The Euclid Consortium Newsletter - Spring 2017

News from the Bridge

Dear EC members and colleagues.On the eve of opening the Euclid Consortium Annual Meeting in London it is an immense pleasure to see the vitality of the activities and the progress made since Lisbon last year. After the instruments' Critical Design Review (CDR) periods it is up to the payload module and then the spacecraft to enter the CDR process that will then provide the final shape of the Euclid satellite. As the Science Ground Segment and the definition of the Euclid survey are also progressing very well, Euclid researchers have a much better understanding of the overall potential of the Euclid mission. It generated a flourishing period of excellent and very interesting scientific papers from the Euclid Consortium addressing in great detail all points regarding all scientific objectives of the Euclid mission, in particular the statistical analysis of Euclid data, its performance and the Euclid forecasts. These papers are listed in https://www.euclid-ec.org/?page_id=817 and I recommend you have a look at them.

As you will see during the London meeting many young scientists are involved in these efforts and I would like to thank and congratulate them, on behalf of the the Euclid Consortium Board, for their remarkable contributions to the preparation of the mission. I have no doubt that with the recent release of the Euclid Flagship Simulation, the scientific activities will continue to grow and new superb results will be shown again at the next Annual Meeting in Bonn next year. Prior to open London, let me give thoughts to Pierre Binetruy. Pierre was a leading person to promote gravitational wave missions and prepare e-LISA, but was also a member of the Euclid Consortium and a most active and enthusiastic supporter of the Euclid mission and the exploration of the dark universe .

I wish all of you a very good Euclid Meeting in London and take this opportunity to warmly thank the SOC, Mark Cropper (chair), Libby Daghorn, Tom Kitching, Ofer Lahav, Bob Nichol, Keith Noddle, Richard Massey, Andy Taylor, on behalf of all members of the Euclid collaboration.

Yannick Mellier

From the editors

Welcome to the spring newsletter of the Euclid consortium. We are happy to provide with an update of many aspects of the Euclid mission - in this issue the emphasis is on the bedrock of the mission: the ground segment. We have updates from several of the Science Data Centres, an update on the third Scientific Challenge and update from three Organisational Units. This newsletter also celebrates the arrival of the first Euclid flight hardware - both for the visible and the near-IR instruments, so the mission is becoming more real by the minute.

In order for Euclid to reach its goals, it is essential that we get the necessary external data, thus in addition to the update from OU-EXT, we also have updates from the coordination group for external data and the Javalambre survey. And last but not least, we are welcoming the arrival of Canada to the consortium and Ray Carlberg also outlines their external data contribution.

Enjoy!

Jarle Brinchmann & Stefania Pandolfi,

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The Euclid Consortium Meeting 2017 In London

The next EC meeting will be held in London from Monday June 5th to Thursday June 8th 2017. The Local Organising Committee (LOC), chaired by Prof. Mark Cropper from the Mullard Space Science Laboratory (MSSL) at University College London (UCL), looks forward to welcoming you to the capital city of the UK, and has arranged a full and diverse schedule of scientific and cultural events for delegates. All EC members are encouraged to join the meeting to learn of the latest information about the mission, as well as interact with colleagues via the numerous planned splinter meetings. Registration is open and details for the conference can be found at http://euclid2017.london

As with previous EC meetings, the first day will provide a comprehensive update on Euclid, including plenary talks about the on-going satellite construction, instrument development and testing, survey planning and operations, and the science ground segment. The first day will end with a reception allowing delegates to meet and discuss plans for the rest of the week as well as reflect on the present progress of Euclid.

The second day will be dedicated to splinter meetings on a variety of key aspects of Euclid science and preparations. These splinter meetings will be arranged by individual science working groups and OUs. The second day will also provide an opportunity for "Young Euclidian" (early career researchers) to make plenary presentations to the whole conference. The deadline for these contributions is May 8th and please see announcements regarding these presentations from Yannick Mellier. The second day will end with a public event hosted by Prof. Lucie Green from UCL (http://luciegreen.com) and will include a art and science performance by "Entropy" (https://tinyurl.com/lxyqqps) including EC member Dida Markovic. All delegates are encouraged to attend alongside members of the public.

The third day will be a mixture of plenary talks, providing more information on the status of Euclid, and splinter meetings. The day will also continue our public engagement activities via a "Schools Day" for the first time at such an EC meeting. During the morning, children from local schools will be invited to attend a range of hands-on activities at the conference in parallel to the EC splinter meetings. These activities will include "meet a scientist" and spectroscopic experiments helping to promote the wonder of science and technology to the next generation of students. More details about this schools programme will be provided at the conference. The third day will end with a special scientific debate for conference delegates. Details of this event will be released soon, but will include two prominent cosmologists debating the status of cosmology and key issues with our present cosmological model. The event is meant to be both thought-provoking and entertaining. The fourth and final day of the meeting will be dedicated to further talks from Young Euclidians and splinter meetings.

The conference venue is the UCL Institute of Education in the heart of London. This provides a great opportunity for delegates to explore the city and enjoy a wide variety of activities and restaurants. Details can be found on the website. There are also travel and accommodation details on the website.

The LOC and SOC welcomes you to London and looks forward to a successful and enjoyable meeting. Please register as soon as possible.

▪ *Mark Cropper and Bob Nichol*
on behalf of the Local Organising Committee

An update from the ESA Project Scientist and Manager

One very important spacecraft subsystem for Euclid is the K-band transponder. Operating at a transmission frequency of 26 GHz it enables a scientific data rate of 74 Mbps providing 850Gbit of data in 4 hours. This is unprecedented for an ESA science mission. One should realise that without the availability of the K-band system Euclid would not be able to meet its survey requirements (15000 deg^2 in 6 years) with the required instrument pixel sizes and number of dithers per field.

The choice for the K-band introduced a number of technologies which are new for an ESA led science mission. It demands a large on-board data storage which has been implemented with the solid state mass memory (SSMM), using the same hardware technology (Flash NAND) as is used commonly in USB solid state memories. With a total end-of-lifetime storage capacity of 4 Tbit, the SSMM guarantees a continuous storage of data without ground contact for three days during the nominal mission. The ESA ground stations in Cebreros and Malargue have been upgraded to support the K-band transmission, and the CCSDS File Delivery Protocol (CFDP) has been introduced for science data file transfer between the spacecraft at L2 and the ground station about 1.5 million km away. The protocol in combination with the SSMM is novel, and supports automatic retransmission of elements lost during the communications, as if we are doing an ordinary FTP between the spacecraft and ground.

We mention the development of this (mostly) hardware to point out that it only makes sense in combination with proper survey planning, data handling and data processing, including calibration, and data distribution. In the past years we have been busy designing and developing the mission operations, science operations, and the science ground segment. This activity is very "human intensive" as the effort concentrates on system processes, interfaces, algorithms and software development. To make this a success we need a very good level of organisation and a willingness by all individuals to make Euclid happen, since no contractual relationships exist among the various parties. In that respect, the science and IT challenges, currently on going, of the Science Ground Segment are good opportunities to experience the interactions and to make improvements where necessary. Although interacting with many people working in different groups and often with different (cultural) backgrounds can be tedious, it provides a lot of satisfaction to see people collaborating – despite their differences – enabling the best scientific return of Euclid.

By the end of this year we have to pass the ground segment design review where among other review objectives we have to demonstrate that the required survey can be performed and that the enormous data stream can be properly processed. The preparation of this review forces us to understand the operational activities after launch beyond 2020, not only to scope the resources needed for operations, calibration and data validation, but also to envision how the data will be used by the scientists, initially during the proprietary period, and eventually after the data releases for the best usage by the worldwide scientific community.

René Laureijs and Giuseppe Racca

Satellite communication bands

The K-band used for Euclid is very different from an astronomer's K-band, near 2 μm, and belongs to the set of L, S, C, X, and K bands used for satellite communication (see ESA's overview). But note that the K-band itself (18–27 GHz) is not used due to water vapour in the Earth's atmosphere - satellites use instead the K_u (12–18 GHz) or K_a bands (26.5–40 GHz). Euclid will use the K_a band, also used by the Kepler spacecraft.

First Euclid flight hardware delivered - VIS detectors

An important milestone has been passed in the development of Euclid with the delivery of CCD detectors for the VIS instrument.

Over the first months of 2017, the first 26 CCDs detectors procured by ESA for the VIS instrument have been delivered to Mullard Space Science Laboratory (MSSL) by UK company e2v. The remaining CCDs (36 Flight Models in total plus Flight Spares and Engineering Models) will be delivered to MSSL by August.

The CCD detectors are tailor-made to meet the demanding requirements of the mission, with extremely high efficiency, low noise, good radiation tolerance, and 12-micron pixels to match the resolution of the telescope optics. They are fabricated on high resistivity silicon with an anti-reflection coating optimized for longer wavelengths (for observing distant, red-shifted galaxies).

Each CCD comprises 4096 x 4132 pixels so that the entire VIS instrument will generate 610-megapixel images. Unlike Gaia, Euclid VIS will not employ binning or windowing on-board. Instead, all focal plane pixels will be transmitted to the ground, making these the largest astronomical images from a space telescope.

The image pixels have a 4 phase electrode structure with no anti-blooming drain. This architecture meets the requirements for modulation transfer function, high full-well capacity (and hence dynamic range) and allows flexibility in clocking schemes for good charge transfer efficiency (especially following radiation damage). There is no Supplementary Buried Channel (SBC) since this gives limited benefit in the presence of significant diffuse optical background (due to the long VIS integration time) and because an SBC would significantly reduce the full well capacity in a 12-micron pixel. The entire image section is split into two halves which are clocked in opposite directions to two separate serial registers.

> Supplementary Buried Channels are used to reduce the effect of charge traps and anti-blooming drains are useful for situtations when very bright sources are observed at the same time as fainter ones, reducing charge bleeding. Both techniques are used on Gaia - see this overview for instance.

Euclid VIS CCD during final inspection
Credit: e2v

The serial register pixels have a 3 phase electrode structure allowing the image to be read-out through either of two readout amplifiers located at each end of the register. In normal operation, the image will be split and read out through both amplifiers. This means that the full CCD image is divided into four quadrants and read out through four amplifiers simultaneously. The readout speed of each amplifier is limited to 70 kpixels/second (for optimum noise performance) giving a total readout period of almost 80 seconds. The VIS instrument includes a mechanical shutter which will be closed during this readout period.

The CCD package is similar to the design developed for Gaia. It is made from silicon carbide with flex-circuits attached to the sides allowing close butting of the CCDs in the VIS focal plane.

