Euclid newsletter

Issue 2, November 2012

http://www.euclid-ec.org/

News from the Bridge

Dear Friends of Euclid. After the exaltation following the adoption of Euclid by ESA last June, the organisation of the project is re-shaping in order to move from the definition to the implementation phase. ESA has set up the ESA Euclid Project Office, with Giuseppe Racca as Project Manager and Rene Laureijs as Project Scientist. The Project Office team is now almost complete and operational and I am happy to welcome the whole ESA Euclid team in the Euclid Odyssey. The "Euclid Seminar" organised last September was an opportunity to set the whole Euclid Organisation and imprint this "Kick Off" in 2 movies that will be made public to the Consortium soon.

On the Euclid Consortium side, the VIS instrument team has a new Project Manager, Sabrina Pottinger. Sabrina started at MSSL this summer and will progressively replace Richard Cole. Richard has not left yet, but I would like to use this opportunity to warmly thank Richard, on behalf of the Consortium, for his impressive dedication and masterful contribution to the design of VIS and to the successful selection of Euclid. On the US side, NASA has now selected 40 NASA-appointed scientists who are expected to integrate into the EC in early 2013.

On the technical side, beside the on-going EC activities on VIS and NISP, ESA issued the Invitations To Tender (ITTs) for the procurement of the VIS CCDs this spring and the NISP NIR detectors this fall. A most important step started last July when ESA issued the ITT for the Payload Module (PLM). ESA received the responses from industry on October 9 and started the selection process that should end by December 2012. We should therefore have important details on the Euclid telescope soon, so that the VIS and NISP teams can consolidate the interfaces with the PLM by next spring and ESA can issue the ITT for the Service Module (SVM) by the end of this year. If everything keeps on schedule, the SVM and the industry Prime Contractor will be selected by the end of June 2013.

The Euclid Consortium is also preparing the Preliminary Requirement Review of the Science Ground Segment (SGS PRR). With this most important milestone of the Euclid mission in mind, the EC SGS, the SWGs and ESA are now entering in an very active phase, with the delivery of the SGS PRR documents to ESA in May, as primary target of 2013 (likely the week after the Euclid Consortium Conference in Leiden).

At this early stage of the project, I am very happy to see that the momentum generated by the selection has not declined. The enthusiasm inside the Consortium and ESA is still there and indeed is very well illustrated by the incredible activity inside the COMS group. The selection of a logo is important for the Consortium, and it is also important that the selection is made by all of you, so that all EC members recognize themselves through it and use it in all Euclid documents... so I wish you a good logo selection!

Yannick Mellier

From the editors

Welcome to the second edition of the Euclid newsletter. Members' continuing enthusiasm to write articles has been fantastic - thank you to all those who have sent or volunteered text. One of the main aims of the newsletters is to share information across the consortium. This issue includes our first article about the ground segment - starting with the French SDC - plus descriptions of both OU-VIS and the VIS instrument. We report updates from science working groups across the consortium, plus an in-depth article this issue on baryon acoustic oscillations and redshift space distortions. Stefania Pandolfi is a new a co-editor with special responsibility for the science section. A digest of Euclid-related press-releases joins the regular sections explaining acronyms and advertising upcoming events. We wish to make this a regular feature, so please inform us about any releases you organize.

Jarle Brinchmann, Richard Massey & Stefania Pandolfi

The Logo Competition - The Candidates

Earlier this year, 43 members of the consortium submitted 88 entries to the logo competition. The COMS team and Euclid Consortium Board selected a shortlist, then engaged three professional graphic designers to work with your submissions. The professional designers polished four options, which have now been approved by the board. What is missing now are your votes! All EC members will have received an email with voting instructions - read carefully and choose wisely - the deadline is **December 4**.

The COMS group (see p2 "News from the COMS group")

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News from the Project scientist

Now that Euclid is in the implementation phase, the study phase feels like a distant past. Starting a few months before the adoption of the mission by the Science Programme Committee in June, the ESA four-person Study Team was transformed into a much larger Euclid Project Team. This team has grown to 17 ESA staff, who were recruited within ESA from other project teams. After a course "Euclid for Engineers" held at IAP (10-14 September), the team got the specific knowledge of the Euclid mission. The lectures were organised by the Euclid Consortium and provided a unique in-depth view on the mission and its science. It caused a great boost in motivation for all participants.

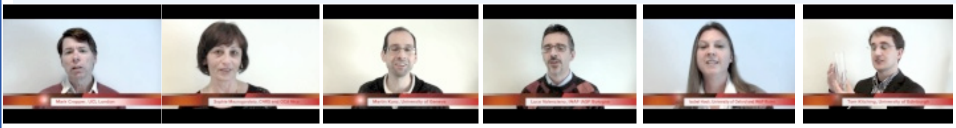
With the overarching Project Team in place, several activities were immediately started. The Invitation to Tender of the payload module (PLM) was released to industry in July, only a few weeks after the adoption. This could only happen thanks to the combined effort of the Euclid Consortium and the Project Team. The PLM design and development are driven by the required image quality of the Euclid telescope and the accommodation of the VIS and NISP instruments. Also the procurement of the detectors and supporting electronics has been initiated. The detector assemblies and the primary mirror are "long lead" items. These are flight critical hardware which require a substantial time to manufacture. An early start ensures timely delivery of the instruments and telescope.

Meanwhile the flow down of the requirements are reviewed by EC and ESA in order to prepare for the selection of the Prime Contractor who will be responsible for the overall system and the spacecraft service module (SVM). The selection procedure of the Prime Contractor will start as soon as the PLM design is known. According to the planning, the PLM contract will be kicked-off in December, and the contract with the System Prime will start before July next year. Until that time ESA will act as the system prime for the PLM.

In the coming months new teams and groups will appear - you may be a member or you may start interacting with them. I will enumerate a few of these to give an impression of the activities. We will have two independent industrial teams manufacturing the detector assemblies, a Euclid team at JPL supported by GSFC for the delivery of the near-infrared flight detectors, the Euclid Mission Operations Centre (MOC) in Darmstadt and the Science Operations Centre (SOC) in Madrid for the ground segment, the industrial contractor for the PLM, the Euclid Steering Committee for the funding agencies, the US participation of 40 scientists, a number of mission wide working groups for the survey, calibration, data management, etc., and most importantly, the Prime Contractor. In addition, EC members organised in SWGs, OUs, and SDCs will be preparing the Preliminary Requirements Review for the Science Ground Segment in July 2013.

With the formation of the new teams we will meet in some cases familiar faces, but more often we will meet new individuals who are going to provide their contribution to Euclid. This is one of the most fascinating aspects of a space mission: it brings together hundreds of engineers, scientists, and many others with different backgrounds, different nationalities, and maybe different opinions, but with a strong willingness to make the mission a success.

