ANR COMPASS

SCIENCE REQUIREMENTS REPORT

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1. INTRODUCTION

1.1 Summary of the COMPASS project

The European Southern Observatory is leading the design phases for the European-Extremely Large Telescope (E-ELT), a 39m diameter telescope, to provide Europe with the biggest eye on the universe ever built, with a first light foreseen in 2022. The E-ELT will be the first telescope that will entirely depend, for routine operations, on adaptive optics (AO), an instrumental technique for the correction of dynamically evolving aberrations in an optical system, used on astronomical telescopes to compensate, in real-time, for the effect of atmospheric turbulence. The two first light instruments: ELT-CAM (a wide-field imager) and ELT-IFU (an integral field spectrograph) are both designed to be coupled to AO modules. The PHASE partnership, gathering most of French AO community is one of the core contributors to the AO modules, being strongly involved in both consortia selected to lead the final design studies for the two first light instruments. The proposed COMputing Platform for Adaptive optics SystemS (COMPASS) shall provide the PHASE community with powerful means to lead the development of both these AO modules as the final design phases should begin in 2012. Based on a total integration of software with hardware and relying on a high performance heterogeneous architecture, the COMPASS platform will be used to perform end-to-end simulations of the AO system behavior and performance as well as to design and test new concepts for the Real-Time Computer (RTC), a core component of any AO system. It will also provide critical decision tools for optimizing the opto-mechanical design of the instruments that will be developed for the E-ELT. The simulation of an AO system involves multiple physics from atmospheric turbulence models to tomographic reconstruction to control theory. Moreover, full length E-ELT simulations are compute-intensive applications and as such good candidates for considering the use hardware accelerators like manycore processors. Among those accelerators, the CUDA hardware was designed to provide graphics processors (GPUs) equipped with HPC-compatible features. The proposed platform will rely on a scalable heterogeneous architecture, based on GPUs as accelerators and using commodity components, able to provide sufficient computing power at a reasonable cost. The main objective of the COMPASS project is to provide a full scale end-to-end AO development platform to the PHASE community, able to address the E-ELT scale and including a real-time core that can be directly integrated on a real system. Additionally, one of the key topics of this project is the development of a prototype for a high speed, low latency, image acquisition and processing system dedicated to AO systems and fully integrated in the simulation framework. The goal of the COMPASS project is to lead developments along four main axis: AO modeling, real-time control for AO, low-latency image acquisition and E-ELT instruments design. While these developments are mainly driven by the E-ELT instrumentation needs, it could have other applications like the real time processing of image streams for detection, recognition and identification in the surveillance and decision-help contexts as in defense, industry, security or medical surgery. This project will federate the efforts of various teams with complementary expertise from high performance computing to adaptive optics systems to astrophysics around a high performance development platform. Spin-offs in each of these domains are expected from such a multi-disciplinary collaboration.

1.2 Scope of the document

This report presents the top level requirements for the COMPASS end-to-end instrument simulator(s) to be developped in the frame of the project. These simulators will be used to assist science and technical trade-offs during the development of the E-ELT instruments. Such simulations are essential to a scientific assessment of the abilities of the instrument concepts to meet the requirements derived from the science cases and, therefore, their ability to carry out the science cases. They also will be extensively used to estimate the expected performances of the different E-ELT instrument concepts.

1.3 Methodology

The Science Requirements were captured by the COMPASS Science Working Group [SWG] through a series a telecon that took place on April 16, May 14, and June 14, 2013. Its first work was to collect all science cases for which instrument simulations were to be expected over the next few years in the frame of the development of the E-ELT instruments within the COMPASS partners, and then define for each science case the associated input parameters and requested data, as well as the needed input/outputs. To ease the process, a simulation sheet collecting all this information was established. Each member of the SWG circulated this template in the respective labs to ask experts in the different science cases potentially interested in getting E-ELT instrument simulations to fill it out. These simulation sheets were then collected and discussed to finally extract the science requirements for the instrument simulator(s), which are summarized below. As a second step, these requirements are meant to be used to define the interfaces between the instrument and AO simulation codes.

2. E-ELT Science cases to be simulated

This section collects the simulation sheets filled out by experts within the different COMPASS laboratories. Each section corresponds to a single sheet which synthetises a Science Case that will require specific instrument simulations. The corresponding sheet can be found in Annex A. Science cases are presented in random order.

2.1 List of Science Cases

2.1.1 The mass assembly of galaxies out to z~5.6

See Annex A.

2.1.2 High resolution imaging of distant galaxies

See Annex A.

2.1.3 Probing the epoch of reionisation – spectroscopy of the « first light objects »

See Annex A.

2.1.4 Mass Assembly and internal structures in z>1 galaxies

See Annex A.

2.1.5 Spectral characterization of giant exoplanets from direct imaging

See Annex A.

2.1.6 The formation of massive stars

See Annex A.

2.1.7 Exoplanets direct imaging

See Annex A.

2.1.8 Study of the merger-starburst-agn connection in low-z galaxies

See Annex A.

2.1.9 Galactic Center in SCAO mode

See Annex A.

2.1.10 The close environment of evolved stars

See Annex A.

2.1.11 Characterization of exoplanets from Jupiter down to earth-masses.

See Annex A.

2.2 Comparison with the E-ELT Design Reference Mission

« The E-ELT Design Reference Mission (DRM) encompassed a detailed, hands-on exploration of a selected sample of science cases through the analysis of simulated E-ELT data. The purpose of this exercise was (i) to provide a quantitative assessment of the extent to which the E-ELT will be capable of addressing key scientific questions, (ii) to assist the project in making critical trade-off decisions by quantifying their consequences in terms of scientific gains and losses, and (iii) to support the development of the E-ELT Science Case. The overarching aim of the DRM was to help ensure that the E-ELT will be aligned with the scientific aspirations of its community as much as possible.

In summary, the DRM simulations have provided quantitative evidence of the transformational nature of the science programme envisioned for the E-ELT: the E-ELT will undoubtedly revolutionise several fields of astrophysics. However, the simulations have also demonstrated that a fair fraction of this programme lies at the edge of feasibility, leading to the conclusion that much of the science encapsulated by the DRM will indeed require a 40m-class telescope. In addition, the simulations have verified that the site chosen for the E-ELT conforms to the science plans, and that almost none of the capabilities required by these science cases are missing from current adaptive optics and instrumentation plans. » (from http://www.eso.org/sci/facilities/eelt/science/drm/).

The complete and final DRM report can be found at :

www.eso.org/sci/facilities/eelt/science/drm/drm_report.pdf

The DRM cases provide us with an ideal benchmark for evaluating the completeness and representativeness of the science cases and whether important omissions were done during the process. Table 1 compares the DRM simulated science cases with those requested within COMPASS. Most of prominent E-ELT science cases are at least partly covered by the simulations requested within COMPASS. Only two science cases related to galaxies and cosmology are not covered at all :

- Is the low-density intergalactic medium metal enriched?
- A dynamical measurement of the expansion history of the Universe

The first omitted science case will require high resolution spectroscopy (R~50,000), while the second one will require ultra-stable spectrocopy at a level of ~ 3.5 cm/s over ~ 15 years. These two requirements represent specific values of technical requirements (high spectral resolution and stability) that are already included in the other science cases. This comparison therefore indicates that the resulting science requirements will not omit any crucial capability necessary to the E-ELT instrument simulations.

	Science case	Related COMPASS SCs
Planets & Stars	From giant to terrestrial exoplanets: detection, characterization and evolution	Spectral characterization of giant exoplanets from direct imaging + Exoplanets direct imaging + Characterization of exoplanets from Jupiter down to earth-masses.
	Circumstellar disks	Characterization of exoplanets from Jupiter down to earth-masses
	Young stellar clusters and the Initial Mass Function	The formation of massive stars
Stars & Galaxies	Imaging and spectroscopy of resolved stellar populations in galaxies	The close environment of evolved stars + TBD
	Black holes and AGN	Study of the merger-starburst-agn connection in low-z galaxies + Galactic Center in SCAO mode
Galaxies & Cosmology	The physics of high redshift galaxies	The mass assembly of galaxies out to z~5.6 + Mass Assembly and internal structures in z>1 galaxies
		High resolution imaging of distant galaxies
	First light – the highest redshift galaxies	Probing the epoch of reionisation – spectroscopy of the « first light objects »
	Is the low-density intergalactic medium metal enriched?	
	A dynamical measurement of the expansion history of the Universe	

Table 1 : Comparison betwen the E-ELT DRM and COMPASS science cases.

3. Defining the simulations

Table 2 lists the main characteristics of the simulations, which are detailed in the following sub-sections.

3.1 Objectives

The different simulations can be classified according to their objectives and the kind of output data they need to provide. We identified three different but non-exclusive objectives :

- « ETC-like » : Simulations that consist in estimating the observational limits as a function of the properties of the astrophysical source (e.g., which aim at answering questions such as « what is the detection limit as a function of the size/magntiude of the source ? »). Such simulations can be considered as an improved Exposure Time Calculator [ETC], which takes into account second order effects such as variations in the flux profile or size of the source. In these simulations, the instrument parameters are typically fixed to a given or a set of value(s), while the properties of the astrophysical source (hereafter the « physical parameter space ») is explored ;

- « Design trade-off » : Simulations that directly constrain the instrument design. These are designed to assist trade-off within the instrument parameter space (e.g., which aim at answering questions such as « what is the optimal spatial resolution for distinguishing a galaxy rotating disk from a merger ? »). In these simulations, the physical parameter space is fixed to a grid of values describing the range of expected observations, while the instrument parameter space is explored iteratively until a given scientific goal is reached ;
- « Analysis constraints» : Simulations that are designed to constrain analysis software measuring or estimating PSF-fitting photometry, astrometric solutions, etc. In these simulations, the physical and instrument parameter space are fixed to a grid of values, while the observational parameter space is explored to probe realistic conditions and provide test data for analysis software.

3.2 Simulation input/outputs

All simulations start with high resolution data that describe the astrophysical source to be simulated and capture the relevant physics. These data are either (1) high resolution observations from current facilites, (2) high resolution hydrodynamical simulations, or (3) high resolution analytic models. Existing data were identified for all simulations. They involve a very large range of scale and flux, as well as morphology diversity (from planetes to galaxies). The spatial/spectral resolution and noise properties of these data will have to be degraded to mimick expected outputs of future E-ELT observations. We identified four kinds of different outputs to be produced by the simulations :

- 2D images in FITS format mimicking imaging data ;
- 1D spectrum mimicking slit spectroscopy or mono-aperture spectrocopics data ;
- 3D datacubes mimicking integral field spectroscopy data ;
- Polarimetric data.

Of note, polarymetric data are required only for the cases involving high dynamical contrast (e.g., exoplanet search). Simulations generally require long-term exposures with the exception of high-contrast data that will require modelling short-term PSFs as well as maps of the complete electromagnetic fields (amplitudes and phases).