With a launch planned close to solar maxi-

The e2v team responsible for producing the Euclid CCDs with scientists from MSSL and ESA at the Euclid VIS CCD delivery meeting.

mum, one of the major challenges facing Euclid astronomy will be to correct the distortion of galaxy shapes due to electron trapping following radiation damage in the CCDs. The CCD operating temperature will be around -120 °C; this is far colder than necessary to eliminate dark current and has been chosen in order to reduce the effect of radiation damage by "freezing in" the dominant slow trap species.

In addition, a charge injection structure has been included. This will have negligible corrective effect in the presence of the high VIS optical background, but is included as a tool for monitoring and calibrating fast and intermediate trap species (measuring First Pixel Response and deferred charge trails). The Euclid Fine Guidance Sensor uses the same CCDs as VIS but operates with a very short, 2 second integration time. In this case, there will be negligible optical background and regular charge injection is likely to be needed following radiation damage to fill slow traps and reduce the effects of charge loss and distortion in the guide star images.

The delivered CCDs will soon undergo extensive calibration with the flight electronics at MSSL in Surrey before being integrated into the VIS focal plane at CEA in Paris. Meanwhile, the Critical Design Review (CDR) for the VIS instrument is underway and this will be followed by the CDR for the telescope later in the year. The VIS instrument will be integrated into the telescope at Airbus facilities in Toulouse in 2018.

Alexander Short & Giuseppe Racca

Alexander Short is the Instrument Engineer in the ESA Euclid Project team responsible for the CCD procurement and Giuseppe Racca is the ESA Euclid Project Manager.

The first NISP hardware delivered

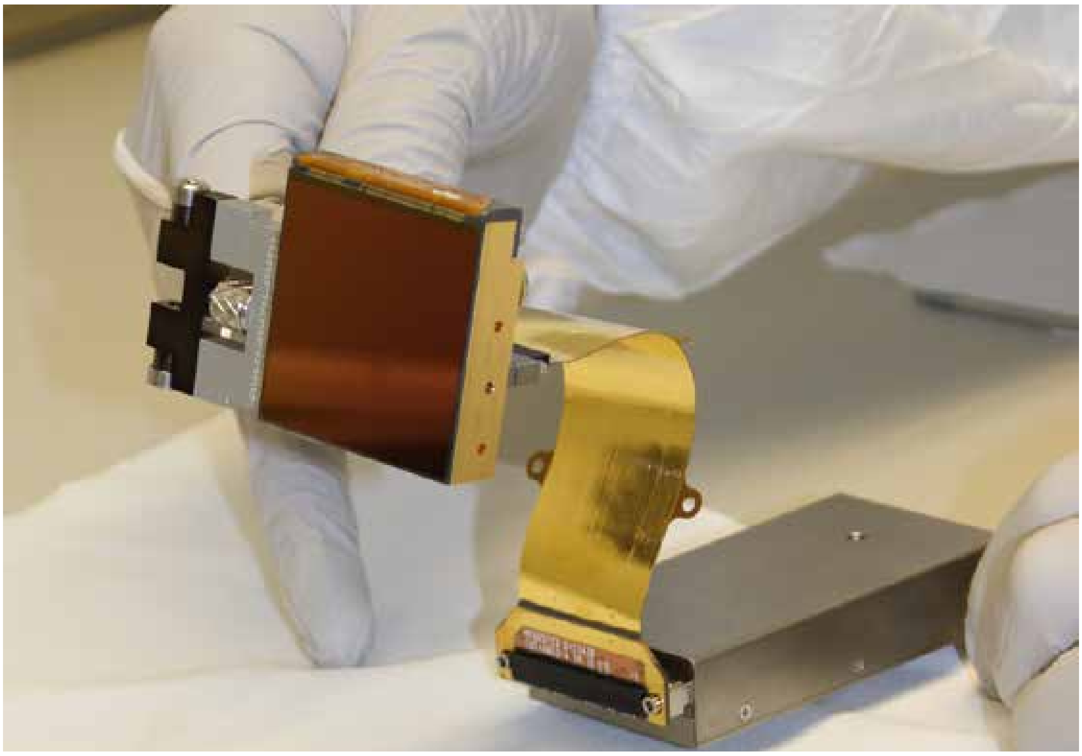
The Euclid mission passed another important milestone with the delivery of the first three state-of-the art detectors for the Near-Infrared Spectrometer and Photometer (NISP) instrument).

To achieve its objectives, Euclid will carry two wide-field instruments: a Visible imager (VIS) and NISP. A dichroic plate enables incoming light to be shared by both instruments, so that the observations can be carried out in parallel through both channels, and the arrivals of the first hardware for the instruments were also closely matched in time.

NISP is being developed under the responsibility of the Euclid Consortium, with CNES (the French space agency) and LAM/CPPM (Laboratoire d'Astrophysique de Marseille and the Centre de Physique de Particules de Marseille) as the main contributors. Other institutes and industries across Europe – in France, Italy, Germany, Spain, Norway, and Denmark – are also involved.

The NISP detectors were procured in the USA because such advanced devices were not available in Europe at the time. ESA started a Euclid-dedicated development programme with Teledyne Imaging Sensors of Camarillo, California, the leader in the manufacture of near-infrared detectors used in astronomy.

Following the successful qualification of a new type of detector, in a partnership with NASA, the flight models were designed, procured,



This picture shows one of the state-of-the-art detectors for Euclid's Near-Infrared Spectrometer and Photometer (NISP) instrument.The NISP instrument will include 16 such detectors, each of them is composed of 2040 × 2040 pixels and is 18 microns in size.

and tested by NASA's Jet Propulsion Laboratory. They were then tested and characterised in the detector lab at NASA's Goddard Space Flight Center before being delivered to Europe.

On 24 March 2017, the first three HgCdTe (mercury cadmium telluride) near-infrared detectors for the NISP instrument, fitted with proximity electronics which are designed to operate at extremely cold, cryogenic temperatures, were delivered to LAM/CPPM in France.

When completed, the NISP instrument will include 16 of these detectors. Each of them is composed of 2040 × 2040 pixels, 18 microns in size. The detectors will cover a field of view of 0.53 square degrees – slightly larger than twice the area covered by a full Moon. The photometric channel is equipped with 3 broad band filters (Y, J and H) covering the wavelength ranges 900-1192 nm, 1192-1544 nm and 1544-2000 nm. The spectroscopic channel is equipped with four different, low-resolution grisms – grating prisms that split incoming, near-infrared light into different wavelengths.

Onboard data processing is required to reduce the data stream generated by the 4 Megapixel detectors by a factor over 100, since it is impossible to deliver to the ground all the raw detector data.

In Euclid, as in other astronomy missions, the scientific instruments are the first flight hardware to be delivered because the spacecraft is assembled around them. Similarly the detectors are the first instrument hardware to be readied, as they are the first part of the "chain" to be characterised and assembled.

The arrival of the first NISP detectors is an important step in the development of the spacecraft's instrumentation. Every pixel of the NISP near-infrared detectors will now be thoroughly characterised at CPPM. They will then be assembled to form the NISP focal plane and finally integrated with the rest of the instrument for the instrument tests at LAM. The NISP instrument will be delivered for integration into the Euclid payload module in the second half of 2018.

Giuseppe Racca, René Laureijs

Based on an ESA press-release

Euclid Developers' Workshops

Since 2014, the SGS Common Tools team (part of the SGS System Team) organize a yearly Euclid Developers' Workshop which aims to share common tools, rules and best practices between Euclid developers These workshops are open to any member of the Euclid Organisational Units (OUs) or Science Data Centres (SDC) and they are all welcome to submit their own presentations.

The first one, organized by SDC-FR, took place at CNES Toulouse in 2014 with a friendly bowling contest as the social event; the second one, organized by SDC-CH, at Campus Biotech Unige in Geneva in 2015 with a fondue party as social event.

The third Euclid developer workshop took place from October 11th to 13th 2016 near Munich. It was organized by SDC-DE and hosted at Max-Planck Institute for extraterrestrial Physics in Garching.

Among the 74 attendees, 19 speakers provided training to new and more experienced developers on the development environment, tools and practices in the Science Ground Segment (SGS).

One of the goals of this last workshop was to provide a complete working knowledge of development for the ground segment: from the software repository to pipeline job submission including the management and quality insurance activities SDC (maturity gate, documentation, and so on).

The three days of intense work started precisely with an overview of the development process and project management inside the ground segment. It was followed by an extensive tutorial covering mostly the basics of software development in the local environment (LODEEN): project setup, job triggering with the pipeline runner and use of the data model. The Common software development environment (CODEEN) (see newsletter 4) was also presented. In order to be as practical and realistic as possible, the tutorial was based on a real code i.e. OU-SIR pipeline (see newsletter 6), adapted for the purpose of the training.

Day 2 and day 3 were alternating presentations and feedback from projects on the same subject. The talks were addressing more complex issues than the tutorial and the feedback from projects were given so that know-how and lessons learnt could be shared among the participants.

More specifically, day 2 covered technical question about software architecture, building, debugging, testing, parallelisation, optimisation and documentation. Day 3 was the opportunity to present the main infrastructure tools (EAS, IAL, Git, Redmine, and others) and common scientific libraries. Finally, this time the social dinner gave a taste of the Bavarian food and beer tradition.

The next Developers' Workshop will be organized by SDC-IT, based at INAF-Astronomical Observatory of Trieste, from October 10th to 12th, and hosted at the International School for Advanced Studies (SISSA).

It will be structured in three main sessions: Beginners, General and Advanced. Besides the updates and tutorials from the SGS common infrastructure, this year the workshop will benefit from the availability of examples from more mature SGS pipelines; it will also cover additional topics, including the EAS query and ingestion services (including its REST API), a comparison of image processing libraries, design patterns and tips from the currently developed processing functions and how to perform their integration tests and validation.

For more information see: https://euclid.roe.ac.uk/projects/codeen-users/wiki/User_DevWorkshops

Frederic Raison (SDC-DE), Marco Frailis (SDC-IT), Maurice Poncet (SDC-FR)

The Science Data Centres

The Science Ground Segment (SGS) is one of the pillars of the Euclid Consortium and the nine Science Data Centres (SDCs) make up the foundation of the Science Ground Segment. They provide infrastructure and expertise that will allow the scientific aspects of Euclid to be carried out.

Finland - SDC-FI

The personnel of SDC-FI is based at University of Helsinki (Department of Physics and Helsinki Institute of Physics) and University of Turku (Tuorla Observatory and Finnish Centre for Astronomy with ESO). Before Euclid the group participated in the Planck mission.

The CSC Kajaani Data Center (site of SDC-FI hardware), on the left, is located in a former paper mill.