René Laureijs



Several video interviews with EC members made in Copenhagen by Valeria Pettorino from the COMS group are available through YouTube, see the EC web site for further links.

Update from the COMS group

The last year has been extremely busy for the COMS group as we start to deal with improving the internal communication and education and public outreach (EPO). We are eager to hear from people in the consortium interested in such issues and as a start, encourage you to contact Bob Nichol (for internal COMS), or Anais Rassat and Richard Massey (for EPO).

The most pressing issue is the selection of **a new logo** for Euclid. At the Euclid Consortium meeting in Copenhagen in May, the COMS group launched a competition for a new Euclid logo (set up by Richard Massey). The response from the consortium was overwhelmingly positive, with 43 members submitting 88 entries. The COMS team and the Euclid Consortium Board selected a shortlist, then engaged three professional graphic designers to work with your submissions. The professional designers adapted the best of the public submissions to generate the four options shown on the previous page, which have now been approved by the board. Voting on these four options is now open - each Euclid member will receive a unique URL with which to vote. The COMS group is looking forward to your votes.

As a centralised location for COMS information, the Euclid COMS **redmine** wiki is accessible to all Euclid members. It currently hosts information on the Euclid Calendar (set up by Valeria Pettorino) as well as information for new members and EC guidelines for online collaboration tools. We expect this wiki to grow in the future, to host further internal COMS documents as well as EPO resources. In the near future, the administration of the Euclid redmine will be transfered from Edinburgh to ESA, providing a more stable platform for this hugely successful wiki. We thank our Edinburgh colleagues, especially Keith Noddle and Tom Kitching, for their wonderful work so far in starting and maintaining the redmine. In future newsletters, we will update everyone on the redmine progress.

An updated **COMS** section in the Euclid **management plan** is currently in preparation, which should be ready for the new year. This will underline an important goal of the COMS group, which is to prepare a report on all EPO activities undertaken by Euclidians (which we expect annually or biennially). In order to do this, we are preparing an online **EPO tracking form**, which anyone undergoing EPO activities will be asked to fill out once a year. The goal of this report will be to help the COMS group understand how best to reach our EPO communication goals and to recognise the immense amount of work undertaken by Euclidians in EPO activities. We expect to launch the tracking form in the new year.

In other news, the COMS group is happy to see the Newsletter edited by Jarle Brinchmann and Richard Massey continue, with Stefani Pandolfi joining as co-editor for the second edition.. The Euclid website which is currently maintained by Raphael Gavazzi, has been updated to include the twitter feed (#euclidmission) videos, internal documents and the calendar. Once you have chosen the logo and technical support will be found, we plan to revamp the website accordingly.

Anais Rassat, Bob Nichol, Richard Massey.

The Science Ground Segment and Instruments

The Science Ground Segment

The organisational activities needed to plan and design the implementation of the Science Ground Segment (SGS) for the Euclid mission are progressing at full speed, in complete cooperation with ESA's Science Operations Centre (SOC). The aim is to prepare a complete and convincing implementation plan by mid-2013, when the SGS will undergo the Preliminary Requirements Review (PRR). A meeting of the SGS Organisation Group, gathering the leaders of the Organisation Units (OUs) and Science Data Centres (SDCs), was held at the Observatory of Rome at the end of October; before that, in mid-October at IAP, the interfaces between the OUs and the Science Working Groups (SWGs) were discussed in the OU-SWG "garage days", the first of a set of meetings which will be held with a four-months cadence.

Data Processing Flow

As an entry point in the SGS documentation, the need for a Data Processing Flow document has been identified. The purpose of this document is multiple. First it will help demonstrating the match between the requirements placed on the SGS (in the Ground Data Processing Requirement Document and in the Calibration Concept Document part B) and the SGS development. This is indeed much clearer to see in a global view of the SGS activities than when they are broken down in their OU and SDC parts. Secondly it will identify the interfaces between the different OUs by locating the areas of the global data processing flow where more than one component of the SGS is a stakeholder. Finally this Data Processing Flow document will consider the issues related to the cadence of the data processing, the possible iterations between different stages of the processing, as well as the associated data volumes and transfer rates between stages, all elements that are necessary to derive the applicable constraints to the implementation solutions. A project has been created under the Project Office section in Redmine (Data Processing Flow) where progress on the document can be tracked. Note that access to the Redmine is for EC members only.

Architecture and Infrastructure

Remarkable progress was achieved in the System Team (ST), which deals with engineering aspects of the Euclid SGS. The feasibility of the envisaged SGS architecture needs to be demonstrated, and this is being done by the implementation of a mock-up system (including a basic data model, an embryo archive, a simple abstraction layer to allow the code portability across computer platforms) on which tests and benchmarks are being performed. This activity, coupled with the gathering of technical requirements on the SGS infrastructure, is leading to the compilation of an "Architecture Dossier" that will form the core of the technical documentation for the mid-2013 SGS review. All SGS ST activities are tracked within Redmine. Additionally, a scenario document defining the Euclid archives has been prepared as a joint effort between the Consortium and the ESA/SOC team: this defines the concept of a single system capable of handling distributed data and centralised metadata, and of servicing both public and Consortium-only data access.

Management

Formal activities, maybe more boring but just as necessary, are also being carried out. They have been mainly devoted to the tailoring to the Euclid SGS of the standards from the European Cooperation for Space Standardization (ECSS). This exercise will allow the SGS to be compliant with the management techniques (configuration management, risk management product assurance, etc.) needed to control a project having such a complexity.

Fabio Pasian & Marc Sauvage

The French SDC

The French Euclid Science Data Centre (SDC), also named SDC-FR, is one of the eight SDCs that are part of the Euclid Consortium Science Ground Segment (EC SGS). It is composed of two main units : the development part (SDC-DEV) and the production part (SDC-PROD). The SDC-FR is lead and managed by CNES, the French space agency.

The SDC-DEV aims to provide development infrastructure and to develop (i.e. design, coding, tests and scientific verification and validation) and to maintain of the Euclid processing software (scientific pipelines). While the SDC-PROD aims to provide the computing and storage infrastructure, and to operate the pipelines running on it.

The French SDC-DEV infrastructure is hosted at the APC lab and is namely based on the continuous integration paradigm. A first version of this platform named CODEEN (as COllaborative DEvelopment ENvironment) is already available and may be used by any development team (see http://redmine.euclid-ec.org/projects/codeen-users for more details - EC members only).

The French SDC-DEV relies on a development team coming from 9 French labs (APC, CPPM, IAP, IAS, IPNL, IRAP, Irfu, Lagrange, LAM), with contribution from other SDCs, working in strong coordination with the corresponding Organization Units (OUs are in charge of the definition of data processing algorithms and optionally of the development of code prototypes).