Science Case	Objective	Inputs	Outputs	Specific effects to be simulated	Limiting factor
The mass assembly of galaxies out to z~5.6	ETC-like + Design trades-off	High resolution observations + Hydro. Sims.	Datacubes	OH and telluric lines AO average residuals	Photon starved
High resolution imaging of distant galaxies	Analysis Constraints	High resolution observations + Hydro. Sims.	Images	PSF variation over the FoV	Photon starved
Probing the epoch of reionisation – spectroscopy of the « first light objects »	ETC-like + Design trades-off	High resolution observations + Hydro. Sims.	Datacubes + 1D spectra	Sky background variations AO average residuals	Photon starved
Mass Assembly and internal structures in z>1 galaxies	ETC-like + Design trades-off	High resolution observations + Hydro. Sim. + Lens analytic models	Datacubes	OH and telluric lines	High resolution sampling, photon-starved
Spectral characterization of giant exoplanets from direct imaging	ETC-like	Analytic models	Datacubes	Aberrations AO residuals Coronography	High Strehl, high contrast
The formation of massive stars	ETC-like	Analytic models	Images + 1D spectra	PSF spatial variations	Photon-starved
Exoplanets direct imaging	ETC-like + Design trades-off	Analytic models	Images	Field rotation + quasi-static aberrations + jitter + seeing temporal evolution + AO residuals + ADC chromatic residuals + Fresnel propagation + coronography	High Strehl & Contrast
Study of the merger / starburst / agn connection in low-z galaxies	ETC-like + Analysis Constraints	High resolution observations	Images + 1D spectra + Datacubes	PSF spatial variations	High Strehl
Galactic Center in	ETC-like	GR analytic simulations	Images +	Aberrations	High Strehl

SCAO mode		(GYOTO)	1D spectra		
The close environment of evolved stars	ETC-like + Design trades-off	3D hydro models	Images + Datacubes	Thermal emission up to Q	High Strehl AO, high brightness objects (limited by saturation)
Characterization of exoplanets from Jupiter down to earth-masses	Design trades-off	Analytic models	Images + Polarimetry + Datacubes	Quasi-static aberrations + Fresnel propagation + Chromatic aberrations (ADC residuals + DAR) + Polarimetric effects + coronography	Extremely high Strehl and high contrast

Table 2 : Summary of the science cases to be simulated and their main characteristics.

3.3 Defining the parameter space

3.3.1 Physical parameter space

The properties describing the astrophysical sources vary as a function of the nature of the object :

- Galaxies are defined by their morpho-kinematic type (elliptical, spiral, merger, clumpy galaxy) or detection technique (LBG, LAE). High resolution templates describing the flux distribution and kinematics of these objects will have to be rescaled in terms of size, flux, and velocity gradient as a function of mass and redshift ;
- Stars are defined by their spectral type (OBAFGKM). Spectral or color templates will have to be rescaled in terms of flux. For the brightest and nearest stars, the size of the enveloppe will be an additional parameter. Orbiting trajectories around central black holes will have to be simulated for the galactic center case using the GYOTO code ;
- Planetes are defined by their rocky/gaseous state. Spectral template will have to be rescaled in terms of flux. The separation from the parent star will be an additional parameter ;
- Stellar cluster are defined by the type (density). Analytic profiles (King) will have to be generated and rescaled to different fluxes.

3.3.2 Instrument parameter space

The instrument parameter space can be splitted into the parameters describing the telescope and those describing the instrument, including the AO system. Table 3 summarizes the parameters related to the instrument with the requested range of variation.

Parameter	Range/Units	Comments
Spectral resolution	50-20,000	R
Spectral sampling rate	2	Nyquist-Shannon
Spatial sampling	2-900 mas	Rectangular
$\Delta\lambda$	I-Q	Spectroscopy : +/- 5 nm range around the emission line Imaging : Broad-band and narrow-band filters + OH suppression + coronography
Transmission	30 %	Atmosphere + Telescope + Instrument
FoV	Several 2x2 arcsec² areas within a ~ 7 arcmin patrol field (MOAO)	FoV to be simulated and corrected by AO – need for average performance only
	Several 2x2 arcsec² areas within a ~ 1-5 arcmin fully corrected field (GLAO/MCAO)	Need variation of the AO correction over the FoV
	Single 1to 100 arcsec diameter FoV with AO correction (SCAO/LTAO)	
	Single 1x1 arcmin² area with AO correction (MCAO)	Need variation of the AO correction over the FoV
AO Correction	EE=30 % within 80x80 mas² in H SR=20-70 % in H-K (GLAO/MCAO/XAO)	Spec. given at λ_{spec} Imaging driven by SR, spectro. by EE

Table 3 : Summary of the main intrument parameter space needed for all the requested simulations.

It can been seen from Table 3 that all sort of AO systems will need to be simulated :

- single FoV with size of a few arcsec : SCAO or LTAO depending on sky coverage
- several patches of a few arcsec within a larger field of ~1 arcmin : MCAO
- several patches of a few arcsec within a much larger field of a few (>5) arcmin : MOAO
- single FoV fo a few arcsec with extremely high Strehl Ratio : XAO

Regarding the modeling of the instrument, two kind of simulations will be required :

- Simulations for which all the light propagation can be captured into a single PSF, i.e., those for which the propagation of light does not need to be simulated in detail. However, the level of detail in the PSF modelization vary between the science cases, as shown in Table 2. In all these cases the instrument simulation can rely on very a simple « integrated » model, i.e., *observations = template * PSF + noise + systematics ;*
- Simulations involving high constrast techniques, for which modeling the exact propagation of light between all optical surfaces is essential (e.g., Fresnel effects due to out-of-focus optics). These simulations cannot be simulated using the above « integrated » model.

All simulations require relatively long timescales (long-term exposures) with the exception of simulations involving high dynamical contrast in which the motion of the source provides the dominant timescale in the simulations.

3.3.3 Observational parameter space

The observational parameter space describes the observing conditions (sky, exposure time). Typical exposures will have individual integration times ranging between 1 to 3600s (DIT), with a number of frames ranging between 1 and 100 (NDIT). It is required to simulate a complete background (sky including continuum, OH, and telluric lines and thermal contribution from the telescope and instrument) as well as its temporal and spatial variations. It will be also necessary to simulate the effect of the Differential Atmospheric Refraction.

Residual atmospheric turbulence incorrected by AO systems will have to be included into the PSFs, as well as temporal, chromatic, and spatial variations.

3.4 Additional constraints from the COMPASS project

In addition to the scientific drivers listed above, the COMPASS project aims at offering the instrument simulation codes as a full public facility. This implies the following additional requirements on the instrument simulator(s) :

- an user-friendly interface to minimize the time needed to access and run simulations ;
- the computers hosting the simulation codes will have to meet usual security network requirements ;
- simulations will have to be completed within a reasonable amount of time (i.e., no more than a few hours).

3.5 Summary of the Top-Level Requirement for the COMPASS instrument simulator

TLR	Name	Description	Comments
TLR1	Objectives	Should allow us to fulfill the three objectives defined in Sect. 3.1	ETC-like Design trade-off Analysis Constraints
TLR2	Outputs	Should allow us to provide the ouputs listed in Sect. 3.2	Images or spectra in 2D or 3D FITS files ; full E.M. Field in FITS files.
TLR3	Inputs	Should allow us to mimic observations of all astrophysicial sources listed in Tab. 1	From planets to clusters of galaxies
TLR4	Level of accuracy	Should allow us to incldue all effects listed in Tab. 2	See column 5 of Tab. 1. Driven by TLR1
TLR5	Parameter space	Should allow us to explore all the parameters listed in Tab. 3 & Sect. 3.3	Driven by TLR1
TLR6	Usability	Should be user-friendly	
TLR7	Security	Should follow all usual security network requirements	
TLR8	Time	Should allow us to conduct simulations within a few hours maximum	

Table 4 : summary of the COMPASS instrument simulator TLRs

4. Architecture of the instrument simulation code

The above requirements suggest that two instrument simulation codes will be needed to fullfill all the needs. On the one hand, apart simulations involving high dynamical contrast techniques, all the requirements should be met by upgrading the « websim » instrument simulator developed at GEPI, which is fully described in Puech et al. (2010), Proc. SPIE 7735, 183 (and references therein). On the other hand, it is unlikely that full end-to-end simulations for the high dynamic cases will be achieved within the lifetime of the COMPASS project, given the much higher level of complexity and refinement needed. Efforts will have to be concentrated on essential parts of the XAO simulation code still missing, as well as to the interface between this code and the end-to-end instrument simulation code developped in the frame of the SPHERE project. Therefore, in the following, high contrast simulations will be considered as a driver for the AO simulation code only and not for the instrument simulator.

4.1 *Architecture of the COMPASS instrument simulation code*

Figure 1 illustrates the proposed architecture for the COMPASS simulator, which is based on the one used for websim. Access to the simulator, which is hosted on a secured server, is password-protected using a SQL database, which lists all registered users (i.e., the member of the science team). This architecture allows us to meet both science requirements (i.e., an user-friendly access to the simulator as described below) as well as security considerations. Once the web form describing a simulation set-up (see Fig. 2) has been filled out, a request is sent to a science server which runs an IDL code corresponding to the core of the instrument simulator. Products (FITS files) are sent back to the web server, from which they can be downloaded. The web server keeps the corresponding files during three days after which they are automatically removed, which implies that a limited space disk storage capacity is necessary (<1To). The IDL language offers a very good compromise between simulation and developement speeds[1]. The science server used for websim is a 8 CPU cores, on which simulations take from a few minutes up to a few hours with the current IDL simulation code. Multi-CPU processors are therefore well-suited to the computation power required for the COMPASS instrument simulations. Such an overall architecture has already been tested, validated, and succesfully used during the E-ELT instrument phase A studies and therefore offer a good level of readiness.

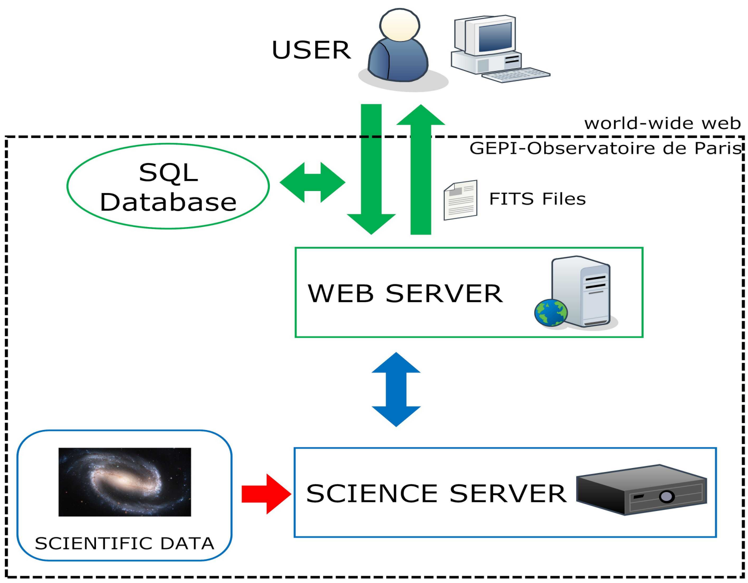

Figure 1 : overall proposed architecture of the intrument simulator.

Figure 2 illustrates the web interface that allows the user to set up a simulation. It is divided into the telescope instrument parameter space (not relevant here since the

1 Python would offer an attactive alternative with parallelization capabilities and open licenses. However the current version of the simulation code is written in IDL so keeping the same language will minimize development times and efforts, while providing still reasonable computation time, as described below.

telescope design has now been fixed, at least for the parameters relevant for the COMPASS simulations), the instrument parameter space, the physical parameter space, and the observational parameter space. Compared to this interface, several improvements will have to be made to reach the COMPASS requirements :

- The present interface allows the user to run a single simulation at a time. It will be required to add a « batch » mode to allow the user to run a series of simulations and explore more efficiently the parameter spaces. This implies in turn an efficient task management to spread the simulations amongst the different CPU cores ;
- The different parameter spaces will have to be expended to accomodate all the needs described in Sect. 3 ;
- Additional effects will have to be implemented, tested, and added to already existing the IDL code (see Table 2).

