First Light And Reionization Explorer

FLARE

Introduction

Denis Burgarella
Laboratoire d'Astrophysique de Marseille
Aix-Marseille Université

- Welcome to Marseille and Thank You for participating to this FLARE Meeting.

Live streaming and videcon

- Live-streaming will be available on Monday and Tuesday morning:

  http://streaming-c.osupytheas.fr/embed/live.html

- If you have any problem, please send an email to: L. Bouguerra:

  ludovic.bouguerra@kalyzee.com

- On Tuesday afternoon and Wednesday morning, a videoconf is planned for people outside LAM. I will send the information later today.

What are the objectives of this meeting?

- Start the identification of the 3 to 5 key-questions that we will address with FLARE and that any other projects will not before 2028 – 2030.
- Start building the consortium that will build FLARE by defining who can do what and when.

The preliminary agenda is organized as follows:

Agenda

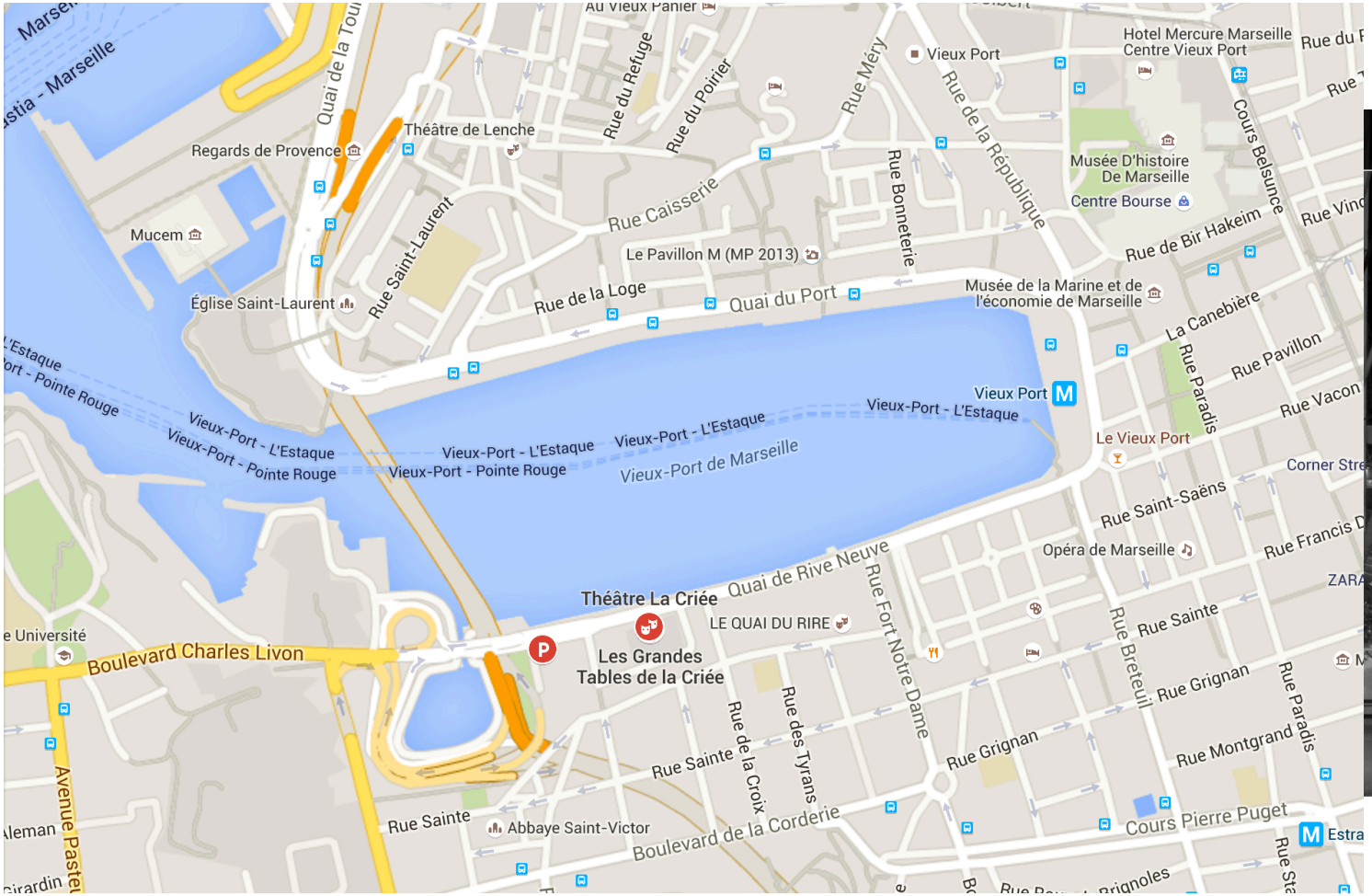
Date	Start	End	Duration	Questions	Name	Title
Monday March 14	09:30	10:00	00:30	00:00	Coffee	
	10:00	10:50	00:40	00:10	Denis BURGARELLA	Introduction to FLARE: context and science
	10:50	11:30	00:30	00:10	Patrick LEVACHER	Introduction to FLARE: the telescope and the instruments
	11:30	12:00	00:20	00:10	Sebastien VIVES	Introdution to FLARE: optical designs
	12:00	13:30	01:35	00:00	Lunch in LAM	
	13:30	14:10	00:30	00:10	Pierre FERRUIT	JWST NIRSpec (via videocon)
	14:10	14:40	00:20	00:10	Benoit EPINAT	HARMONI & E-ELT spectroscopy
	14:40	15:05	00:15	00:10	Olivier MOUSIS	FLARE SWG Theme 5: Solar system science
	15:05	15:45	00:30	00:10	Sergio MOLINARI/Laurent PAGANI	FLARE SWG Theme 4: MW Science
	15:45	16:15	00:30	00:00	Coffee Break	
	16:15	16:55	00:30	00:10	Ikuru IWATA	FLARE SWG Japan
	16:55	17:35	00:30	00:10	Daniel Schaerer	FLARE SWG theme 2: First Light and Building elements
	17:35	17:50	00:15	00:00	Planning the next meeting in Sept.-Oct.	

18:30 to 23:30 « π-day » Théâtre de la Criée with π and pies (free entrance, http://www.piday.fr/)

Tuesday March 15						
	09:30	10:10	00:30	00:10	Rychard BOUWENS	FLARE SWG theme 1: First Light and Reionization
	10:10	10:50	00:30	00:10	Asantha COORAY	FLARE SWG USA
	10:50	11:20	00:30	00:00	Coffee	
	11:20	12:00	00:30	00:10	Karina CAPUTI	FLARE SWG theme 2: Massive galaxies at very high redshifts
	12:00	12:40	00:30	00:10	Dave ALEXANDER	FLARE SWG theme 3: high-redshift quasars
	12:40	14:10	01:30	00:00	Lunch in LAM	
	14:10	16:10	02:00	00:00	FLARE consortium	Defining the instrumental organization
	16:10	16:40	00:30	00:00	Coffee	
	16:40	17:40	01:00	00:00	FLARE consortium continued	Defining the instrumental organization
	17:40	17:40	00:00	00:00	End of the day	
Wednesday March 16	09:00	10:30	01:30	00:00	FLARE consortium continued	Summary and preliminary organization
	10:30	11:00	00:30	00:00	Coffee	
	11:00	12:00	01:00	00:00	Visit of LAM	
	12:00	13:30	01:30	00:00	Lunch	
	14:00	14:00	00:00	00:00	End of the Meeting	

(videocon available outside presentations)

π-day from 18:30 to 23:30
Théâtre National de la Criée



Rendez-vous le **14 Mars 2016 (3.14)** au Théâtre National de **La Criée** pour une inoubliable soirée-spectacle (entrée gratuite).

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Context: ESA M5 Call

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ESA M5 Call

- 20 July 2015: The Director of Science and Robotic Exploration of the European Space Agency plans to release, in late 2015 or early 2016, a Call for the M5 "Medium-size mission" with a **planned launch date of 2029-2030** ("M5 Call" in the following).

- The Call is foreseen to solicit proposals for a mission with a cap to the ESA Cost at Completion of **550 M€**.

- The planned launch date for the M5 mission is 2029-2030. The actual launch date of the mission is likely to be driven by the mission's complexity and development schedule, rather than by the budget profile. In particular, **missions of lower complexity (and thus likely of lower cost) might have a faster development schedule and thus an earlier launch date.**

ESA M5 Call

- Proposals in response to the M5 Call **in cooperation with other partners will be welcome.**
- The feasibility of the proposal for the Science Programme is strictly dependent on **the willingness of the potential partner to engage in the proposed collaboration**. While contacts among interested scientists are of course a conditio sine qua non for the start of a partnership, **verification of the scope of the potential partnership requires inter-agency discussions.**
- The proposals submitted in response to the M5 Call will be subject to an **initial strict technical and programmatic screening**.
- Proposals that pass the technical and programmatic screening would be subject to **a scientific peer-review evaluation**, resulting in the **selection of a small number of mission concepts (typically ≤ 3) for a study phase**.

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ESA M4 Call and before

- Following the recommendation by a peer review committee, Alvaro Giménez, Director of Science and Robotic Exploration, decided that three candidate concepts submitted to its M4 mission call will be studied further:
  - the Atmospheric Remote-Sensing Infrared Exoplanet Large-survey (**Ariel**),
  - the Turbulence Heating ObserveR (**Thor**),
  - the X-ray Imaging Polarimetry Explorer (**Xipe**).

- The three mission concepts were chosen from **27 proposals** that were submitted in response to the mission call made by ESA to the scientific community.

- After a study period aimed at making a detailed technical and scientific definition of the three concepts, one mission will be selected to fill the fourth medium-class (M4) opportunity in ESA's Cosmic Vision 2015–2025 Plan, for **launch in 2025**.

- **Solar Orbiter**, **Euclid**, and **PLATO** have already been selected as medium-class missions and are scheduled for **launch in 2018, 2020 and 2024** respectively.

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ESA TENTATIVE SCHEDULE FOR THE M5 CALL

Event	Tentative date	Updated Tentative date
M5 Call release	December 2015	March 2016
Letters of Intent due	January 2016	April 2016
Proposals due	April 2016	September – October 2016
Evaluation process	May–June 2016	October – December 2016
Selection of proposals for study phase	June 2016	January 2017
Phase 0+A completion	June 2018	September 2018
Down-selection to one mission	November 2018	February 2019
Phase B1 completion	June 2020	September 2020
Mission Adoption Reviews	September 2020	December 2020
Mission adoption	November 2020	February 2021
Launch (for an ESA-only mission)	Mid–2029 to mid–2030	Mid–2029 to mid–2030

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(What happened to WISH?)

- WISH not selected by JAXA (comment: excellent project by in competition with SPICA).
- FLARE project started with the complete agreement of WISH's Toru YAMADA (PI) and Ikuru IWATA (PS)

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Short description of FLARE Science

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Main Science Objectives

I. First Light And Reionization (~70-80%)

- The main objective of FLARE will be to understand the end of the dark ages and study the formation of the first objects in the universe.
- This is related to ESA's 4th theme in the Cosmic Vision 2015 – 2025 programme: « *How did the universe originate and what is it made of?* » and more specifically, « **4.2 *The universe taking shape*** »:
- *« Tracing cosmic history back to the time when the first luminous sources ignited, thus ending the dark ages of the Universe, has just begun. At that epoch the intergalactic medium was reionised, while large-scale structures increased in complexity, leading to galaxies and their supermassive black holes. ».*
- One of the most important goals will be to: « *Find the very first gravitationally-bound structures that were assembled in the Universe – precursors to today's galaxies, groups and clusters of galaxies – and trace the subsequent co-evolution of galaxies and super-massive black holes. »*

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Main Science Objectives

II. Formation of Stars (and Planets) in the Milky Way (~10-20%)

- A second objective will be to understand the formation of stars.
- This is related to ESA's 1st theme in Cosmic Vision: « What are the conditions for planet formation and the emergence of life? » and more specifically, **« 1.1 From gas and dust to stars and planets »**:
- *« We still lack a comprehensive theory explaining why and how stars form from interstellar matter. The formation of planets has to be considered in the wider context of star formation and circumstellar disc evolution. »*
- The goal will be to: « *Map the birth of stars and planets by peering into the highly obscured cocoons where they form* » by *« Investigating star-formation areas, proto-stars and proto-planetary discs. »*

