Rubin/LSST status report
Conseil Scientifique de l'IN2P3 2020

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Vera C. Rubin Observatory in construction at Cerro Pachòn (Chile, August 2020)

1 Executive Summary

Understanding the nature of dark energy is one of the most fundamental challenges facing physics and cosmology today: is it a dynamic field, a fixed cosmological constant, or a sign of modified gravity? To address these questions, one of the main science objectives behind the Legacy Survey of Space and Time (LSST) conducted by the Rubin Observatory in Chile is to increase the sensitivity of dark energy equation-of-state determinations by one order of magnitude, and to measure the growth of structures. To achieve this, during 10 years starting 2022 Rubin observatory will image repeatedly 18000 deg^2 of the austral sky down to magnitude 27 in 6 bands *ugrizy* and pursue studies with all known dark energy probes:

- Type Ia supernovae
- Weak gravitational lensing
- Galaxy cluster evolution
- Large Scale structures

The key issue facing these studies is understanding and mitigating systematic errors. In this context, photometric calibration and the unbiased measurement of galaxy shapes for weak-lensing observations are critical elements for the dark energy analysis. These dark energy drivers [1] are also at the core of IN2P3 effort in the Rubin project, both regarding the construction of the LSST camera, the calibration and computing effort, and preparing for the scientific return.

LSST Camera The IN2P3 contribution to the 3.2 GPixel camera focuses on two key elements: the filter exchange system, and the CCDs. IN2P3 scientists will earn their data rights through these deliverables. The **filter exchange system** was built thanks to a successful collaboration of 5 IN2P3 laboratories, and is now under commissioning at SLAC, with a delivery to Chile expected 2022. The **focal plane** is now fully assembled and under testing at SLAC. Characterization of the CCDs led to the important discovery of the brighter-fatter effect, which acts as an source of systematics for the measurements of weak shear. The impressive expertise acquired with CCD electronics was acknowledged by a Cristal du CNRS awarded to Claire Juramy at LPNHE.

Calibration and commissioning The commissioning of Rubin auxiliary telescope gave IN2P3 the opportunity to increase their effort on calibration in synergy with the early commissioning of the sensors. In addition to the development of the StarDICE project, these will provide an order of magnitude improvement on the calibration with respect to the initial project expectations. 5 IN2P3 laboratories are collaborating in this topic.

Computing With a stream of 20 TB of data per night produced by the survey, computing is perhaps one of the most challenging tasks to be addressed during operations. CC-IN2P3 will provide 50% of the computing processing capacity needed for the annual Data Releases. This will secure a full copy of Rubin data in France, and allow additional French researchers to acquire data rights. Preparation of this major endeavor entailed reprocessing earlier data sets similar to LSST. A major project still ongoing is the full production of 300 $\deg^2$ of simulated data at 5 years depth of the survey. So far, CC-IN2P3 is the only center having demonstrated the ability to process Rubin data at such a scale. In addition, the alert stream of Rubin Observatory is of interest for a broader scientific community within IN2P3, and a proposal to host an **alert broker** at CC-IN2P3 is underway. One of its goal is to provide the alerts to the multimessenger community.

Science IN2P3 teams are actively involved in the Dark Energy Science Collaboration (DESC), where they represent 15% of active members. The scientific strategy is to build upon the technical developments mentioned above to mitigate crucial sources of systematic uncertainties: most of the added value will therefore take place before the data enter catalogs. IN2P3 teams are focusing on 3 promising probes: supernovae, weak lensing and clusters. As this is a scientific council devoted to synergies, it is important to stress that each of these probes will benefit from external data: supernovae need follow-up, as well as enhanced dataset covering very nearby and very far away objects, cluster physics is by no way complete without access to X or SZ data, and weak lensing measurement will greatly benefit from improved redshifts, as well as shape data from space, not mentioning the role of N body simulations for systematics studies.

2 Institutional context

2.1 Overview

The Rubin Observatory, formerly known as the LSST[1], will conduct an unprecedented survey of the southern hemisphere, for 10 years, with a start of operation officially scheduled for the end of 2022. First proposed in 2004, the Rubin/LSST was designed to address the scientific challenges faced by the astronomical and cosmological communities in 4 key science areas :

- Understanding Dark Matter and Dark Energy
- Hazardous Asteroids and the Remote Solar System
- The Transient Optical Sky
- The Formation and Structure of the Milky Way

This project was selected by the US 2010 decadal survey as the main astronomical survey of the 2020 decade. In 2014, two US agencies, DOE and NSF, partnered with a non-profit organization, LSSTC, to fund the construction via the Rubin Observatory Project office, whose purpose is to deliver the facilities needed to conduct the LSST: a large-aperture, wide-field, optical imaging telescope; a multi-gigapixel camera ; and a data management system. In addition, the project is actively developing public engagement.

The purpose of the the Observatory is to deliver data to the astronomical community. In this model, the science will be conducted by astronomers, considered as users of the Rubin Observatory data products. The 8 Science Collaborations are independent entities, endorsed and partly supported by LSSTC, welcoming researchers from their scientific perimeter, although it is not mandatory to belong to a science collaboration to analyse Rubin data. The Dark Energy Science Collaboration, devoted to understanding the nature of Dark Energy, is the largest of these collaborations and the only one which receives direct funding from DOE.

As the start date of LSST approached, a new body, called Rubin Observatory Operations, was created jointly by DOE and NSF in 2019 and will take over from the Project office at the start of the survey.

2.2 IN2P3 in the LSST/Rubin ecosystem

IN2P3 is one of the earliest partners of the LSST/Rubin project, alongside with the country of Chile. After strong R&D efforts on the LSST camera started in 2007, a team from 10 IN2P3 laboratories (APC, CC-IN2P3, CPPM, IJCLab, IP2I, LAPP, LPC, LPNHE, LPSC, LUPM) have now joined the construction and the scientific preparation, with an active participation within the Dark Energy Science Collaboration. Up to end of 2021, our participation to the project is accounted by 2 MoAs signed with LSSTC. The first one is granting Rubin data rights to any researchers from the 10 aforementioned IN2P3 labs, through a contribution at the level of 10% of the camera construction. The second relates to the planned contribution at the level of 50% of the data release processing, in exchange of a full copy of the Rubin data at CC-IN2P3, and some additional data rights. These additional data rights possibilities are

[1]LSST means now the Legacy Survey of Space and Time conducted by Rubin observatory

intended to broaden the participation to Rubin for INSU or CEA scientists, a process which is still ongoing. In 2019, the US agencies revisited the model to acquire Rubin data rights, and the MoAs will have to be renegotiated with the US agencies. Given the high level of implication of IN2P3 from the very early stages of the project, this process should in principle be straightforward for us.