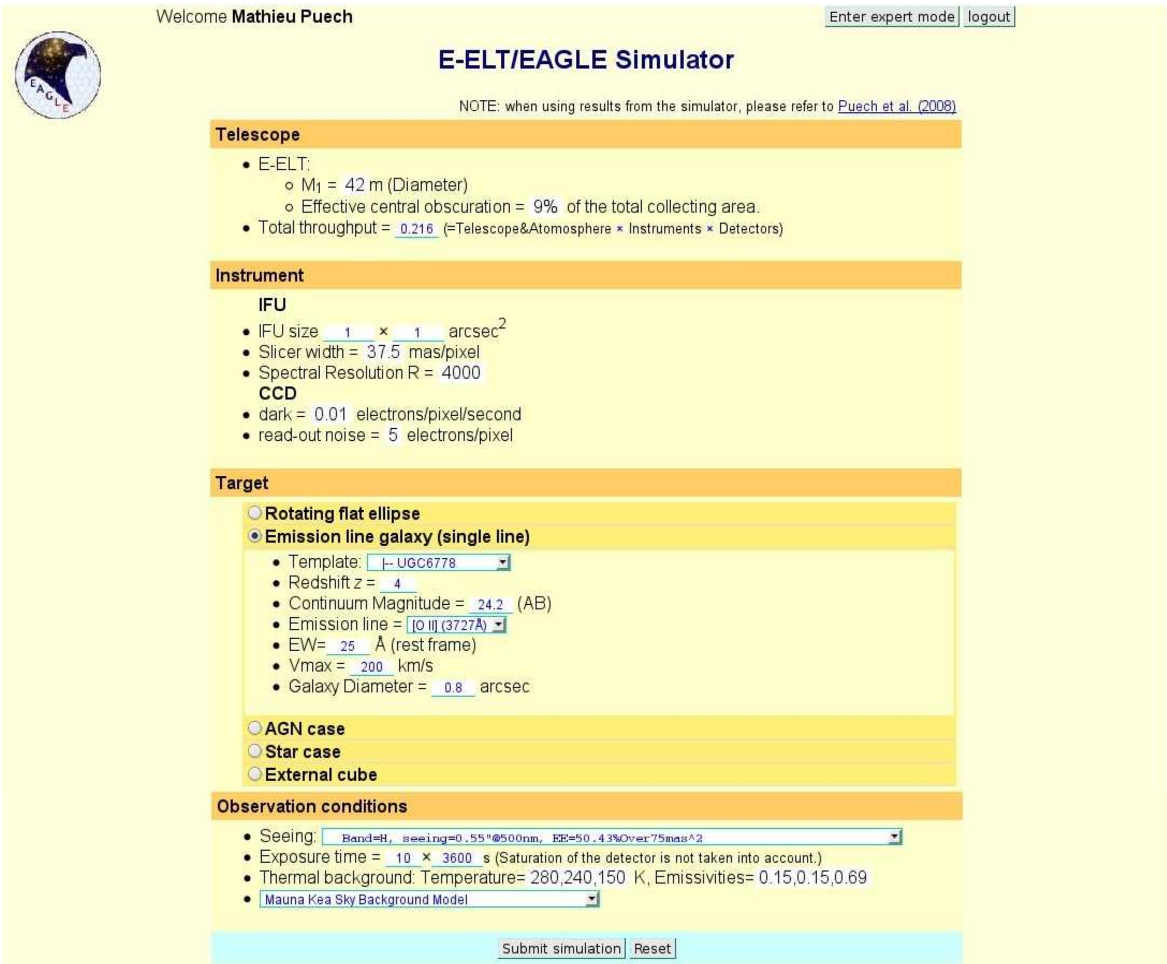

Figure 2 : web interface of the EAGLE instrument concept simulator

4.2 Defining the interfaces between instrument and AO simulation codes

Compared to the phase A studies, the number of input templates and AO PSF will increase significatively (see Sect. 3). These data will have their own scientific attractivity *per se*, regardless of their use as inputs to the instrument simulator. Managing and offering a public access to all this information in an efficient way will require to set up three databases, which will host :

- An extensive PSF library spanning a large range of AO systems and optical effects (as listed in Sect 3). This database will need to contain basic high-level information for each PSF, such as wavelength, Strehl Ratio, Ensquared Energy, N/LGS asterisms, AO system configurations (WFS type and characteristics, DM actuator density, control loop characterstics, etc., see below) ;
- An extensive library of high-resolution data describing the astrophysical sources to be used as high resolution templates for the instrument simulations. This database will have to list important information about each template, such as its nature (flux or velocity distribution), origine (instrument/telescope if observation, simulation parameters, etc., see below) ;
- A library of full Electro-Magnetic (E.M.) maps to be used for high dynamic constrat simulations. This database will store maps of amplitude, phase, and/or polarimetric values of the E.M. Field to be further coupled will coronographic PSFs.

The top-level requirements of these three databases are defined below in Sect. 4.4.

4.3 User scenarios and user mode

In Sect. 3.1, we identified three different but non-exclusive scientific objectives for the COMPASS instrument simulator(s), which we summarize in Table 5.

Scientific objective	Parameter space explored	Parameter space fixed	Typical User	User scenario
ETC-like	Physical	Instrument Observational	Astronomer	Astro-user
Design trade-off	Instrument	Physical Observational	Instrumentalist	Expert-user Super-expert-user
Analysis constraints	Observational	Physical Instrument	Astronomer	Astro-user

Table 5 : Correspondance between the scientific objective of the simulator and the user scenarios

We also define in this Table three different user scenarios depending on which parameter space (see definition in Sect. 3.3) are to be explored :

- Astro-user : in this case the user is typically an astronomer (e.g., a member of an instrument science team) with no specific technical for whom the instrument is a « black box ». He/she will run simulations to explore the scientific performances of an instrument concept (« ELT-like » application) or to test/constrain analysis software on simulated data (« Analysis constraints » application) ;

- Expert-user : in this case, the user is typically an project/instrument scientist with explicit technical knowledge, who wants to explore the scientific impact of a given technical choice (e.g., spatial samplaing). However, the user is not considered to be an AO expert, and he is assumed to be interested only in « typical » AO corrections, i.e., it is assumed that the expert-user will not be interested in exploring in detail the instrument parameter space associated to the AO system ;
- Super-expert user : in this last case, the user is assumed to have a very detailed technical knowledge about the instrument and the AO system (e.g., instrument scientist or system engineer). He/she will use the simulator to explore the performances of the AO system and assess the impact on the instrument performances/capabilities.

4.3.1 Astro-user case

The astro-user case is further illustrated in Fig. 3. The expected sequential use of the simulator if the following :

1. The user's first choice consists in selecting an instrument concept with its associated AO mode (in addition to the baseline GLAO mode provided by the telescope) :

   - ELT-CAM+SCAO
   - ELT-CAM+MCAO
   - ELT-IFU+SCAO
   - ELT-IFU+LTAO
   - ELT-MOS+MOAO
   - ELT-PF+XAO

   This choice fixes the instrument parameter space (including the AO system) to a set of pre-defined values. The use will still have the option to choose between different but limited options corresponding to typical choices or configurations of the system. For instance : pre-defined pixel scales or spectral resolutions ;
2. The user will be able to fully explore the astrophysical template database to pick up the source of interest. He will have the hability to submit its own data as an input template, if not already present in the database ;
3. The observational parameter space will also be fixed but the user will have the choice between typical values (e.g., sky background in dark or bright, conditions) ;

4. The exploration of the PSF database will be narrowed down to the systems associated to the instrument concept considered and to typical values, or, when the associated parameter space is too large, to typical choices. For instance : different seeing values (median, 16th and 84th percentiles) or in the SCAO mode, typical configuration choices such as distance and magnitude of the natural guide star.

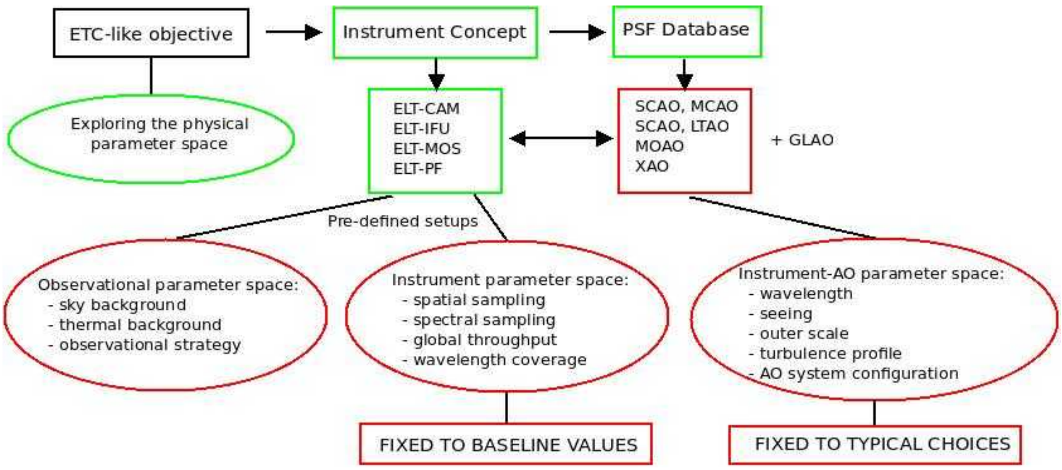

Figure 3 : illustration of the astro-user case exploring the physical parameter space.

The analysis constraints use will be similar to Fig. 3 except that the user will fix the physical parameter space and explore the observational parameter space to produce test data.

4.3.2 Expert-user case

The expert-user case is further illustrated in Fig. 4. The expected sequential use of the simulator if the following :

1. The user's first is no longer an instrument concept but an instrument capability (imaging, spectroscopy, etc.) ;
2. The user chooses the values associated to the instrument parameter space corresponding to the selected instrument capability :

   - Imaging : FoV, pixel scale, wavelength coverage, global throughput, detector characteristics, etc. ;

   - Slit spectroscopy : FoV, slit width and length, spectral resolution, global throughput, etc. ;

   - 3D spectroscopy : FoV, IFU spaxel size, spectral resolution, global throughput, etc. ;

   - Complete Electro-Magnetic Field : spatial sampling of the amplitude, phase, and/or polarimetric maps, FoV, etc.
3. The PSF database is narrowed down to all choices compatible with the patrol FoV chosen during the previous step (e.g., MCAO will be excluded if the patrol field is required to be >

5 arcmin).

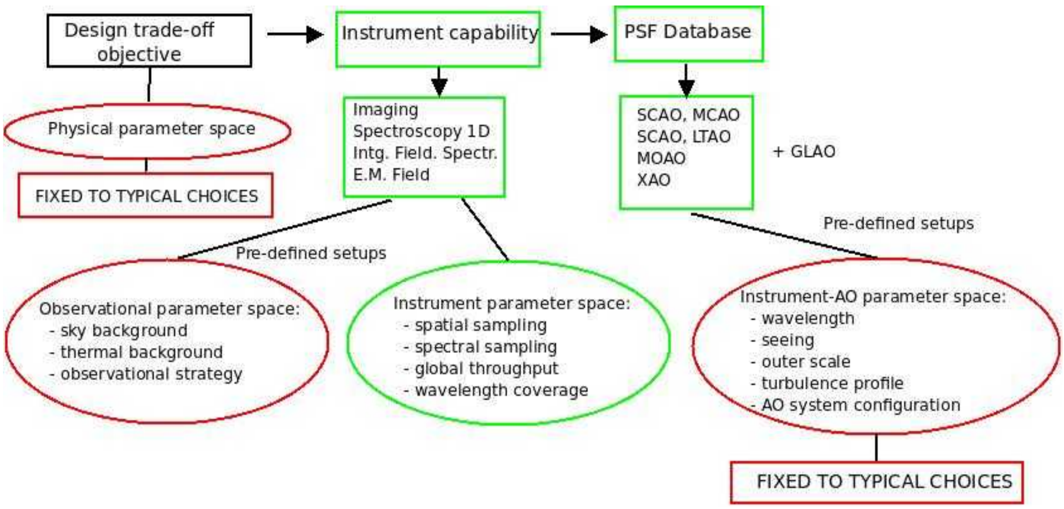

Figure 4 : illustration of the expert-user case exploring the instrument parameter space.