The new facility building at the CC-IN2P3 computing centre in Villeurbanne, France, which provides 850 m2 space for computing and storage resources. Source: CC-IN2P3.

In particular, the French SDC is responsible for the software development of the OU-VIS, OU-SPE and OU-LE3 pipelines, according to the algorithm specifications, prototypes and tests kit coming from the corresponding OUs. It also contributes to the software development of the Level 1, Level Q, QLA, OU-SIM, OU-MER, OU-EXT and OU-SIR pipelines.

The French SDC Production Centre relies on the existing National Institute for Nuclear and Particle Physics Computing Centre (CC IN2P3). CC-IN2P3 federates the main computing resources for High energy physics, Nuclear physics and Astroparticle physics in france. In particular it is a Tier-1 centre for the CERN LHC and is hosting a Point of Presence in the French academic network Renater (a Renater PoP).

A brand new building of 850 m² has just been built in order to be able to host new computing resources and storage resources at least over the 10 next years.

To date, the IN2P3 CC processing, storage and networking capacity are the following :

• 16 000 processing cores

What is the continuous integration paradigm? It is a software engineering practice where a project is rebuilt almost immediately after each modification. For instance automatic builds, tests, quality checks and documentation of a software project can be done each time modified code is submitted to a repository. This way problems can be identified rapidly and one avoids problems of integration of different branches of a project.

• 10 PB of disk storage

• 4 robotic silos (up to 40 PBytes capacity)

• 10 Gb/s internet access

It is foreseen that in 2015, the processing capacity will be about 80 000 equivalent cores and that the disk storage will be about 120 PBytes at IN2P3 CC. See http://cc.in2p3.fr for more details."

Maurice Poncet for SDC-FR

OU-VIS

OU-VIS -- or the "Euclid Visible Data Organisational Unit", to give its full and unwieldy name -- is one of the Euclid OUs which works "close to the metal". By this I mean we will the receive raw data from the VIS camera directly from the Euclid's chilly orbit out at the second Lagrange point ("L2") where the satellite will maintain a delicate balance between the gravitational pull of the Sun and the Earth.

Of course, "directly" still means that this data must pass through a lot of tubes before reaching ground-based data processing centres. After arriving at one the big dishes of ESA's tracking stations (distributed globally to ensure maximum visibility of the satellite from Earth) images are passed onto the mission operations center at Darmstadt where packets arriving from the telescope are formatted into files and tagged with "meta-data". This "meta-data" will tell us the exact state the VIS camera was at the moment the images were taken, along with any other information which might help us to do our job. It's equivalent to an incredibly detailed observation log that might have been made by a telescope operator in days gone by. Most of the data arriving from Euclid will be images from VIS, and it will be the highest data rate from any satellite sent at L2, several hundred gigabytes per day.

And that job? It is to deliver calibrated images as free of instrumental signatures as possible and which record faithfully the shapes of distant galaxies. As explained by Mark Cropper in his accompanying article describing Euclid's visible camera, one of the key scientific objectives of the mission is to detect how these shapes are minutely deformed by presence of dark matter along our line of sight. This means that in the work we do in OU-VIS will have to walk a thin and precarious line between removing annoying traces of the instrument such as pixel-to-pixel sensitivity variations -- and removing too much, and thereby altering or perturbing the imprint left by dark mater in the shapes of objects recorded in our images.

What does all this mean in practice? It means understanding in detail every single step of the image processing pipeline; it means counting up any and all effects not of cosmological origin which could perturb the shapes of distant objects and erase the signal of distant dark matter. This signal is astonishingly weak and, even worse, becomes weaker at larger angular separations. Measuring precisely this perturbation on degree scales or larger is extremely challenging and is almost impossible on ground-based data as a consequence of myriad tiny instrumental effects, not the least of which is our unstable atmosphere -- something that Euclid will not have confront. As we have seen, every aspect of the Euclid experiment has been carefully designed to produce a stable, reliable instrument where every instrumental effect is listed and explored in order to be precisely controlled. In this framework it's essential that Euclid data processing "does no evil" and produces calibrated images in which the cosmological signal remains intact.

Finally, calibration itself is one of the most important tasks facing OU-VIS. Some calibrations we expect to be less challenging than others-- for example, assuming the Gaia satellite provides us with a grid of reference stars across the sky, we expect that tying our images to an absolute celestial reference frame will be relatively easy. On the other hand, one of the key issues that OU-VIS will have to tackle is to provide a detailed and reliable model capable of describing how incoming light is altered by detector and telescope distortions -- the "point spread function". Many of the approximations used in the past in this kind of work are no longer applicable in the regime of extreme precision that Euclid will operate in -- the point spread function is expected to vary as function of position, wavelength and in time. This model will be derived from stellar sources in our images, and it will be one of the most important data products produce by OU-VIS; knowledge of the instrumental point-spread function is crucial for shape measurement.

Our pipeline will provide a river of data to the next OUs down the line — such as OU-SHE, which will carry out the highly precise shape measurement — a river of images where we will be able to confidently read the shapes of objects and see the traces of distant, invisible structures. Once transferred to OU-MER, the images from from OU-VIS will represent also an incredible legacy: more than ten thousand square degrees of sky will be imaged at a resolution more than an order of magnitude better than anything available today from the ground, and will cover hundreds of times the area of two decades of Hubble Space Telescope observations. Our challenge in the coming months and years to devise a robust, reliable way of producing these images.

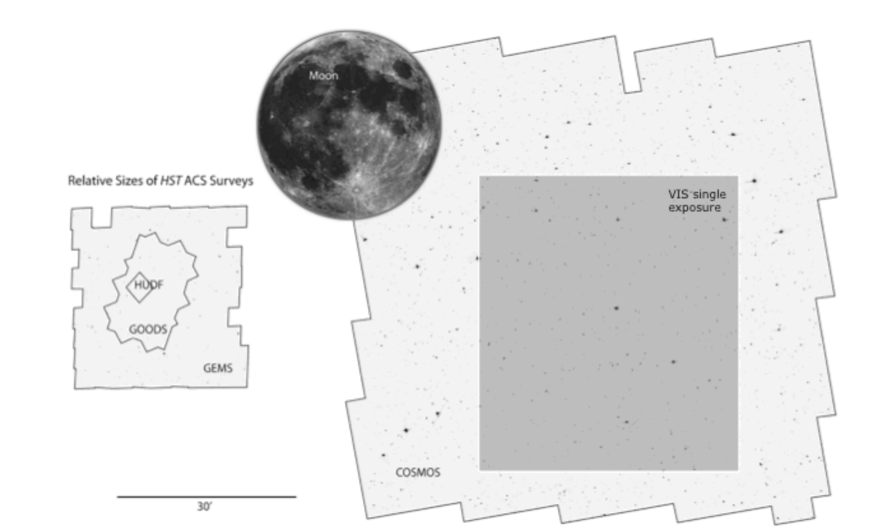
H.J. McCracken, for the OU-VIS team.