First Light And Reionization Explorer in FLARE

Main Science Objectives

II. Formation of Stars (and Planets) the Milky Way (~10-20%)

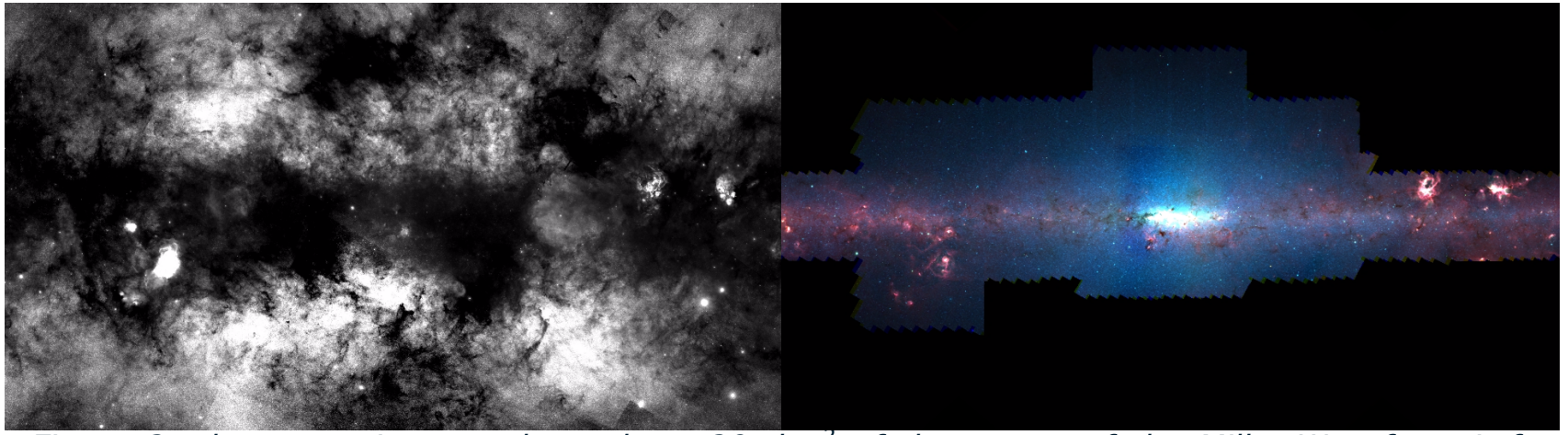

Figure 2: these two images show about 20 deg^2 of the center of the Milky Way from Left, optical image (DSS2 red). Right, near-infrared composite IRAC image from several programmes (GLIMPSE, SAGE, SAGE-SMC and SINGS). Two important points emerge : a) the near-infrared range clearly allows to study the star formation regions that obscured even in the red and b) the near-infrared coverage is not complete, even at Spitzer's IRAC angular resolution.

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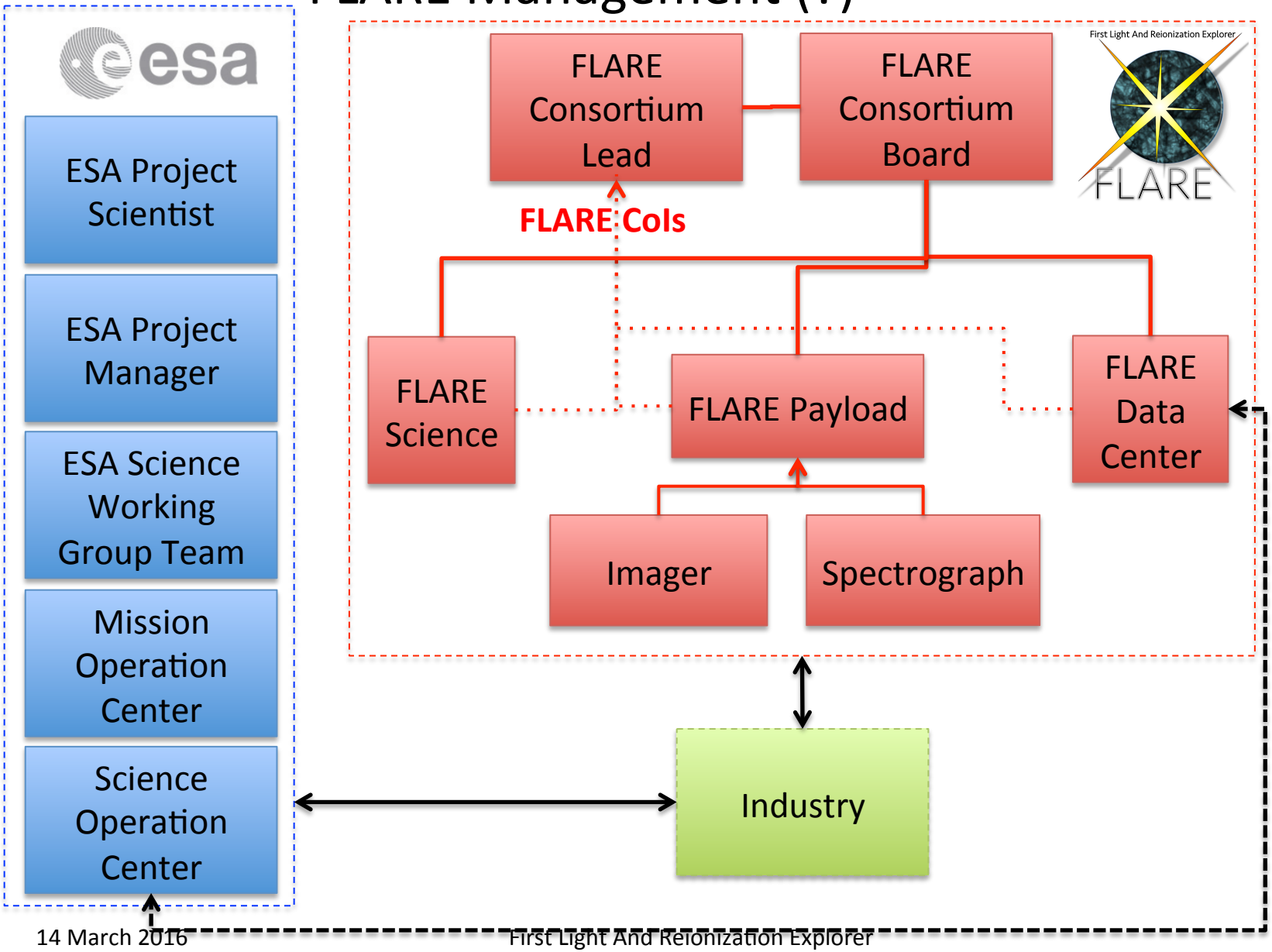
FLARE Concept

FLARE Management (?)



Industry

- Thales-Alenia-Space: discussions started in December 2015 with possible Implications mainly related to the spacecraft (To be confirmed)

FLARE Management (?)

The possible modes of participation to the FLARE might be:

- Principal Investigator (PI), heading the instrument consortium;
- Co-Principal Investigator (Co-PI) may be appointed if a major development is carried out in a country/institution different from the one of the PI; A Co-PI will have similar rights as a PI, but the PI will remain the formal interface to the Project Office;
- Co-Investigator (Co-I), a member of an instrument consortium providing an instrument; Each Co-I should have a well defined role either with regard to hardware/software delivery or with regard to scientific support of the investigations within the instrument consortium.
- Science Steering Committee member for each instrument (if needed?);
- Guest Investigator (GI), a scientist participating in the data analysis of one or more instruments;
- Interdisciplinary Scientist (IDS), an expert in specific overarching science themes connected FLARE's science

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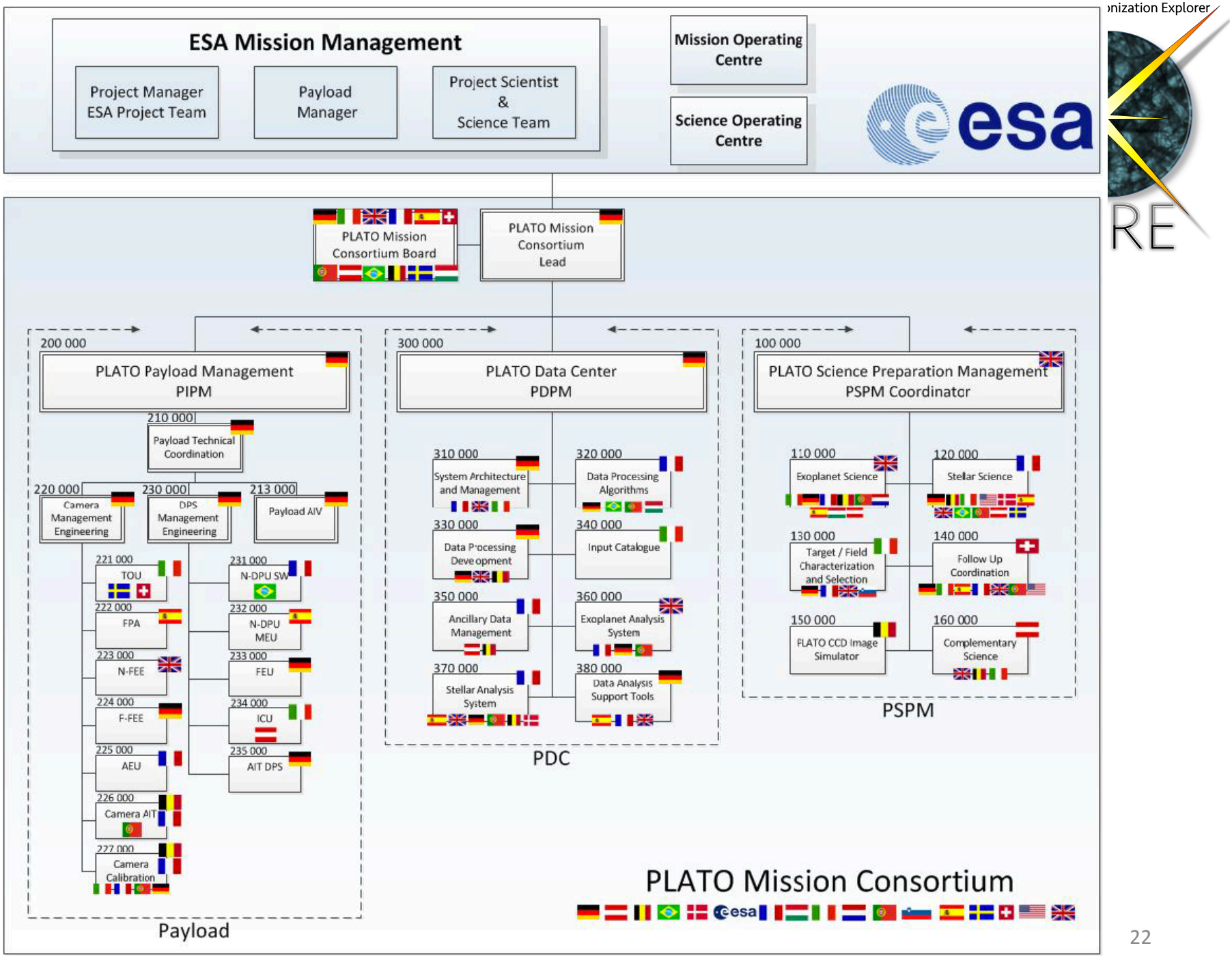
FLARE's Science Working Group

- Group First Light And Reionization:
  - Rychard BOUWENS(Netherlands)
  - Véronique BUAT(France)
  - Andrew BUNKER(United Kingdom)
  - Asantha COORAY (USA)
  - Giovanni FAZIO (USA)
  - Andrea FERRARA(Italy),
  - Ikuru IWATA (Japan)
  - Claudia MARASTON (United Kingdom)
  - Agnieska POLLO (Poland)
  - Giulia RODIGHIERO (Italy)
  - Daniel SCHAERER(Switzerland)
  - David SOBRAL(United Kingdom / Portugal)
- Group First Quasars
  - Jose AFONSO(Portugal)
  - David ALEXANDER(United Kingdom)
  - Raffaella SCHNEIDER (Italy)
- Group Milky Way Science:
  - Laurent CAMBRESY (France)
  - Sergio MOLINARI (Italy)
  - Laurent PAGANI (France)

- Possible additions
  - 1 person from Chili
  - 1 person from Spain
  - System Solar Group
  - Any other relevant person