4.3.3 Super-Expert-user case

The super-expert-user case is illustrated in Fig. 5. The expected sequential use of the simulator is expected to be the same as in the expert user case except that in this case, the user will have the hability to fully explore the PSF database with no restrictions. In case there is no suitable PSF in the database, the user will have to be redirected towards the COMPASS AO simulator directly to ask for new PSFs.

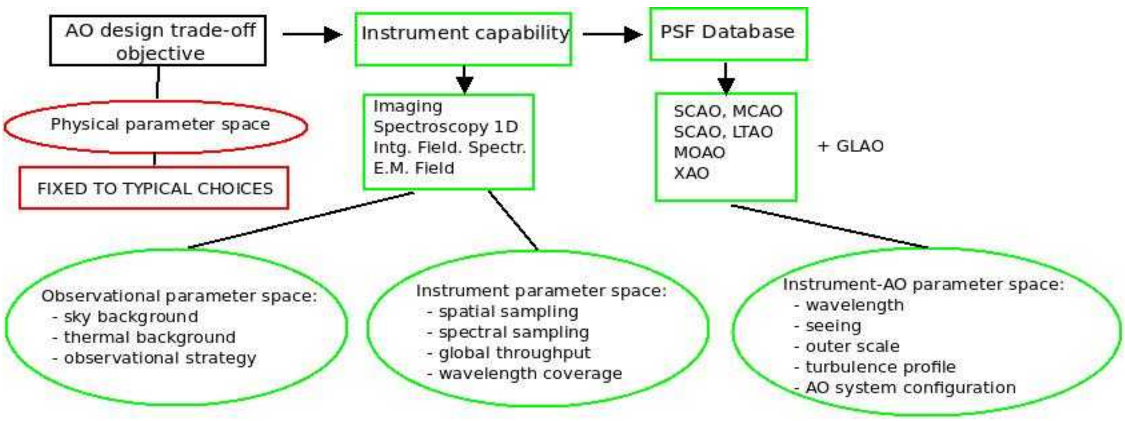

Figure 5 : illustration of the super-expert-user case exploring the instrument parameter space.

4.3.4 User mode

In order to fulfill TLR8 (i.e., to have a user-friendly simulator), each user scenario will be associated to a user mode in which the user will have more or less limited options to set up a simulation :

- The astro-user scenario will be implemented as a « regular mode », which corresponds to the most limited user mode (see Fig. 3) ;
- The expert-user scenario will be implemented as an « expert mode », which will provide the user with an extensive but guided freedom in setting up the simulation parameters (see Fig. 4) ;
- The super-expert-user scenario will be implemented as a « full expert mode », which will give the user the hability to tune any parameter and request new PSFs (see Fig. 5).

4.4 Top-level requirements of the interface databases

4.4.1 TLRs of the PSF database

- Storage of all kind of PSF (short or long exposure PSFs, coronographic PSFs) in FITS format : 2D or 3D for time sequence PSFs (corresponding, e.g., to a time sequence seeing variation) ;
- Storage of scalars or vectors associated to each FITS file. These will describe to the parameters describing the AO simulation from which the PSF was generated (see Tab. 6) ;
- Exploring tools depending on the PSF characteristics:
  - narrowing down the PSF choice depending on the user case (i.e., AO system or PSF characteristics) ;
  - picking up a PSF with given EE or SR for a given AO mode.

4.4.2 TLRs of the full EM database

This database will be explored in super-expert mode only. The database will store maps of amplitudes, phase, and/or polarimetric values in FITS format.

4.4.3 TLRs of the high resolution astrophysical data database

- Storage capabilities of all kind of data in FITS format with associated ASCII high-level description ;
- Exploring capabilities as a function of the astrophysical nature of the source ;
- Possibility to submit new data and automatic check of format compatibility (TBC) ;

Parameter	Description	Comments
Telescope/Instrument		
Telescope size	Diameter, central obturation	
AO mode	SCOA, MCAO, LTAO, MOAO, XAO	
Wavelength coverage	Filter width and central wavelength	Part of the instrument setup
Turbulence		
Cn2 profile	Altitude max, resolution	Defines the number of layers
Layer Description	Von Karman model	r_0, L_0
Wind model	Amplitude, direction	For each layer
AO System		
FoV to be corrected	Diameter of the FoVto be corrected	
Targets	Positions of interest in the corrected FoV	Directions along which PSFs will have to be simulated
NGS	Number, directions, magnitudes	
LGS	Number, directions, magnitudes	
WFS	Number of WFS and type Reconstruction algorithm	
WFS sub-pupils	Number, size, and shape Exposure time ; readout frequency and mode	
Control loop	Algorithm and delay	
DM	Type, number, pitch, positions, temporal response	

Table 6 : Main parameters defining an AO simulation.

Annex A : simulation sheets

Science Case

Science Case : The mass assembly of galaxies out to z~5.6
Instrument concept : ELT-MOS

Laboratory : GEPI
Deadline : mid 2014

Summary of the Science Case (15-20 lignes max) : Integral field spectroscopy can now routinely provide us with spatially-resolved properties of galaxies out to z~3. However, the samples gathered so far at z>1 suffer from selection biases which result from the lack of redshift surveys that are representative in terms of stellar mass at these redshifts and/or only the brightest objects can be detected by the 8-10m telescopes. One of the major goals of the E-ELT will be to assemble uniforme, complete, and representative samples of galaxies between z~2 and 5.6. These samples will allow us to measure the main physical and chemical *spatially-resolved* properties of galaxies (kinematics, metallicity, dust distribution, and star formation rate). This will allow us to better understand the mechanisms responsible for the mass assembly of galaxies as a function of time, as well as those driving the formation of sub-structures observed in local galaxies (disks, bulges, halos).

Description

Goal of the simulations : The goal is to simulate 3D spectroscopic observations of galaxies at different redshifts covering the expected galaxy types (rotating disks, mergers, clumpy disks). The simulated datacubes will help constraining the optimal spatial resolution and sampling allowing us to distinguish the different types of galaxies as a function of *z* and mass (flux/size). The galaxies will be observed in their emission lines ([OII] λ372.7 nm or Hα λ656.3 nm depending on *z*). It is only required to simulate a small spectral domain ~ +/- 5 nm around the expected position of the emission line.

Analysis of the simulations : Each spaxel of a simulated datacube will be fitted by a Gaussian in emission in order to derive the velocity fields and velocity dispersion maps of the redshifted targets. These will then be used to distinguish between rotating disks and mergers as a function of size and flux. Spatial resolution will be quantified using the EE (Ensquared Energy) provided by the AO system. The spatial sampling corresponds to the simulated spaxel of the simulated datacube.

Input parameter space

Physical parameters:

Objects to be simulated	Range/units	Comments
Local disk galaxies	Types S0 to Sd	Barred or not
Distant clumpy galaxies	N_{clumps}=2-5	Number of clumps
Merging galaxies	D_{prog}=5-50 kpc	Distance between progenitors

Note: The GHASP or CALIFA databases of 3D observations of local galaxies cover a very large range of morpho-kinematic types, which can be used as inputs. Existing idealized hydrodynamical simulations can be used to cover the remaing types.

Parameter	Range/units	Comments
Redshift *z*	*z*=2,4,5.6	
Integrated magnitudes	mag_{AB}=20-28	Depends on mass/distance
EW[emission line]	3 nm	Equivalent width of the simulated emission line
Velocity Gradient	90-300 km/s	Depends on mass
Size	0.3-3.4 arcsec	Diameter. Depends on masse/distance

Note : The integrated properties are set by the mass function of galaxies at a given redshift . Then the integrated magnitude, rotation velocity, size, and equivalent width can be determined from scaling relations between these quantities as a function of z.

Observationnal parameters :

Parameter	Range/units	Comments
Spectral resolution	4 000	R
Spectral sampling rate	2	Shannon
Spatial sampling	50-120 mas	Rectangular
DIT	3600 s	Integration time of an individual frame
NDIT	1-40	Number of frames
$\Delta\lambda$	Y-K	It is only required to simulate a +/- 5 nm range around the emission line

Transmission	30 %	Atmosphere + Telescope + Instrument
FoV	2x2 arcsec²	FoV to be simulated

AO parameters :

Parameter	Range/units	Comments
EE	30 % within 80x80 mas²	Spec. given at λ_{spec}
FoV corrected	2x2 arcsec²	20 areas to be corrected within a 7 arcmin patrol field (MOAO)
λ_{spec}	1.6 µm	H band

Output data

Output data	Type	Comments
Datacube	FITS 3D	Including noise, sky/background subtracted
Datacube without noise	FITS 3D	Same as before but without noise (for testing purposes)
Simulated background	FITS 2D	Simulated background spectrum
EE	Scalar / keyword to be written into the datacube header	EE measured within 2x2 spaxels

Science Case

Science Case : High resolution imaging of distant galaxies
Instrument concept : ELT-CAM

Laboratory : GEPI
Deadline : late 2014

Summary of the Science Case (15-20 lignes max) : We propose to simulate very high resolution images of high-redshift galaxies (z>1-2). Such observations will be taken at the diffraction limit of the telescope (6, 8, 10 mas in J , H , K for a 42 m telescope). The resolution will be approximately 60 pc in physical length and will be of comparable quality to 1 arcsec imaging of Virgo galaxies. They will give typically more than 100 resolution elements over the galaxies and produce detailed information about the morphology, dynamical state, and variations in physical parameters across the galaxy. These observations will image galaxies beyond (redward of) the Balmer break up to z=4.5, enabling the separation of old and young stars. High contrast observations of QSOs will produce host morphologies, colours, and physical properties. At lower redshifts, the E-ELT will offer exquisite diffraction-limited images of galaxies, which will provide unrivalled details about their morphological structure.

Description

Goal of the simulations : The goal is to simulate broad-band high resolution images for a sample of distant galaxies with different morphological types (rotating disks, mergers, clumpy galaxies) and sizes/masses as expected in the distant Universe. The depth and impact of OH-filtering were explored in the E-ELT DRM so these simulations will focus on the recovery of the detailed morphological structure of distant galaxies using standard fitting software such as GALFIT. Different resolution will be explored (limit of diffraction vs. JWST-like resolution). Only stamps of sizes ~ a few times the galaxy size need to be simulated, ie, there is no need for simulating complete 10s-arcmin wide images typical of imaging surveys. The impact of the AO correction in the field (GLAO vs. MCAO) and as a function wavelength (broad-band filters) will be explored.

Analysis of the simulations : The simulated images will be analyzed using GALFIT to measure their Bulge-to-Total luminosity ratio, size, and surface brightness. These parameters will be compared to the original (un-redshifted) values to quantify the precision and accuracy of AO-corrected images in the recovery of such morphological parameters. The performance of the AO correction (GLAO vs. MCAO) will be measured using the SR.

Input parameter space

Physical parameters:

Objects to be simulated	Range/units	Comments
Local galaxies	E to Irr types	Barred or not
Clumpy galaxies	N_{clumps}=2-5	Number of clumps
Mergers	D_{prog}=5-50 kpc	Distance between progenitors

Remarques : hydrodynamical simulations or HST images are required as input. HST Images of Lyman Break Analogs will be used for simulating distant clumpy galaxies.

Parameter	Range/units	Comments
Redshift *z*	*z*=2,4,6,8	
Magnitudes intégrées	mag_{AB}=20-30	Depends on mass/*z*
Taille sur le ciel	0.3-6 arcsec	Diameter. Depends on mass/*z*

Remarque : scaling relations between mass and size will be used to rescale the high resolution templates as a function of *z*, as well as empirical relations between mass and magnitude.