Almost all IN2P3 scientists are involved within the DESC collaboration, where we represent 32 out of 222 Full members, that is, 15% of active membres. Within DESC, we hold key roles: we are represented in almost every DESC committes by a total of 15 IN2P3 representatives, we have one member in the management team, and we ensure the joint leadership of 5 out of 18 working groups. However, due to the structure of the collaboration, IN2P3 is not represented as an institution, and there are no MoA signed. The contribution is therefore on a best effort basis, with the expectation that IN2P3 contributes at the level of the fraction of its Full Members. This is mostly achieved through computing capacity provided by CC-IN2P3.

As of today, the IN3P3 Rubin/LSST team counts 124 active people from 10 laboratories, for a total of 60.6 FTE, including:

- 25.3 FTE for 49 active scientists, 89% of the effort being of the preparation of science, and 11% for constructing the LSST camera;
- 18.5 FTE for 62 engineers and technical staff including 2.5 FTE of non-permanent staff, 43% of this effort is on camera construction, 13% are support staff for machine learning, and 44% work on computing for Rubin data;
- 16.8 FTE for 22 postdocs and PhD, 56% of which being involved with precursor surveys.

The Rubin/LSST effort at IN2P3 is funded in part by an Infrastructure de Recherche (IR) covering the camera construction and commissioning, and now starting to fund the computing equipment. IN2P3 funding for the construction is now mostly spent, with a total of 4.4 M€ for the hardware, 1.6 M€ for travel expenses and 152 FTE.yr of technical work on the construction period (2014 to 2023). The current estimate for the infrastructure and running cost for computing is around 33 M€ from 2020 to 2031 which is also partly funded through the CC-IN2P3 IR. Scientific expenses are covered by Subvention d'Etat (SE) for ~200 k€ per year. In addition, we benefit from the resources of 1 ERC and 2 ANR. Coordination is made through a monthly meeting of the group leaders.

The Rubin/LSST project at IN2P3 benefits from a dedicated communications officer. The goals of the communication activity are twofold. First, it promotes the role of IN2P3 within the project at an international level and within the Institute itself. Second, the communication plan aims at promoting the project to the general public, which also includes the development of strong connections with schools and scientific institutions such as planetariums. Regarding these goals, the main actions over the last five years were to ensure the presence of the project on the web[2] and social networks, with a storytelling about the construction of the filter exchange system and its transfer to SLAC[3] relayed by our partners. Major scientific events were organized to reinforce the visibility of the IN2P3 community in the project (i.e., LSST@Europe3, LSST-DESC Summer 2019 meetings, and a booth at the EWASS 2019 conference). Tools and exhibition panels were also created to present the Rubin Observatory during outreach events.

[2] http://www.lsst.fr

[3] https://twitter.com/LSST_France/status/1174392892074418177?s=20

3 LSST Camera construction at IN2P3

The LSST camera will be largest digital camera ever constructed. The 64 cm diameter focal plane is made from a mosaic of 201 silicon sensors with 16 Megapixels (4k x 4k) each for a total of 3.2 billion pixels. The sensors are deep depletion, back-illuminated devices with a highly segmented architecture (16 channels) that enables the entire array to be read out in 2 seconds. They come from 2 vendors, E2V and ITL. The refrigeration and electrical systems will be located in the "utility trunk" at the back of the camera. The front of the camera will host the refracting optics, the filter exchange mechanism and the mechanical shutter. This 1.65 by 3.7 meter camera, with a weight of 3 tons will be located in the middle of the secondary mirror. This science-driven innovative optical design comes at a cost: there is very little room for the camera "services" such as the filter exchange system. The status of the contribution of IN2P3 to the camera construction is summarized in this section.

3.1 The Filter Exchange system

Filter exchange system during its integration in LSST camera at SLAC (Jan. 2020)

The Filter Exchange System holds five large optical filters, any of which can be inserted into the camera field of view for a given exposure. A sixth optical filter will also be fabricated which can replace any of the five via a procedure accomplished during daylight hours. This system is a major deliverable under full IN2P3 responsibility. The LSST camera filter exchange system is unique in many aspects:

- Its size, imposed by the number of filters to handle and by their individual size (70 cm in diameter with mass of 30 to 44 kg each);
- Its compactness due to the limited space available;
- Its ability to prevent filter damage, including in the event of big earthquake of mag 7;

- Its stability, repeatability and limited access for maintenance. The success of LSST implies a smooth running for at least 10 years.

The length and the stability requirements of the LSST imply a qualification process for the design of this ground-based facility close to what is needed in space projects. The development plan has been split in 3 phases: design, prototyping, and construction. The filter exchange system passed its design review in 2015. The prototyping included the construction of a full-scale demonstrator and passed with success the Manufacturing and Readiness review in 2017. The construction of the full system then began, with a successful delivery at SLAC in 2019. Integration at SLAC was performed until early 2020 when it was stopped by the pandemic. It is expected to resume in 2021, before the ensemble is shipped to Chile in 2022. The system achieved an impressively short time to swap 2 filters: 123 seconds only, to be compared for instance to the 30 minutes needed to swap a filter on HSC. This is however above the specs of 90 seconds, and some tuning is still necessary.

The successful delivery of the filter exchange system relied on a large IN2P3 team from 5 IN2P3 laboratories, each of them in charge of a sub-system:

- APC is in charge of the slow control;
- CCPM is in charge of the auto-changer, that swaps the filters between the focal plane and the carousel;
- LPC is in charge of the test bench that emulates the camera & telescope movement, of mechanical dummies used to qualify the demonstrator and the final system, and of the metrology of the running system;
- LPNHE is in charge of the carousel that holds up to 5 filter out of the telescope beam and present one of them to the auto-changer. In a dedicated clean room, LPNHE hosted the assembly and test of the demonstrator and of the final system;
- LPSC is in charge of the manual changer used to insert filters in the camera and of the box used to store the filters when they are not in the camera at summit.

Once the full system will be fully delivered, the demonstrator will remain active for 10 years to serve as a training facility for maintenance operations.

3.2 The Camera Control system

The LSST Camera Control System (CCS) controls and coordinates the various camera subsystems, makes sure that camera operations proceed efficiently, and monitors camera performance, reporting errors. It interacts with the Rubin observatory, telescope, and data management, sending and receiving the data necessary for coordinated operations. It also provides human interfaces both for the display of status information and for testing, diagnostic, and debug capability. A major contribution was made by IN2P3 for the initial concept of the design of the Control Command Software (CCS) for the LSST camera. The implementation was performed by a joined APC and US CCS team. Our responsibilities are in the CCS core development, and in the Filter Control System. The CCS has been successfully commissioned on the Auxiliary telescope, one of the first operational elements of Rubin Observatory dedicated to atmospheric control. The FCS is now being qualified on the filter exchange system, remotely.

3.3 The Focal Plane

Sensors are one of the key element that we need to fully understand in order to control the systematic errors linked to the formation of the signal, an area of strong expertise by IN2P3 teams. Our participation to the project was thus in the procurement of the sensors for 2 M€, the focal plane electronics which control the behavior of CCDs, and the ongoing characterization tools to understand the sensors. The latter is conducted both within the Rubin observatory project and the DESC collaboration.