The hardware of SDC-FI is operated in collaboration with the national academic scientific computing center CSC and is located in their Kajaani Data Center, in north-central Finland. The northern location of the center was chosen in part for energy efficiency (it's cold, so less cooling needed). Currently SDC-FI hardware consists of 10 newer compute nodes with 24 cores and 256 GB each, and 10 older compute nodes with 16 cores and 64 GB each. The hardware is operated as virtual machines based on OpenStack cloud software. With hyperthreading the newer compute nodes can have 48 virtual CPUs; so that the maximum number of virtual CPUs at SDC-FI is 640. SDC-FI has currently 22 TB of disk space; more will be purchased when needed. We have also access to the CSC computers, e.g. a Cray supercomputer.

SDC-FI participates in the Data Quality Common Tools (DQCT) work package of the System Team, in OU-SIM, and in OU-LE3 (in particular in the validation of the GC processing functions).

Hannu Kurki-Suonio

Italy - SDC-IT

The Italian Science Data Center (SDC-IT) is the primary SDC of the NIR, SIR and MER processing functions (PFs). It also contributes significantly, as an auxiliary SDC, to the development and integration of the LE3 and SPE processing functions; and finally, it is responsible for the specification and delivery of the Level 1 pipeline, for the "editing" of the NISP raw science frames. The SDC-IT is currently composed by a team of 10 members and is based at the Astronomical Observatory of Trieste, which is part of the Italian National Institute for Astrophysics (INAF).

The Italian SDC originated as the Data Processing Centre of the Low Frequency Instrument (LFI) for the Planck ESA mission, and was responsible for the instrument flight operations and its end-to-end data reduction, starting from the raw telemetry processing down to the delivery of the final scientific data products of the mission. Since 2011, the team has been progressively involved in the activities for the Euclid mission.

The SDC-IT first contributed to the common infrastructure of the EC Science Ground Segment (SGS), collaborating on the definition of the data products in the first drafts of the EC Common Data Model, developing the Distributed Resource Manager (DRM) of the Infrastructure Abstraction Layer (IAL) and the image handling in the SGS common scientific libraries.

Between 2015 and 2016, the SDC-IT successfully coordinated the Scientific Challenge #2, which is part of the SGS Verification and Validation (V&V) Plan activities. Its main objective was to design and develop the first prototypes of the VIS, NIR and SIR PFs, integrate them with the SGS Infrastructure components (the Euclid Archive System, Common Data Model, IAL, CODEEN) and process the VIS and NISP raw frames simulated by the SIM PF.

Since September 2016, the team has been deeply involved in the development and integration of the NIR, SIR and MER PFs targeted for the Scientific Challenge #3 tests. Significant progress has also been made on the LE3 processing functions, in particular the 2-point correlation function and the power spectrum for the LE3 Galaxy Clustering, where a complete re-engineering and implementation in C++ has been performed.

Since March 2017, the SDC-IT has access to a new computing infrastructure, providing a total of 800 cores, ~400 TB of raw storage and a Mellanox 56 Gbps Infiniband interconnection. The virtualization technology currently adopted is based on Singularity containers (http://singularity.lbl.gov/), simplifying the deployment and the update of the SGS reference software infrastructure.

Marco Frailis

France - SDC-FR

The Euclid France Science Data Center (SDC-FR) is one of the 9 Euclid SDCs constituting the Euclid Consortium Science Ground Segment (EC SGS) in addition to the 11 Organization Units (OUs) and its Project Office (PO). The SDC-FR endorses three main responsibilities that are: development or contribution to the development of Euclid Processing Functions (PFs), hosting and management of the Euclid SGS continuous integration, delivery and deployment platform (aka CODEEN) and a computing centre covering a significant part of the EC SGS processing and storage needs.

The SDC-FR is led by the French Space Agency (CNES) and relies on 11 French scientific laboratories distributed over 6 locations: Lyon, Marseille, Nice, Orsay, Paris and Toulouse. These 11 labs are the following: APC, CPPM, IAP, IAS, IPNL, IRAP, Irfu, Lagrange, LAM, LERMA and LPSC. This SDC-FR involvement will imply around 90 FTEs from 2017 to 2020 distributed over around 40 people under either permanent of fixed-term contracts.

At the PF development side, the SDC-FR is in charge of the following PFs:

- VIS PF under IAP lead with the contribution of UK labs
- SPE PF under the LAM lead with the contribution of SDC-IT
- LE3 PFs under the Irfu lead with the contribution of Lagrange, IRAP, LERMA, SDC-IT and SDC-UK

The SDC-FR also contributes to the development of the following PFs:

- LE1 as an IAP contribution by the development of the VIS part of the LE1 PF
- IR as an IRAP contribution to SDC-IT
- SIM as a contribution to SDC-ES, with SDC-FI : namely KIDS and DES simulators by the APC, NIP-S simulator (aka TIPS) by the CPPM and VIS simulator by the IAP
- MER as an IAS and LERMA contribution to SDC-IT and SDC-DE
- EXT as an APC contribution to SDC-DE and SDC-NL
- PHZ as a LAM and IRAP contribution to SDC-CH.

SDC-FR PFs are developed by integrated OU/SDC teams, called PF Team, OU activities being mostly devoted to algorithm definition, prototyping, test data and validation, while SDC activities are more focused on software design, development, tests and maintenance.

At this stage, the SDC-FR is deeply involved in the SGS Scientific Challenge Number 3 (SC3, see the dedicated article in this issue of the Newsletter). In particular, the SDC-FR provides the VIS PF and contributes to the SIM, MER and EXT PFs release integrated into the SC3.

As a major contribution to the SGS System Team Common Tools, the SDC-FR hosts, manages and maintains the common SGS continuous integration, delivery and deployment platform (CODEEN, see newsletter 4). CODEEN aims to automatically extract source code from the SVN/GitLab repositories, build corresponding binaries, run tests, generate software documentation, check quality markers, compute trends, package RPMs, and deploy each of the SGS software components .This platform is hosted and managed at the APC lab and will soon migrate to the CC-IN2P3 cloud infrastructure. Thanks to the CernVM-File System we are now close to being able to continuously deploy both development and production versions of the existing PFs on the 9 SDCs.

Another SDC-FR contribution to the SGS System

Team Common Tools worth mentioning is the development by CNES team of the Catalogues library and Spectrum library.

Last but not least, the SDC-FR computing infrastructure is hosted by the IN2P3 Computing Centre (CC-IN2P3) located in Lyon. This computing centre already hosts many projects in particle physics and Astrophysics areas. In particular, it is one of the Tier-1 for the CERN LHC. CNES and IN2P3 committed last year the CC-IN2P3 involvement up to 2023 for the Euclid Data Release number 1 (DR1) in terms of computing, storage, network and support such as being able to cover around 20% of the current estimations of the whole EC SGS production needs. Needs and allocations are revisited on a yearly basis thus being able to purchase new hardware at the right time with the most effective cost. In 2017, the allocated resources are up to 600 cores, 250 TB of disk and 500 TB of tapes. These resources will be mainly used for PF prototypes, simulations and tests, SC3 and Science Performance Verification #2 (SPV02). For 2021, the target is around 2000 cores, 1 PB of disk and 10 PB of tapes.

Maurice Poncet

SDC-FR Lead for the SDC-FR Team

Switzerland - SDC-CH

The Swiss SDC is composed of a team of 7 people (6 FTE) at the Department of Astronomy of the University of Geneva. As for the other national SDC, its task is on the one hand, to prepare the infrastructure for the operations and, on the other hand, to prepare analysis pipelines for the Euclid data processing. The SDC-CH is developing software for the photometric redshift determinations and for the strong lens detection, following specifications provided by the OU-PHZ and the OU-SHE, respectively. It is also providing the so-called Elements common framework. Elements is a C++ and Python CMake-based building and packaging framework. It is used in all Euclid pipeline software projects, which are as a consequence, organized into a number of independent modules conforming to a standard repository structure. The building instructions are provided through CMakeList.txt files and underlying CMake processes automatically generate usual Makefiles (see https://euclid.roe.ac.uk/projects/elements/wiki/for more information).

Even if different options continue to be tested, an overall scheme is emerging for the photometric-redshift determination pipeline. It involves both template fitting and machine learning methods, applied in parallel and optimized for different regions of the input parameter space. The best combination of the results is then achieved with a machine learning algorithm, trained with a spectroscopic redshift sample. For each cell of the input color space, a further bias correction step is applied by shifting the photometric redshift distribution mean value to that of the spectroscopic redshifts falling on the same color cell.

For the template fitting method, the pipeline is calling Phosphoros, a new C++ program developed by the SDC-CH team. It produces Probability Density Functions (PDF) providing probabilities as a function of redshift values. It can also produce PDFs along any other axis of the parameter space for determinations of physical parameters, such as galaxy mass or star formation history for example. Phosphoros can take input priors along any of the parameter space axes, including luminosity (luminosity priors can be specified as luminosity functions). It currently also includes options to add emission lines and it implements a new scheme for handling galactic extinction. Phosphoros is expected to be further completed and maintained throughout the full Euclid mission lifetime (see http://isdc.unige.ch/euclid/phosphoros/ for more information) . For machine-learning methods, the Primal Python package has been developed. It is a Euclid compliant Python project wrapping the scikit-learn (http://scikit-learn.org/) package. In this way, any of the machine learning methods implemented in this package, such as AdaBoost or Random Forest, can be invoked in the pipeline. Primal is used to produce photometric redshifts, to optimally combined the results from the different methods and to classify sources. Discussions are also ongoing to integrate the PhotoRaptor code (http://dame.dsf.unina.it/dame_photoz.html#photoraptor) into the Euclid pipeline.

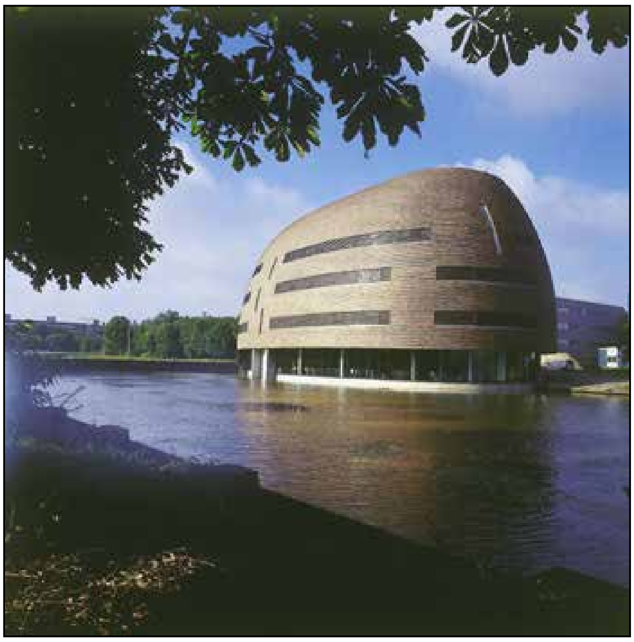
In the frame of the strong lens detection related work, a collaboration with colleagues from the SHE processing function has been achieved to tests different algorithms of source (including strong lens) detection and de-blending. In parallel, an assessment of the long-term update and maintenance plans of SExtractor (one of the most successful astronomical software tools), made clear about two year ago that time was up to consider the development of a new SExtractor implementation. We realized that starting a new C++ project could benefit many of our Euclid colleagues and provide at the same time a solid basis for a Euclid strong lens detection pipeline. SDC-CH members bring modern expertise in modular object-oriented architectural design. A single responsibility is attributed to each code element, software interfaces are used in a systematic manner and many design patterns are at the heart of the new project. A modular framework (together with aperture photometry functionalities) is now in place, as well as a preliminary proof-of-concept version of multi-frame model fitting. A first version of the new SExtractor project should be release to the Euclid collaboration at the end of this year.