Observationnal parameters :

Parameter	Range/units	Comments
Filters	J-H-Ks	
Spatial sampling	4-30 mas	DL & JWST cases
DIT	600 s	Temps d'intégration d'une pose individuelle
NDIT	1-60	Up to 10 hr long exposures
Throughput	~ 50 %	Atmosphere + Telescope + Instrument (TBC)
FoV	2x2 $arcsec^2$	FoV to be simulated

AO parameters :

Parameter	Range/units	Comments
SR	TBC	Typical performances of GLAO & MCAO

Output data

Output data	Type	Comments
Image	FITS 2D	Noise included ; background subtracted
Image without noise	FITS 2D	Testing purposes
Background	FITS 2D	Background image
SR	Scalar / keyword to be written in the Image Header	

Science Case

Science Case : Probing the epoch of reionisation – spectroscopy of the « first light objects »
Instrument concept : ELT-MOS

Laboratory : GEPI
Deadline : mid 2014

Summary of the Science Case (15-20 lignes max) : The current telescopes of the 8-10 meter class can detect galaxies up to z~7-8. However, such samples remain very limited in size and very few sources have been confirmed beyond z~6, which corresponds to the end of the reionisation era. During this important phase of the history of the Universe, the neutral inter-galactic gas is fully ionized. However, the astrophysical sources responsible for this re-ionisation phase remain largely uncertain, probably because they are very faint and compact. One of the major goal of the E-ELT will be to gather an ultra-deep survey of a statistical sample of such sources, i.e., a systematic search and detection of the most distant sources in the Universe, the very first galaxies. These will be searched in emission (« Lyman Alpha Emitters », LAE) or using the variations of their continuum (« Lyman Break Galaxies », LBG). The goal is to study the integrated properties of their interstellar medium (stellar populations, winds, ionizing flux using the Lyman Alpha and UV interstellar lines) as well as their spatially-resolved properties for the brightest ones.

Description

Goal of the simulations : The goal is to simulate spectroscopic observations of LAEs and LBGs in order to determine the best observing mode (3D vs. simple aperture), as well as the main instrumental caracteristics (spatial sampling and resolution). Then we will quantify what is the limit to retrieve the properties of their interstellar medium (relaitve position between nebular and ISM lines, stellar populations, velocity field). Only a spectral range ~ +/- 5 nm around the position of the different lines needs to be simulated (Lyman α λ=121.6 nm, Lyman break at 912 nm, UV interstellar lines around 120 nm).

Analysis of the simulations : We will compare the signal to noise ratio obtained for different observing modes as a function of the spatial sampling and resolution, as well as as a function of the physical properties of the sources (size, flux). The limiting sensitivity corresponding to S/N=5 on the integrated spectrum of each mode will be estimated to determine the best observing strategy. Then the corresponding simulations will be used to estimate the depth limit for which a velocity field can be measured. Spatial resolution will be quantified using the EE (Ensquared Energy) provided by the AO system. The spatial sampling corresponds to the simulated spaxel of the simulated datacube or to the aperture of the spectrograph on sky.

Input parameter space

Physical parameters:

Objects to be simulated	Range/units	Comments
LAE	EW(Ly α)=1-15 nm	EW varying with luminosity
LBG	J(AB)~25 à 30	Size varying with flux

Note : The flux vs. Size plan will be populated using current observational constraints (e.g., Grazian et al. 2012). The LBG stacked UV template from Shapley et al. 2033 will be used to model the spectral features to be detected. A diffuse and large-scale halo has been detected around LBGs at z~3 (Steidel et al. 2010) but it remains uncertains in more distant sources. The impact of such a possible halo will be investigated in a second step.

Parameter	Range/units	Comments
Redshift *z*	*z~7-9*	*z* can be fixed to target a region free of OH sky lines in which the line will be detected
Integrated magnitude	mag_{AB}=25-30	
Kinematics	~200 km/s	Central part dominated by outflows (simple constant in the Ly-α line at small spatial scalecan be used). Large-scale diffuse halo : biconic jet seen in projection.
Size	0.1-0.25 arcsec	Depends on flux

Note : The intrinsic properties of the sources will be set using current empirical constraints at z~3-7 (e.g., Swinbank et al. 2008 ; Vanzella et al. 2009 ; Jiang et al. 2013a,b).

Observationnal parameters :

Parameter	Range/units	Comments
Spectral resolution	4 000	R
Spatial sampling rate	2	Shannon
Spatial resolution	40-900 mas	IFU and simple aperture cases to be simulated
DIT	3600 s	Integration time of a single exposure
NDIT	1-40	Number of exposures

$\Delta\lambda$	Y-K	Only +/- 5 nm around lines is needed
Transmission	30 %	Atmosphere + Telescope + Instrument
FoV	2x2 arcsec²	FoV to be simulated

AO parameters :

Parameter	Range/units	Comments
EE	30 % dans 80x80 mas²	Spec. at λ_{spec}
FoV corrected	2x2 arcsec²	20 areas to be corrected within a patrol field of 7 arcmin (MOAO), or simple GLAO for integrated spectra.
λ_{spec}	1.6 µm	H band

Output data

Output data	Type	Comments
Datacube	FITS 3D	Including noise, sky/background subtracted
Datacube without noise	FITS 3D	Same as before but without noise (for testing purposes)
Simulated background	FITS 2D	Simulated background spectrum
EE	Scalar / keyword to be written into the datacube header	EE measured within 2x2 spaxels

Science Case

Science Case : Mass Assembly and internal structures in z>1 galaxies
Instrument concept : ELT-IFU

Laboratory : LAM
Deadline : -

Summary of the Science Case (15-20 lignes max) : Currently, adaptive optics can't be used with reasonable exposure times for high redshift galaxies (z>1) with star formation rates (SFR) similar to those commonly observed in the nearby Universe (SFR~1 Msun/yr). In addition, spatial resolution available so-far using 10-m class telescopes is still below the resolution obtained for z<0.03 galaxies in seeing limited observations by a factor around 5.
For the first time, the ELT used with ELT-IFU instrument (Harmoni) will allow to compare resolved physical properties (kinematics and metallicity) of local and high-z galaxies (z<3) at the same scale and with similar depth. In particular, lensed galaxies are the best targets to obtain the deepest observations and the highest spatial resolution.
These data should enable (i) to study internal structures formation and evolution (spiral arms, bars, clumps), (ii) to compute mass models from high resolution rotation curves to constrain dark matter halo profiles at high z, (iii) to constrain accurately local gaseous velocity dispersion measurements and to compute metallicity gradients from line ratio without any beam smearing biases.

Description

Goal of the simulations : The proposed simulations will provide 3D spetroscopy data at both high spatial and spectral resolutions in various galaxy types in the Universe between z=1 and z=3 (isolated galaxies, interacting galaxies, mergers). Depending on the spatial resolution, we might be able to target galaxies with SFR as low as 1 Msun/yr.
We will focus on ionised gas emission lines (Ha, Hb, [OII], [OIII], [NII]).
Depending on the size of the galaxies, we will use different spatial resolutions. The usefull spectral domain is still to be defined. However, in principle, we could use small spectral ranges (~+-2 nm) around each line of interest.
The number and magnitude of AO reference stars should also be constrained using these simulations in order to know how to proceed for target selection.

Analysis of the simulations : Line momentum (flux, position, width) will be computed for each line and each spaxels. We will derived kinematics maps, line flux maps, line ratio maps. The results will be compared to simulation input data. The influence of the spectral resolution and spatial PSF shape will be studied to infer the optimum sampling and resolution that will enable to study the internal structures at high redshift.

Input parameter space

Physical parameters:

Objects to be simulated	Range/units	Comments
Spiral galaxies	Type S0 à Sd	Barred and non-barred
Mergers	D_{prog}=5-50 kpc	Distance between progenitors
High-z galaxies	M*=10^9 – 10^11 Msun	From hydrodynamical simulations
Lensed galaxies		Idem as previous but lensed

Remark : We can use observationnal databases (e.g. GHASP) as well as numerical simulations databases (e.g. GALMER, RAMSES) that are available publicly or in development at LAM. Tools that enable lensing simulations will have to be included but can be available through colaboration between LAM and CRAL (LensTool). This can be done in a second step.

Parameter	Range/units	Comments
Redshift	1, 2, 3	
Taille sur le ciel	0.5-2 arcsec	Diamètre qui dépendra de la masse et du redshift
Flux		Flux intégré de la raie d'émission principale
Largeur		Largeur de raie
Magnitude		Magnitude du continuum
Masses	M*~10^9 - 10^11 Msun	Masse stellaire

Observationnal parameters :

Parameter	Range/units	Comments
Pouvoir de résolution spectrale	10 000	R
Taux d'Échantillonnage spectral	2	Shannon
Échantillonnage spatial	20 mas	Rectangulaire
DIT	600 s	Temps d'intégration d'une pose individuelle
NDIT	60	Nombre de poses
Bandes	Y-J-H-K	Bandes spectrales

Transmission	~30 %	Atmosphère + Télescope +Instrument
Champ	5x2.5 arcsec²	Champ des données à simuler

AO parameters : LTAO ? (Harmoni)

Parameter	Range/units	Comments
Énergie Encadrée	30 % dans 40x40 mas²	Spec. souhaitée à λ_{spec}
FoV corrigé	5x2.5 arcsec²	1 zone unique à corriger
λ_{spec}	1.6 µm	Bande H

Output data

Output data	Type	Comments
Cube de donnée	FITS 3D	Inclus bruit, et soustrait du ciel/fond thermique
Cube de donnée sans bruit	FITS 3D	Identique au précédent mais sans bruit (pour tests)
Fond de ciel simulé	FITS 2D	Spectre de fond de ciel utilisé pour l'étape de soustraction (inclus le bruit)
Cube PSF	FITS 3D	Cube contenant une étoile PSF de référence.
EE	Scalaire / keyword à insérer dans le cube de donnée	Mesure de l'EE obtenue dans 2x2 spaxels

Science case

Name of the science case : *Spectral characterization of giant exoplanets from direct imaging*

Associated instrumental concept : *ELT-IFU*

Laboratory : *LAM*
Estimation of due date : *end 2014*

Summary of the science case: Spectral characterization of giant exoplanets detected with direct imaging is a fundamental step for understanding the formation processes of these massive objects (a few Jupiter masses, M_{Jup}) at orbital separations of 10-50 astronomical units (AU). The new generation of instruments dedicated to direct imaging on 8-10 m-class telescopes (e.g. VLT/SPHERE, Gemini/GPI) is soon going to provide a new insight in this field by surveying young stars of the solar neighborhood in a systematic way, looking for planetary mass companions at large separation. However, the characterization capabilities of these instruments will be limited to low resolution spectroscopy (R<50) in the near-infrared. One of the main assets of the future E-ELT will be to bring a significant gain in contrast and angular resolution, allowing a fine characterization of physical and chemical properties of the cool atmospheres of these objects thanks to spectra obtained at much higher resolutions (R>1000). To reach this goal, the use of a single-conjugate adaptive optics (SCAO) system and of a coronagraph is however necessary to obtain sufficient attenuation of the star. Coupled with an integral field spectrograph (IFS), these systems will allow characterizing planetary systems previously identified with 8-10 m-class telescopes.

Description of the simulations

Goal of the simulations: The goal is to simulate data combining SCAO, simple coronagraphy and 3D spectroscopy to obtain data cubes that represent typical observations with an instrument such as HARMONI (ELT-IFU) in its small-field (1x1 arcsec^2), low-resolution (R~4000) mode. Two types of data will be simulated: images with the coronagraph (standard Lyot or apodized Lyot), and reference PSFs without the coronagraph that will be used to simulate fake planets inside the datacubes to estimate the detection performance. The simulation will not include detection noise to be able to simulate the photometry *a posteriori* in various cases. However, the magnitude of the star will be a simulation parameter to be able to simulate different levels of AO correction: bright (R_{mag}=4, favorable case), intermediate (R_{mag}=7) and faint (R_{mag}=10, unfavorable case). The simulation will also need to include a realistic level of instrumental aberrations, ideally with AO-filtered atmospheric residuals. Finally, the simulation of images will require a proper sampling (Shannon or better) over a wide spectral range (e.g. YJHK), to be able to use advanced data analysis methods to subtract speckles and reveal the signal of the fake planets introduced into the data.