ESA Mission Management
Project Manager ESA Project Team
Payload Manager
Project Scientist & Science Team
Mission Operating Centre
Science Operating Centre
esa
PLATO Mission Consortium Board
PLATO Mission Consortium Lead
200 000
PLATO Payload Management PIPM
210 000
Payload Technical Coordination
220 000
Camera Management Engineering
230 000
DPS Management Engineering
213 000
Payload AIV
221 000 TOU
222 000 FPA
223 000 N-FEE
224 000 F-FEE
225 000 AEU
226 000 Camera AIT
227 000 Camera Calibration
231 000 N-DPU SW
232 000 N-DPU MEU
233 000 FEU
234 000 ICU
235 000 AIT DPS
Payload
300 000
PLATO Data Center PDPM
310 000 System Architecture and Management
320 000 Data Processing Algorithms
330 000 Data Processing Development
340 000 Input Catalogue
350 000 Ancillary Data Management
360 000 Exoplanet Analysis System
370 000 Stellar Analysis System
380 000 Data Analysis Support Tools
PDC
100 000
PLATO Science Preparation Management PSPM Coordinator
110 000 Exoplanet Science
120 000 Stellar Science
130 000 Target / Field Characterization and Selection
140 000 Follow Up Coordination
150 000 PLATO CCD Image Simulator
160 000 Complementary Science
PSPM
PLATO Mission Consortium

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Starting to build the FLARE consortium will be on the agenda of Tuesday afternoon and Wednesday morning

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« builder » team (as of SoI)

Institute	Expertise	Country	ESA Member ?
Laboratoire d'Astrophysique de Marseille	Management, Mechanics, Optics, Assembly, Integration and Tests	France	Yes
Centre de Recherche Astrophysique de Lyon	Mechanics, Optics, Assembly, Integration and Tests	France	Yes
Scuola Normale Superiore, Pisa	S/W calibration, Optics	Italy	Yes
Universidad Complutense Madrid	Control System	Spain	Yes
Rutherford Appleton Laboratory	Spacecraft Systems, Cryogenics, Operations	UK	Yes
University of Leicester	Structural Design and Manufacturing	UK	Yes
The Open University	Contro H/W and S/W, testing	UK	Yes
National Centre for Nuclear Research, Jagiellonian University, Space Research Center of Polish Academy of Sciences	On-board Electronics and Mechanical elements	Poland	Yes
Observatoire de Genève	Instrument Control Center	Suisse	Yes
National Observatory of Athens	Software, Calibration	Greece	Yes
Smithsonian Astrophysical Observatory	Detectors	USA	No
Caltech/JPL/University of California	Detector Characterisation	USA	No
University of Antofagasta	Software Development, TBD other	Chile	No

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FLARE's Strategy and Performances

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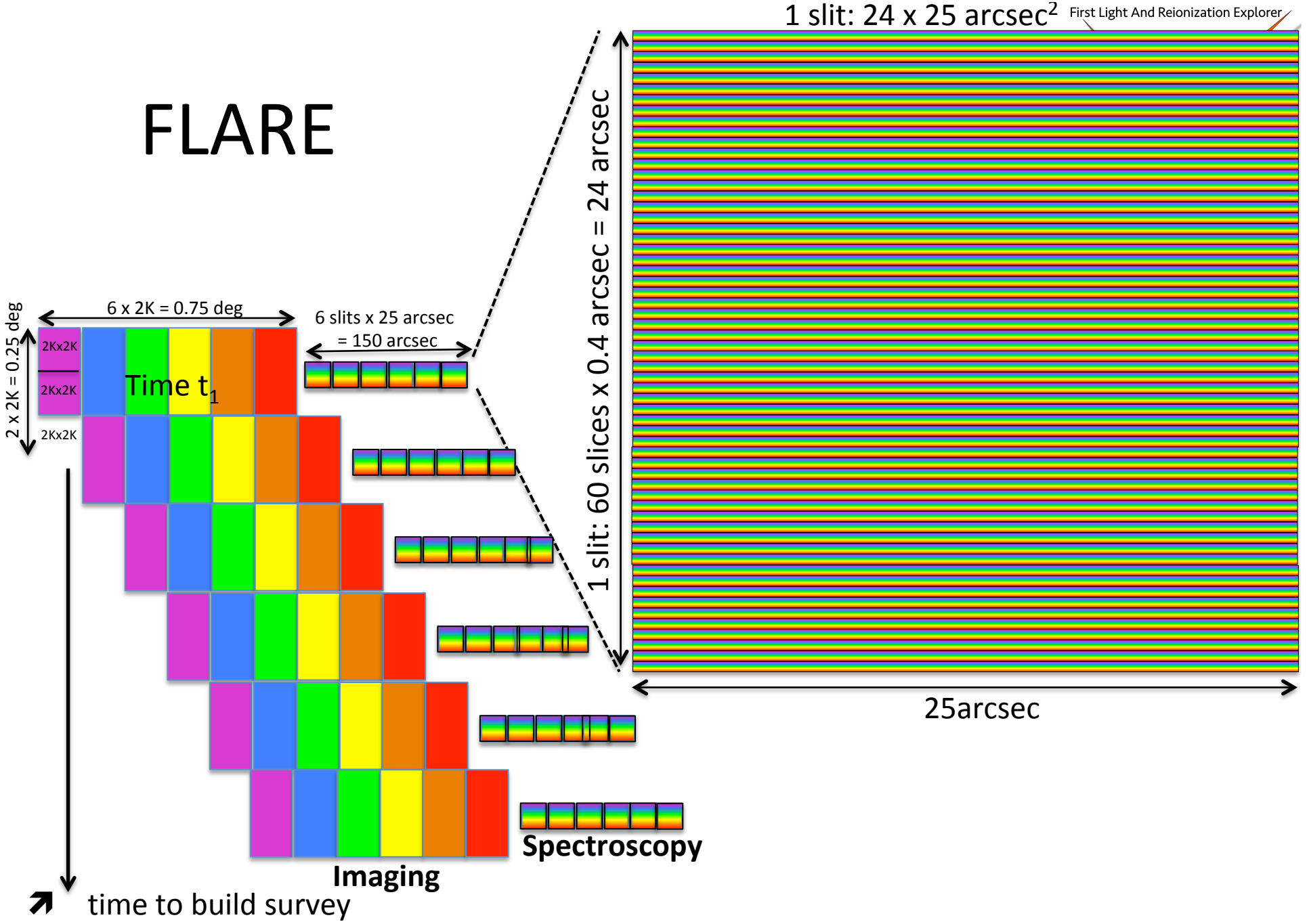
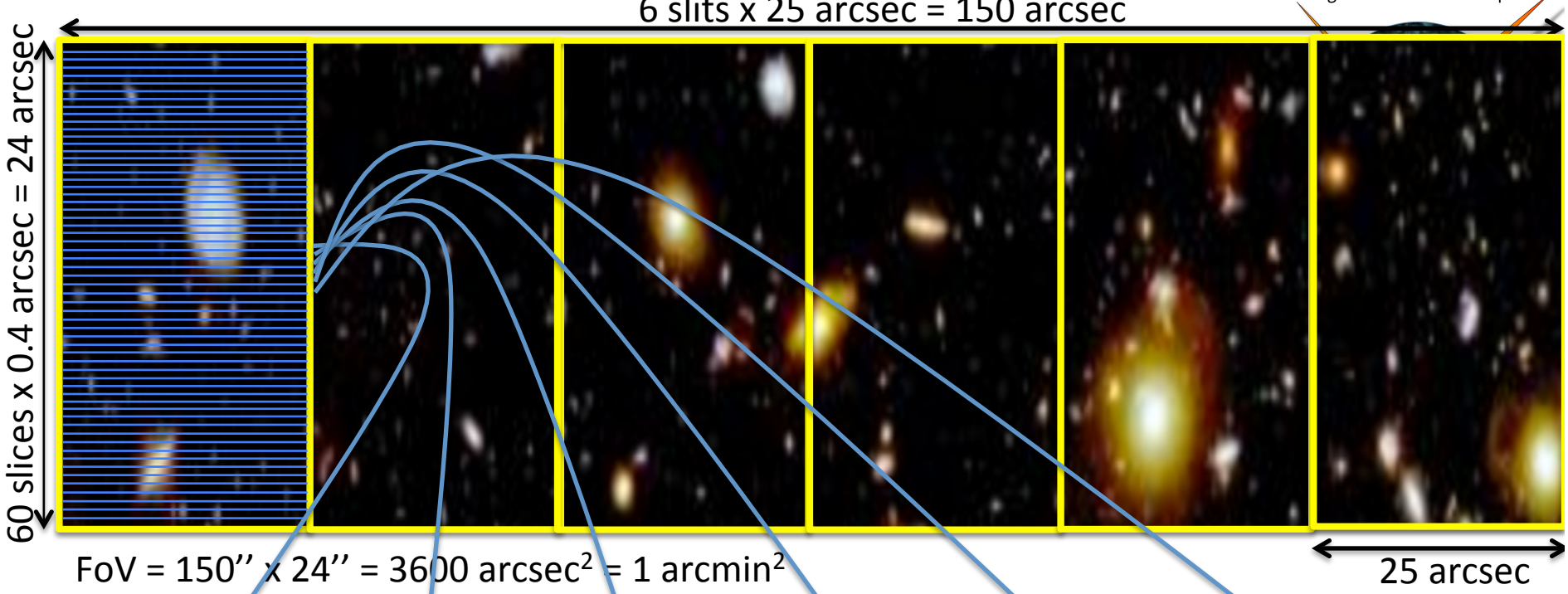
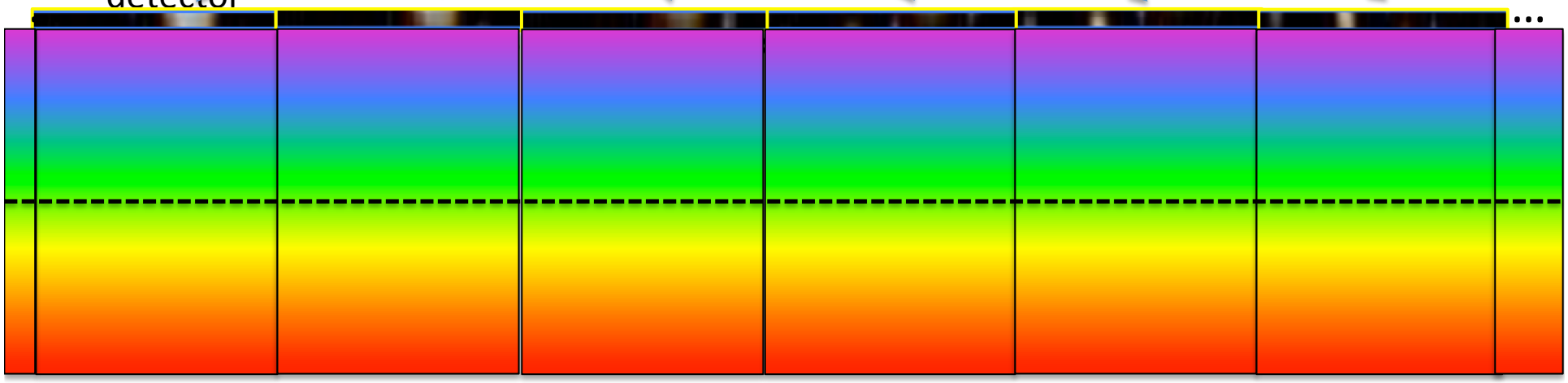

1 slit: 24 x 25 arcsec^2
1 slit: 60 slices x 0.4 arcsec = 24 arcsec
25arcsec
6 x 2K = 0.75 deg
2 x 2K = 0.25 deg
2Kx2K
2Kx2K
2Kx2K
Time t_1
6 slits x 25 arcsec
= 150 arcsec
Spectroscopy
Imaging
time to build survey



FoV = 150'' x 24'' = 3600 arcsec^2 = 1 arcmin^2

Each of the 60 slices of the 6 slits aligned as below

=> 2 x 2K = 4096 pxl / 60 slices = 68 pxl / slice => 25 / 68= 0.366 arcsec / pixel on the detector



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Imaging (12 2K x 2K detectors):

Imaging FOV: 0.75 x 0.25 deg^2 with photometric pixel scale: 0.22 arcsec

(6 x 2K) x (2 x 2K) = 12 x (2K x 2K) = (6 x 2048 x 0.22) x (2 x 2048 x 0.22)

= 2703.36'' x 901.12'' = 2 436 052 arcsec^2

⇒ **Imaging FoV** = 2 436 052 arcsec^2 = 677 arcmin^2

= **0.75 x 0.25 deg^2 = 0.188 deg^2**

The photometric survey will be: 170 deg^2, we need 170/0.188 ~ 900 tiles of 0.188 deg^2

Available exposure time for FLARE extragalactic surveys:

=> 80% x 80% x 5yr x 365d x 24h x 3600 sec = 100 915 200 sec

Exposure time per photometric tile: 1.0 10^8 / 900 = 111 600 sec or 31.0 h

=> we need 31.0 h / 6 filters = **5.12 h for each filter**.