3.3.1 Electronics

IJCLab and LPNHE were in charge, from the design to the production, of the front-end ASIC for the LSST camera focal plane electronics: the ASPIC, dedicated to the analog processing of the CCD outputs. This element has been fully built, qualified and integrated into the focal plane, now under commissioning. The firmware at the core of the focal plane electronics has been designed, implemented and qualified by LPNHE, and will be supported by LPNHE during the 10 years of operation of the camera. The implemented design (ASIC & firmware) has taken into account the optimisation and diagnostic needs of the focal plane, with no direct access to the 3216 electronic video chains fully inside the cryostat. The on going commissioning has confirmed the expected performance of all these deliverables, IN2P3 playing a key role in the focal plane performances optimisation.

3.3.2 CCDs

At LPNHE, a laboratory devoted to the CCD characterization has been built over the years. This IN2P3 facility is a key tool for the construction and optimisation of the LSST camera focal plane. It has been used and is used by the Rubin project for: precise CCD characterization , interaction with CCD vendors and diagnostic and optimization of CCD & readout.

This test bench enabled the discovery of the brighter-fatter effect [2]: localized distributions of charges (resulting from star illumination or laboratory luminous spots) tend to broaden linearly with increasing brightness by up to a few percent over the whole dynamic range. This has a sizable impact on weak lensing signal extraction.

Within DESC, a Sensor Anomaly Working Group (SAWG) has been setup, to which the LPNHE contributes both scientific work and a convener. Understanding the physics at play in CCD sensors is the driver of our activity on LSST camera sensors, as we believe that understanding sensor physics is mandatory for precision measurements (typically photometry, astrometry, or shape), and we regard the involvement of the IN2P3 team in these matters as strategic. The SAWG working group is in practice very well integrated with the camera team, and fully participates to the camera integration and test. Over the past years, the French contributions to these actvities have consisted of:

- Tuning the clocking, and more generally the operation scheme of the CCDs, using our own testbench, in particular to address the difficulties discovered during the integration of the camera;
- Developing and testing a precise model of the variance-average relation (the so-called photon transfer curve) of CCDs in general, and ours in particular, that we have eventually published in 2019 [3];

- Developing the analysis of the test data and participating to the performance diagnostics of science sensors.

We have not been able to measure the 2-point correlation function of flat-field exposure in all science sensors, which is a key ingredient for predicting the flux dependence of the point spread function. We hope that this measurement will be soon possible, once the full focal plane resumes operations, in the coming weeks. The preliminary data from science sensors we have so far indicate a good reproducibility of sensor electrostatic properties. These activities give a good visibility to the French group, both in terms of invitation to conferences and refereed publications.

3.3.3 CCOB

The Camera Calibration Optical Bench (CCOB) consists of two distinct devices designed at LPSC to (i) produce an accurate measurement of the focal plane relative response (CCOB-WB) and (ii) contribute to the commissioning of the integrated camera (CCOB-NB). While the full focal plane is being commissioned, CCOB data will provide early access to full focal plane data.

CCOB wide beam projector (CCOB-WB) The CCOB-WB is a light projector aimed at the characterisation of the CDD relative response at the 0.2% level. It consists of 6 LEDs (shining light in each of the LSST bands), mounted on an integrating sphere fixed to an x-y stage that allows the beam to be moved over the entire focal plane. Doing so, the CCOB-WB will produce a composite flat field over the full array of CCDs. A control photodiode, also mounted on the sphere, allows us to control the stability of the emitted light. The final device, obtained after several years of development at LPSC, was delivered at SLAC in 2018 and has now been used several times as part of the standard suite of tests performed on the raw focal plane. The data taken so far has allowed us to demonstrate that the CCOB-WB will be able to meet the 0.2% precision requirement on most of the focal plane and to finalize the analysis software. The CCOB-WB will be used momentarily over the full focal plane, one of the final tests before the integration of the camera with the otpics.

CCOB narrow beam projector (CCOB-NB) The scientific goal of the CCOB-NB is twofold: (i) measure the throughput of the system and (ii) contribute to the commissioning, in particular by the measurement of ghost images on the focal plane that will allow us to check the alignment of the optical system. It will be used with the integrated camera, that is with the lenses and filters in place. The CCOB-NB uses a numerically-controlled monochromatic light source (LASER excited plasma). A fiber optics guides the light up to a moving head where a thin - a few millimeters wide - parallel beam is formed. This head features 2 translation and 2 rotation degrees of freedom so that any point on the focal plane can be hit at the desired angle. A calibrated photodiode can be remotely put on the optical path to perform an absolute measurement of the delivered light. The light source has been received and tested at LPSC. It fulfills the requirements that were not met by the solution from a previous vendor. The mechanical structure has been tested and assembled and fulfills the requirements as well. The software allowing the interface with the CCS has been written and the electronic racks are gathered together to command the full CCOB-NB. The analysis software is currently being developed.

4 Calibration and commissioning

4.1 The importance of calibration

The Hubble diagram of type Ia supernovae is the most sensitive probe of the evolution of the expansion rate in the late universe. The measurement in itself boils down to the comparison of the apparent luminosity of SNe Ia at low and high redshift, which requires exquisite knowledge of the calibration ratio between the visible photometric bands (in which the nearby supernovae are observed) and the infrared photometric bands (in which the high redshift supernovae are observed). The limited accuracy of the calibration references is currently the second limiting factor, closely following the statistical uncertainty due to the finite number of observed SNe-Ia. With the ten times increase in the statistics of available SNe-Ia provided by forthcoming photometric surveys such as ZTF, DES, SSP, and LSST, substantial progress on the accuracy of calibration references are required.

Recent studies have helped quantifying how calibration accuracy affects the performances of cosmological supernova surveys. Figure 1 summarize our own assessment of the scientific promise associated with the achievement of 0.1mmag accuracy for a combined 2 years ZTF-LSST survey. The so-called Dark Energy Figure of Merit $(\sigma_{w_p}\sigma_{w_a})^{-1}$ jumps from 149 to the very interesting level of 438 where Dark Energy models are challenged. Although 0.1mmag represent a stretched goal, most of the calibration benefit is already haversted at 1mmag with a corresponding FoM of 319. This goal of 1mmag is within the demonstrated accuracy of the rest of the SNe Ia metrology chain, including differential photometry of SNe Ia [4], but the primary calibration references themselves.

