. In addition, the importance of the cosmological measurements that Euclid will produce for particle physics should be emphasised and, in particular, for the constraints that will be obtained on masses of neutrinos, and their order. The cosmology may, in fact, contribute a lot to understanding the properties of neutrinos using different methods to which INFN is used to, such as the direct measurement experiments conducted using detectors on Earth. The Planck mission demonstrated that it is possible to deduct fundamental characteristics of neutrinos in the context of consolidated cosmological models. Thus, by both testing cosmological models and enormously increasing the precision of the measurements of mass and number of neutrinos, Euclid will be in a privileged position to test the laboratory measurements.

What phenomena and cosmological properties will Euclid investigate?

To determine the structure and expansion of the universe, Euclid will concentrate on two main aspects: the weak lensing effect and galaxy clustering. The first is the phenomenon of distortion of the shape of the galaxies observed due to the gravitational action exercised by nearby masses or the presence of dark matter; the second concerns the position of galaxy clusters in three-dimensional space. These two observable phenomena will be studied by measuring the shape of the galaxies, which will be done thanks to observations in the visible band by VIS, and measuring the distance of the galaxies themselves, defined starting from the redshift of the spectra they emit, analysed by NISP. If Euclid will provide useful clues for reconstructing the distribution of dark matter in the various stages of the universe's life, thanks to the observation of weak leansing on a large scale; and, by measuring the spectrum of galaxies, it will provide information on how old the galaxies are and thus on the earlier stages of the universe’s evolution.

How did INFN contribute to the development and implementation phase of the telescope, and which facilities were involved?

INFN contributed to the creation of Euclid by providing its specific experiences and expertise, through the involvement of approximately 70 researchers coming from the Bologna, Ferrara, Genoa, Lecce, Milan, Padua, Rome, and Turin INFN Divisions. INFN was responsible for everything related to the telescope's on-board electronic. And afterwards, it also worked on broader activities, such as the tests for integrating and operating the project on Earth. Specifically, INFN was responsible for the so-called “warm electronics” of the NISP detector and the operational checks of two specific objects, the Data Processing Unit (DPU) and the Instrument Control Unit (ICU). In the operational phase of data collection, INFN will work on the production of scientific data and the data analysis, and it will also provide providing the Italian component of the mission with part of the computing resources necessary for the data analysis and for simulations of scientific results that will be obtained.

After the first images of Euclid released at the end of July, what are the next important events and when is the data acquisition phase expected to start?

Euclid completed the standard commissioning phase, dedicated to checking the correct operation of the systems on board the telescope. This stage lasted a few days longer than anticipated due to an issue, which caused a simple rescheduling of the observational campaign without affecting data acquisition, as the evocative images, already transmitted during the final stage of Euclid’s journey towards its observation point at Lagrange point L2, show. After commissioning, the performance-verification should have started to test the validity of the scientific results. During this phase, lasting about a month, checks and calibrations of the two instruments VIS and NISP are carried out, with images produced to determine the actual capabilities of the two detectors. This phase was postponed to late September due to a software problem in the satellite's guidance pointing, reallocating Euclid to commissioning while waiting for the problem to be solved. The actual data taking phase should therefore begin around December.