Analysis of the simulations simulations: The raw simulation results will be scaled photometrically, and noise will be added, to represent realistic data as a function of the system age and distance. Advances data analysis methods to attenuate the speckles noise (e.g. “spectral deconvolution") will be applied to test the detectability of the planets introduced into the data. By varying the properties of the star and simulated planets, we will explore the parameter space (separation; contrast) that is accessible to an HARMONI-like instrument, and possibly update the original science case of such an instrument for what concerns the characterization of giant planets.

Input parameter space

Physical parameters:

Type of objects to simulate	Interval/units	Comment
Star	A- to M-type	
Planet	Giant gaseous planets	

Comment: both the stars and planets can be simulated using synthetic spectra at high-resolution

Parameter	Interval/units	Comment
Size on the sky	Unresolved objects	
Distance	d = 10-100 pc	Distance of the systems
Age	5 – 100 Myr	Age of the systems
Stellar magnitude	R_{mag} = 4, 7, 10	
Planetary mass	M = 1-15 M_{Jup}	
Separation	1-50 AU = ~0.02-0.50 arcsec projected on sky	Orbital separation of the planets

Comment: apart from the stellar magnitude that drives the level of AO correction, the other parameters that influence the photometry (age, spectral type, noises, sky and instrumental transmission, etc.) will be simulated *a posteriori* to have access to a wider range of planetary systems without requiring heavy calculations.

Observational parameters:

Parameter	Interval/units	Comment
Spectral resolution	4 000	R
Spectral sampling	2	Shannon
Spatial sampling	4 mas	
DIT	10 s	Single exposure integration time
NDIT	1-100	Number of exposures
Spectral domain	YJHK	
Transmission	10-20%	Atmosphere + telescope + instrument
FoV	1x1 arcsec^2	FoV of the data to simulate

AO parameters:

Parameter	Interval/units	Comment
SR	50-70%	Strehl ratio in K-band, for a 0.85" seeing
Corrected FoV	1x1 $arcsec^2$	
λ_{spec}	2.0 µm	K-band
Number of actuators	80x80	
Correction frequency	500 Hz	

Expected output data

Output data	Type	Comment
Data cube **without** coronagraph, **without** noise	FITS 3D	Star simulated without coronagraph, without noise
Data cube **with** coronagraph, **without** noise	FITS 3D	Star simulated with coronagraph
Simulated sky background, without noise	FITS 2D	Spectrum of the sky background used in the sky subtraction step
EE	Scalar / keyword to insert inside the datacube	Measure of the encircled energy in 2x2 spaxels
Residual tilt RMS	Scalar / keyword to insert inside the datacube	For simulations that include the atmosphere, RMS of the residual tilt

Science Case

Science Case : The formation of massive stars
Instrument concept : *ELT-CAM / ELT-IFU / ELT-MOS / ELT-PF*
Imagery + spectroscopy

Laboratory : *LAM*
Deadline :

Summary of the Science Case (15-20 lignes max) :
The massive stars (M > 8 Msun) are the main agent of the physical, chemical and dynamic evolution of galaxies. In the past, they had also a major impact during the evolution of the Univers (re-ionisation, formation of the first heavy elements). However, the processus leading to the formation of the massive stars are still not well understood. Indeed, it is expected that these stars ignite the hydrogen burning while still accreting the surrounding matter. The radiation pressure hence generated stop the matter accretion and then limit the final mass of the star to a lower value than observed. To understand how the massive stars form it is then important to observe them from their earliest phase of evolution to their final stable state and then to compare these observations to the existing models.

If it is clear that massive stars form in cold and dense clumps located in the interstellar medium filaments (observed in the far-infrared and sub-millimetric) it appears that massive stars often form into dense stellar clusters while sometimes they form isolated.
In the near-infrared, the band which will be covered by the first generation instruments of the E-ELT, these stellar clusters are observed in an evolution state very close to the formation which allow us to study the formation process. Indeed, the dynamic evolution of these clusters is not yet advanced which make the primordial properties during the formation conserved.

We plan to take advantage of the E-ELT instruments, in particular those with an adaptive optic module (like HARMONY) to adress the following topics :

- Distribution of the stars in stellar clusters containing massive stars: what is the initial mass function ?
- Properties of the stars in stellar clusters containing massive stars : chemestry and dynamics
- The massive stars in external galaxies : what is the impact of the metallicity to the process and the products of the stellar formation ?
- The primordial massive stars : formation of the massive stars at high redshift.

Description

Goal of the simulations : We would like, thanks to simulation, to estimate the capability of the E-ELT to observe in imagery and spectroscopy massive stellar clusters at different redshifts (from clusters in our Galaxy to extragalactic clusters at different redshifts). In particular we would like to know the detection and the resolution limit for these clusters in imagery and, for the spectroscopy point of view, to understand how the spectral information evolve respectively to the distance of the cluster (integrated and redshifted spectral information). In particular we would like to understand how the observed mass function and the spectral signature from these clusters is observationnaly impacted due to the distance.

Analysis of the simulations : The main data to simulate respectively to the increasing distance (redshift) to the cluster are : the color-magnitude diagrams, the stellar density profiles, the luminosity and mass functions and the integrated spectrum. The goal is to quantify the observationnal biaises affecting these data and to determine the highest z up to which these clusters could be observed with pertinence.

Input parameter space

Physical parameters: The objects to simulate are young stellar clusters. These clusters follow a King profile and have caracteristic size between 0.1 and 2 pc. They contain few tens up to few hundred of stars.
Depending on their evolutionary stage these clusters can be deeply embedded in their parental molecular cloud and then they can exhibit stars with large infrared excess.
We already have high angular resolution NIR images of a cluster which could be used as input for the simulations.

Objects to be simulated	Range/units	Comments
Stellar clusters	Type OCs to ECs	Stellar clusters at different evolutionnary stage (more or less embedded)

Parameter	Range/units	Comments
Apparent Size	61" – 0.6"	A typical size of 3 pc placed between 8 kpc (Galactic) and 1 Mpc
Central Density	Between 3 and 40 stars / pc^{-2}	
Surface density profiles	King profile	Or image available for input
Limit magnitude	mk = 20 (at d ~ 3.5 kpc)	To adjust with the distance

Observationnal parameters :

Parameter	Range/units	Comments
Spectroscopy :		

Spectrale resolution	4 000	
Spatial resolution	20 mas	
Spectrale domain	2 – 2.5 µm	
Imagery :		
Band	K	
Saptial resolution	20 mas	
FOV	100" - 2"	To adjust to the apparent size of the object.

AO parameters : *description sous forme de tableau du type de correction souhaitée (métrique : SR, EE, taille du champ corrigé). Indiquer à quelles longueurs d'onde se réfèrent les spécifications.*

Parameter	**Range/units**	**Comments**
Énergie Encadrée	30 % dans 80x80 mas²	Spec. souhaitée à λ_{spec}
FoV corrigé	3x3 arcsec²	20 zones à corriger dans un champ global de 7 arcmin de diamètre (MOAO)
λ_{spec}	1.6 µm	Bande H

Output data

Output data	**Type**	**Comments**
Imagery :		
Simulated Images	FITS 2D	Including noise and background substraction
Simulated Background sky	FITS 2D	Background used for the correction step.
Spectroscopy :		
Images	FITS 3D	Data-Cubes

Science Case

Science Case : *Exoplanets direct imaging*
Instrument concept : *ELT-CAM*

Laboratory : *LESIA*
Deadline : *Rapidement*

Summary of the Science Case (15-20 lignes max) :
For the exoplanet science case, ELT-CAM and its SCAO mode is for the ELT what NACO is for the VLT, a general-purpose imager with adaptive optics offering the highest possible Strehl ratio and contrast on axis. The same kind of instrument on a ~40-m telescope will improve the angular resolution by a factor of 4 to 5. Assuming the same level of contrasts are achievable than with NACO, a beta Pic b-like object is detectable at ~2 AU instead of 8-10AU. ELT-CAM will have the capability to reach closer physical separations than NACO and even SPHERE on nearby targets (<50 pc). This range is overlapping the one probed with RV, which now starts to be applicable on young early type stars (Lagrange et al. 2012b) although active. Therefore, it will be possible to infer the true mass of a planet from the minimal mass measured by RV and the inclination measured from imaging (several epochs needed). A more precise calibration of evolutionary models will become feasible hence with the advantage to perform better spectral characterization. In addition, ELT-CAM will be able to search for young giant and massive planets (10 MJ) on wide orbits (>20-30 AU) around young star associations that are more distant than those observed with SPHERE (100-150 pc rather than 30-90 pc). Therefore, the number of potential targets is larger. Moreover, these observations performed in several bands (JHK) will allow to derive near IR colors and to put constraints on some atmospheric properties like temperature and surface gravity.

Description

Goal of the simulations : *décrire le type d'observations à simuler (images, spectres 1D, cubes de données) et quel(s) Parameter(s) lié(s) au design de l'instrument doi(ven)t être optimisé(s)* in fine. *On décrira aussi rapidement quel est la structure spatiale/spectrale que l'on cherchera à détecter dans les simulations (par ex. : raie en émission/absorption).*

A typical observation with ELT-CAM involves a bright star (which provides on-axis wavefront sensing), and a pupil tracking mode to benefit for angular differential imaging (ADI), in combination with a coronagraph in the focal plane and broad band filters. ADI processing uses the field rotation while the stellar components (speckles) are nearly static.
A simulation must account for this observing mode to allow a realistic estimation of the contrast in the field around the on-axis star.
Basically, the simulation should provide a temporal sequence of wavefront errors (amplitude+phase: ElectroMagnetic (EM) field) to be interfaced with a coronagraph simulation.
The EM field arrays in the pupil plane upstream the coronagraph must account for AO correction of : the atmospheric turbulence, static aberrations, jitter, slowly evolving pattern (with a temporal spectrum). The characteristic timescale if the one of the slowly evolving pattern not the one of the atmospheric turbulence. Observing time should last at least 1 hour and rather 2h.
Take into account seeing evolution.

Chromatic effects should be also included: propagation in the atmosphere, ADC, propagation in the instrument optics.
Parameter to optimize :
* AO :
    - type of wavefront sensor
    - temporal bandwidth and loop optimization
    - atmospheric conditions
* Corono :
    - Type de corono (phase, Lyot, apodized Lyot)
    - IWA optimum vs OA residuals

Analysis of the simulations : *type d'analyse qu'il est prévu de faire sur les données simulées. Rappel : les outils d'analyse ne font pas partie du pipeline de simulation et restent à la charge de chaque Laboratory responsable des simulations associées à chaque concept d'instrument (WP 7). Donner une brève description de l'analyse prévue afin de comprendre quels sont les enjeux de chaque simulation. Préciser également s'il y a lieu comment les Parameters instrumentaux à optimiser seront quantifiés à partir des simulations.*

Simulated EM fields will be used as input of a High contrast Imaging simulation which provides coronagraphic images at the detector level. Detection noises will be added. The ADI processing (various algorithm) will be performed. We will be able to compare the performance in terms of contrast after processing.
In a future development, the coronographic image simulation could also be done in COMPASS.