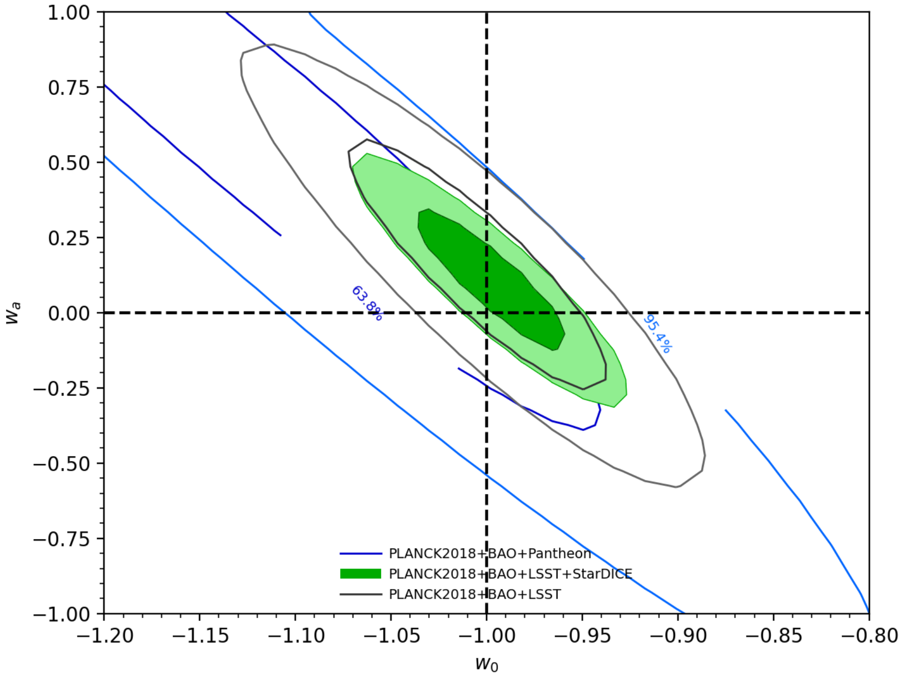


Figure 1: *Confidence contour in the $w - w_a$ plane for a Hubble diagram combining ZTF, SSP and 2 years of LSST (39800 SNe Ia). The light gray contour assumes no progress on calibration, that is a 5mmag error on filter zero points. The green contour assumes the achievement of a complete reduction of calibration uncertainties at the 0.1 mmag level.*

4.2 StarDICE

The state of the art of calibration references is currently held by the numerical modeling of the spectral energy density of three white dwarfs. Those 3 fondamental spectrophotometric standard stars are routinely observed by spectroscopic and photometric instruments to infer their response curve. The accuracy of the models themselves was however never fully assessed. The internal consistency of the set of 3 models is at the 2mmag level across the visible. This however does not exclude the existence of common error modes in the modeling affecting equally the 3 stars. As such, subsequent revisions of the models over the past decade to incorporate refined physical effects have shown differences as large as 1%, worrying for cosmological results.

Building on the expertise acquired on a previous setup [5], the aim of StarDICE, a LPNHE-IJCLab-CPPM-LUPM instrumental project, is to anchor the flux of the 3 fundamental standards in the 6 *ugrizy* photometric bands with 1 mmag accuracy to laboratory flux reference defined by the NIST cryogenic radiometer POWR (0.001% definition of optical watt). To do so involves building a polychromatic artificial star, whose flux stability is controlled at the 0.1mmag level and with traceable calibration to the NIST scale at the 1mmag level, which serves as in-situ calibration reference for a small photometric instrument dedicated to the observation of spectrophotometric standards in the 6 bands. The measurement is repeated over a long duration ($\sim 200 - 400$ nights) to beat down the $\sim$ 10mmag noise in the nightly determination of atmospheric extinction through modeling and airmass regression.

From a 16 nights technical faisability study conducted at OHP, we concluded that the photometric instrument is reasonnably stable on the night timescale and that the most time-efficient way to infer top of the atmosphere fluxes from ground-based observations is to combine a photometric follow-up of a single target along its airmass trajectory with simultaneous monitoring of the line of sight photometricity and time evolution of the atmospheric composition.

The instrumental setup is installed at Observatoire de Haute Provence, in one of the two domes of the Jumelés. The MoU for the next three years of observation has been signed as of October 2020.

4.3 AuxTel

In order to constrain the variability of the atmospheric transmission, the Vera Rubin Observatory has installed a 1m class telescope on the same site than the primary telescope, called the Auxiliary Telescope (AuxTel). This instrument is equipped with a camera using one of the LSST detectors. It has a full range of optical filters, as well as a dispersor allowing for slitless spectroscopy. In addition to its primary scientific goal, the AuxTel is also the first place where all the Rubin control and data taking system is assembled. As such, the involvement of IJCLab, IP2I and LPNHE in analysing and taking data with this instrument constitutes our closest implication to Rubin commissioning and data analysis.

While construction and integration falls under the responsibility of the Project, we have been leading the development of holographic dispersors that aim at increasing the quality of the spectra observed with the AuxTel.

We are also closely involved in the data analysis of the AuxTel at the level of the sensor qualification, at the level of slitless spectra extraction, and in the extraction of information and constraints on atmospheric transmission. We conduct this work within DESC where we are convener of the corresponding working group.

5 Computing

A small fraction of DC2 simlation data once reconstructed by Rubin software at CC-IN2P3. This covers an area and a depth equivalent of 1 CCD of LSST observed for 5 years.

In 2015 a Memorandum of Agreement between IN2P3, LSSTC, Rubin project office and NCSA was signed to formalize the IN2P3 commitment to contribute the resources, both equipment and labor, to process 50% the raw Rubin images and to produce the related catalogs during the operations phase of the project. In return, LSST was granting 45 PI data rights to France. After the redefinition of the data rights policy in 2019, the IN2P3 / Rubin agreement has been unchanged. The sharing of the Data Release Processing (DRP) effort is still subject to discussions for the UK part but could be 50% in France, 25% in the US and 25% in the UK.

From the scientific point of view, this agreement will allow IN2P3 to hold a complete copy of the Rubin data thus providing a significant advantage to the French scientists. The total investment at CC-IN2P3 has been estimated to 20 M€ for hardware and 13 M€ for operations for the 2020-2031 period. The construction of the French DRP facility at CC-IN2P3 has started and several engineers have been hired and assigned to the project under the coordination of Fabio Hernandez (CC-IN2P3).

The whole French Rubin computing effort is now organized in such a way to maximize the scientific return of this important investment and to provide the best possible analysis environment.

5.1 Software Distribution

The Rubin/LSST Data Management team develops the software suite to perform image processing and to populate and access the astronomical catalog [6]. Daily, weekly and stable releases are produced and made available to the wider community.

Since several years now, at CC-IN2P3 we deploy weekly and stable releases and deliver them to the local compute and login nodes via CernVM FS[4], a software delivery mechanism initially developed for the needs of the LHC experiments and now widely used by many scientific projects. CC-IN2P3 distribution is replicated by NERSC, CERN and OpenScience Grid and used by scientists in their personal computers.

5.2 International Connectivity

Excellent transatlantic connectivity to the Rubin US Data Facility is key for CC-IN2P3 to fulfill its role of data processing center and permanent storage site.

After having experienced chronic difficulties, early 2020 the 20 Gbps transatlantic link between CC-IN2P3 and NCSA (National Center for Supercomputing Applications)[5] in Illinois, USA was finally delivered. This connectivity is provided by RENATER and GEANT within Europe and across the Atlantic and Internet2 for the segment within the USA.