The SDC-CH organizes its work around OU meetings and Euclid challenges. It participated in particular into the infrastructure challenges. It is not yet involved into the parallel series of scientific challenges, which concerned so far only the early stage of the Euclid data processing. The new programs were however tested through two photometric redshift and one strong lensing challenges. This challenge-driven approach has proven to be an amazingly efficient method for steering large collaborations towards common goals. Capitalizing on the recent successes, it provides a promising path to complete the full analysis system on time, before the Euclid launch.

Pierre Dubath

The Netherlands - SDC-NL

The Netherlands Euclid Science Data Centre (SDC-NL) is jointly hosted by the Kapteyn Astronomical Institute and the Centre for Information Technology in the University of Groningen, together with significant contributions from Leiden Observatory. The SDC-NL has particular responsibilities for the development of the Euclid Archive System and the EXT pipelines. The Euclid Archive System is being developed in co-operation with ESA. The SDC-NL has responsibilities for two archive components, the Data Processing System and the Distributed Storage System. The ESAC Science Data Centre in Madrid, leads the development of the third



The Centre for Information Technlogy of the University of Groningen, hosts the computer systems operated by the SDC-NL

component, the Science Analysis System. The EXT pipelines are currently being developed in cooperation with SDC-DE. In addition the SDC-NL contributes to the development of NIR pipelines, which is led by SDC-IT.

The archive development and the EXT pipeline development in the SDC-NL draw heavily on the many years of development of information systems in the University of Groningen. This technology now underpins many active systems, both inside and outside the astronomy domain. Inside the astronomy domain it is used by Astro-WISE (OmegaCAM), the Lofar Long Term Archive, and the Muse processing system. In the future it will be used by Micado on ESO's Extremely Large Telescope.

The SDC-NL hardware is currently based around a large GPFS file system (10 PByte) with the processing performed on the university Peregrine cluster. The database facilities are provided by a Oracle RAC system. The storage system is currently being replaced by a Lustre files system and a new high availability database system, using Solid State Disk storage. The SDC-NL currently has 16 members, including the associated scientists from the Netherlands in OU-EXT, with which we work as a unified team.

Rees Williams

The USA - SDC-US

The SDC-US is based at Caltech/IPAC in Pasadena, California, USA. IPAC provides scientific operations support, data-intensive processing and archiving services to a large number of space missions, including NASA involvement in the previous ESA missions ISO, Planck & Hershel. SDC-US is part of the Euclid NASA Science Center at IPAC (ENSCI). ENSCI participates in the EC's Science Ground Segment, providing algorithm and software development, participating in data quality assurance, and performing data processing. In addition, ENSCI supports the research community by providing expert insight into the surveys, data processes, calibration, and products.

The first rack of dedicated SDC-US equipment in the IPAC data center.

The ENSCI team includes both scientists and engineers working closely together. The ENSCI Director is George Helou, the ENSCI science lead and SDC-US lead is Harry Teplitz, and the SDC-US system engineer is Ben Rusholme.

SDC-US is part of the distributed processing and archiving effort for Euclid. We will provide about 5% of the Euclid processing budget. We work closely with the System Team and participate in the science and infrastructure challenges.

ENSCI/SDC-US scientists and software engineers work with OU-NIR and OU-SIR. ENSCI is responsible for several NIR and SIR work packages, including detector-level calibrations, absolute flux calibration, and spectroscopic decontamination. The team also works closely with the Science Operation Center to define Data Quick Look Analysis for NISP.

We are currently running a prototype of the SDC on 2 servers, taking part in the recent infrastructure challenge 6 and science challenge 2. We have just purchased and are integrating our first dedicated hardware for the (more challenging) upcoming science challenge 3.

One particular issue for SDC-US is our geographical separation, and thus bandwidth and latency to the other SDCs. We are investigating high-performance, low-friction science-DMZ as part of the Pacific Research Platform initiative as mitigation

Harry Teplitz

Canada joining the Euclid consortium

Canadians became provisional members of Euclid in the fall of 2017. The Canadian Euclid Consortium has agreed to provide access (along with French co-Is) to the Canada-France Imaging Survey (CFIS) and various scientific data products for the purpose of photometric redshift estimation. In return Euclid has agreed to provide full membership into Euclid to a group of about twenty Canadian scientists and ex-officio representatives.

CFIS (Sea-Fizz) is a joint Canada-France CFHT Large Program that has been allocated 271 nights over six semesters (17A to 19B, from Feb. 1st 2017, to Jan. 31st 2020). The CFHT is operated by the National Research Council of Canada, the Centre National de la recherche Scientifique of France and the University of Hawaii.

CFIS has two survey components, one in r-band and one in u-band. CFIS-r WIQD (Wide + Image Quality + Deep) will image ~5000 square degrees over 154 nights in the r-band. Covering the sky above a declination of 30 degrees, and outside the galactic plane, it will produce a panoramic survey with exquisite image quality (~0.6 arcsecond) to a depth of 24.1 (point source, SNR=10, 2 arcseconds diameter aperture). CFIS-u LUAU (Legacy for the U-band All-sky Universe) will survey ~10000 square degrees over 117 nights, covering the region above a declination of 0 degrees, and outside the galactic plane, to a u-band depth of 23.6 (point source, SNR=10, 2 arcseconds diameter aperture).

The CFIS is a legacy survey for the Canadian and French communities. Alan McConnachie and Jean-Charles Cuillandre are the co-PIs. .All data are proprietary within the Canadian and French communities until Feb. 1st, 2021, at which point a public release will occur. This will contain everything from the raw data to the many advanced products curated by the CFIS Collaboration. The CFIS collaboration is very interested in collaborations to extend the survey to other bands and to enhance the analysis with spectroscopic observations.

An MOU is being finalized. Provisional Canadian members are: Michael Balogh, Dick Bond, Jo Bovy, Ray Carlberg, Scott Chapman, Pat Cote, Nick Cowan, Sebastian Fabbro, Laura Ferrarese, Renee Hlozek, Mike Hudson, John Hutchings (ex officio), JJ Kavelaars, Dustin Lang, Denis Laurin (ex officio), Alan McConnachie, Adam Muzzin, Laura Parker, Chris Pritchet, Marcin Sawicki, David Schade, Douglas Scott, Kendrick Smith, Christine Spekkens, James Taylor, and Chris Willot.

Ray Carlberg

EXTERNAL DATA

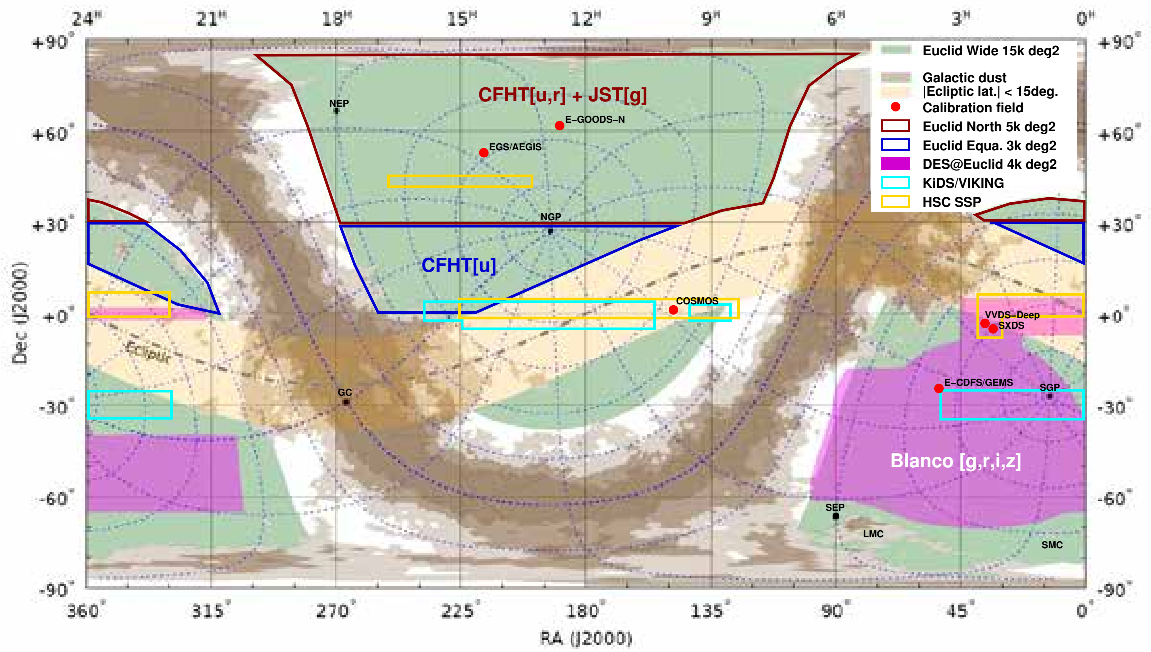
Euclid Complementary Observations Group

Last November the Euclid Consortium established a new working group, the 'COG', to coordinate the provision of data that will not be taken by the Euclid spacecraft. The group consists of Peter Capak (Caltech), Jean-Charles Cuillandre (CEA Saclay/Obs. de Paris) and Konrad Kuijken (Leiden, chair).

For the Euclid mission to be able to meet its goals, a large volume of essential data are needed in addition to what the satellite VIS, NIR and NISP instruments will provide. The main requirements are to measure optical colours of all Euclid targets, and to provide a spectroscopic redshift calibration sample.

Optical colours are essential to measure photometric redshifts. At a depth of r~24.5 (10-sigma, extended), sufficiently accurate colours can be obtained from the ground with large wide-field cameras, and it was therefore considered unjustified to equip the VIS channel with multiple filters. Making these measurements from space would have multiplied the data volume as well as extending the required mission lifetime, at great cost: therefore Euclid follows the 'from the ground what you can, from space what you must' principle. A comprehensive data set of ugriz images over the full wide survey therefore needs to be acquired, on a timescale compatible with the Euclid data taking. OU-EXT is tasked with turning such data into 'Euclidized' pixel data, ready for photometry and photometric redshift estimation by OU-MER and OU-PHOTZ.