The VIS Instrument

Those of you who saw the first newsletter will have read how the cosmos can be studied with weak gravitational lensing. This allows direct mapping of dark matter, and by looking at how this has evolved with time, provides strong constraints on the properties of dark energy. Weak Lensing causes small distortions in the shapes of galaxies. Measuring these distortions requires images of a very large number of galaxies, recorded with the highest spatial resolution and stability. While each galaxy has its own intrinsic shape and inclination to the line of sight, once millions are averaged in a part of the sky, the shear caused by the weak lensing signal becomes clear. These shears are only of the order of a percent, so in order to do the averaging successfully, all of the residual inaccuracies, called biases, have to be minimised, and very well quantified.

This is the difficult part of a weak lensing experiment: making sure that everything is extremely well understood. For example, to measure the shape of a galaxy, the system (end-to-end) point spread function has to be known extremely accurately because each point in the galaxy image on the sky is blurred by this function when it is recorded on the detectors. There are many contributors to the point spread function: the telescope optics, the satellite pointing and the charge spreading within the detector are the main contributions. Fortunately, stars recorded in the survey images provide direct measures of the point spread function. This can be modelled at the star positions, and then interpolated to the position which would be found under the galaxy. Of course, because of diffraction, the point spread function is larger for redder objects, so it will be different for each star and galaxy, depending on its spectrum, so the point spread function model also has to take into account the wavelength dependence. There are many other contributions affecting how well the modelling can be carried out, and some of these require special calibrations. But then we must take care that the calibrations are made with the same (or as similar as possible) instrument state as the normal observations.

An illustration of the size of the Euclid VIS imager compared to the size of various HST surveys. For comparison the COSMOS ACS survey consists of 575 ACS pointings and the HST part of the survey took 10% of all HST time over a two-year period.

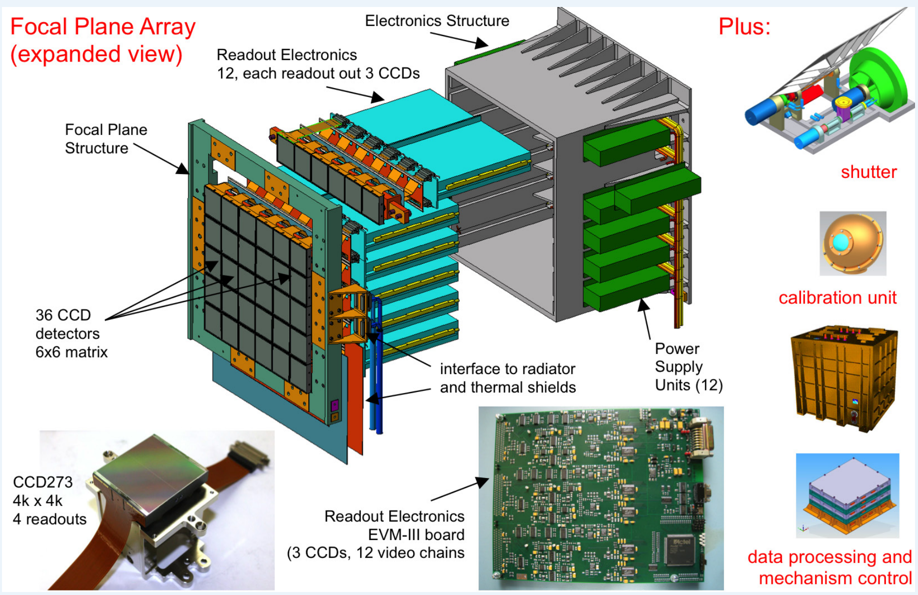


Credit: Space Telescope Science Institute/Nick Scoville (Caltech)

The weak lensing measurements in Euclid are made using the VISible instrument. VIS has a single broad bandpass, 550 – 900 nm, and is fed in reflection from the dichroic beamsplitter in Euclid which separates the optical and infrared beams. It is a large imager, with 36 4kx4kpix CCD273 detectors specially developed for Euclid by e2v, a company with substantial space experience. These sample a field of view of 0.56 square degrees at a spatial resolution of 0.1 arcsec, just sufficient for the typical galaxies Euclid will measure. The figure above shows the comparison of the VIS field of view with the major Hubble Space Telescope surveys.

A limiting magnitude mAB = 24.5 at 10s is reached for a combination of 4 exposures lasting roughly an hour. They are slightly offset from each other: this allows some spatial resampling onto a finer grid, the covering of the gaps between the detectors, the identification and removal of cosmic rays and some mitigation against radiation damage, of which more below.

The figure on the right provides an overview of VIS. The CCD matrix is arranged in a 6x6 pattern. Each CCD is read out through a set of low-noise high performance electronics which digitise the signals. The CCDs have to be held in a cold and extremely stable structure to ensure they are placed at the telescope focus, while the readout electronics and power supplies operate at much warmer temperatures. This requires very careful thermomechanical design. There also needs to be a shutter, so that the CCDs can be read out at the end of an exposure (this has to operate flawlessly for many years), a calibration unit to flood the CCDs



with light so their pixel-pixel non-uniformity can be measured and corrected, and two electronics units in the spacecraft service module. The first of these takes the digital data from the CCDs and reformats and compresses them, passing the images on to the spacecraft bulk memory for sending to the ground. The second manages the instrument mechanisms, heating and power switching.

Another critical aspect of the galaxy shear measurement with VIS is radiation damage to the CCD detectors. This causes a trail behind each image, which affects its shape. This can be corrected using special algorithms, which, however, depend on knowing the characteristics of the detectors in exquisite detail. A substantial laboratory characterisation of the CCD273 is under way in several institutes.

VIS is built in the UK, France, Italy and Switzerland, in a collaboration which brings together years of experience in realising many front-ranking space instruments. With VIS, Euclid will transform our ability to make weak lensing measurements, and provide the observational constraints we need to understand the nature of dark energy. Of course, for the weak lensing measurements, VIS is only the start of the process: the Euclid Science Ground Segment will be responsible for treating the data from VIS, applying the calibrations and making the shear measurements, and that is a whole story in itself.