Input parameter space

Physical parameters: *description de la nature (étoile, galaxie,...) des objets astrophysiques à simuler (sous forme de tableau si réponse multiple). On pourra préciser les données à haute résolution pouvant être utilisées en entrée des simulations si elles sont connues (penser que celles-ci doivent être de résolution spatiale/spectrale plus élevées que les données à simuler). Préciser ensuite les propriétés décrivant ces objets (taille sur le ciel, flux, vitesse, ...) sous forme de tableau. Indiquer l'intervalle de variation souhaité pour chaque Parameter.*

Objects to be simulated	Range/units	Comments
Star + planet	Contrasts of 10^{-4} à 10^{-8}	Spectral type : A, G, M
Star + disk	Contrasts of 10^{-4} à 10^{-8}	

Parameter	Range/units	Comments
Separation	8 mas à 1 arcsec	Voir jusqu'à 3 arcsec
Flux de l'étoile	R=14 à 0	Integrated flux

FoV	3 to 10 arcsec	

Observationnal parameters : *description des conditions d'observation (télescope, instrument, ciel). Indiquer sous forme de tableau l'intervalle de variation souhaité pour chaque Parameter (échantillonnage/résolution spatiale/spectrale, multiplex, transmission globale, domaine de longueur d'onde, ...). Ne pas indiquer les Parameters génériques non dimensionnant liés au télescope et à l'instrument n'ayant pas vocation à être variés (par exemple : diamètre de l'E-ELT, obturation centrale, courant d'obscurité, bruit de lecture,...), sauf si ceux-ci prennent des valeurs atypiques.*

Parameter	**Range/units**	**Comments**
Spatial sampling	2 pixels per resol elt	Shannon
Domaine spectral	1.0 to 2.5 µm	Start with H band (λ_o=1.6, R=5). Polychromatic image
Echantillonnage spectral	R=50	For spectroscopy (optionnal)

AO parameters : *description sous forme de tableau du type de correction souhaitée (métrique : SR, EE, taille du champ corrigé). Indiquer à quelles longueurs d'onde se réfèrent les spécifications.*

Parameter	**Range/units**	**Comments**
Contrast around star	Optimized on the correction zone	Spec. at λ_{spec}
EM Field [illegible]	In pupil or focal plane : TBC	Only for the star
Corrected FoV	All the corrected field	
λ_{spec}	1.6 µm	H band (5 to 10 λ in the band)
Speed of correction	Up to 2 to 3 kHz	[illegible] C
Seeing	Variable along the observation	
Segmented pupil		

Output data

Décrire sous forme de tableau le type de données que la simulation doit délivrer en sortie et qui serviront comme données d'analyse ou de test, par exemple : cube de donnée, image, spectre, quantités scalaires à estimer (niveau de bruit, S/N), données sans bruits et/ou avant dégradation de la résolution spatiale, etc. Indiquer si les données simulées correspondent à des données parfaitement réduites ou si des effets particuliers essentiels doivent être pris en compte (par exemple : réfraction atmosphérique différentielle, variation spatiale du fond de ciel, variation de la PSF dans le champ, mesure spécifique du fond de ciel avant soustraction,...).

Output data	**Type**	**Comments**

EM field temporal datacube for each wavelength	FITS 3D	Data in focal plane (TBC) per wavelength
AO parameters	Scalar / keyword	Parameters defining the EM field computation

NOTE FINALE : merci de libeller les fichiers sous la forme SC_*labo*_*acronyme*.doc.

Science Case

Science Case : Study of the merger-starburst-agn connection in low-z galaxies
Instrument concept : ELT-CAM / ELT-IFU

Laboratory : LESIA
Deadline : late 2014

Summary of the Science Case (15-20 lignes max) :
Star formation that is associated with the encounter of two galaxies is particularly intense since it leads to a rate as large as 1000 times that of the Galaxy (1 Msol / year). These galaxies are called ultra-luminous in the infrared. Indeed, the dense dust associated with the concentration of gas that triggered the starburst, is heated efficiently and converts into the thermal radiation most of the stellar luminosity. The cocoon remains optically opaque during the first phase, so near-infrared bands are privileged to study this phenomenon. Star formation is concentrated in the form of compact but extremely bright stellar clusters which can contain up to the equivalent of 10,000 O7 star. Called SSC (Super Stellar Cluster) these clusters have no equivalent in the Galaxy. Understanding their characteristics is important because it is a key aspect of galaxies structural and chemical evolution. One must be able to detail the distribution in mass, in size, in stellar content, in brightness and in Super-Novae of these SSC in a significant sample, representative of ULIRGs so as to establish links and general laws. These objects are so distant that the use of high angular resolution is mandatory. These super star clusters (SSC) are rare and distant (d = 150 Mpc) with a diameter smaller than the resolution achieved with adaptive optics on a telescope of 8 -10m. The resolution achievable with the E-ELT (10 mas, i.e. 8 pc 150 Mpc) will allow us to take a great leap for three types of programs:

- Characterize the starburst on objects five times more distant than our ongoing program on low-z mergers with 8-10m telescope
- Resolve the closest SSCs of our current program to address many questions such as : Schmidt law, filiation with globular clusters, spatial structure (IMF, HII regions, dust clustering etc.).
- Understand the links between the merger, the starburst and the presence of a central super-massive black hole.

Description

Goal of the simulations : Our goal is to simulate imaging, 2D spectroscopy and 3D spectroscopic observations of a sample of interacting galaxies low redshift, harboring a starburst and possibly one or more active nuclei. The results will be analyzed in terms of optimal spatial resolution and sampling to be able to resolve SSC and central structures depending on the redshift of the objects. The galaxies are observed using broadband near IR imaging (1.65 to 2.5µm) and the emission lines of molecular (2.12µm) and ionized (2.17µm) hydrogen whose wavelength will be adapted to suit redshift. Instrumental choice (MCAO vs. LTAO, IFU vs imaging) will be analyzed in relation to these objectives.

Analysis of the simulations : Concerning imaging observations, accurate photometry on every SSC is crucial for this study. These sources are rather faint (~18th magnitude at H) and lie on the background of the host galaxie. To avoid any bias, photometry thus requires a perfect knowledge of the PSF to minimize the contribution of galactic background. The data will be analyzed using either PSF fitting or reconstructed PSF. The simulated data shall be used to test both approach and eventually strengthen the case for the development of an accurate PSF reconstruction method. The inhomogeneity of the PSF in the field is an important parameter. Spectroscopic observations : TBD !

Input parameter space

Physical parameters:

Objects to be simulated	Range/units	Comments
Galaxies en fusion	D_{prog}=5-50 kpc	Distance entre les progéniteurs

Parameter	Range/units	Comments
Redshift	< 0.1	
SSC luminosity	M_H = 18	Integrated flux
SSC diameter	10-50 pc	

We can use the data acquired by HST NICMOS on closer objects (such as the sample of Haan et al.) and the data of our current program as a reference to extrapolate on what will be obtained at a given (larger) redshift.

Observationnal parameters :

Parameter	Range/units	Comments
FoV	1x1 $arcmin^2$	Imaging
FoV	2x2 $arcsec^2$	IFU
Échantillonnage spatial	5 mas	Rectangular
DIT	1-100s	Exposure time
NDIT	1-40	Number of exposures
Transmission	30 %	Atmosphere + telescope + instrument
Pouvoir de résolution spectrale	4 000	R

Taux d'Échantillonnage spectral	2	Shannon

AO parameters :

Parameter	**Range/units**	**Comments**
Lambda	1.5-2.5µm	
Strehl ratio	50 % @2.2µm	TBD
Corrected FoV	80x80 arcsec²	
Strehl variation in the FoV	< 10 %	TBD
Impact of Na variations	On Strehl	This program requires the use of LGS

Output data

Output data	**Type**	**Comments**
Imaging data / Data cube (IFU)	FITS 2D / 3D	Including noise and background
Imaging data / Data cube without noise	FITS 2D / 3D	Identical but without noise
Simulated sky and thermal background	FITS 2D	
Strehl map	FITS 2D	Imaging only
PSF cube (spatial / spectral)	FITS 3D	PSF at various position in the FoV (imaging) and for various wavelength (IFU)
AO telemetry data	FITS 3D	Data needed to reconstruct the PSF (slopes, commands, noise estimate, R_0 estimate)

Science Case

Science Case : Galactic Center in SCAO mode
Instrument concept : *ELT-CAM*

Laboratory : *LESIA*
Deadline : *mi 2014*

Summary of the Science Case (15-20 lignes max) : Study of the environment and of the parameters of Sgr A* to constrain the history of stellar formation around Sgr A* and to contrain the flare process.

Description

Goal of the simulations : *Detection of post-newtonian effects on S-stars already known and with the smallest peri-astron values, detection/follow-up of stars closer than the already known S stars to constrain Sgr A* environment and parameters, study of the accretion zone around Sgr A*. Instrumental parameters to be adjusted : mainly pixel size and spectral resolution.*
These simulations will make use of GYOTO (the code for computing orbits and raytraced images in General relativity) to compute to stars orbits and the raytraced images of these stars. Rsults from GYOTO will be coupled to an instrument model to derive the simulated observations.

Analysis of the simulations : *Astrometric errors, line flux errors.*

Input parameter space

Physical parameters: Stellar orbits : stars in orbit around Sgr A* and extended mass around Sgr A* ; accretion zone around Sgr A* : hot spot in orbit around Sgr A*

Parameter	Range/units	Comments
Apparent size	ponctual	
Flux	K from 17 to 22 for star K>13 for the orbiting hot spot	

Observationnal parameters : *description des conditions d'observation (télescope, instrument, ciel). Indiquer sous forme de tableau l'intervalle de variation souhaité pour chaque Parameter (échantillonnage/résolution spatiale/spectrale, multiplex, transmission globale, domaine de longueur d'onde, ...). Ne pas indiquer les Parameters génériques non dimensionnant liés au télescope et à l'instrument n'ayant pas vocation à être variés (par exemple : diamètre de l'E-ELT, obturation centrale, courant d'obscurité, bruit de lecture,...), sauf si ceux-ci prennent des valeurs* *atypiques.*

Parameter	Range/units	Comments
Spatial sampling	2 to 10 mas	
Spectral resolution	2000 to 5000	

AO parameters : *description sous forme de tableau du type de correction souhaitée (métrique : SR, EE, taille du champ corrigé). Indiquer à quelles longueurs d'onde se réfèrent les spécifications.*

Parameter	Range/units	Comments
FoV corrigé	Qq x qq arcsec²	
λ_{spec}	1.6 et 2.2 µm,	Bandes H et K

The AO simu should ideally account for the different E-ELT characteristics : M4 actuator geometry, telescope windshake residuals. Ideally, it should also allow one to account for a Kalman filter control law and a pyramid WFS. The reference source, in the visible, is ~15 arcsec away from the science target.

Output data

Décrire sous forme de tableau le type de données que la simulation doit délivrer en sortie et qui serviront comme données d'analyse ou de test, par exemple : cube de donnée, image, spectre, quantités scalaires à estimer (niveau de bruit, S/N), données sans bruits et/ou avant dégradation de la résolution spatiale, etc. Indiquer si les données simulées correspondent à des données parfaitement réduites ou si des effets particuliers essentiels doivent être pris en compte (par exemple : réfraction atmosphérique différentielle, variation spatiale du fond de ciel, variation de la PSF dans le champ, mesure spécifique du fond de ciel avant soustraction,...).

Output data	Type	Comments
Cube de donnée	FITS 3D	Inclus bruit, et soustrait du ciel/fond thermique
Cube de donnée sans bruit	FITS 3D	Identique au précédent mais sans bruit (pour tests)

NOTE FINALE : merci de libeller les fichiers sous la forme SC_*labo_acronyme*.doc.

Science Case

Science Case : *The close environment of evolved stars*
Instrument concept : *ELT-CAM / ELT-IFU / ELT-PF*

Laboratory : *LESIA*
Deadline : *2014-2015*

Summary of the Science Case (15-20 lignes max) :
Evolved stars are the main contributors to the enrichment of heavy elements in the interstellar medium, and more generally play a central role in the chemical evolution of the Universe. Their close environment, at the interface between the star itself and the interstellar medium, is the place where most of the chemical evolution of the ejected material takes place. From the formation of molecules to the condensation of dust particles, these phenomena are concentrated in a relatively small volume located between 1 and ~100 stellar radii. The high angular resolution provided by the ELT will be a major asset to study the environment of nearby evolved stars, either giant (e.g. Mira, VY CMa, Gamma Cru, R Dor, L2 Pup…) or supergiant (e.g. Betelgeuse, Antares,…).