A second use of optical colours lies in the shear measurements. Over the wide band of the VIS images the nearly diffraction-limited Point Spread Function varies dramatically, by almost a factor of two in width. The shear measurements require an accurate PSF model in order to correct the observed VIS galaxy shapes, and this can only be done if the SED of each galaxy is known: blue galaxies will require a different PSF correction than red ones. Without the ground-based data therefore, the fundamental OU-SHE processing cannot proceed.



The Euclid sky. The green area outlines the full extent of the Euclid-Wide survey, as it avoids the ecliptic and galactic planes. The various complementary ground-based surveys are indicated, as well as the currently ongoing Hyper SuprimeCam and KiDS lensing surveys

No single ground-based survey is at present able to provide all Euclid imaging need: instead this will take a combination of several surveys (see Figure on the previous page).

In the South, the eventual plan is to use the LSST survey, but on current planning this facility will not start operating until 2021. In the meantime, the Dark Energy Survey will cover a large part of the Southern Euclid sky and the plan is to use these data for the first Euclid data release. The Kilo-Degree Survey also overlaps somewhat with Euclid-Wide in the South: its data are being used already to validate the EXT work.

The Northern sky is more complicated. We are currently contemplating a patchwork of surveys in different filters, but the picture is not yet complete. With wide-field imagers such as CFHT, Pan-STARRS, HyperSuprimeCam on Subaru and (soon) CEFCA's JST, there is certainly the capacity to cover the Northern sky well: agreements have already been made with the French and Canadian CFHT communities (r,u) and CEFCA (g), and discussions with other potential partners are underway. Getting firm commitments to ensure timely coverage of the Euclid Northern sky is currently the highest priority for the COG.

Another aspect of shear calibration is to use deep HST images (HST has nearly twice the spatial resolution of Euclid, and narrower filters), and thus map out the intrinsic distribution of galaxy shapes. This is another key input to the SHE measurement pipelines. Also here, several ambitious programmes are underway, both from the Archive and with new (proposed) observations.

The COG is also tracking and coordinating spectroscopic observations. Several campaigns are underway, with Keck and VLT, to provide samples of galaxies down to Euclid-Wide depth for photometric redshift calibration. A total of some 100 nights of 8-10m telescope time is being devoted to these programmes. The result will be a comprehensive coverage of galaxy colour space with spectroscopic redshifts, ensuring adequate calibration of the photometric redshifts that provide the vital third dimension of the Euclid map.

The beauty of the Euclid mission is that, apart from its primary cosmology science goal, the data the satellite will provide will include some of the best sky images ever taken. The enormous legacy value this provides will be enhanced tremendously with the complementary multi-colour imaging the mission has sparked already. The collaboration between the many surveys from ground and space that is happening now is an excellent example of a 'whole that is greater than the sum of its parts'.

The COG leads

The Javalambre-Euclid Deep Imaging Survey in g band (JEDIS-g)

The Javalambre-Euclid Deep Imaging Survey in g band (JEDIS-g) will be the contribution of the Centro de Estudios de Física del Cosmos de Aragón (CEFCA, Spain, www.cefca.es) as OU-EXT to the Euclid mission.

Following a memorandum of understanding signed between CEFCA and the Euclid Consortium in September 2016, CEFCA is committed to provide the Sloan g band data of 5000 deg^2 of the Northern Sky in common with the r data from Canada-France Imaging Survey (CFIS) reaching a depth of ~24.7 for extended objects at SNR=10. The baseline of the delivery of the data means that CEFCA will provide a total of 1250 deg^2 in 2023, reaching 2500 deg^2 in 2025 and the final 5000 deg^2 in 2027. The data provided will include raw images, reduced and astrometrically calibrated images, and catalogues constructed from the reduced images.

The observations of JEDIS-g will be carried from the Observatorio Astrofísico de Javalambre (OAJ, oajweb.cefca.es) which is a brand new astrophysical facility located at the Pico del Buitre summit, Teruel, Spain, which is managed by CEFCA.

Figure 1: Image of JST/T250 (large) and JPCam in the clean room of OAJ (inset)

The main goals of the OAJ and CEFCA are the production and exploitation of the data for the Javalambre PAU (Physics of the Accelerated Universe) Astrophysical Survey (**J-PAS**, www.j-pas.org) and the Javalambre Physics of the Local Universe Survey (J-PLUS, www.j-plus.es) projects. For this purpose, the two main instruments of the observatory are two large etendue telescopes equipped with large field of view cameras: the JAST/T80 and the JST/T250. The JAST/T80 (Javalambre Auxiliary Survey Telescope) is an 83cm telescope with a 2deg field of view (FoV) equipped with a 9.2k x 9.2k new generation e2V CCD and a set of 12 filters: 5 SDSS-like filters and 7 filters on specific stellar features for calibration purposes. On the other hand, the JST/T250 (Javalambre Survey Telescope) is a 2.5m telescope with a FoV of 3deg (Figure 1). During 2017/8 the JST/T250 will be provided with the Javalambre Panoramic Camera (JPCam) (Figure 1, inset), a new generation 1.2 Gpixel camera integrating a mosaic of 14 T80Cam-like CCDs covering a 4.7deg^2 area of the sky. The camera will mount the photo-z optimized J-PAS filter system, a set of 54 narrow band overlapping filters (FWHM~140Å) from ~3700Å to ~9200Å plus two broad band filters on the extremes providing continuous coverage from ~3450Å to ~10000Å. This filter system will be complemented with broad-band filters in u, g, r and i bands.

Given the large etendue of the JST/T250 and its optimal efficiency around 5500Å, it has been considered an optimum instrument to provide the ground-based Sloan g-band data for the determination of photometric redshifts within the Euclid project.

Currently, the OAJ is finished and operating. JAST/T80 is working on J-PLUS and offering 20% of open time since 2016, meanwhile JST/T250 is in commissioning phase. JPCam is being commissioned off-the-telescope at the OAJ and a camera called Pathfinder, which is a twin of T80Cam, is already installed at JST/T250 to carry out the commissioning of the mechanical parts of the interface between JPCam and JST/T250 with the possibility of carrying out observations at scientific level. Pathfinder received its first light on 20th February and on the night of 8th March the image quality reached a PSF FWHM ~0.4" (Figure 2). Pathfinder has allowed also to obtain the first measurements of the overall throughput of the system, fitting the estimated value used for the first evaluation of JST/T250 as provider of the g-band data for the Euclid Consortium. These results highlight the quality of the skies

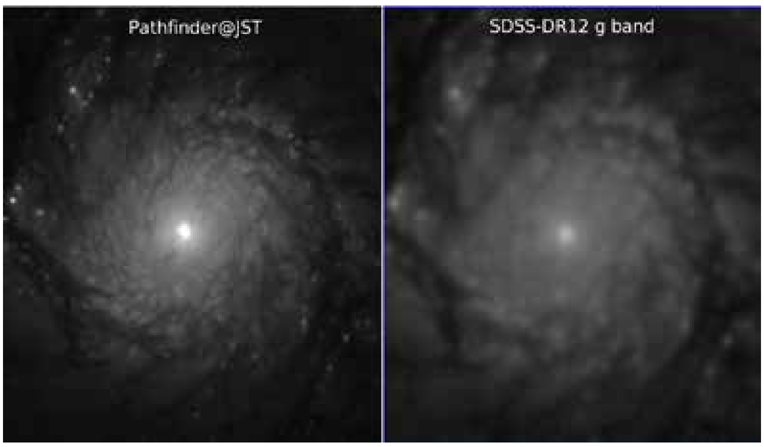


Figure 2: Comparison of the image quality of a coadded image of the central part of M51 resulting from the combination of six 10s single exposures with no filter (left) and the g band image from SDSS (right). The FWHM of the PSF in the Pathfinder image is ~0.4". The Pathfinder image is a cutout of only 1/30 of the original full frame.

and the performance of the system.

Finally, CEFCA has already all the hardware systems for processing and storing the images coming from the OAJ with a datacenter of more than 20 computing nodes with more than 500 cores, a storage disk cluster for up to 1.1PB of data and a tape library adding 4.0PB more of storage space. Regarding the software, CEFCA has developed is own reduction pipeline based on open-source code and it is routinely processing the images from JAST/T80 which have the very similar characteristics from those that will come from JPCam since both cameras are mounted with the same CCD.

In summary, CEFCA and OAJ will be soon ready to start JEDIS-g to provide the Euclid Consortium high quality g-band images from the ground.

Jesús Varela

OU-EXT

External ground-based imaging is an essential component of the Euclid Mission. The photometric redshifts required for the weak-lensing tomography will be derived using multi-band optical ground-based imaging covering the Euclid Wide and Deep Surveys. These images will also be used to measure the spectral energy distribution of stars. This is needed to characterize the wavelength dependence of the VIS Point Spread Function.

The external images will be acquired through at least four different surveys each observed with a different wide-field camera on a different ground-based telescope (see the article on the Complementary Observations Group for details). All surveys use Sloan type filters but differ in their instrumental passbands. Furthermore, the surveys have different constraints on the allowed atmospheric conditions during observations. It is the task of the Organizational Unit External Data to develop the Processing Function to deliver to the SGS:

Ground-based images that are consistent with the Euclid VIS images in terms of photometry, PSF characterization and astrometry, products with identical format for all surveys. This is called the Euclidization of external ground-based images.

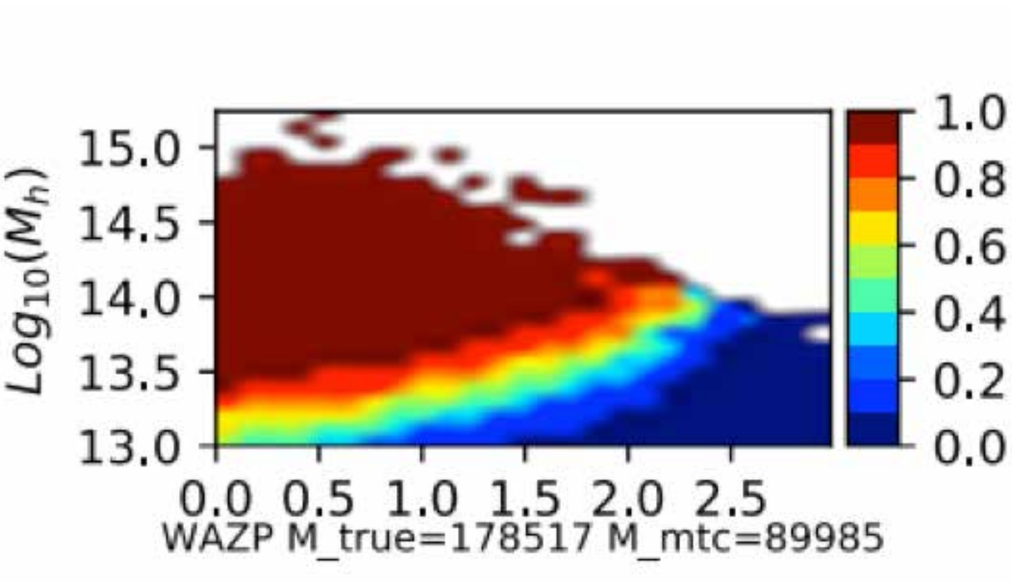
OU-EXT together with SDC-NL and SDC-DE are participating in Euclid's Scientific Challenge 3. A first version of the EXT Processing Function calibrates and stacks simulated raw Kilo-Degree Survey (KiDS) and Dark Energy Survey (DES) observations delivered by OU-SIM. The calibrated images are then input to the MER Processing Function. The main purpose for EXT is to verify functional requirements. Initial validation of scientific requirements is performed as well.