VIS will produce the most amazing images of almost all of the whole extragalactic sky. Each image is enormous, 24k x 24k pix, more than 0.5 Gpix. It will be the second biggest imager in orbit, after Gaia, but unlike Gaia, all of the data will be sent down to Earth. At 0.15 arcsec resolution, the images will be similar to those produced by HST WFPC2. These images will be widely used for every purpose in astronomy, beyond the cosmology, especially when combined with the Euclid infrared imaging and spectroscopy. The survey will provide a superb resource for the other more targeted facilities at that time, JWST, the ELTs, ALMA, and SKA. But more than that, VIS images will become iconic, entering everyone's lives, and shaping our view of the cosmos.

Mark Cropper

Credit: Tom Jubb (Durham University

Science with Euclid

Mapping the large-scale structure of the Universe in time and space with Euclid

Over the past few decades, a fundamental contribution to the emergence of what we call today the "standard" cosmological model has come from redshift surveys. With this term, astronomers describe systematic campaigns to measure the distances of large samples of galaxies and map the large-scale structure of the Universe over vast regions. It is the expansion of the Universe itself that provides us with a method to estimate these distances: the wavelength-shift (or red-shift, as galaxies are generally moving away from each other with the cosmic flow) of galaxy spectral lines with respect to their laboratory value, combined with a model of the expansion tells us when those photons were emitted, from which a distance can be inferred.

The resulting maps of the 3D galaxy distribution reveal a complicated structure, with galaxies distributed in clusters, filaments and sheets surrounding huge empty voids. On very large scales, this pattern is a relic of the physical processes that happened in the early Universe setting up the seeds that will grow to become galaxies, combined with evidence of the opposing forces upon them – expansion and gravity. Thus, quantitative measurements of galaxy clustering directly probe the values of the crucial parameters regulating the cosmological model. It is these measurements, from surveys of $\approx 10^6$ galaxies like the Sloan Digital Sky Survey and the 2-degree Field Galaxy Redshift Survey, which have convinced us that the apparent acceleration of cosmic expansion (see below) indicated by the observation of distant Type Ia Supernovae is indeed real. This implies that, in addition to a significant amount of dark matter, the Universe contains even more dark energy, which is responsible for the current acceleration of the overall expansion.

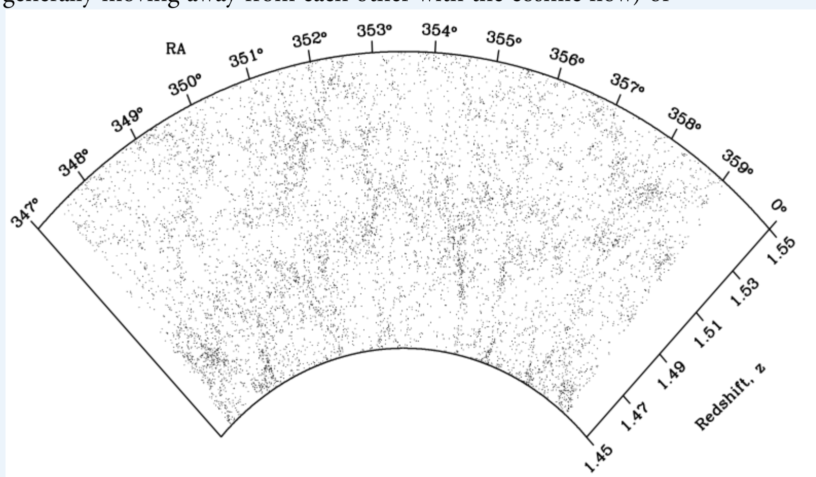


Figure 1 Simulation of a small patch of the Universe as surveyed by Euclid. This 100 deg² patch covers approximately 1/150 of the final sample, and 1/15 of the depth. The expected large-scale structure can clearly be seen in the pattern of dots – each dot representing an observed galaxy.
Credit: Alex Merson, Carlton Baugh, Durham University

Remaining open questions

Despite its overall success, this concordance model leaves a number of questions open. The mathematically simplest dark energy model is the Cosmological Constant, a parameter introduced and later on discarded, by Einstein himself. Its practical effect is to dress space with a vacuum energy density, such that while the Universe expands its volume, the total energy increases proportionally. There are several problems in accepting this scenario and several alternatives seem physically attractive although mathematically more complicated. Accurate measurements of both the global expansion rate of the Universe and the growth rate of structures inside it can distinguish between these models. Galaxy clustering provides a means to do both these measurements simultaneously through techniques called, respectively, "Baryon Acoustic Oscillations" and "Redshift-Space Distortions".

The Euclid redshift survey

In parallel to its Weak Lensing experiment (described in the previous two articles and in more depth in the previous newsletter), Euclid is going to perform a gigantic redshift survey of ~50 million galaxies located in the distant past. The survey will cover a total area of 15,000 deg^2 (1/3 of the sky), and the light from the galaxies was emitted when the Universe was between 3.3 and 7.3 billion-years old. The volume covered, measured as it has expanded to at the current epoch (what is called comoving volume), is approximately 7 x 10^{30} cubic light years, i.e. about 50 times that of the Sloan Digital Sky Survey! Euclid will build up its map by tiling the sky with a mosaic of pointings, obtaining spectra of all emission-line objects within its field of view. Redshifts will be obtained by identifying one specific feature, the Hα line emitted by hydrogen when it is heated by young stars or other energetic sources. Given its target redshift range, Euclid will perform its observations in the Infrared (λ>1100 nanometres), i.e. the band into which the Hα line is redshifted from its laboratory position of 656.3 nanometres.

Baryon Acoustic Oscillations

The unique maps of the distribution of galaxies over space and time built in this way contain all the information needed to measure the expansion and structure growth rates. First, large-scale structure is characterized by a specific scale (the so-called Baryonic Acoustic Oscillation, or BAO, feature), which was imprinted near the epoch when the Universe became transparent and matter decoupled from radiation. This fact, combined with Cosmic Microwave Background observations such as those from the Planck satellite, gives us a way to know the intrinsic value of this scale, which can be compared to that measured from the redshift survey data. The match at all different redshifts measured by Euclid will give us the best set of parameters describing cosmological expansion, and in particular show at which level, if any, the cosmological constant is not constant.