We assume we have 30 x 30 = 900 tiles = >900 x 0.188 deg^2 ~ **169.2.5 deg^2** and it will take 900 x 6 x 5.12 h ~ 3.16 years / 0.8 / 0.8 ~ **4.9 years for FLARE extragalactic surveys**

Spectroscopy (12 2K x 2K detectors):

6 slits x 25'' = 150'' with 1 slit = 60 slices x 0.4''= 24''

Spectroscopic FoV = 150''x 24'', i.e., spectrocopic FoV = 3600 arcsec^2 = **1 arcmin^2**

For each slice: 25''/ 0.366'' = 68 pixels, i.e. 6 slits x 60 slices x 68 pixels = 24480 pixels or about 12 x 2K

Exposure time per spectroscopic tile (same as photometric tile): **5.12 h**

The spectroscopic survey will be: 1.0' x 900 tiles x 6 filters = 5400 '^{2} = **1.5 deg^2**

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First Light And Reionization Explorer (FLARE)
A mission proposal for ESA M5
The Starry Night - Vincent van Gogh - Arles 1889
dénis.burgarella@lam.fr

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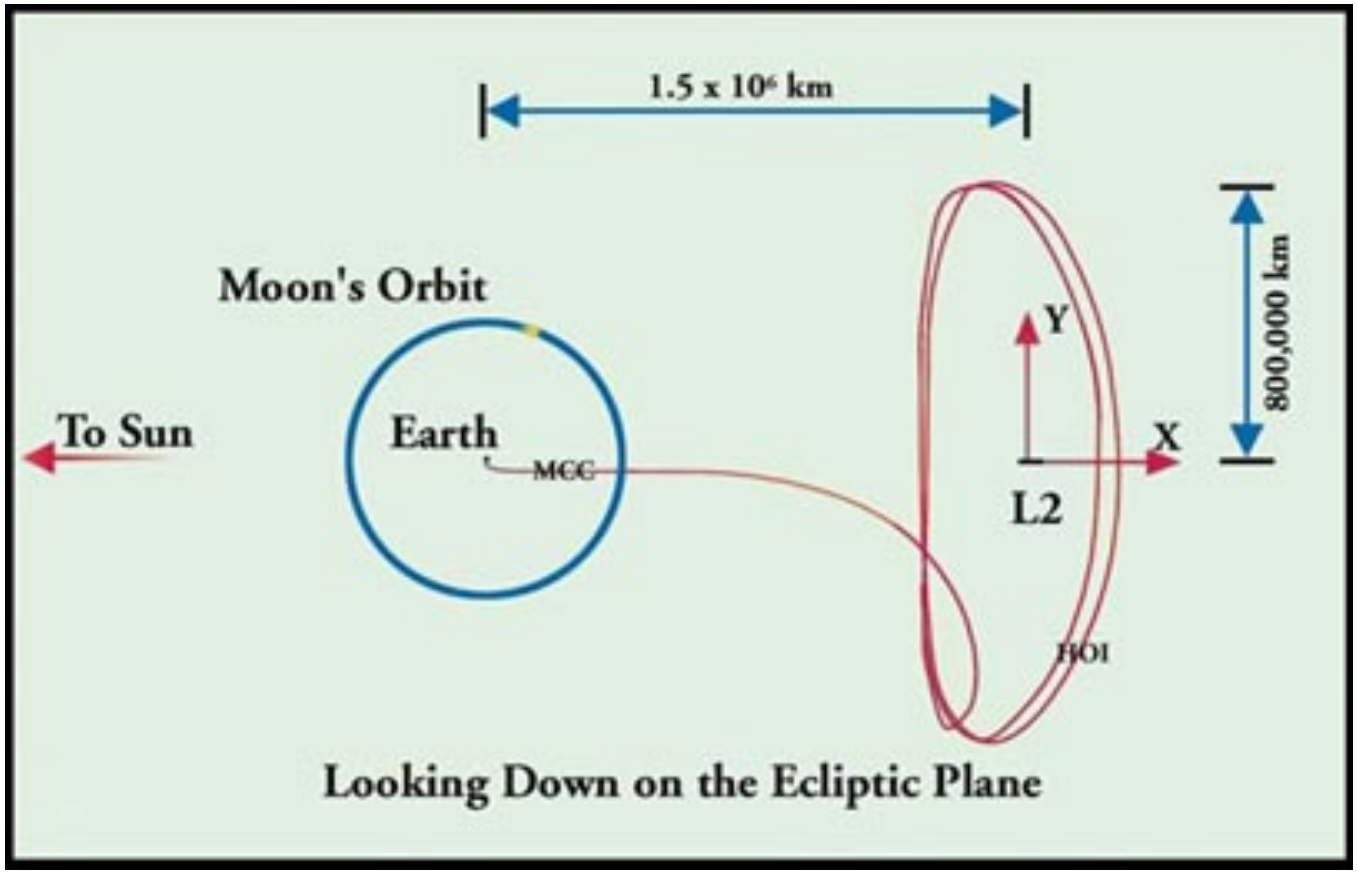
FLARE orbiting L2



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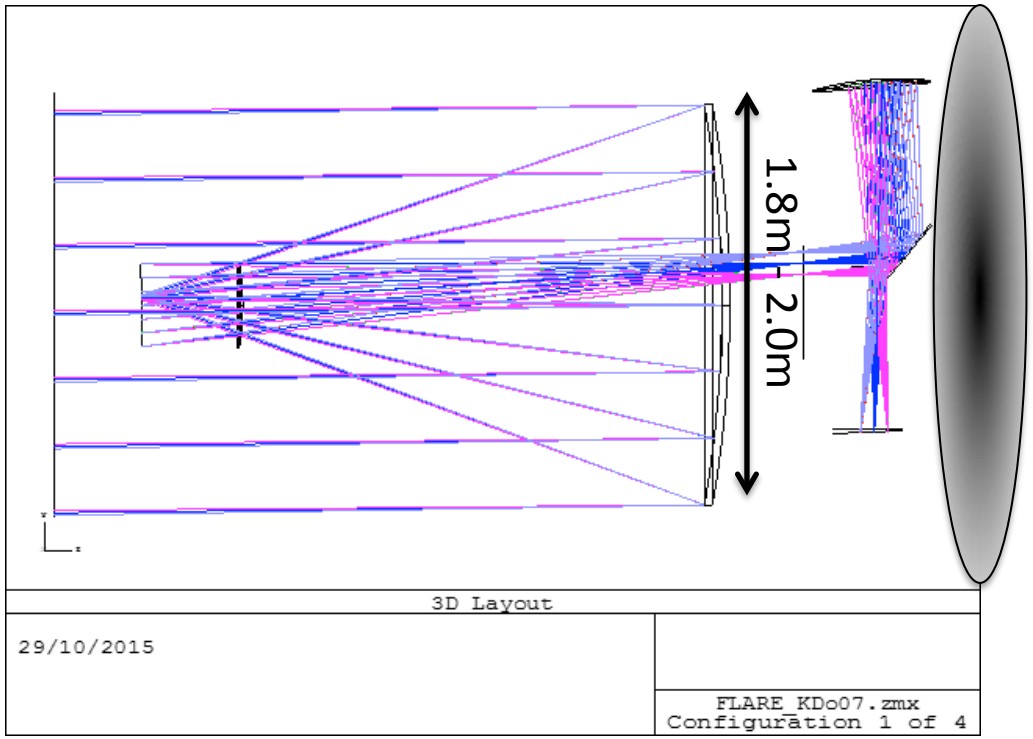
FLARE: design telescope #1



Sun shield

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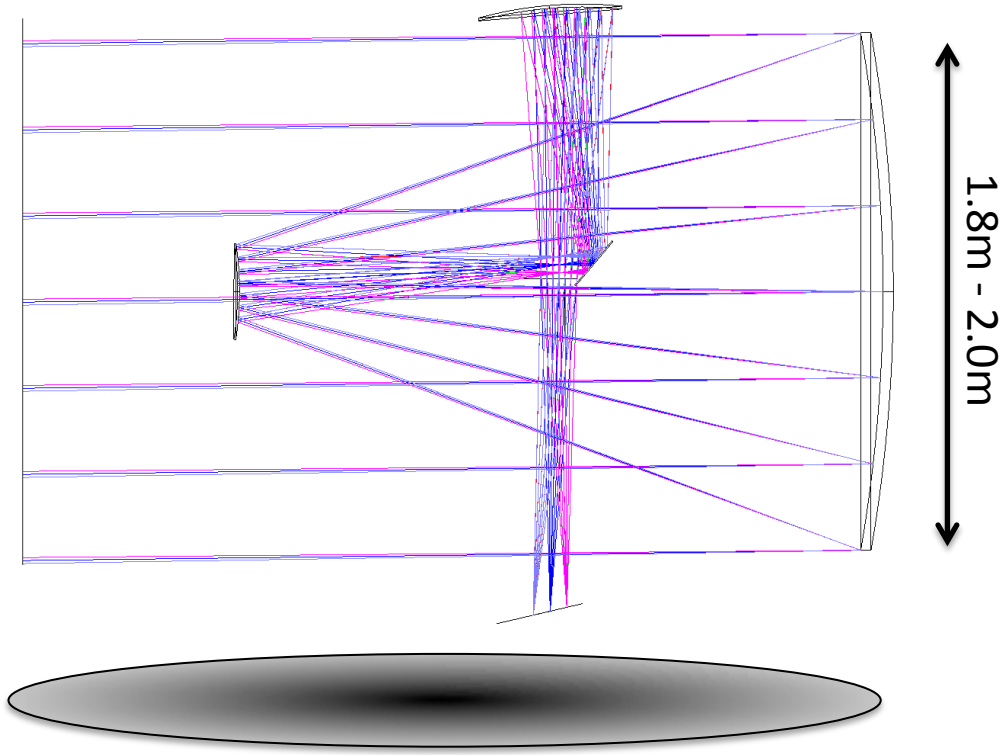
FLARE: design telescope #2



Wavelength range	1 – 5 μm
6 filters	Identical to JWST NIRCam wide-bands
Imaging sensitivity	Better that m_{AB} = 27 - 28
Spectroscopic sensitivity	Better than $f_\lambda = 3\times10^{-18}$ erg/cm²/s&
Primary mirror (M1)	2.0 m
Secondary mirror (M2)	18.7% of M1: 0.374 m
Imaging pixel scale	0.22 arcsec
Transmission telescope	4 mirrors: 0.97^4 = 0.885
Encircled energy at first PSF minimum	0.885
First PSF minimum	0.441 arcsec @ 3.4um for 2.0m
Strehl ratio	0.90
Spectral resolution imaging R	4
Length of each slice	0.4 arcsec
Spectral resolution spectroscopy R	750
Integrated area to compute SNR imaging	[int(0.441 / 0.15)]^2 pixels
Collecting area	π [r(M1)^2 – r(M2)^2] cm²
Pixel scale spectroscopy	1 slice = 0.4 arcsec
Integrated area to compute SNR spectroscopy	0.4^2 arcsec
Transmission spectrograph	10 mirrors (0.97^10) * grism (0.70) = 0.516
Emissivity for thermal emission	5%
Temperature of telescope	80K
Individual sub-exposure imaging	500 sec
Individual sub-exposure spectroscopy	500 sec
Read-out noise	15 e-
Temperature detector	50 – 60K
Dark	0.05 – 0.10 e-/sec/pix
QE (assumed constant)	0.75
ADU	1.53 e-/ADU
Total survey time per pixel (imaging and spectroscopy)	~18000 sec for 2.0m-telescope to reach the depth