An increase in the bandwidth of this link was initially scheduled for the first quarter 2021 to reach 100 Gbps one year before the start of the operations phase. The US agencies funding the Rubin project are considering the relocation the US Data Facility and the final decision is expected by 2021. Once the new location of the future USDF will be known we will resume our efforts to get CC-IN2P3 well connected to that facility.

5.3 Image Processing for Annual Data Release Production

In 2017 DESC launched a major project, called DC2 [7], aimed at simulating 5 years of a realistic LSST-like survey over 300 deg^2. State of the art n-body simulations and a detailed image simulation based on a realistic optical model of the instrument and of the atmosphere were used. Image processing relied on the official science pipeline, thus offering a crucial at-scale test bench to the project data management team. This last effort has been entirely handled by IN2P3 and executed at CC-IN2P3, thanks especially to the extremely fast deployment led by LUPM of a workflow management system distributed between SLAC and IN2P3, used by Fermi-LAT since 2009 for Monte Carlo production. It is worth noting that DC2 showed that high throughput computing architecture turns out to be a huge advantage to run these I/O intensive data processing tasks, compared to the HPC system available at NERSC[6]. Furthermore, This DC2 represent a crucial milestone to identify, validate and tune the hardware and middleware which will be necessary at CC-IN2P3 for the needs of annual data release processing for Rubin. As a recognition of the key impact of IN2P3 in DESC computing activities, a French researcher is co-leading the corresponding working group.

[4] https://cernvm.cern.ch/fs

[5] University of Illinois at Urbana-Champaign, http://www.ncsa.illinois.edu

[6] https://www.nersc.gov, the main US computing resource center for DESC

5.4 Data Access

Efficiently accessing the data from the Rubin Observatory is a complex task requiring original developments. At the level of the project the data access is a combination of a large shared-nothing highly distributed database system internally developed by Rubin (SLAC + LPC Clermont) named Qserv and of a Science Platform orchestrating various services to access the catalogs in Qserv and the images on disk and to provide online analysis tools based on Jupyter notebooks.

A Qserv platform has been running for several years at CC-IN2P3 thanks to a partnership with Dell who donated initial hardware. The Qserv platform has been recently completely renewed with modern, well configured hardware and constitutes the first building block of the service that will be put into production at Rubin start up. LPC and LAPP are actively working on Qserv data ingestion and are running extensive tests to assess the database performance from the technical and scientific point of view. Alternative data access methods to catalog data are also tested such as Apache Spark which has been explored by IJCLab.

The Rubin Science Platform (RSP) is being assessed by LAPP in the framework of the ESCAPE EU project[7] for which it is considered as a use case. Both Qserv and RSP rely on complex architectures based on the Kubernetes containers' orchestrator which is now a de facto standard in both the industrial and scientific worlds. It is expected that the RSP design will be general enough to be reused and customized for other science projects and to provide a framework for multi-wavelength / multi-messenger astronomy.

5.5 Computing for science

The main computing platform for DESC is based on a high performance computing system located at NERSC (Berkeley). We maintain a fully compatible computing environment at CC-IN2P3 providing access to both the software developed in the framework of the DESC Analysis Working Groups and to the official set of catalogs. The main interface for accessing those resources is a Jupyter notebook-based platform which provides the required flexibility for the scientists' individual needs. The system is designed in such a way that an analysis developed at CC-IN2P3 can run at NERSC and vice-versa, without any modification.

The full dataset (images and catalogs) produced by the DESC DC2 are available at CC-IN2P3 (and at NERSC) and are used on a daily basis to develop and test science analyses.

5.6 Fink: the French alert broker

Fink is a broker designed to enable science with large time-domain alert streams such as the one from the upcoming Rubin observatory [8]. During a decade, the Rubin observatory will take $\approx 1,000$ images per night, detecting up to 10 million candidates of transient events every night. These candidates will be communicated to a selection of brokers through a data stream every 30 seconds.

To harness the full power of Rubin data, promising candidates must be identified within this alert stream. This task includes many challenges: first, the stream will contain diverse astrophysical phenomena which are challenging to disentangle. Second, identification of promising

[7] https://projectescape.eu

candidates must be done in a timely manner due to their transient nature, with time frames spanning from seconds to months. Third, the alert rate forecast for Rubin will be at least an order of magnitude larger than current surveys and it will trigger on typically fainter objects, making it difficult for currently available systems to operate efficiently with current tools. To tackle these challenges, Fink was born within the IN2P3 community and is the confluence between big data infrastructure and astronomy.

The broker is designed to maximise scientific exploitation of the Rubin alert stream. It fulfils traditional broker tasks: (i) ingest the Rubin alert stream, (ii) enrich all alerts, (iii) filter alert stream, (iv) redistribute alerts. Moreover, it goes beyond basic requirements, expanding these tasks and aiming to optimise its technology for Rubin and its related Science Collaborations such as LSST-DESC. We currently operate a prototype of the broker on the VirtualData OpenStack-based cloud, a shared computing and storage infrastructure at University Paris-Saclay.

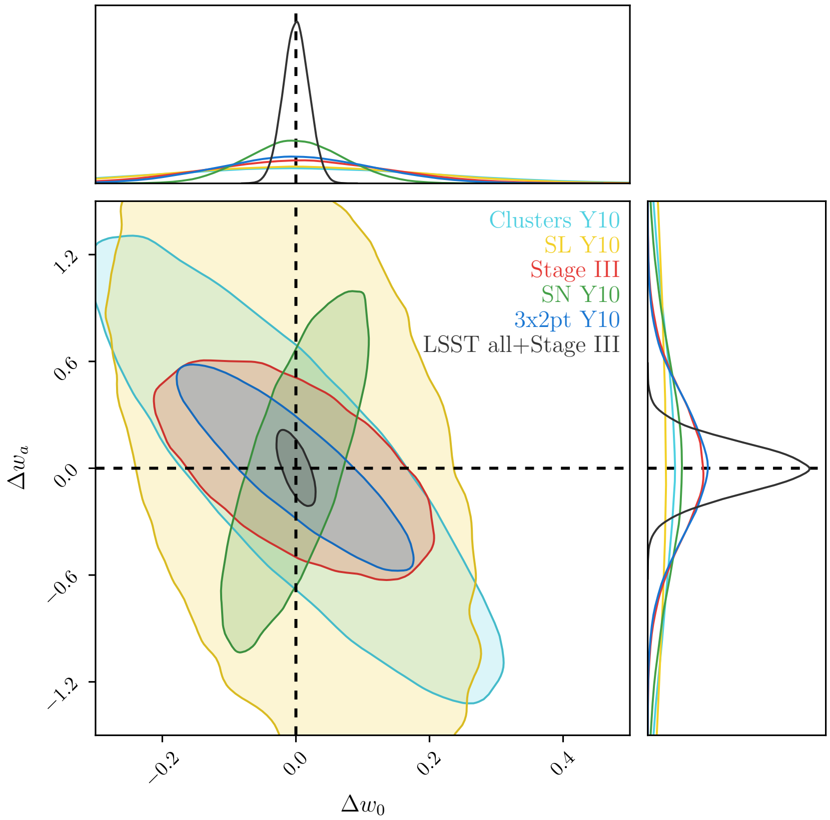
The goal of the Fink collaboration is to enable discovery in many areas of time-domain astronomy. The broker has been designed to be flexible and can be used for a variety of science cases, from stellar microlensing, to extra-galactic transients and cosmology. To enable these the broker processes alerts, adds contextual information that can be useful for the scientific community, and provides preliminary classification for a variety of objects. This is crucial for filtering the million of candidates every night to select those promising for follow-up efforts and to produce scientific results. For this, Fink relies in state-of-the-art machine learning algorithms (e.g. Active Learning, Recurrent and Bayesian Neural Networks [9, 10]) and big data solutions.