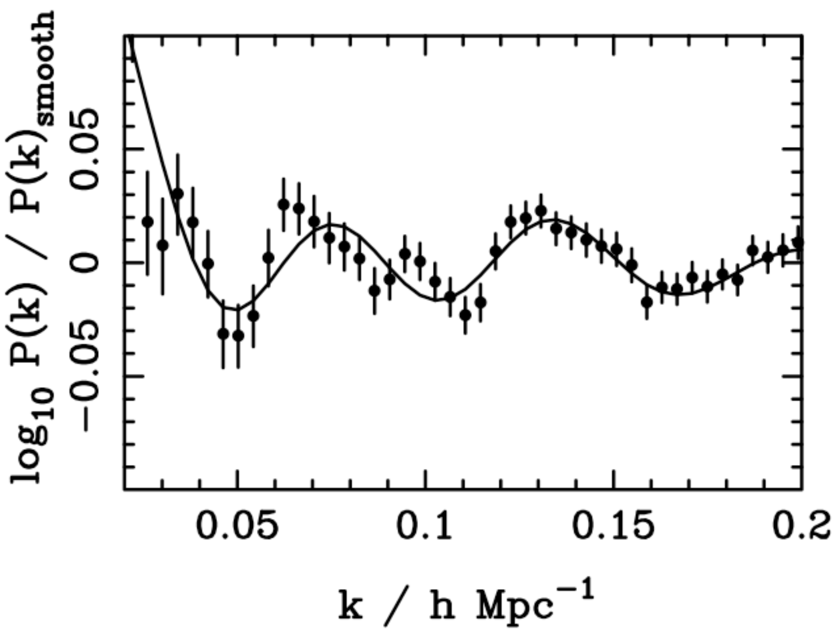


Figure 2. The current best-ever measurement of low-redshift Baryon Acoustic Oscillations from the Baryon Oscillation Spectroscopic Survey (BOSS). These features in the clustering power spectrum act as a standard ruler allowing the expansion of the Universe to be measured. Credit: The BOSS team, Anderson et al. (2012; arXiv:1203.6594)

Redshift-Space Distortions

At the same time, the measured redshifts contain an extra, extremely important contribution, which is produced by their motions driven by the gravitational growth of structures. This effect adds as a Doppler effect to the cosmological redshift, and translates into a spurious deformation of the clustering pattern along the line-of-sight if we assume only cosmological expansion when translating redshifts to distances. This effect, called Redshift-Space Distortion (RSD), can be modelled to our benefit, and a direct measurement of the growth rate of structure at different epochs obtained. A discrepancy between the measured growth rate and that computed assuming General Relativity and given the observed expansion rate will indicate a problem in the laws of gravity. In practice, the two quantities are interlaced and will be measured together. One main effort for the scientists involved in the Euclid mission will be, over the next few years, that of optimally combining and modelling these effects, as to extract the most precise and unbiased measurements of the crucial cosmological parameters. As well as providing such a large data set, Euclid's uniqueness comes in its ability to control such potential systematic biases, by cross-comparing the measurements of the very same quantities obtained from its weak-lensing and galaxy-clustering cosmological probes. Thus the measurements are expected to be the most accurate for both statistical errors, driven by the map size, and systematic errors, driven by the data quality.

Luigi Guzzo & Will Percival

What does the acronym stand for? MOCD

This stands for the Mission Operations Concept Document and is split in part A and part B. Part A contains all assumptions and constraints which were considered for the construction of the reference sky survey, while the actual sky survey implementation is discussed in part B.

The Primeval Universe

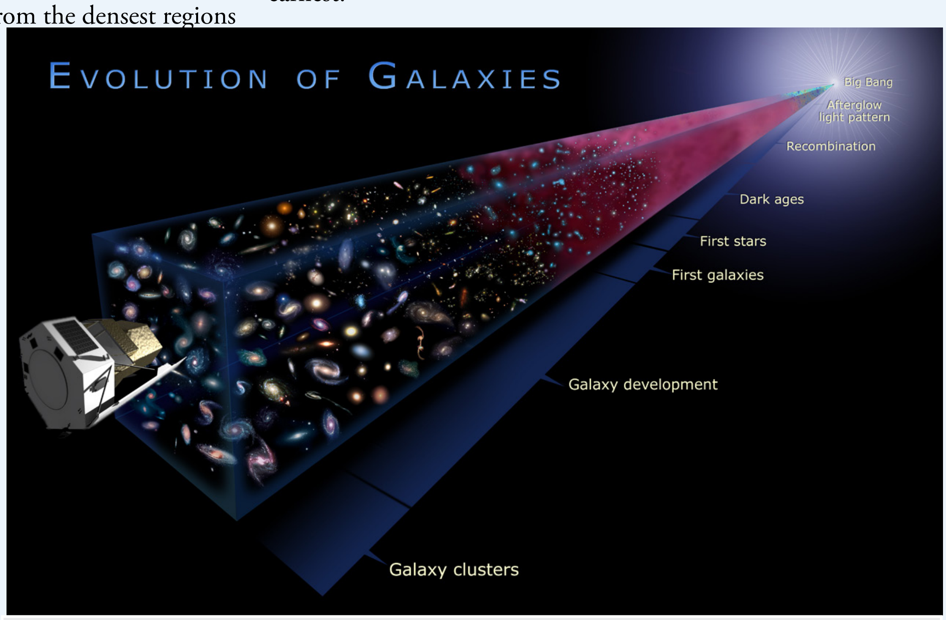
One of the most important scientific discoveries of the previous century is that of the cosmic microwave background radiation. The results from the COBE, WMAP and now also the ESA Planck mission show that the matter density at the time when radiation decoupled from matter, though extremely homogeneous, had small density fluctuations at the level of a few parts in a million. The inflation scenario suggests that these anisotropies originated from quantum fluctuations in a microscopic part of space-time that was inflated (through one or more phase transitions in the fundamental interactions a tiny fraction of a second after the big bang) into the macroscopic regime, and hence became our entire observable Universe. Truly, this is a staggering scenario.

When we look out in the Universe, away from the densest regions of our cosmic habitat - The Milky Way - it is Galaxies that meet the eye. Why do galaxies exist, what are the properties of Galaxies, when and how did they form, how do they evolve, and in which variety do they exist through out the cosmic ages? The answers to these questions are not known, but during the last 10-15 years the big picture has come more and more into focus. It is now clear that the dark matter is a crucial component in the Galaxy cooking recipe. Without dark matter there would be too little time for the gravitational instability to grow the primordial density fluctuations into the structure observed in the local Universe. Unfortunately, the very nature of dark matter prevents us from seeing it (with photons). What we can see is the baryons (stars, gas and dust). The fantastic fact is that the entire history (or at lest the vast majority of it) of the Universe is available for observation due to the finite speed of light. We simply (although it is not simple) have to observe a sufficiently distant part of the Universe to look back to the epoch when galaxies first appeared. Obviously, this become increasingly difficult as we move to larger and larger distances: the sources get fainter and most of the radiation gets redshifted into wavelength regimes where there is much more background noise. It may sound incredible that we should be able to look back more than 13 billion years to when the first galaxies formed, but this is exactly what is becoming technically possible now.

Approximately 380,000 years after the Big Bang, as the Universe expanded and cooled, the plasma constituting the Universe started to recombine, creating a gas of neutral atoms. A few hundreds of millions of years later (between redshifts 20 to 6 approximately) the gas was re-ionized again by the ultraviolet photons emitted by the first stars and quasars formed in the Universe.