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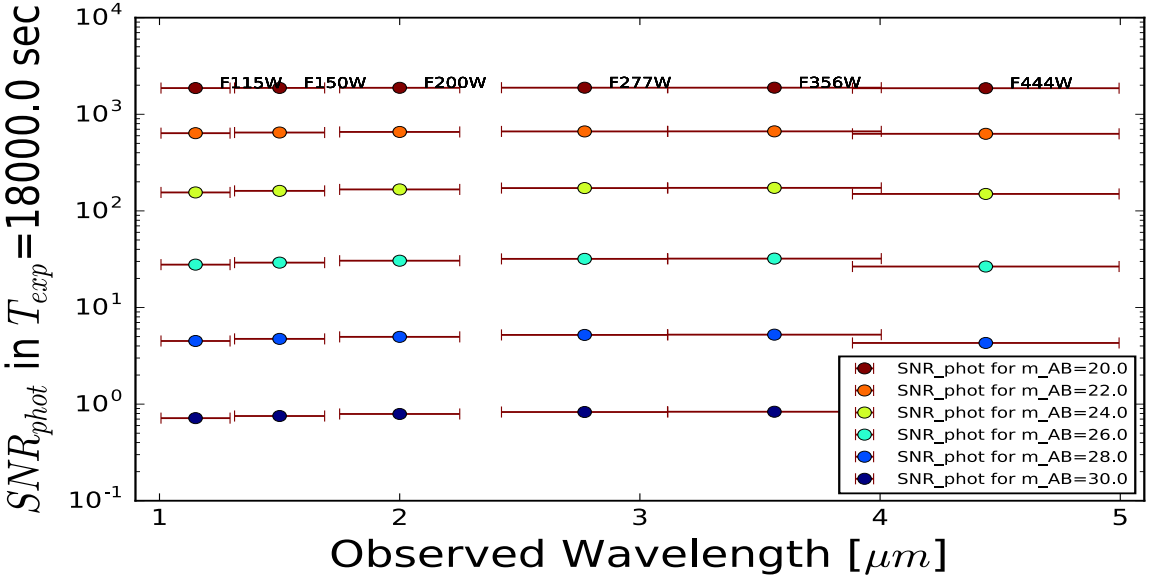

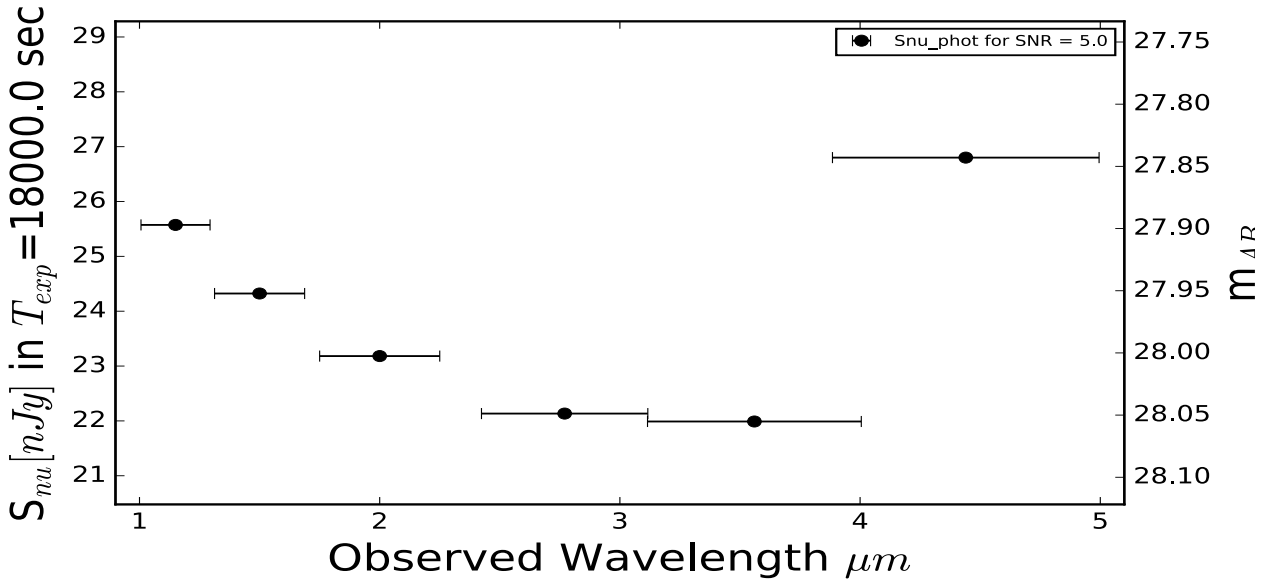

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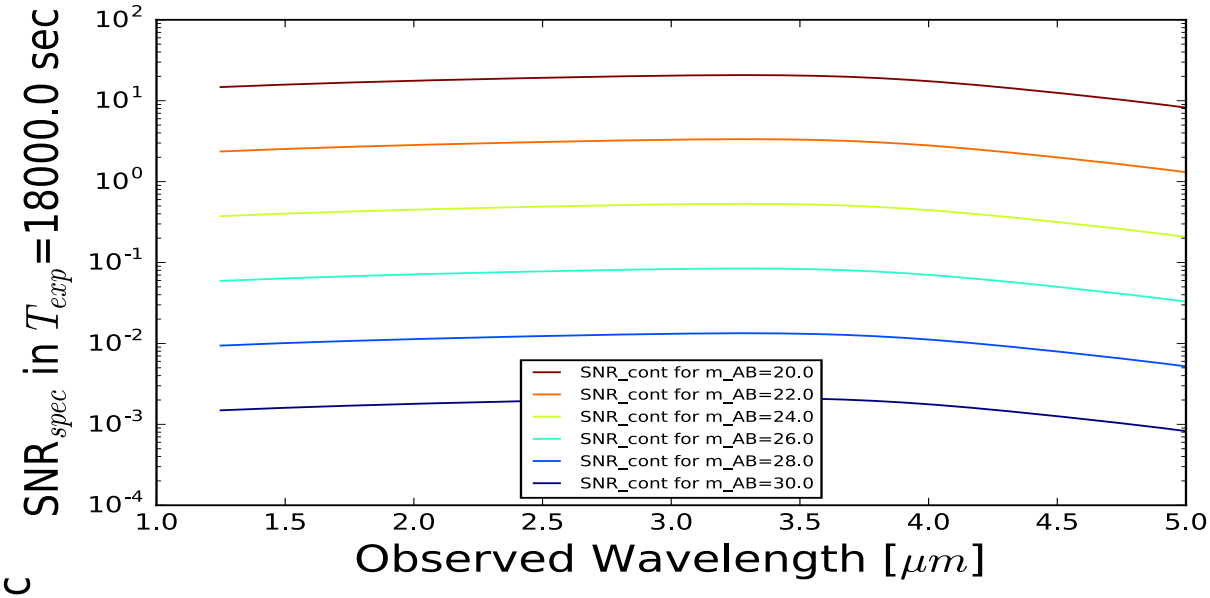

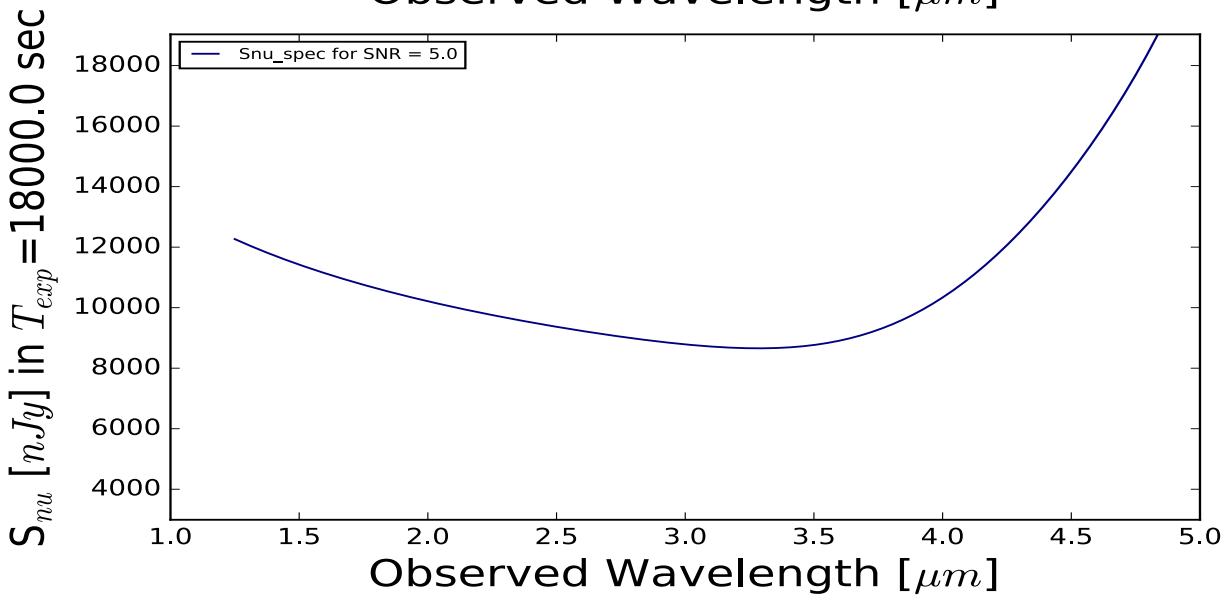

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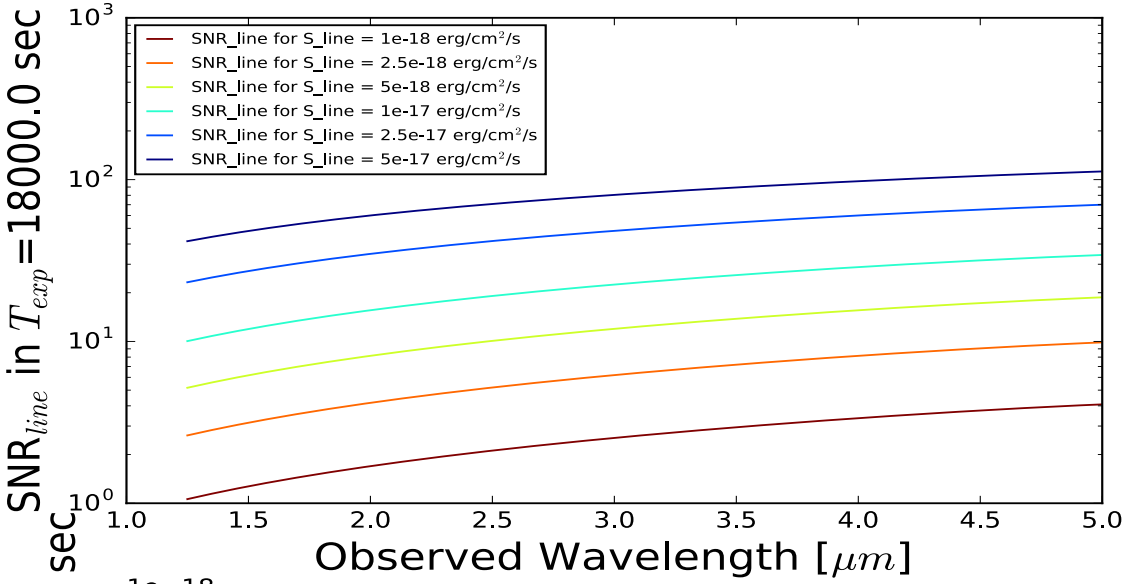