Nevertheless, to fully exploit this abundance of data from Rubin observatory, it is paramount to connect different surveys together and promote coordination of resources. The study of the transient sky has entered to a new era, with instruments being able to detect sources in the whole electromagnetic band from radio to TeV photons but also through high energy neutrinos, very high energy cosmic rays and gravitational waves. The transients detected by Rubin observatory will also benefit from current space and ground instrumentation such as KM3NeT neutrino detectors, the extension of LIGO/Virgo and KAGRA for gravitational waves, the Square Kilometre Array telescopes in radio bands, the Chinese-French SVOM satellite for gamma and X rays, CTA and many others. We are currently discussing together with these collaborations, and we started active work with SVOM and GRANDMA teams in order to prepare efficiently the start of LSST, taking advantage of widely used services and tools in astronomy, thus benefiting from standards in place and ensuring communication between different surveys, science collaborations and observational facilities.

Early 2020, the Fink collaboration signed a memorandum of understanding (MoU) with the Zwicky Transient Facility (ZTF)to receive the live public data stream (multi-GB alert stream sent each night) and has been since then performing technical and science tests with this data. It has already shown its performance by selecting microlensing, Gamma Ray Bursts, supernovae and Solar System objects events in the ZTF alert stream.

Fink is currently competing to become one of the Rubin observatory brokers (among 15 other brokers). The final proposal will be submitted in December 2020 and selection will be official in 2021. Fink is in excellent position to become an official broker due to its performance in the big data ecosystem, broad science cases and its national and international community support. In addition, its natural connection with the CC-IN2P3 is a unique advantage with respect to other broker proposals to access the local copy of Rubin data that can be efficiently exploited to enhance the broker data products.

6 Preparing for science



The forecast dark energy constraints after 10 years from each probe individually and the joint forecast including Stage III priors [11].

Almost every field in astronomy will be impacted by the huge dataset collected by Rubin observatory, since it will produce a deep survey with images taken at many epochs for each field, well suited for both deep sky science and sky variability science. In the sector of our science driver, the Dark Energy, the goal of LSST is to reduce by 1 order of magnitude the current errors on the Dark Energy equation of state. This will be achieved by the combination of all dark energy probes, the most sensitive of which being the so called 3x2pt correlation of Weak Shear and Large Scale Structures, followed by type Ia supernovae whose performances for cosmology will highly depend on the details of the survey design. With more than 20 billion galaxies collected and hundreds of thousands of supernovae, LSST results on dark energy will be systematics limited. The mitigation of these systematics is at the core of IN2P3 effort within the Dark Energy Science Collaboration (DESC), one of the 8 science collaborations of Rubin observatory, and IN2P3 scientists are active in 14 out of the 18 working groups of the collaboration. Outside Dark Energy, IN2P3 scientists have also expressed an interest for the Transient and Variable Stars collaboration.

Within DESC, our overall scientific strategy is to target the most impactful probes, and to address key sources of systematics and challenges building on our strong links with the Rubin project: at IN2P3, we have the advantage over the US that we don't make an institutional distinction between what is DESC and what is Rubin, and our researchers can easily move from one to the other and build upon the expertise acquired in one context for the benefit of both. Within DESC, we have therefore the strongest impact within the technical working groups, which address critical issues related to the signal extraction for supernovae and weak lensing: building accurate catalogs is at the core of our strategy to mitigate the systematics. We detail this hereafter for each probe of interest addressed at IN2P3.

6.1 Cosmology with Type Ia Supernovae

The Hubble diagram of type Ia supernovae (SNIa) was the first probe to provide us with an evidence for an accelerated expansion of the Universe. Since the pioneering measurements of the SCP and Hiz-SN teams, IN2P3 has been active in the SNLS and SNFactory surveys, where the teams acquired an international recognition, SNLS results being still today a reference when combining cosmological probes. It is striking that this latter analysis was conducted with 740 SNIa only. With the promise of $O(10^5)$ objects, the game will change radically for LSST. Finding supernovae will not anymore be an issue. However, constructing light-curves of sufficient quality still depends on the details of the observing strategy. Another game changer is the spectroscopic follow-up of the SN candidates: with such statistics, it will be no longer possible to identify all live objects with spectroscopy, which puts new challenges for the control of the sample. Just acquiring the redshifts of the Hubble-diagram grade candidates represents a significant observational effort. Finally, in order to be competitive with other probes, the control of systematics needs serious improvements: this implies a quality of light-curve extraction beyond Rubin project requirements, improvement of the calibration (as described earlier in this document), and a better control of nuisances from astrophysical origin. On the bright side, such amount of data opens for new scientific opportunities, including the recent development of SNIa peculiar velocities as a probe of the growth of structures in the late Universe.

6.1.1 Preparing SN within DESC

IN2P3 teams from CPPM, IP2I, LPC and LPNHE have been very active in preparing for the LSST supernova program, working in 45% of DESC SN-related projects[8] and with success as the DESC supernova working group is co-lead by a scientist from LPC. One of the important achievement was to improve the grand design of supernova cosmology with LSST, working on the survey strategy.

- We have proposed a global strategy to achieve a DETF Figure of Merit (the inverse area of the errors in the w_a, w_0 dark energy plane) of 319, by 2025 [12]. This would make SNIa the best single cosmological probe for LSST, well before the end of 10 years of the survey. The key elements for this strategy are an improved calibration at the per mil level, and complementing the follow-up of high redshift supernovae in the IR with data from space, be it HST or later on NGRST. A coordination of pointings with Euclid in their Deep Drilling Fields may also benefit the SNIa cosmology.
- We also have shown that the default regular cadence of the survey is unsuited for supernova cosmology, as it implies large gaps in the light curves. Following our studies [13, 14], it is possible to gain a factor 5 in statistics with rolling strategies, where the survey focuses on a fraction of the sky with increased cadence a given year, and switches

[8] A DESC project is a DESC-approved project, advertised in the collaboration, and that should yield a DESCnote or paper.

to another fraction on subsequent years. The rolling strategy is now acknowledged by the Rubin project, even if they still fail to implement it properly in their simulations. A clear line of action for the near future is to keep looking closely at the cadence proposed by the project in order to monitor their progesses.