The Gaia all-sky stellar photometry, spectrophotometry and astrometry have clear potential to become an excellent reference system for Euclid-compliant calibration and validation of the ground-based surveys. This has become clear with the Gaia Data Release 1 and with the outcome of the Euclid Photometric Calibration workshop, both in September 2016. Therefore OU-EXT has created a new architectural design for the EXT ground-based processing in which the Euclid-compliant photometric and astrometric calibration and validation makes use of Gaia in addition to survey-internal relative calibration via observation overlaps. Furthermore it ensures efficient handling of recalibrations over the lifetime of the Euclid mission taking advantage of the updated releases of the Gaia data. The approach avoids expensive pixel re-processing operations.

Gijs Verdoes Klein

OU-LE3

Since the setup of the ground segment OU-LE3 has been the largest OU in place, with more than 500 scientists and over 40 processing functions to deliver. OU-LE3 is charged to develop and implement into the SDCs the algorithms that will be used to deliver to ESA the final Euclid data products such as weak lensing Mass maps, weak lensing and galaxy clustering two-point correlation functions and power spectra. In addition, LE3 will also provide higher order statistics codes for clusters of galaxies detection, galaxy distribution bi-spectrum, or the selection functions of both the photometric and spectroscopic Euclid surveys. To cater for this large effort, The Finnish and Romanians Science Data Centres (SDCs) are complementing the Italian, French and UK contributions to the LE3 SDC efforts.



Completeness vs. redshift of a selected algorithm from the Cluster Challenge run by LE3 which led to algorithm selection and implementation in the SDC pipeline currently in progress.

Algorithm development has progressed well and all the high-priority processing functions have candidate prototype algorithms. A recent data challenge for the Cluster finding algorithm PF has led to the selection of one method, and on-going investigations will allow the selection of a second one, complementing the first one. This included effort from a very active cluster community within LE3, the Cluster SWG and a large input form the cosmological simulations working group.

Given the multi science aspect of this OU, there are often joint meetings organised with one or more scientific working groups. The next planned meeting will take place this year during the London consortium meeting. A joint meeting with the Galaxy Clustering Working group and focusing on the ongoing Science Performance Verification is also scheduled in July in Sexten. These meetings are vital and allow for synergies and collaborative work to take place between those who will be using the data and those who will be producing the pipelines for Euclid.

SDCs will run OU-LE3 code and will generate the deliverables that the consortium will make available to the community after Euclid data becomes public. These are the data products that will bring Euclid new discoveries, including the most exciting results we will have on the nature of dark energy and dark matter.

Filipe Abdalla, Jean-Luc Starck & Enzo Branchini

OU-NIR

Since the second half of 2016, NIR activities have been focused on the preparation of the Processing Function for the reduction of simulated NISP photometric observations within the framework of the Scientific Challenge #3. While basic functionalities were already implemented for the previous challenge, this time we are increasing significantly the complexity of the NIR pipeline in order to account for detectors and instrumental features such as saturation, non-linearity, quantum efficiency, and PSF. This is being achieved through the development of dedicated calibration pipelines for master dark and master flat production. It is worth to mention that part of this will also be used by the OU-SIR for the pre-processing of simulated spectroscopic frames. We are also setting forth the basic structure for relative and absolute photometric calibration that will be fully implemented during forthcoming months with the development of further dedicated calibration pipelines.

All these activities stimulated a tight positive interaction with different actors of the Euclid Consortium, such as the NISP Instrument Team, the Calibration Working Group, and the OU-SIM.

At the time of writing, we are currently completing the reduction of a first SC#3 (see article later in the newsletter) simulated field at the SDC-IT, who provided crucial support during all the development process, and we are eagerly looking forward for OU-MER to run on NIR data products.

Beside completion of the SC#3, in the next few weeks we will be focusing on a thorough validation of the NIR Processing Function, which will be the basis for the next important Challenge we will be facing this year, the Design Review of the Euclid Science Ground Segment at the end of 2017.

Gianluca Polenta

A zoom on a composite image of a simulated SC3 field from a preliminary version of the stacked frames for the Y, J, and H filters produced by the NIR Processing Function

News from the SPE OU/processing function

What is SPE?

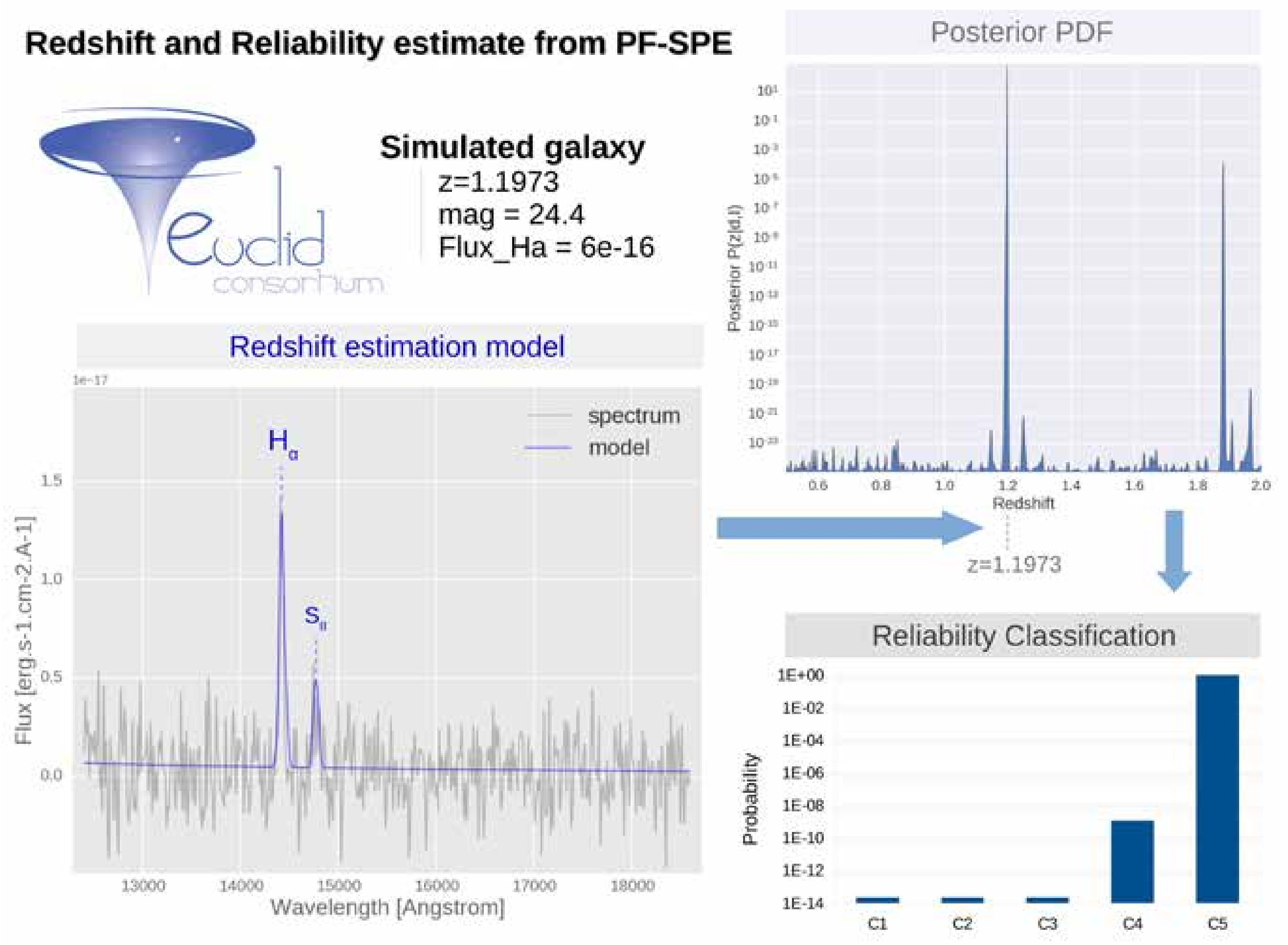
The main purpose of the SPE Organisation Unit and associated processing function is to provide spectroscopic redshift measurements of the galaxies observed by NISP in the slitless spectroscopy mode. Together with the redshift, the aim is to deliver statistical estimates of its reliability, and provide spectral measurements, most importantly the flux of the Hα emission line. The most relevant requirement is the completeness of the redshift measurement, which shall be greater than 45%, for an (Hα) emission line flux > 2×10^{-16} erg $cm^{-2}s^{-1}$ and a redshift in the range $0.9<z<1.8$.

SPE receives flux and wavelength calibrated combined spectra from SIR, corresponding for the wide survey to 4 individual exposures and 3 grism orientations, as well as associated noise. After processing, the SPE deliverables are then available for other processing functions, most importantly LE3, including those related to galaxy clustering measurements.

Automated redshift and line (Hα) measurements

There are several key challenges for SPE:

First and foremost, measurements on spectra need to be fully automated. Tens of millions of spectra are expected within the 15000 deg^2 of the wide survey, it is evidently out of ques-



PF-SPE redshift measurement on a simulated galaxy with a redshift z=1.1973, a bright Hα emitter with a line flux 6x10^{-16} erg s^{-1} cm^{-2} $Å^{-1}$.The PF-SPE redshift measurements algorithm proceeds by fitting the observed spectrum with different models built on line emission, line absorption, and continuum, as well as on reference templates. The top right panel presents the posterior redshift probability distribution function (PDF), obtained from combining the PDF from the different models, with the redshift correctly identified. The classification algorithm based on machine learning, indicates that the spectrum at this redshift in in class C5, meaning that it has more than a 99.999% probability to be correct.

tion to measure the spectra or even control them by hand, contrary to what has been done for most galaxy surveys up to now. Another challenge is the processing speed, as one day of observations needs to be processed in less than a day. The expected data flow leads to 4.6 million spectra to be processed per week, as one wants to go digging into the noise of the slitless spectra images in hope not to miss any faint continuum sources with significant line emission.