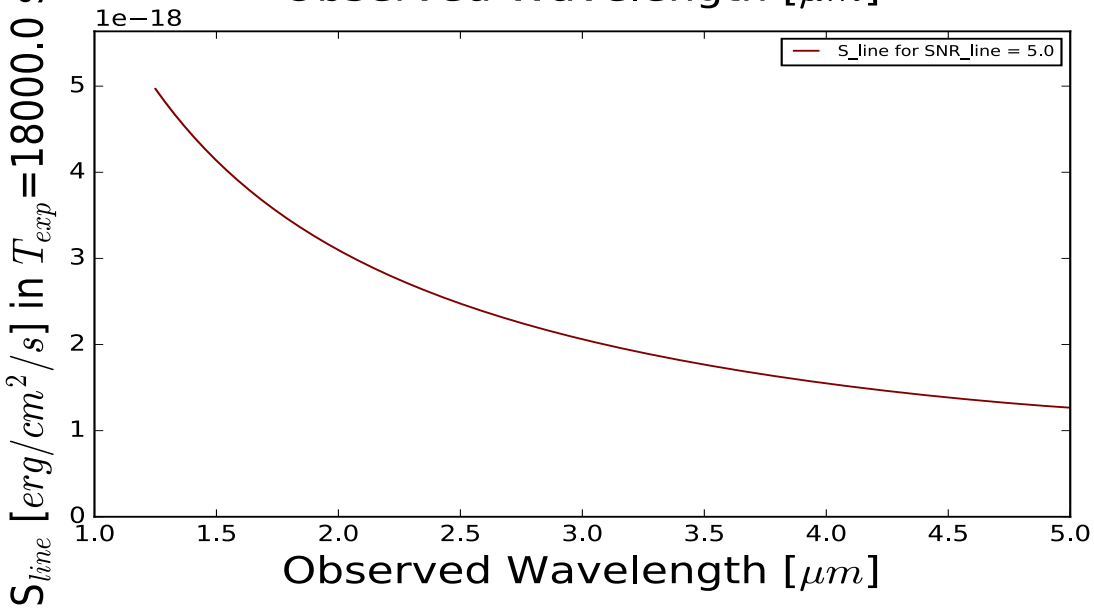

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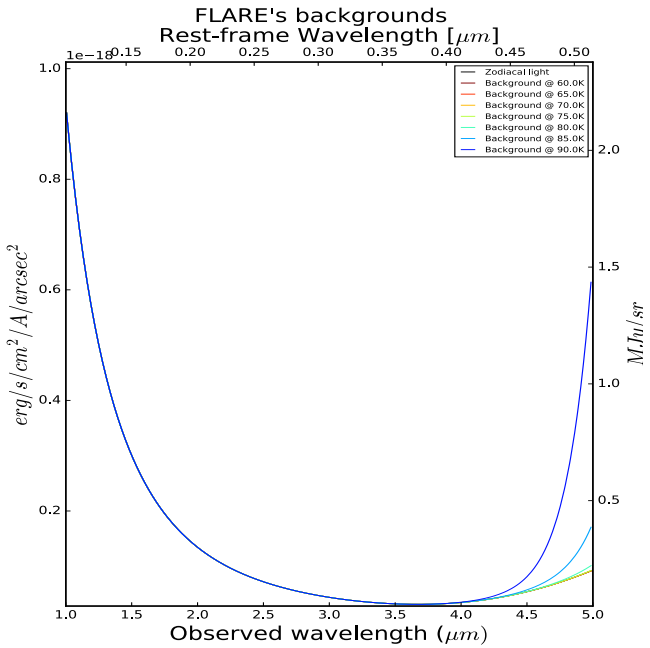
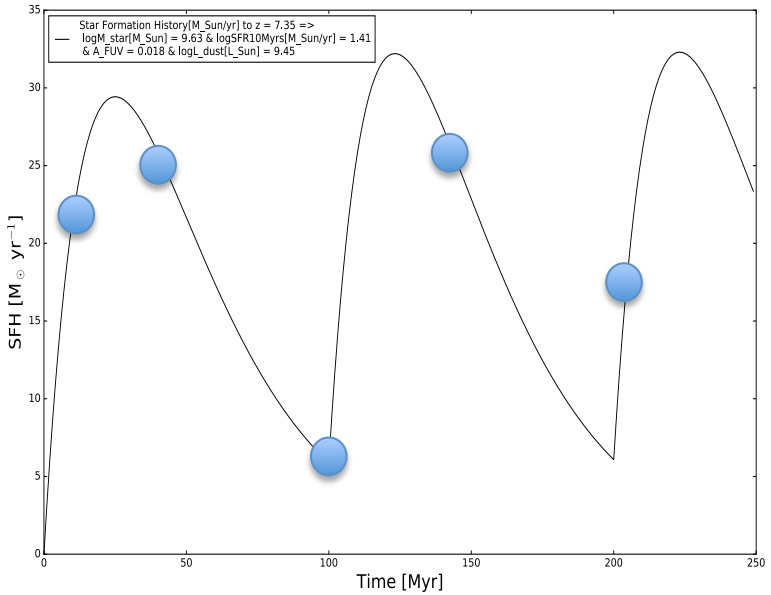
Simulations observations

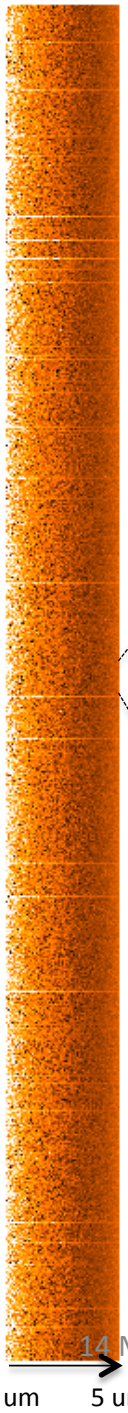


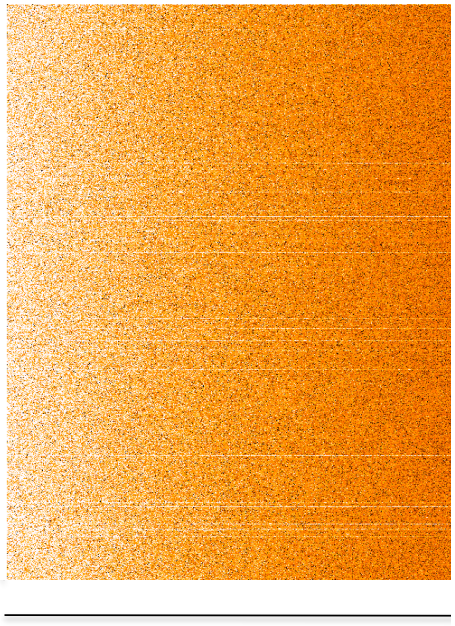


Zodi+thermal+détectors

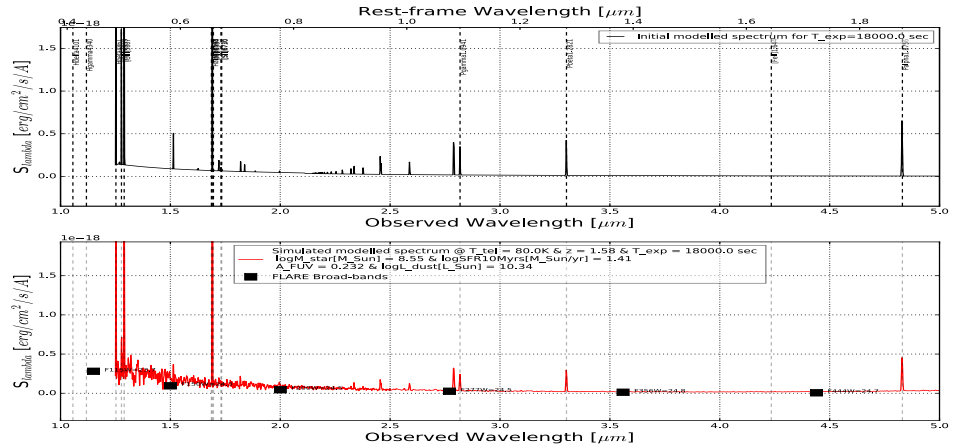
Emission of the galaxies along their Star Formation History using all the parameters allowed in *CIGALE* (stars, dust, AGN, gas, IGM)

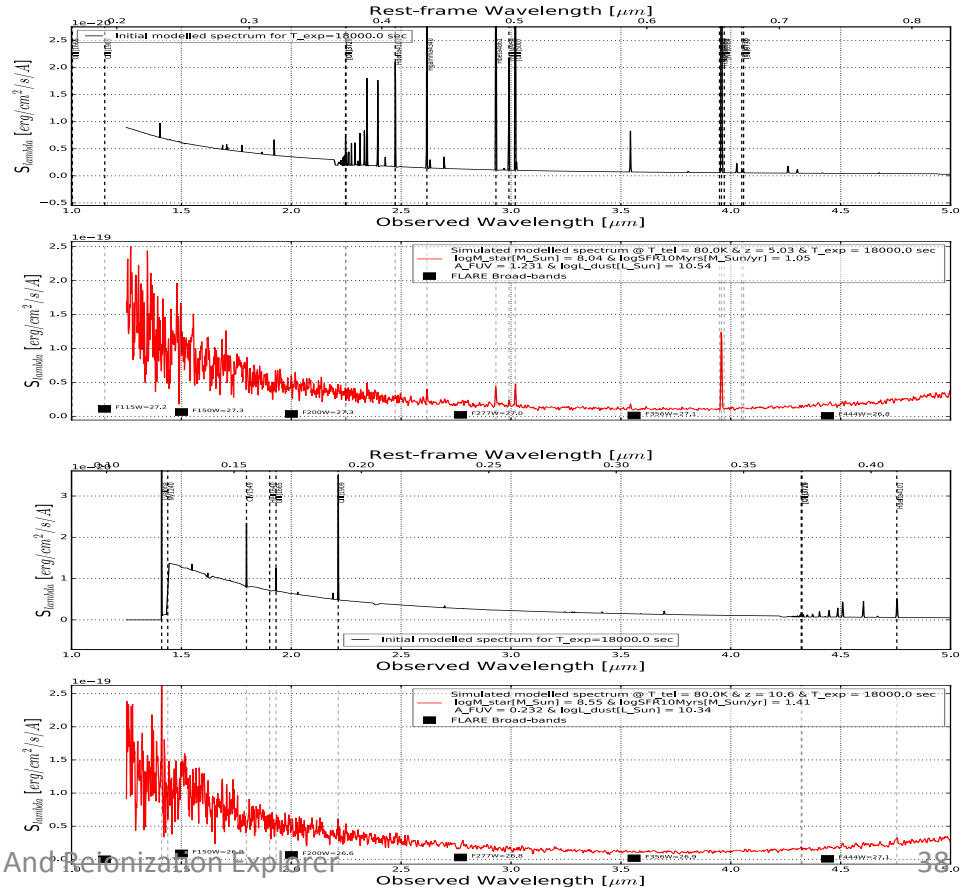
About 5000 galaxy (N(z) from from eGalics semi-analytical model, Cousin et al. 2015) spectra included in these FLARE simulations at z = 1.58, z ~ 5 and z ~ 10 (from top to bottom).