- Beyond the dark energy FoM, we have shown the cosmological capabilities of employing nearby SNIa velocity fields (up to $z < 0.2$) to constrain the growth rate of structures with a precision of 5% of fD [15]. This requires precise redshifts for all objects, and therefore a dedicated spectrograph. There is a clear synergy between ZTF and LSST as they both scrutinize different hemispheres.

The spectroscopic followup of $O(10^5)$ live SNIa is not feasible. For most objects, the identification will rely on photometric typing, which is the realm of machine learning. However, this requires a handful of correctly tagged objects to train classifiers. We have shown above how the Fink broker will address the issue of sending live transient to spectroscopy. One of the challenges that DESC has to solve for the years to come will be to secure the additional follow-up resources needed.

Machine learning development included (i) the constitution of a reference dataset representative of LSST transients to train machine learning tools [16]. This data set was presented as a Kaggle challenge to a broad community of ∼1100 competitors. (ii) the development of performant machine learning algorithms based on deep neural network architecture, Pelican [17] and SNN [10]. (iii) the use of Active Learning, a novel machine learning technique which optimizes the acquisition of costly data, here the spectra, in order to improve the subsequent classification. We have proposed its application to LSST SNIa data [9, 18], and are working on its implementation within Fink.

6.1.2 The role of precursor surveys

The extraction of SNIa photometry from pixel data is best studied on precursor data sets. Two algorithms need to be qualified: the difference image analysis, which exhibits new detection by image differencing, and scene modeling, an optimal extraction of the flux from a stack of images, first developed for SNLS by LPNHE [4]. This requires accurate knowledge of astrometry and PSF. Rubin data management does not plan to provide this photometric quality in the catalogs, they will only rely on the photometry coming from the image differencing. Thus, providing scene modeling photometry will be an IN2P3 added value to DESC data, and corresponding effort are conducted both within DESC and with the precursor surveys.

This technique is currently employed for HSC data in the SSP program [19] to extract SNIa lightcurves. The 2 year program of data acquisition of this survey is completed now, and analysis is underway. ZTF provides another source of real data for testing photometric algorithms, and IN2P3 would benefit from the possibility to participate to ZTFII to maintain expertise before the start of LSST.

Once extracted and calibrated, supernova analysis requires light-curve fitting. For long, the traditional paradigm has been a stretch-color correction. One recent result has been the construction of a full spectral energy density model with data from SNFactory, which leads to promising results with respect to the state of the art [20].

Supernova astrophysics also plays a role as a source of systematic uncertainties. This was studied on precursor data. A known effect is the evolution with the environment: supernovae exploding in more massive hosts tend to be fainter after correction. This effect was confirmed as linked to the local star formation rate on SNFactory data [21], which may have an impact on the determination of H_0, and we benefit from the USNAC ERC to further the study on ZTF. This effect was confirmed on photometric data from SNLS data [22], opening its study for LSST.

6.2 Shear estimators

Weak lensing is a phenomenon related to General Relativity that causes a deformation of the images of background galaxies by a shear transformation, due to the presence of matter inhomogeneities in the line of sight. The study of the spatial correlations of these deformations, commonly called cosmic shear, is one of the most powerful probes to constrain not only the dark energy equation of state, but also deviations from General Relativity. It is however a challenging probe as the shear induced by cosmological distortion of the apparent ellipticity of distant galaxies is very small compared to all other sources of ellipticity, be it the natural ellipticity of the galaxies themselves, their cosmological alignment, or the modification of apparent ellipticity induced by the atmosphere and the instrument. LSST has been designed to mitigate the latter by repeated observation of the sky over the 10 years of observation. Apart from photometric redshift determination which acts as a common source of systematics for many probes, weak shear systematics are mostly sensitive to the additive and multiplicative bias coming from shape measurements, including detector effects (detailed earlier), PSF modeling errors and blending.

6.2.1 PSF

The propagation of light through the atmosphere and the optics of the instrument induces a point spread function (PSF), which induces spatially correlated deformation on the focal plane, analogous to the shear signal, but higher in magnitude. Another source of error comes from astrometric residuals, which tend to circularize the signal as it is extracted from the wrong centroid: this induces a multiplicative bias, weakening the shear signal. It important to stress that all other analyses of shear systematics, be it blending, model bias, intrinsic alignement, suppose that the PSF and the astrometry are perfectly reconstructed, which is not the case.

Major work has been done at LPNHE which greatly improved the PSF and the astrometric model within the PSF working group of DESC, co-lead by an IN2P3 postdoc. A major breakthrough has been the careful use of gaussian processes to interpolate the PSF and atmospheric distortions in the full focal plane, and this has been successfully applied to 2 precursor surveys: DES and HSC.

- Within DES, a full model of the PSF has beed developed, distinguishing the optical aberrations, the atmospheric contribution and its spatial variations, and a static part covering residual effects. This has been implemented as the Piff package[9] which was tested on DES 3 year data, showing with respect to DES 1 year data a significant improvement of PSF residuals, with a gain up to 1 order of magnitude. Piff is nowadays the new standard for PSF estimation.
- Within HSC, we have shown that the astrometric residuals were due to coherent atmospheric distortions over the focal plane, and the correction is able to eliminate up to 90%

[9] https://github.com/rmjarvis/Piff

of the scalar component of the distorsions. This will improve not only the shear signal, but also the flux extraction for supernovae.

None of these studies would have been possible on simulation data, which highlights the need of precursor data, and the role of synergies between current and future projects.

In addition to understanding the PSF residuals, it is important to control externally the multiplicative bias. A novel idea was proposed at LPNHE: the cross-correlation of the shear signal with the magnification of Type Ia supernovae. Indeed, weak lensing acts not only on the shape, but also on signal intensity. However, one need a standard candle to probe the latter. This novel use of type Ia supernovae as calibrators for the shear estimate is powerful enough to also constrain post-GR parameters, and this development highlights the importance of studying multiple probes at IN2P3.

6.2.2 Deblending

At the depths achieved by LSST, one major source of systematic error is the blending of galaxies due to line-of-sight projection, with an expected fraction of blended galaxies of up to 50%. At APC (ANR AstroDeep), a team is exploring the use of deep neural networks to estimate the photometry of blended pairs of galaxies [23]. The interest of combining Rubin and Euclid data for such studies is detailed in the dedicated presentation of this scientific council session.