Description

Goal of the simulations : *décrire le type d'observations à simuler (images, spectres 1D, cubes de données) et quel(s) Parameter(s) lié(s) au design de l'instrument doi(ven)t être optimisé(s)* in fine. *On décrira aussi rapidement quel est la structure spatiale/spectrale que l'on cherchera à détecter dans les simulations (par ex. : raie en émission/absorption).*

The simulations should produce images and data cubes. The starting images will be provided e.g. by 3D hydro models, and will include surface features, typically convective cells at the surface of red supergiants (see e.g. simulations by Chiavassa et al. 2011). These structures will be partly resolved by the ELT for the nearest targets (e.g. Betelgeuse, Antares, R Dor,…). The input images should also include gaseous/dusty features in the close environment of the stars. The presence of different molecular species, and the changing temperature results in the formation of emission lines at various distances from the star. In addition, dust is known to form relatively close to these stars (depending in particular on their effective temperature), and it should be included in the simulations. Dust is particularly apparent in the thermal infrared domain.

Analysis of the simulations : *type d'analyse qu'il est prévu de faire sur les données simulées. Rappel : les outils d'analyse ne font pas partie du pipeline de simulation et restent à la charge de chaque Laboratory responsable des simulations associées à chaque concept d'instrument (WP 7). Donner une brève description de l'analyse prévue afin de comprendre quels sont les enjeux de chaque simulation. Préciser également s'il y a lieu comment les Parameters instrumentaux à optimiser seront quantifiés à partir des simulations.*

The simulated data will be analyzed to determine the level of details that will be achievable in the *characterization of the envelopes (chemical composition, physical conditions) and the surface features (spatial distribution of convective cells, contrast of spots and other features,...). This analysis will allow us to determine which model parameters will be efficiently constrained by the ELT observations, and determine a coherent observing strategy with existing or foreseen interferometric facilities (e.g. VLTI/GRAVITY) operating at higher spatial frequencies. It is importnat to notice that the foreseen observations will be conducted on very bright targets, for which the photosphere will be resolved, hence with an extremely high surface brightness on the instrument detector. The produced simulations should therefore help define the type of attenuation that will be necessary for the wavefront sensors and the science instrument detector.*

Input parameter space

Physical parameters: *description de la nature (étoile, galaxie,...) des objets astrophysiques à simuler (sous forme de tableau si réponse multiple). On pourra préciser les données à haute résolution pouvant être utilisées en entrée des simulations si elles sont connues (penser que celles-ci doivent être de résolution spatiale/spectrale plus élevées que les données à simuler). Préciser ensuite les propriétés décrivant ces objets (taille sur le ciel, flux, vitesse, ...) sous forme de tableau. Indiquer l'intervalle de variation souhaité pour chaque Parameter.*

Objects to be simulated	Range/units	Comments
Star	Giants and supergiants	Surface features from 3D hydro simulations
Circumstellar envelope	Extension : from 1 to ~100 R* Surface brightness : 10% to 0.1% of the star	Envelope features extrapolated e.g. from VLT/NACO or VISIR observations

Parameter	Range/units	Comments
Extension on the sky	milliarcseconds	From ~10 to ~ 1000 mas
Surface brightness	$W/m^2/\mu m/sr$	For star and envelope

Observationnal parameters : *description des conditions d'observation (télescope, instrument, ciel). Indiquer sous forme de tableau l'intervalle de variation souhaité pour chaque Parameter (échantillonnage/résolution spatiale/spectrale, multiplex, transmission globale, domaine de longueur d'onde, ...). Ne pas indiquer les Parameters génériques non dimensionnant liés au télescope et à l'instrument n'ayant pas vocation à être variés (par exemple : diamètre de l'E-ELT, obturation centrale, courant d'obscurité, bruit de lecture,...), sauf si ceux-ci prennent des valeurs atypiques.*

Parameter	Range/units	Comments

Wavelength	0.5 – 20 µm	V to Q bands
Spectral resolution	500 - 50000	For spectro-imaging
Spatial sampling	3 – 5 mas	> Shannon
Spectral sampling	2	= Shannon

AO parameters : *description sous forme de tableau du type de correction souhaitée (métrique : SR, EE, taille du champ corrigé). Indiquer à quelles longueurs d'onde se réfèrent les spécifications.*

Parameter	Range/units	Comments
Encircled energy	?	As high as possible depending on wavelength
Corrected FoV	3x3 arcsec² (?)	The central star will be the WFS reference
λ_{spec}	0.5 - 20 µm	V to Q bands

Output data

Décrire sous forme de tableau le type de données que la simulation doit délivrer en sortie et qui serviront comme données d'analyse ou de test, par exemple : cube de donnée, image, spectre, quantités scalaires à estimer (niveau de bruit, S/N), données sans bruits et/ou avant dégradation de la résolution spatiale, etc. Indiquer si les données simulées correspondent à des données parfaitement réduites ou si des effets particuliers essentiels doivent être pris en compte (par exemple : réfraction atmosphérique différentielle, variation spatiale du fond de ciel, variation de la PSF dans le champ, mesure spécifique du fond de ciel avant soustraction,...).

Output data	Type	Comments
Data cubes with noise	FITS 3D	Including noise sources and sky background
Data cubes without noise	FITS 3D	Data cubes without instrument noise
Sky background	FITS 2D	Sky background with noise

NOTE FINALE : merci de libeller les fichiers sous la forme SC_*labo_acronyme*.doc.

Science Case

Science Case : Characterization of exoplanets from Jupiter down to earth-masses.
Instrument concept : *ELT-PCS*

Laboratory : *IPAG*
Deadline : *mid-2015*

Summary of the Science Case (15-20 lignes max) : Most of the nearby Exoplanets will be detected by the radial velocity (down to Earth mass in the HZ for late-type stars and higher mass planets at larger separations up to a few AU) or astrometric techniques (giant planets up to about 5 AU) in the next decade. The information about these objects is however limited to mass and orbit (with sin-i uncertainty in the case of RV), so it will not be possible to unambiguously demonstrate whether a planet is rocky or whether it resembles Neptune or even a gas giant. Only direct imaging will allow us to characterize the planets and their atmospheres, learn about cloud cover and weather patterns, and ultimately decide whether they may harbor life.The most currently most appealing case is the Earth-size planet orbiting Alpha Centauri B. This planet is seen at an angular separation of 30 mas and a contrast of 10^{-7}, well within the expected capabilities of PCS.
décrire succinctement la problématique du Science Case ainsi que ses objectifs et les quantités mesurées/estimées.

Description

Goal of the simulations : The objective is to combine eXtreme Adaptative optics, coronagraphy and dedicated high contrast instrument to estimate the performance of exoplanet detection with ELT-PCS. The simulation should provide a temporal sequence of Electromagnetic (EM) Fields in pupil focal planes and for a set of wave-lengths. The EM fields will then be used to simulate dedicted detection methods (example : IFS, EPOL, Self-Coherent Camera).
The output EM fields must take into account various features upstream the coronagraph (which may be part of COMPASS module.)

- quasistatic aberrations
- chromatic aberrations (including ADC residuals and propagation through the atmosphere)
- possibly Fresnel effects due to out-of-pupil optics .
- possibly polarimetric instrumental effects

Parameter to optimize :

- XAO type (, number of actuators, frame rate,single /double stage, WFS type, fast control,etc)
- Coronagraph type (may not be part of compass module)

décrire le type d'observations à simuler (images, spectres 1D, cubes de données) et quel(s) Parameter(s) lié(s) au design de l'instrument doi(ven)t être optimisé(s) in fine. *On décrira aussi rapidement quel est la structure spatiale/spectrale que l'on cherchera à détecter dans les* *simulations (par ex. : raie en émission/absorption).*

Analysis of the simulations :. *type d'analyse qu'il est prévu de faire sur les données simulées. Rappel : les outils d'analyse ne font pas partie du pipeline de simulation et restent à la charge de chaque Laboratory responsable des simulations associées à chaque concept d'instrument (WP 7). Donner une brève description de l'analyse prévue afin de comprendre quels sont les enjeux de chaque simulation. Préciser également s'il y a lieu comment les Parameters instrumentaux à optimiser seront quantifiés à partir des simulations.*

The Analysis of the simulations simlations will be intimately linked to the kind of detection method implemented.

Input parameter space

Physical parameters: *description de la nature (étoile, galaxie,...) des objets astrophysiques à simuler (sous forme de tableau si réponse multiple). On pourra préciser les données à haute résolution pouvant être utilisées en entrée des simulations si elles sont connues (penser que celles-ci doivent être de résolution spatiale/spectrale plus élevées que les données à simuler). Préciser ensuite les propriétés décrivant ces objets (taille sur le ciel, flux, vitesse, ...) sous forme de tableau. Indiquer l'intervalle de variation souhaité pour chaque Parameter.*

Objects to be simulated	Range/units	Comments
Star + Planet	Contrast 10^{-6} to 10^{-9}	GKM
Star + Disk		

Parameter	Range/units	Comments
Separation	8mas to 1 arcsec	
Flux	R=9 to 0	Integrated flux

Observationnal parameters : *description des conditions d'observation (télescope, instrument, ciel). Indiquer sous forme de tableau l'intervalle de variation souhaité pour chaque Parameter (échantillonnage/résolution spatiale/spectrale, multiplex, transmission globale, domaine de longueur d'onde, ...). Ne pas indiquer les Parameters génériques non dimensionnant liés au télescope et à l'instrument n'ayant pas vocation à être variés (par exemple : diamètre de l'E-ELT, obturation centrale, courant d'obscurité, bruit de lecture,...), sauf si ceux-ci prennent des valeurs atypiques.*

Parameter	Range/units	Comments
Spatial sampling	2 pixels per resol elt	Shannon

Domaine spectral	600-900nm 950-1650nm	VIS and/or NIR data
Echantillonnage spectral	R=50 (NIR)	For spectroscopy (optionnal)

AO parameters : *description sous forme de tableau du type de correction souhaitée (métrique : SR, EE, taille du champ corrigé). Indiquer à quelles longueurs d'onde se réfèrent les spécifications.*

Parameter	**Range/units**	**Comments**
Contrast around star	Optimized on the correction zone	Spec. at λ_{spec}
EM Field [illegible]	In pupil or focal plane : TBC	Only for the star
Corrected FoV	All the corrected field	
λ_{spec}	1.6 µm	H band (5 to 10 λ in the band)
Speed of correction	Up to 2 to 3 kHz	[illegible] C
Seeing	Variable along the observation	
Segmented pupil		

Output data

Décrire sous forme de tableau le type de données que la simulation doit délivrer en sortie et qui serviront comme données d'analyse ou de test, par exemple : cube de donnée, image, spectre, quantités scalaires à estimer (niveau de bruit, S/N), données sans bruits et/ou avant dégradation de la résolution spatiale, etc. Indiquer si les données simulées correspondent à des données parfaitement réduites ou si des effets particuliers essentiels doivent être pris en compte (par exemple : réfraction atmosphérique différentielle, variation spatiale du fond de ciel, variation de la PSF dans le champ, mesure spécifique du fond de ciel avant soustraction,...).

Output data	**Type**	**Comments**
EM field temporal datacube for each wavelength	FITS 3D	Data in focal plane (TBC) per wavelength
AO parameters	Scalar / keyword	Parameters defining the EM field computation

NOTE FINALE : merci de libeller les fichiers sous la forme SC_*labo*_*acronyme*.doc.