The role of Euclid

For the study of the primeval Universe and in particular the study of the first galaxies that emerged after the Big Bang the most critical part of the Euclid mission is the Deep Survey. The deep Survey is deep enough to be able to locate a large sample of the brightest galaxies at redshifts larger than 7 (corresponding to look-back times of more than 13 of the 13.7 billion years since the so-called Big Bang). This is very important for several reasons. First of all it takes a large-area survey as the Euclid Deep Survey to have sufficient statistics to characterize the rare bright galaxies at these extreme look-back times. These objects will likely be the only that are bright enough for detailed spectroscopic studies even with the next generation of extremely large 30-40 m class telescopes. They are also interesting as they most likely represent the rare density peaks in the universe where the galaxy formation process started earliest.



Euclid will provide a deep prove of the most distant Universe. As this figure illustrates, and the text explains, looking towards the furthest regions of the Universe means looking back into the past. The deep near-IR images produce by Euclid will allow us to study the formation of the most massive first galaxies. Image credits: NASA, ESA, and A. Feild (STScI)

In addition to revealing the brightest galaxies at redshifts beyond 7 the Euclid wide survey will revolutionize the study of the first super-massive black holes, in the form of bright quasars, at these same early times. The most distant quasar we know is at a redshift of 7 and this quasar resembles bright quasars at lower redshifts both in terms of black hole mass and content of chemical elements heavier than hydrogen and helium. It is enigmatic how these extreme objects can form so rapid after the Big Bang and the Euclid Wide survey will be essential for seeing the appearance of the first quasars.

In total, Euclid is expected to discover a few hundreds of galaxies at redshifts higher than 7 and a few tens of quasars at redshifts higher than 8. With this large number of objects, and the information contained in their spectra and in their spatial distribution, Euclid will revolutionize our understanding of the re-ionization of the Universe.

Johan Fynbo & Jean-Gabriel Cuby

Updates from the Science Working Groups

Weak Lensing SWG

The WLSWG has been active over the summer period writing several papers that document some of the work that went into the Definition study report and subsequently. These are, or will soon be on arXiv and cover i) systematic propagation of weak lensing measurement requirements into the dark energy Figure of Merit (Massey, Hoekstra, Kitching, et al 2012, http://uk.arxiv.org/abs/1210.7690) ii) the budget allocation approach used in the requirements flow down (Cropper, Hoekstra, Kitching et al 2012, http://uk.arxiv.org/abs/1210.7691) iii) galaxy colour gradient investigations. The SWG has been working closely with OU=SHE and OU-LE3 on requirements and has initiated a requirements flow down for these areas. Important work has been done on the links between photometric redshift requirements and intrinsic alignments.

The WLSWG has set up several Work Packages that cover the measurement aspects (shape measurement and photometric redshifts), simulations (imaging simulations and cosmological simulations) and Work Packages covering all aspects of the weak lensing science. These Work Packages will report back at regular meetings of the SWG on 6 monthly timescales. The next WLSWG meeting will be in at EPFL, Lausanne from 28th to 30th November 2012; we encourage any Euclid Members interested in the weak lensing aspects to attend.

Henk Hoekstra, Tom Kitching, Karim Benabed

Galaxy Clustering SWG

The Galaxy Clustering Working Group has been defining the scientific work-packages that are needed to get Euclid key science in this field. Specifically, these are required to enable the cosmological investigations based on the quantities computed by work-packages in the Science Ground Segment (SGS). We have worked hard to ensure complimentarily with the SGS work packages to assure a smooth flow of the process, and many of the sub-groups we have proposed are joint with SGS entities. We are now in the process of identifying scientists to work on each of these packages, and are increasing our use of the wiki to enable this. We hold regular telecons on the first Tuesday of every month.

Luigi Guzzo, Will Percival

Galaxy & AGN Evolution SWG

After providing input to the Legacy Data Processing Requirements Document, the Galaxy & AGN Evolution SWG has been spending time setting up a set of scientific work-packages (WPs) to address several areas where work must be done and where it is important that we provide input to the ground segment. In the coming months these WPs will start up projects within the SWG but also, we expect, in collaboration with other SWGs and OUs. There are at least two core goals for the coming months: Ensure that the physical parameters for galaxies that the ground segment will produce meet the scientific requirements of the SWG, secondly to iterate with the ground segment to explore what kind of morphological analysis can be provided automatically - given the wonderful images we will get it is important we extract as much physically relevant information from them as possible.

Jarle Brinchmann, Andrea Cimatti, David Elbaz

Milky Way and Resolved Stellar Populations SWG

There was much discussion within the MW SWG about the potential of legacy science return if some part of the Deep Euclid survey could be located near the Southern Ecliptic Pole (SEP). Although the SEP is only just over 5 degrees from the centre of the LMC most of the region has low extinction and is relatively uncrowded with LMC foreground.

Nic Walton attended the Paris OU-SWG#1 meeting to represent the MW SWG interests regarding the legacy science requirements. One of these is a goal for the overall global photometric calibration of the NIR imaging to be at the 1% or better level. The main driver here is generate accurate SFHs of resolved stellar populations.

There have been several telecons to discuss among other things the software development and simulations and required as part of OU-LE3 activities.

As a final note, Eline Tolstoy took over from Amina Helmi as co-chair of the MW SWG and we would like to take this opportunity to thank Amina for the all the hard work she has put in.

Mike Irwin, Eline Tolstoy

CMB Cross-matching SWG

On the area of CMBXC, the work is gearing up quickly waiting for the forthcoming first cosmological release of Planck data. The group has been structured in working packages, and reference persons for each of those have been identified and report regularly at telecons and meetings. Those WPs concern all the main topics where the Euclid structures play a crucial role in increasing the confidence of our detection of CMB lensing and ISW, and their correlation. Simulations are ongoing using the available N-body simulations in Euclid, in close connection with Euclid-Sim, and Euclid-Theory. An intense forecasting activity is being carried out in order to assess the constraining capabilities of Euclid-CMB on the dark cosmological components. In the coming weeks and months, we foresee publications of these results.

Carlo Baccigalupi, Nabila Aghanim

Extrasolar planets SWG

The Science Working Group on exoplanets has submitted for publication a detailed and realistic simulation of an exoplanet survey with Euclid under consideration as part of the Legacy Science. The Exoplanet Euclid Legacy Survey (ExELS, Penny et al., 2012, MNRAS submitted http://arxiv.org/abs/1206.5296) would be the first survey able to measure the abundance of exoplanets down to an Earth mass for host separations from ~1 AU out to the free-floating (unbound) regime. The cold and free-floating exoplanet regimes represent a crucial discovery space for testing planet formation theories. ExELS would use the gravitational microlensing technique and could detect over 400 microlensing events per month over 1.6 deg^2 of the Galactic bulge. Using conservative extrapolations of current empirical exoplanet mass functions determined from ground-based microlensing and radial velocity surveys, it can expect to detect a few hundred cold exoplanets around mainly G, K and M-type stellar hosts, including ~19 Earth-mass planets and ~3 Mars-mass planets for an observing programme totalling 10 months.