6.3 Clusters

Clusters of galaxies arise as the last stage of the hierarchical structure formation, are the most massive gravitationally-bound structures in the universe, and represent the largest peaks in the matter density field. They have become a widely-used cosmological probe as they provide complementary constraints on the main cosmological parameters but are also a unique tracers of the hierarchical large-scale structure formation. Galaxy clusters are inherently multi-wavelength objects. The hot intracluster gas can be traced in X-rays (Bremmstrahlung) and at mm-wavelength (SZ effect) while cluster galaxies and the gravitationally-lensed background galaxies are observed in the visible or near-infrared. The coming decade will be a game changer as large surveys in the optical or near-IR (Rubin/LSST, Euclid) will come online, and ongoing efforts in X-rays (e.g. e-Rosita satellite) and at mm wavelengths (SPT-3G, AdvACT) will keep going.

The number of dark matter halos at a given redshift and as a function of mass depends on the underlying cosmology. This dependence is particularly strong at the cluster scale ($10^{14} - 10^{15}$ $M_{\odot}$) and explains why measuring the galaxy cluster abundances with mass and redshift is a prime cosmological probe. The determination of the cluster masses is currently the limiting factor of this approach and is where most improvement is to be gained in the future.

Around 2016, LPSC and LAPP teams started getting involved specifically in the determination of clusters masses using weak gravitational lensing (WL). Compared to mass estimates derived from X-ray or SZ, the WL mass does not require assumptions on the thermodynamic state of the clusters (which can bias the estimated mass) and provides an absolute mass calibration. However, the WL mass itself is not devoid of systematic effects (projection effects, miscentering, contamination by foreground galaxies, calibration of the shape measurement method, blending) and understanding and controlling those source of systematic effects is central to our work. We are pursuing this effort as part of the DESC Clusters working group, where we first worked on reprocessing cluster fields from ancillary data using LSST tools and determining their weak lensing masses for comparison to the original measurements[10]. We are currently leading the CLMM[11] DESC project[12] which aims at providing the community with an open-source, flexible and well-tested software, allowing for all things related to the WL mass reconstruction. We are using the CLMM software to study clusters in the DESC Data Challenge 2 (DC2) simulated dataset and have proposed several DESC projects in this context. This work will continue in close collaboration with members of the DESC Clusters working group. Another ongoing project aims at producing multi-wavelength mock observations of the DC2 clusters using baryon pasting techniques and provide a tool to study scaling relations between the various cluster observables, without the need of costly hydrodynamical simulations.

Finally, let us mention that the determination of cluster masses can highly benefit from the synergies between LSST and Euclid and their (at least) 7000 deg2 sky coverage overlap. The combination of LSST 6 optical band photometry and shapes with Euclid galaxy shape measurements and near-infrared photometry could push WL cluster mass determination to $z_{\rm cluster} \sim 1 - 1.3$, in a regime hardly achieved so far. At high redshifts, the combination of richness mass estimates with SZ/X-ray mass proxies will also be crucial, making the multi-wavelength approach all the more important.

6.4 Photometric redshifts

The estimation of galaxy redshifts from broad band photometry, named here photo-Z, which is essential for all the cosmological probes, has become a widely used tool in observational cosmology. These redshift (and galaxy property) estimates are derived from the galaxy spectral energy distributions through a series of broad band filters. Several French teams from CPPM, IJCLab, LPC, LPSC and LUPM are working on this field. On one hand, we have performed a detailed modelling of the photo-z distribution. The isotropic BAO scale has been used to estimate the impact of photo-z smearing: it should stay limited up to z $\simeq$ 1.5, as long as the galaxy number density balances the photo-z smoothing [24]. In parallel, a new atlas of SEDs based on data taken with the FORS2 instrument of the VLT, is in preparation. Prospects using galaxy clustering simultaneously with photo-Z determination in the framework of galaxy clusters are ongoing. On the other hand, a new approach based on a Deep Convolutional Neural Network, used as a classifier, to estimate photometric redshifts and associated probability distribution functions for galaxies in the Main Galaxy Sample of the Sloan Digital Sky Survey at $z < 0.4$ has been developed [17]. For most galaxies, the precision was limited by the SNR of SDSS images rather than by the method. This successful method is currently extended to higher redshift for application on the Rubin data (ANR DEEPDIP). In parallel, deep investigations on the robustness of the method are carried out. Numerical experiments have been conducted using adversary training [25]. The role of training sample has been investigated [26]. Evaluation of photometric redshifts estimators have also been conducted using the LSST DC1 simulations with a participation of IN2P3 people [27].

[10]https://github.com/combet/CLstack2mass

[11]https://github.com/LSSTDESC/clmm

[12]A DESC project is a DESC-approved project, advertised in the collaboration, and that should yield a DESC note or paper.

6.5 Other scientific interests

6.5.1 Dark Matter

The identification of Dark Matter is now a well established and very active working group within DESC, after three years of studies that culminated with a white paper [28] showing the wealth of scientific returns that LSST can provide in the field and the relevance of Dark Energy probes and techniques to also tackle Dark Matter open issues. Given the historical importance of Dark Matter searches at IN2P3, through direct, indirect, and collider searches, it is quite natural to plan for a strong program with LSST as well, which provides a complementary view on the nature of Dark Matter through an unparallel investigation of substructures at all scales, especially the low-mass end, and through time scales ranging from the hour to the decade. More details are available in the contribution to the "prospectives IN2P3" [29]. At this time, current efforts within IN2P3 primarily concern the expected detection by LSST of a swarm of new dwarf satellites of the Milky Way , low-mass structure abundance studies and searches for intermediate mass black holes through lensing, especially microlensing,an area of historical expertise within IN2P3. One can add the more exotic search for Galactic molecular H_2 gas that LSST could detect through scintillation in dedicated short duration and rapid cadence operation mode [30].

6.5.2 The rise of Machine Learning

The volume and complexity of data to be generated by Rubin observatory makes the use of machine learning techniques unavoidable [31]. As is demonstrated in previous sections, the IN2P3 community has been actively working in the development of machine learning techniques tailored to tackle different areas of research related to dark energy (supernova, deblending and photometric redshifts). Moreover, state of the art machine learning techniques are crucial to the added values to be delivered by the Fink broker, among them the characterization of scientifically interesting anomalies. We are working in developing adaptive learning techniques for anomaly detection [32] which will allow Fink to deliver increasingly more accurate anomaly scores throughout the duration of the survey. This effort aims to optimize our chances of fully exploiting the potential of Rubin data, ensuring we will have means to identify known as well as previously unforeseen astronomical events.

6.5.3 The transient sky

With its unprecedented capabilities, Rubin observatory will detect up to 10 million new objects per night, opening a new eye in the transient sky. Its wide field of view and nightly coverage makes it also perfectly suited to screen optical counterparts of high energy events detected by other projects, like SVOM, Ligo/Virgo, CTA or KM3NET. With the help of the Fink broker described earlier, Rubin/LSST community at IN2P3 is broadening its reach to include multi-messenger astronomy: gamma-ray bursts counterparts as well as orphan afterglows, kilonovae physics and gravitational waves, important for cosmologists as they will provide an independent measurement of H_0, high energy neutrinos counterparts and their link to tidal disruption events. 14 physicists from IN2P3 have declared their interest for Rubin transients, including 4 purely on the multimessenger aspect.

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