1 um 5 um



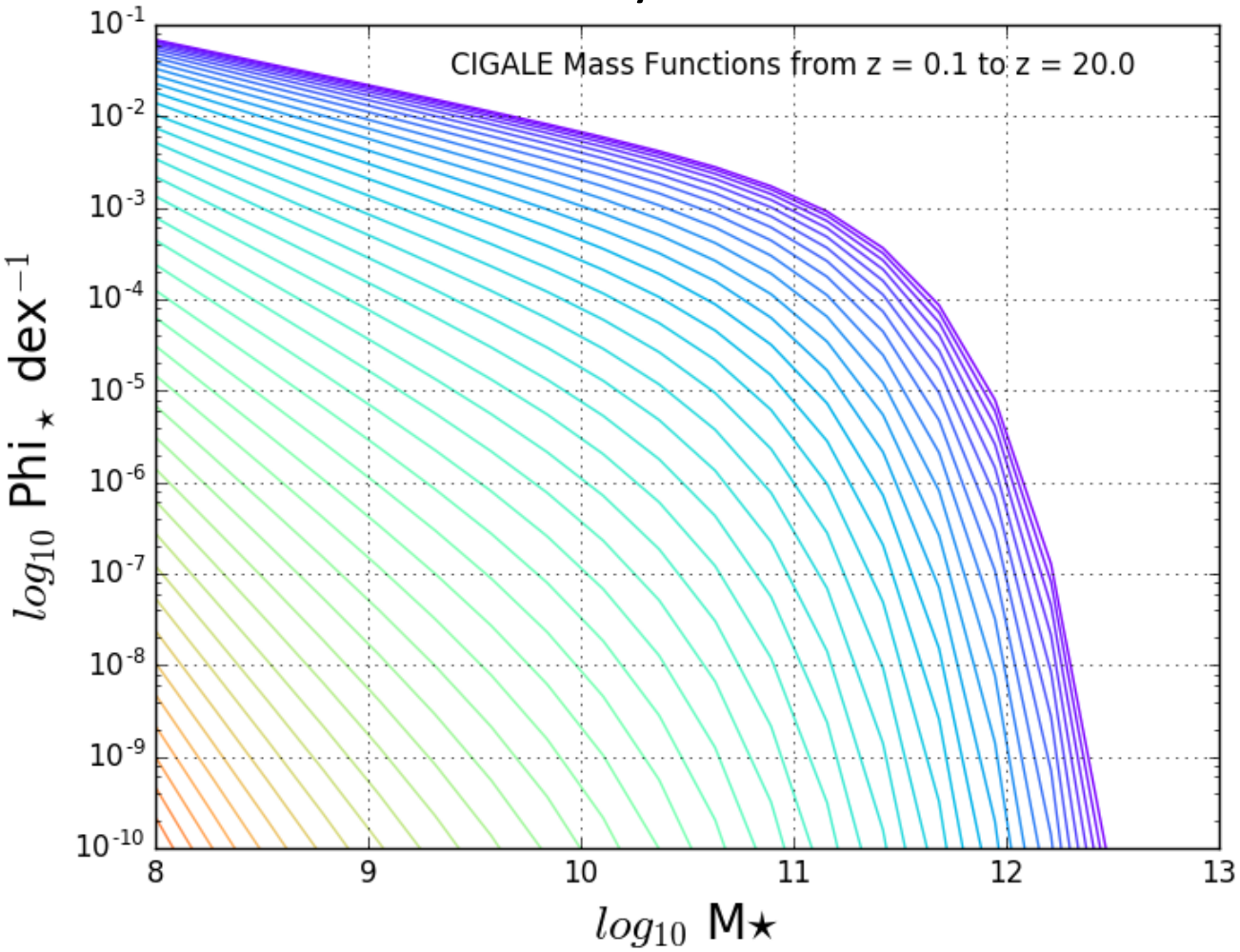


First Light And Reionization Explorer

FLARE

New CIGALE-Sim version in development

- Galaxies constrained by Stellar Mass Functions

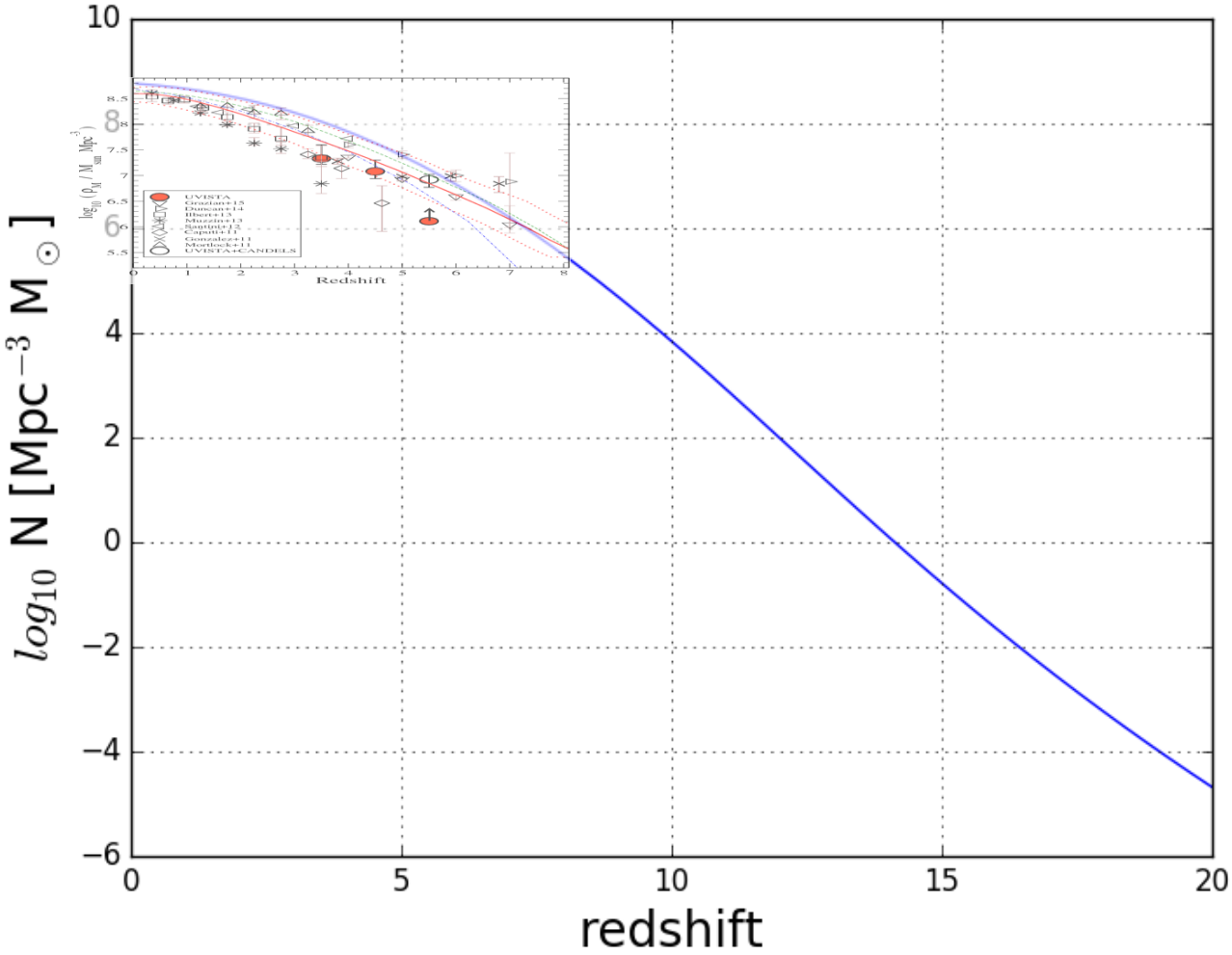


First Light And Reionization Explorer

FLARE

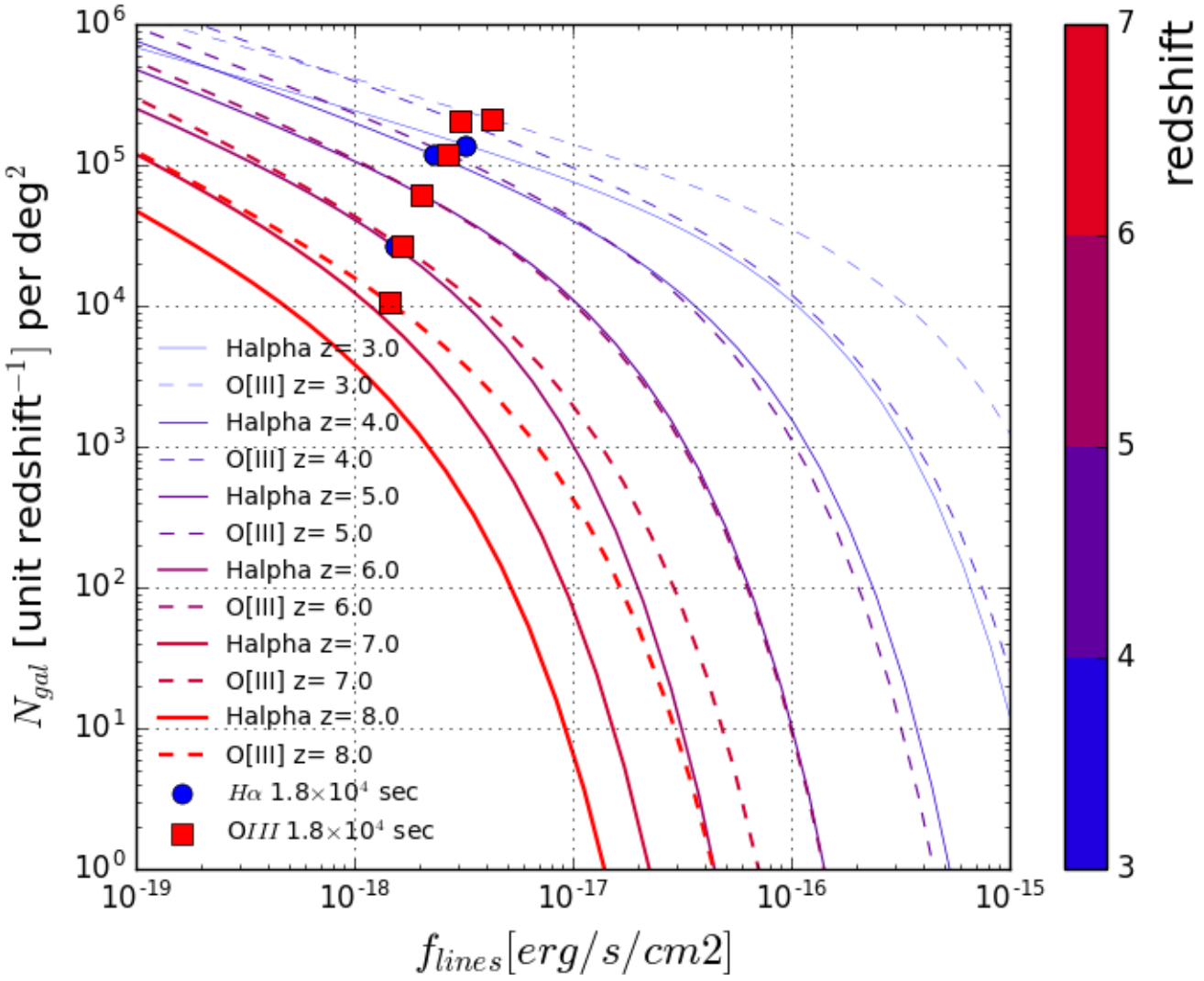
New CIGALE-Sim version in development

- Galaxies constrained by Stellar Mass Functions
- Galaxies constrained by UV Luminosity Functions



First Light And Reionization Explorer

FLARE



Number of galaxies detected at 2.5<z<8.5 in Halpha and [OIII]5007 by FLARE

First Light And Reionization Explorer

FLARE

- Comparison of several (spectroscopic) facilities to perform galaxy physics (**at least 5 lines in the optical range:** *[OII]λ3727, [OIII]λ4959, 5007, Hβ, [NII]λ6584* and *Hα* ratio) and to measure redshifts (at least 2 lines) as a function of the redshift. Note that we do not take UV lines and NIR lines and PAH into account.

• As expected from the usable wavelength ranges of each of the telescopes, FLARE and JWST/NIRSpec are much more adapted to the very high redshift (i.e. z > 3).

• On the spectroscopic side, assuming ~ 1 x 1 arcmin^2 field of view, FLARE **should observe more spectra than NIRSpec**.

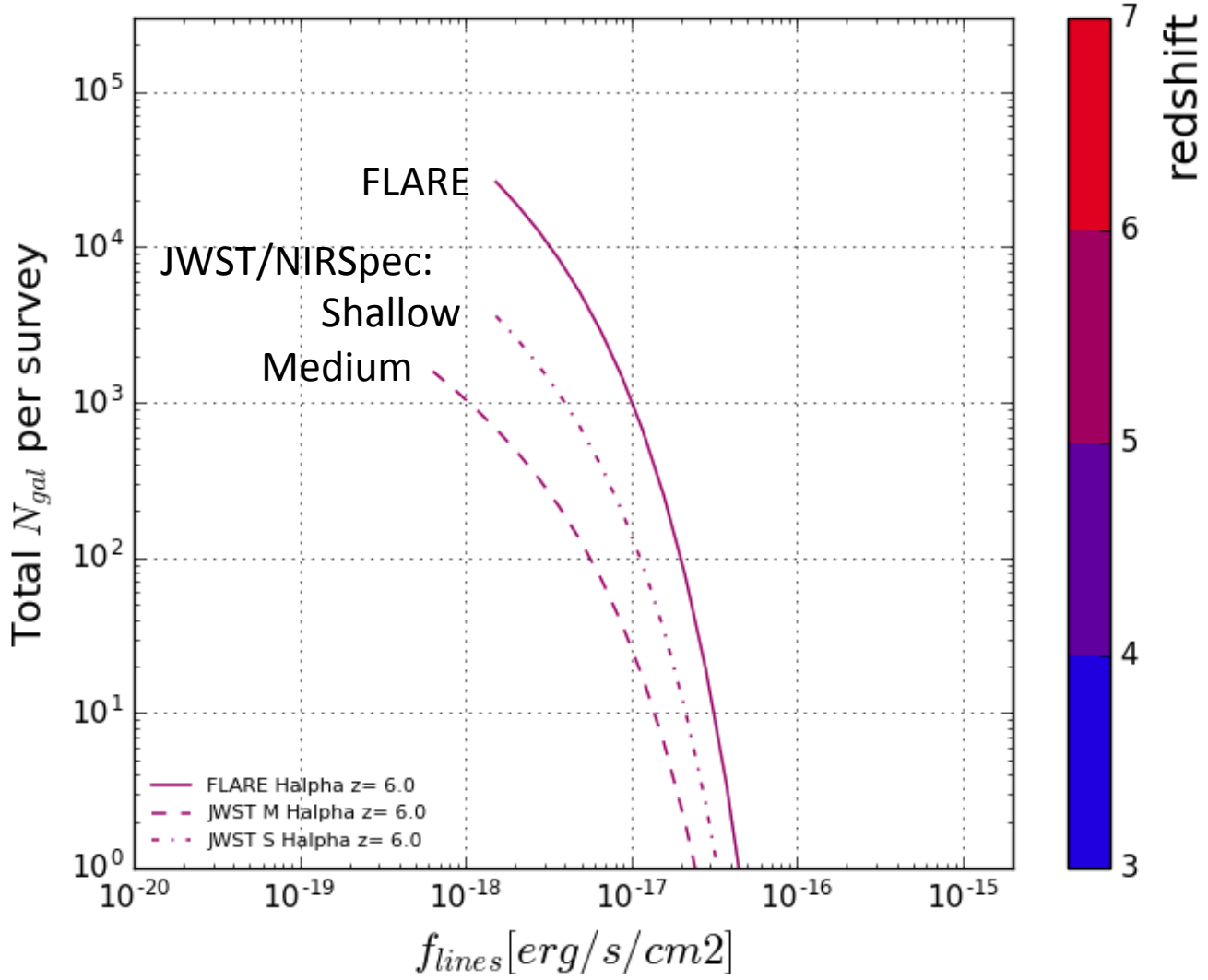
Redshift	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
WISH/Spec	4	7	7	7	7	7	5	5	4	2	2	2	1	1	1
JWST/NIRSpec	4	7	7	7	7	7	5	5	4	2	2	2	1	1	1
EUCLID/NISP	6	7	3	1	0	0	1	1	1	1	1	1	1	1	0
HST/WFC3IR	6	4	1	0	0	0	1	1	1	1	1	1	0	0	0
WFIRST	6	7	3	1	0	0	0	0	0	0	0	0	0	0	0
SPICA/MCS	0	0	0	0	0	0	3	3	4	6	6	6	7	7	7
JWST/MIRI	0	0	0	0	0	0	3	3	4	6	6	6	7	7	7