We have implemented a redshift measurement pipeline, which draws on several key algorithms. A processing element (PE) cross-correlates observed spectra with reference (simulated) templates. Another PE identifies emission lines and runs informed “artificial intelligence” recipes to associate a redshift to the observed lines. Yet another PE extracts continuum information and gets redshift constraints from continuum templates. These PEs are ultimately combined to extract a discretized list of redshifts.

Methods to estimate z_{spec} reliability

Another challenge is to automatically assess the reliability of a spectroscopic redshift measurement. We want to evaluate the probability for a redshift to be right with a high level of certainty, and do it fully automated. Furthermore, we need to measure the flux of identified lines as accurately as possible, hence with their associated errors. This allows maintaining a tight control on the survey selection function, particularly on Hα emitters.

This simple goal is in fact very complex, and solving it proved to be quite tough. A recent breakthrough gives us hope that we have now the keys to fully solving this problem. Informed by the reliability assessment process used by high redshift spectroscopic surveys, we devised a machine learning algorithm using the shape of the PDF of the redshift measurement to produce a homogeneous partitioning of the data into distinct clusters (classes) via unsupervised classification (Jamal et al., submitted). In a proof-of-concept analysis, five classes were identified, nicely reproducing the classes of galaxies in known surveys like the VVDS or VUDS. In principle, the number of classes can be increased, refining the reliability estimates. This depends on the size of the learning sample, a calibration necessary prior to running the survey, which we will need to decide on.

Testing and performances, next steps

As the PF is being developed, we run extensive tests based on simulations delivered by OU-SIM, in a parameter space covering the range of expected line flux and continuum magnitude. The simulations available today allow estimating a high success rate down to the 2×10^{-16} erg cm^{-2}s^{-1} line flux limit, and give confidence in the reliability of the SPE algorithms. This is however an intermediate and internal result which has sometimes been taken over-enthusiastically out of context, and we stress that we do not yet demonstrate that the survey will fully meet the completeness requirement, and that therefore significant efforts need to be invested to complete this work.

Indeed our development roadmap is set to allow verifying compliance with requirements only once the next step of testing and further improving the SPE algorithms will be carried out on “real sky” simulations currently produced by SIM. These include a realistic magnitude, redshift, and flux distribution of the sources, and, most importantly, a realistic handling of spectral contamination due to geometric projection of spectra for each observed grism orientation.

We have all elements to hope that tests on these state-of-the-art simulations will confirm earlier results that the requirements will be met, with, in the end, about 25 million galaxies which will have a robust spectroscopic redshift. This should enable a full realization of the power of the clustering cosmological probe, at the core of the Euclid mission.

Olivier Le Fèvre and Christian Surace
for the OU/PF SPE team

The Cluster of galaxies SWG

The Cluster of Galaxies SWG has started a cluster cosmology challenge coordinated by Jean-Baptiste Melin and Alex Saro with the aim of comparing analysis codes and developing the analysis methodology that will be used by the SWG to constrain cosmological parameters with the Euclid galaxy cluster catalog. The SWG is also weighing in on the validation of the Flagship simulation by evaluating the properties of simulated clusters. The effort is being led by the group's Astrophysics of Galaxy Clusters work package coordinated by Gabriella De Lucia and Simona Mei.

Jim Bartlett, Jochen Weller, Lauro Moscardini

Science Performance Verification for weak lensing

One of the primary objectives of Euclid is to constrain the nature of dark energy and test modified gravity theories by measuring the coherent distortions in the images of distant galaxies caused by the differential deflection of light by intervening large-scale structures. This is because the amplitude of this 'cosmic shear' signal is directly related to the distribution of total matter and the expansion history. The challenge is that the typical change in the ellipticity caused by gravitational lensing is about a percent; which is much smaller than the intrinsic ellipticities of galaxies. To overcome this source of statistical uncertainty, Euclid will measure the shapes of nearly two billion galaxies with unprecedented accuracy. Although it is designed to do so, many corrections need to be carefully applied before we can extract the cosmological signal from the data.

The impact of residual systematics on cosmological parameters was studied in great detail as part of the selection process. For instance, a paper led by Richard Massey (https://arxiv.org/abs/1210.7690) presented a general analytic framework to propagate biases. This was used in a paper led by Mark Cropper (https://arxiv.org/abs/1210.7691) to derive a breakdown of the sources of bias that had been identified at the time. These results form the basis for the requirements on instrument and algorithm performance in Euclid, but also on calibration needs. Although these early studies provided a convenient way to compare the impact of various sources of bias, it is timely to revisit this for a number of reasons as part of the ongoing efforts to verify the science performance of Euclid.

First of all, in order to avoid an implicit preference for implementation, the original papers considered scale-independent systematic effects. In more realistic scenarios, however, spurious signals are introduced on characteristic scales. For example, the PSF model is determined from the full field-of-view; whereas detector effects such as charge transfer inefficiency (CTI) occur on the scale of a single read-out-register. Moreover, the biases may depend on the observing strategy or time since launch, parameters that could not be incorporated in the original studies. An initial study of more realistic scenarios in a recent paper led by Tom Kitching (https://arxiv.org/abs/1507.05334) found that the expected biases in cosmological parameters might be reduced once the correct scale-dependencies are considered. Given the mature status of Euclid, with the spacecraft design essentially finalized, it is therefore timely to revisit the original studies. Another motivation to do so is that in the initial formalism it is not always clear how to compute the aggregate impact of the various sources of bias. Moreover, correlations between effects could not be easily included in the original studies. Finally, thanks to progress in our understanding of the shape measurements, a number of additional contributing factors have been identified.

As part of the science performance verification (SPV) the WL-SWG has started work to improve our estimate of the expected WL performance of Euclid, but without having to rely on a full end-to-end simulation. To do this we exploit the fact that shapes and photometric redshifts are measured for individual galaxies; systematic effects are typically common between galaxies, but the measurement process is not. Therefore as long as the biases are known as a function of galaxy properties (size, shape, color, redshift, etc.) we can propagate these biases in a bottom-up approach, from galaxies to cosmology, rather than the previous method of propagating cosmological biases into requirements on systematic effects. By reversing the flow, we can also compute the residual biases caused by imperfect corrections; these arise because we know the relevant quantities with limited precision. This limited knowledge is captured by appropriate probability density distributions.

We therefore obtain catalogues of observables that contain realistic residual systematics for different scenarios. Compared to an end-to-end simulation, our current approach of starting at the catalog level has the advantage that it is much faster, enabling us to explore many different scenarios. Paniez Paykari has led the ongoing work to develop a modular pipeline in Python that enables us to propagate the systematic signal all the way to the evaluation of cosmological parameters. The current version of the code uses the MICE simulations as the starting point: this cosmological simulation provides a catalog of galaxies in a cosmological setting. We also include a realistic model for Galactic extinction, star counts and Zodiacal light. Once the catalogs from the flagship simulation are released, we will use this as the input universe for our SPV simulations. This unique simulation is also the input for similar efforts for galaxy clustering. Hence it will enable us to explore possible synergies between probes, something that has been discussed in the past, but we were unable to quantify properly.

As a first set of test cases we have considered errors in the point spread function model, imperfect corrections for charge transfer inefficiency and the impact of masked areas in the survey, but we note that the pipeline is capable to simulate a much wider range of effects, such as the impact of varying depths in ground-based data. Moreover we can evaluate the impact of instrument failures, such as the loss of a NIR detector.

Many people have already contributed to the current work on our versatile pipeline, and we thank Ruyman Azzollini, Mark Cropper, Jerome Amiaux, Herve Aussel, Aurelien Benoit-Levy, Ian Fenech Conti, Christopher Duncan, Arun Kannawadi, Lance Miller, Mathias Schultheis, Santiago Serrano, Edo Van Uitert, and Chris Wallis for excellent work. Please contact the WL-SWG leads if you are interested in contributing and joining the WL SPV team.

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Further reading:

Massey, R., Hoekstra, H., Kitching, T., et al., 2013, MNRAS, 429, 661

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Kitching, T., Taylor, A.N., Cropper, M., Hoekstra, H., Massey, R., & Niemi, S., 2016, MNRAS, 455, 3319

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Scientific Challenge # 3

What is it?

The word 'challenge' is a 'catch-all' term in the Euclid Consortium vocabulary. What is set out here is Scientific Challenge #3 (SC3), defined in the development plan of the Science Ground Segment, and one of the major scientific objectives of year 2017 Euclid Processing Pipeline software development activities.

This challenge is a process ensuring that the set of processing functions involved meets a given set of scientific requirements, processes input data retrieved from the archive, updates the archive with its output data products and is running on any production configuration (SDC's); the infrastructure is consequently set up to deploy, install, test and run these software components.

The milestones of the Euclid Science Ground Segment development plan driving the software implementation of the components are twofold:

- the Infrastructure challenges dedicated to functional, performance test of the infrastructure components mostly:
  - Infrastructure Abstraction Layer (IAL),
  - Archive System (central metadata data base, data file storage and transfer),
  - web client to enter processing plans in the archive and orchestrate the production (COORS),
  - monitoring and control (M&C) of the infrastructure services
  - the Scientific Challenges dedicated to the execution of a set of processing pipelines running on the production infrastructure with the support of the infrastructure components and,

Objectives

It is important to note that SC3 is the continuation of the past challenges: Scientific challenge 2, Infrastructure challenge 6. Thus the objectives of the n+1 challenge should remember and implement the lessons from past challenges in terms of management, new features, functional and performances weaknesses corrected, issues to be fixed...

Consequently, the main objectives of SC3 are:

- To design and implement the first prototypes of the MER, EXT/KIDS and EXT/DES Processing Functions (PFs) (see also the articles on external data earlier in the document).
- To release the simulation codes of the VIS/NIR/SIR images plus the true universe and the Mission Data Base (MDB) with new features and/or released instrumental effects and characterization.
- To release the code of the VIS/NIR/SIR processing functions (new features, bugs fixed).
- To integrate the different processing functions codes with the SGS Infrastructure components (Euclid Archive System, Infrastructure Abstraction Layer).
- To deploy each PF on each SDC through the Continuous Developement Integration Validation and Deployment component (CODEEN).
- To run these PFs with simulated input data products: VIS/NIR/SIR/EXT on the different SDC's Prods.
- To analyze / check the output data products of MER and its conformity to a subset of the scientific requirements.

The basic output data product of this challenge is the merged multi-wavelength catalogue of sources with astrometric / photometric information.