Jean-Philippe Beaulieu, Maria Rosa Zapatero Osorio, Eamonn Kerins

SN & Transients SWG

The Euclid-transients SWG continues to have regular bi-weekly telecons, with discussions ranging from survey strategies, to science requirements for various transient types, and the quantification of these.

The splinter session at the Copenhagen meeting earlier in the year was very useful in terms of clarifying the next steps towards a

Euclid transients survey, and identifying issues that still needed to be addressed. A sub-group of the SWG has been working hard to generate FoM estimates that allow a like-for-like comparison to be made with other surveys, e.g. DES.

Given that Euclid would be the first ever large-scale, space-based near-IR search for transients, defining an optimal survey strategy is crucial. Members of the SWG have simulated several possibilities. Our preferred strategy of a dedicated six-month survey split into two campaigns would have several exciting outcomes. For type Ia supernovae, for example, we would expect an unprecedented ~1700 well-sampled events between $0.75 \leq z \leq 1.3$, which would constitute constitute a crucial independent complementary probe of cosmological parameters. A document detailing the Legacy Science requirements for supernovae, including various survey options has been submitted to the science coordinators and survey scientist.

Additionally, the Transients SWG is liaising with the SGS to implement the testing of various transient detection algorithms. An input task list has been prepared for Euclid OU-LE3, and is currently being refined.

As ever, the discussion of the timescales and management of transient alerts, and consequences for ground-based follow-up remain topics of lively debate!

Rubina Kotak, Isobel Hook, Charling Tao, Enrico Cappellaro

Strong lensing SWG

The SL SWG is currently devoting efforts to develop the methodologies that will be used for science exploitation of the Euclid data. Members of the group have quantified the number of strong lensing features that are potentially observable by Euclid on both cluster and galaxy scales. This was done following two complementary approaches. Semi-analytical methods were used to populate an artificial sky with cluster scale lenses. With the help of ray-tracing methods and realistic instrumental simulations, the number of strong lensing features emerging above the expected sky background was quantified. These simulations also helped to characterize the redshift distributions of lenses and sources in the future wide-survey of 15000 deg^2. The results of this study were published in a paper by Boldrin et al. (2012, arXiv:1209.2709, recently accepted for publication on MNRAS). A more observation-oriented approach was used by Pawase et al. (2012, arXiv:1206.3412), who visually searched for galaxy-scale strong lenses in ~7 sq. degrees of HST images. They extrapolated the rate of SL systems in this survey to predict the expected number of galaxy strong-lenses in the future Euclid observations.

Several members of the group are now involved in the development and testing of software for the automatic detection of strong lensing features. The group has started an exciting project, called "The Bologna Lens Factory", whose goal is to create a database of simulated galaxy and cluster scale images, which will be primarily used to test and calibrate the arc finders. The images will be made available to the entire Euclid consortium through a web page. Anybody interested in testing his/her own software on the images will be able to download them and to submit the results of their analysis. The images will include realistic Euclid, HST, Subaru, VST and LSST simulated observations. In this way, it will be possible to quantify the level of completeness and purity of the detections and to study which classes of lenses will be more easily detectable in the Euclid data, also including the additional information from external data. Knowing this is crucial for the group to identify the most promising strong-lensing science cases and to assess what level of precision will be reached on the determination of several lens properties and cosmological parameters.

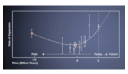
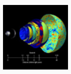
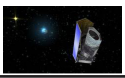
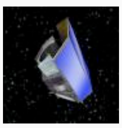
Massimo Meneghetti, Jean-Paul Kneib

Theory SWG

At the consortium meeting in Copenhagen the theory working group spent two days defining work packages for the future. Those have meanwhile been created and are in the process of starting up. The theory working group has also finished the first edition of its review document. It is available as arXiv:1206.1225, and we have submitted it to Living Reviews in Relativity where it is currently under peer-review. Some time soon we plan to start working on a second edition (following roughly a cycle of yearly internal and biennial external releases). Finally, the group moved its wiki from pbworks to the Euclid redmine site, you can find us here: http://redmine.euclid-ec.org/projects/thswg/wiki.

Martin Kunz, Luca Amendola

EUCLID RELATED PRESS-RELEASES

	Astronomers study 'roller coaster effect' of dark energy	University of Portsmouth
	Portsmouth cosmologists help hunt for answers	University of Portsmouth
	Dark energy is real, say astronomers	Royal Astronomical Society
	"Euclid" nimmt die letzte Hürde *(Euclid passes last hurdle)*	Bonn University
	Astrónomos portugueses à descoberta dos maiores mistérios do Universo *(Portuguese astronomers take part in space mission to explore the mysteries of the Universe)*	Lisbon University

What does the acronym stand for? MOC

This stands for the Mission Operations Centre and is where a satellite is controled from launch through its orbit until its demise. ESA satellites have their MOC at the European Space Operations Centre (ESOC) in Darmstadt, Germany.

What is happening in the coming months & years

November-December 2012	Selection and kick-off for PLM contract.
November-December, 2012	The teams that were successfully selected in the NASA AO joins the EC.
December 2012	Invitation to tender for System and Service Module (SVM). This is the module that provides power and control to the satellite.
January 28-29, 2013	OU-SWG meeting at the Royal Astronomical Society in London.
May 13-16, 2013	Euclid consortium meeting in Leiden, the Netherlands.
June 2013	Kick-off for the SVM contract.
October 2013	System requirements review.
Q1 2014	Instrument Preliminary Design Review (PDR)
June 8-12, 2015	Euclid consortium meeting in Lausanne, Switzerland.
Q3/Q4 2017	Flight model delivery
Q2 2020	Launch.

For more information see the Euclid calendar on the internal Euclid Consortium website:
http://internal.euclid-ec.org/

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Euclid documents at RSSD	http://www.rssd.esa.int/wikiSI/index.php?instance=Euclid
Euclid consortium Redmine	http://redmine.euclid-ec.org
COMS pages	http://redmine.euclid-ec.org/projects/referencet/wiki
ESA mission page	http://sci.esa.int/science-e/www/area/index.cfm?fareaid=102
YouTube Euclid Channel	https://www.youtube.com/user/euclidmission
Twitter	#euclidmission