Physics OK Redshift OK BAD

Table valid for the optical lines ***[OII]λ3727, [OIII]λ4959, 5007, Hβ***, ***[NII]λ6584*** and ***Hα***

First Light And Reionization Explorer

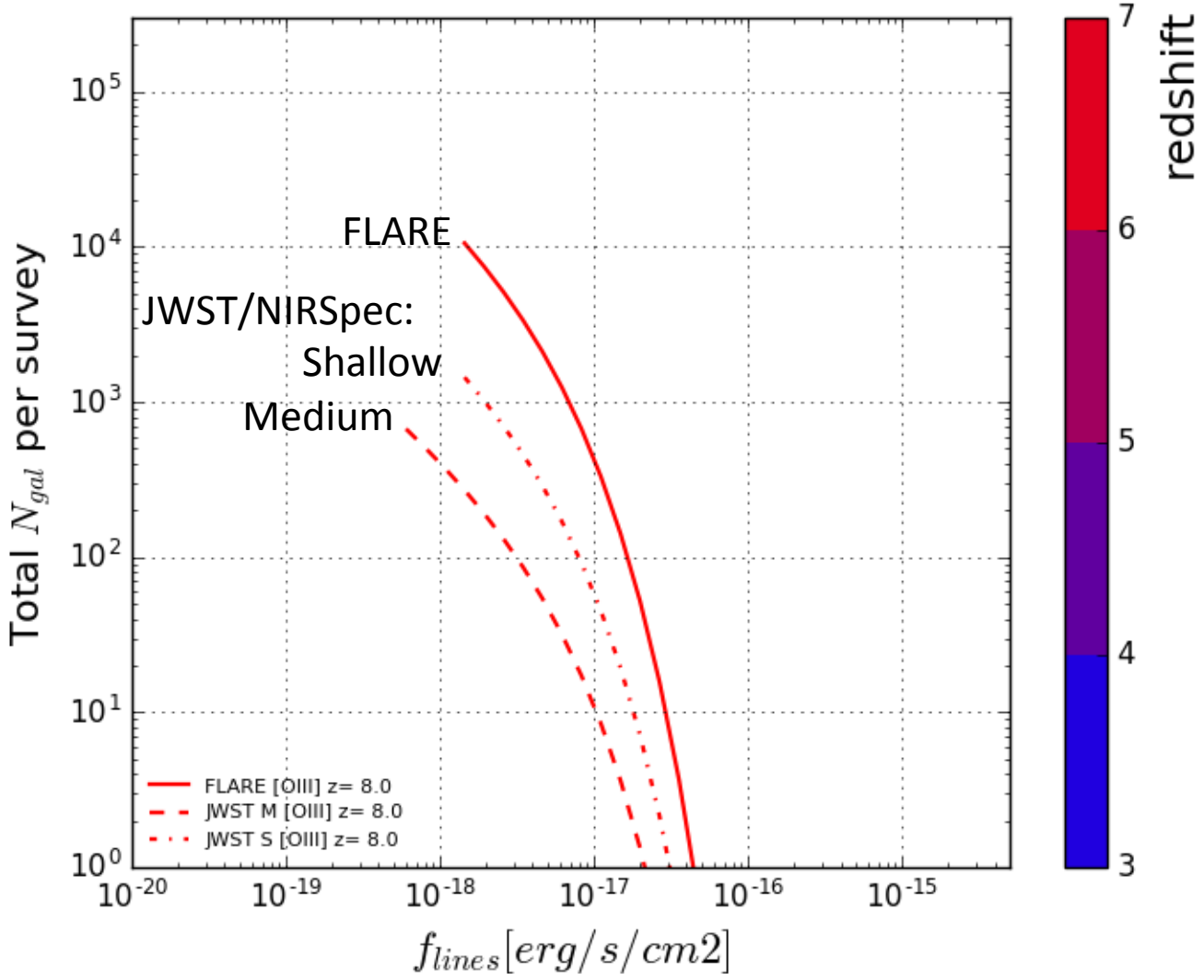
FLARE



Number of galaxies detected at 5.5<z<6.5 in Halpha by FLARE and JWST NIRSpec

First Light And Reionization Explorer

FLARE



Number of galaxies detected at 5.5<z<6.5 in [OIII]5007 by FLARE and JWST NIRSpec

How does FLARE compare To others incoming projects?

	Euclid[a]	WFIRST (DRM1)[b]	WFIRST (NRO)[c]	JWST	FLARE
Mirror	1.2m	1.3m	2.4m	6.5 m	1.8 - 2.0m
FOV	0.55 deg^2	0.375 deg^2	0.375 deg^2	0.0026 deg^2	0.2 deg^2
Visible Imager	0.55 – 0.90 μm	——	——	0.6 – 2.3 μm	——
NIR Imager	0.92 – 2.0 μm	0.73 – 2.4 μm	0.92 – 2.0 μm	1.0 - 5.0 µm	1.0 - 5.0 µm
Lim. Mag. (5σ)	24 AB	26 AB	27.5 AB	29.1 AB[d]	28.0 AB
Survey Area	15,000 deg^2	3,400 deg^2	~ 3,400 deg^2	0.044 deg^2 [d]	170 deg^2
NIR Spectroscopy	1.1 – 2.0 μm	——	Grism 1.3 – 2.0 μm	MOS 3'x 3' IFU 3'' x 3''	Integral Field, R~750, 1' x 1'
Primary Science	Dark Energy, Dark Matter	Dark Energy, Exoplanets, Deep NIR Surveys	Dark Energy, Exoplanets, Deep NIR Surveys	First Galaxies	First Galaxies, Reionization, Galactic Science

[a] [27]; [b] Green et al. [35]; [c] Dressler et al. [22]; [d] JWST NIRCam Mosaic of the Chandra Deep Field South [44];

Activities

before

now

after

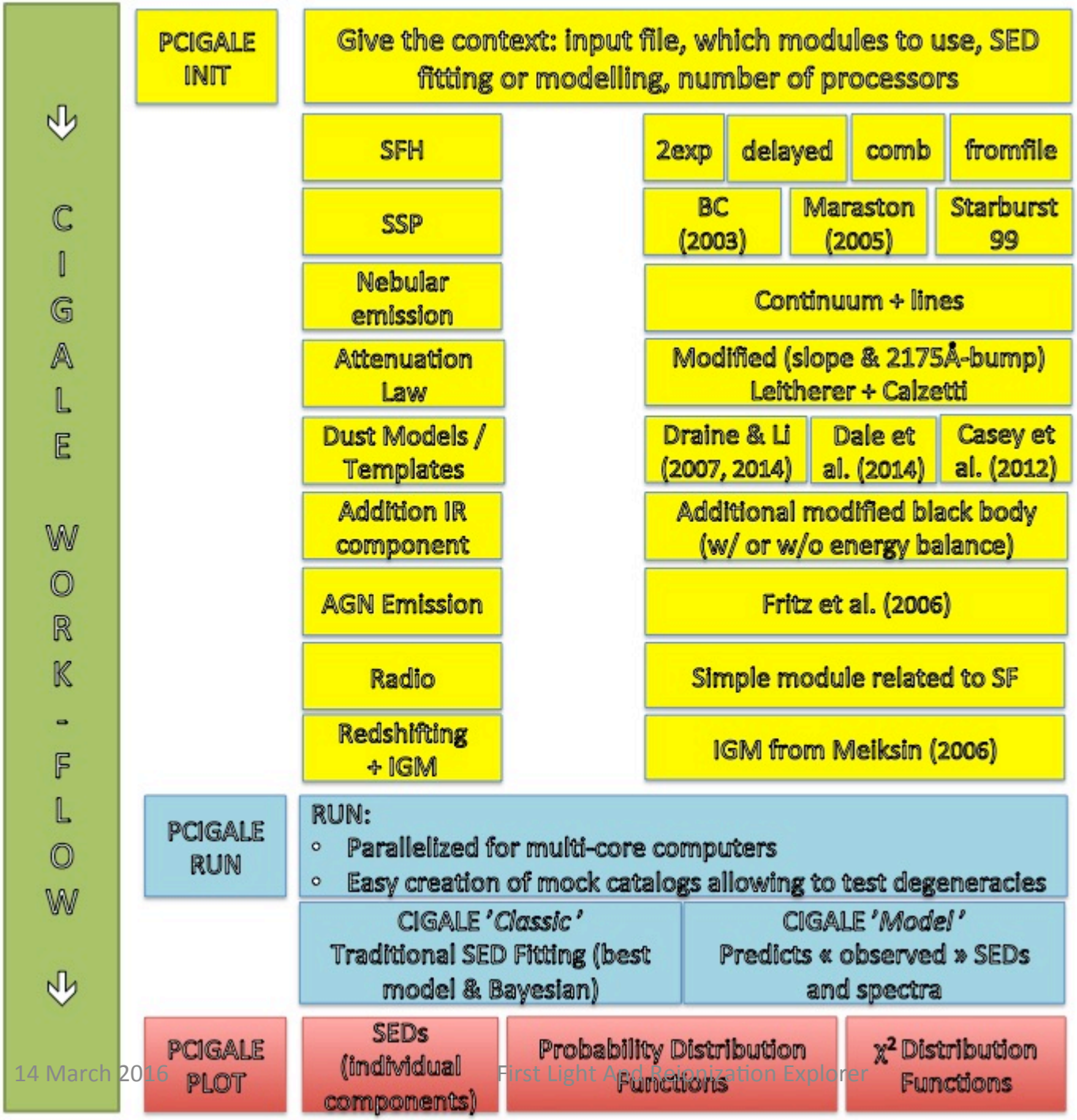
- First general SWG telecon
- Several specific SWG telecon
- Marseille Meeting
- Simulations of observations
- Visits of institutes seriously planning to get technically in FLARE
- Need to present FLARE in and outside Europe
- Work with industry

Conclusions

- Project scientifically ambitious addressing fundamental questions from national and international agencies
  - Statistically significant sample of « first galaxies »
  - Formation of heavy elements
  - Formation of first black holes and role in galaxy evolution
  - Formation planetary systems in Milky Way
- Project technologically realistic using known and tested technologies
  - No mechanisms
  - Passive cooling
  - High TRL detectors in the baseline project
- Strong support from the European and international community

- Caveat: other projects will satisfy the above 3 criteria
  => LOBBYING & COMMUNICATION ARE CRUCIAL

Thank You


CIGALE WORK-FLOW
PCIGALE INIT
Give the context: input file, which modules to use, SED fitting or modelling, number of processors
SFH
2exp
delayed
comb
fromfile
SSP
BC (2003)
Maraston (2005)
Starburst 99
Nebular emission
Continuum + lines
Attenuation Law
Modified (slope & 2175Å-bump) Leitherer + Calzetti
Dust Models / Templates
Draine & Li (2007, 2014)
Dale et al. (2014)
Casey et al. (2012)
Addition IR component
Additional modified black body (w/ or w/o energy balance)
AGN Emission
Fritz et al. (2006)
Radio
Simple module related to SF
Redshifting + IGM
IGM from Meiksin (2006)
PCIGALE RUN
RUN:
Parallelized for multi-core computers
Easy creation of mock catalogs allowing to test degeneracies
CIGALE 'Classic'
Traditional SED Fitting (best model & Bayesian)
CIGALE 'Model'
Predicts « observed » SEDs and spectra
PCIGALE PLOT
SEDs (individual components)
Probability Distribution Functions
χ² Distribution Functions