Euclid Pipeline workflow for SC3

The Euclid pipeline workflow implemented into Scientific Challenge 3 is depicted in Figure 1 below.

Each connector between each box of the workflow has been the subject of a formal interface definition and implementation in XML files and/or fits files.

Each data product supported by each connector and processed by each Processing function is ingested in the Euclid Archive System and so queryable/retrievable with Euclid Archive services.

Processing function per processing function we highlight in the following chapter all the features implemented and tested for the SC3 starting from the simulation that act as first element to

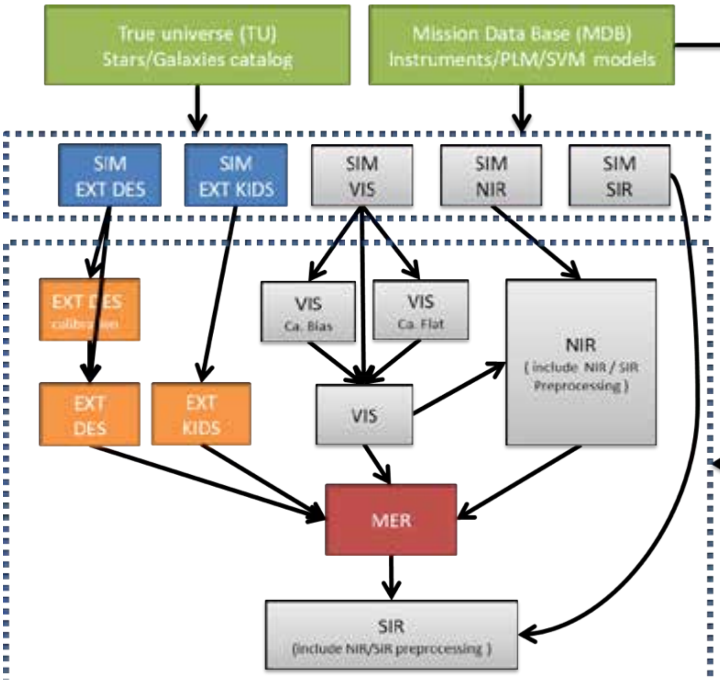

Figure 1: The Euclid pipeline workflow implemented into Scientific Challenge 3

be ingested in the pipeline (instead obviously of the real Data).

Simulation (SIM) features

The input true universe catalogue is common to all simulators and channels. However some channels, like NISP-S, where the detection limit is brighter, might include a brighter magnitude limit cut in the input catalogue to speed up the simulation.

- The star model used is the Besançon model with the Basel 2.2 Spectral Library (M. Schultheis).
- The astrometry catalogues as True input catalogues. No Gaia-like catalogues have been distributed yet
- The current galaxy mock is MICECAT v2

Figure 2 shows the the instrumental effects implemented into the simulators.

In total 3x3 fields have been simulated and be used in SC3. Those fields have been selected with low Star Density and moderate Zodiacal Light contamination.

VIS/NIR/SIR/MER/EXT DES/EXT KIDS features

This section compiles OUs and corresponding primary SDC integrated in the Euclid environment with instrument features to be analyzed during the SC3 Run.

Those are listed in figure 3 for VIS, NISP-P and NISP-S processing function and in figure 4, for the first time, the MER and EXT/DES processing Functions are involved in a Scientific Challenge.

Items marked with an asterisk * are not implemented for SC3

Actors

All the actors of the Science Ground Segment are involved in this process:

- Organization Units (OUs): defining the objectives, contributing to software development, data model (mostly data product definition)

VIS
(Science + Flats + Bias)
Stars (r<24.0 - 24.5)
Galaxies (r<24.0 - 24.5)
Cosmic Rays
Photon Noise
Optical Ghosts
Zodiacal Light
AOCS PSF
Optical PSF
Geometric Distortions
Calibration Lamp
ADC Conversion
ADC Offset
Discretization
ROE non linearity
PRNU
CTI
Saturation Bleeding
Pre/Overscans
Readout Noise

NISP-P
(Science + Dark + Flats)
Stars (r<24.0 - 24.5)
Galaxies (r<24.0 - 24.5)
Cosmic Rays (integration and readout)
Diffuse Scattered Light
Thermal BG
Zodiacal Light
AOCS PSF
Optical PSF
Geometric Distortions
FPS Illumination
Crosstalk + IPC
QE non linearity
Discretization
IntraPixel QE variation
Cosmetic Defects
Dark Current
Saturation Bleeding
Readout Noise
Poisson Noise

NISP-S
(Science+chi2)
Stars (H<22.5 - 23.0)
Galaxies (H<22.5 - 23.0)
Diffuse Scattered Light
Thermal BG
Zodiacal Light
Optical PSF
FPA Metrology
Shutter
QE non linearity
Cosmetic Defects
Dark Current
Saturation
Readout Noise
Poisson Noise

EXT-DES/KIDS
(Science + Flats + Bias)
Stars (r<24.0 - 24.5)
Galaxies (r<24.0 - 24.5)
Sky brightness*
Optical PSFs*
Optical Distortions*
FPA metrology
Bleeding
Cosmetic defects*
Readout noise
ADC conversion
Poisson Noise
Survey Strategy*

* from real observed data

Figure 2: The features of the simulations

VIS
(Science + Flats + Bias)

Bias correction
Non-linearity correction
CTI correction
Dark correction *
PRNU correction
Illumination correction *
Ghost flagging
Background & diffused scattered light calibration
Non diffuse scattered light flagging *
Cosmic ray flagging
PSF modeling
Source detection and classification *
Astrometric calibration
Photometric calibration
Image stacking
Master bias
Master dark *
Master flat field
Saturated pixel masking

NISP-P
(Science + Dark + Flats)

Initialize image
Bad pixel masking
Non-linearity and saturation flag
Dark and bias subtraction
Cosmic ray rejection (single frame, non agressive)
Persistence masking *
Ghost and scattered light *
Satellite trail masking
Flat field correction
Superflat correction
Illumination correction *
Background subtraction
Astrometric calibration
Relative photometric calibration
Absolute photometric calibration *
Image resampling
Cosmic ray rejection on multiple frames
Image stacking
PSF derivation
Source detection and classification
Transient identification *

NISP-S
(Science)

Bad pixel masking
Non-linearity correction
Dark subtraction
Cosmic ray rejection
Persistence flagging
Persistnce flagging
Spectra location
Flat fielding *
Master Background creation *
Background subtraction
2D spectra extraction
Spectra decontamination *
1D spectra extraction
Flux calibration *
Final spectra combination *
ABS flux calibration *
Visibility mask *

Figure 3: the VIS, NISP-P and NISP-S features

MER

Background substraction
VIS Mosaic production
NIR Mosaic production
VIS Mosaic PSF estimation *
NIR Mosaic PSF estimation *
Detection mosaic production
Object detection
Optimal deblending
Object cutouts production *
Transformation kernel from VIS to NIR computation
Transformation kernel from VIS to EXT computation
Cutouts fitting for NIR *
Cutouts fitting for EXT *
Mosaics production
VIS mosaic PSF measurement *
NIR mosaic PSF measurement *
EXT mosaic PSF measurement *
VIS to reference PSF transformation kernel computation
NIR to reference PSF transformation kernel computation
EXT to reference PSF transformation kernel computation
VIS Mosaics PSF matching
NIR Mosaics PSF matching
EXT Mosaics PSF matching
Morphological analysis classification
Multi-wavelength flux determination

EXT / DES

Biascor Pipeline
Flatcor/Band Pipeline
SE Pipeline
Detrending of SE images
Model PSF
Catalog
Astrometric calibration
Mask defects in SE Images *
Extract Zpt Surface *
Extract Photflattening Correction *
Extract Bad Pixel Mask from Flatcars and Biascors *
Coadd Pipeline
Relative Photometric Calibration
PSF homogenization
Coadd Construction
Global Photometric Calibration *

Figure 4: MER/EXT-DES/EXT-KiDS

implementation, and algorithms' validation.

- Science Data Centers (SDCs): implementing the processing functions and transverse components codes, setting up the development production infrastructure.
- System Team: implementing the transverse components (Euclid Archive, IAL, COORS, M&C, CODEEN), supporting the integration and validation tests and the subversion to git migration.
- Project Office: configuration management of the different software release, preparation of the documentation patterns to be provided, arbitration of priorities: schedule vs features implementation vs bug fixing to meet the deadline.

Furthermore Instrument Development Teams also contribute to SC3 by providing the current best estimates of the instrumental models stored in the Mission Data Base and thus used by the simulation code and the related processing functions.

Benefits

The major benefits of the SC3 are:

- to speed up the interactions between all the actors and force them to converge on an accurate, unambiguous definition of their interfaces,
- to implement these interfaces in their code,
- to analyze in depth input and output products,
- to iterate with their data providers and data customers,
- to prioritize/arbitrate the implementation of some features or bug fixing,
- to clarify ambiguities from requirements and/or interfaces definition and reformulate

Once the first simulation data products are provided, a virtuous cycle takes place. Data are tested, validated, new bugs are identified though an in-depth analysis of the data. Processing code is tested against its expected performance for artefact correction (astrometry, non-linearity residuals, ghost detection, saturation, PSF model...). Iterations occur till bugs are corrected and production begins anew. This incomplete list is "based on actual events" taking place in SC3. The key point is that challenges make things real!

Outcomes

The SC3 results in an official SGS software delivery to ESA. This delivery is based on the different tags of the software components used for SC3 production. This list is now quite significant as 100 % of the infrastructure software components are implemented and 50% of the processing functions are running on production infrastructure.

The SC3 gives the opportunity to get a clear snapshot and status of the entire SGS and clarifies and consolidates the roadmap of each component. The documentation produced for SC3 will be an important input for the upcoming Design Review that the SGS should support this year.

Next stage

The next challenges should gradually involve the Shear (SHE), Spectroscopic (SPE), Photometric redshift (PHZ), and level 3 (LE3) processing functions in the game.

All other components SIM/LE1/VIS/NIR/SIR/MER/EXTs will continue releasing their code according to their own roadmap, and taking into account lessons learnt from SC3: this will consist either in new features, change requests, bug fixing, validation completion. It should also be noted that these SIM/LE1/VIS/NIR/SIR/MER/EXTs components will be requested to participate to SC4 to validate their new releases.

The next Scientific Challenge (SC4) will start in November 2017; to anticipate on potential interface issues, the EXT/SIR/NIR/VIS/MER SC3 output products will be provided to SPE/SHE/PHZ for a first iteration useful to early identify interface problem.

Christophe Dabin

Useful links:

The SC3 wiki page:
https://euclid.roe.ac.uk/projects/ec_sgs_challenges/wiki/20160308_Scientific_Challenge_3
The Euclid Mission Database: http://euclid.esac.esa.int/epdb/

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