First Light And Reionization Explorer

FLARE

Outline of the Presentation

- Context
- Scientific Objectives
- What is FLARE?
- Can you get involved? ***[Def. = Yes]***
- Conclusion

Context

- **20 July 2015:** The Director of Science and Robotic Exploration of ESA 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
- **Schedule** will be presented/discussed with the SPC at the February 2016 meeting:
  - *Call in March April 2016*
  - Technical and Programmatic Screening
  - *Deadline in Summer 2016*
  - Selection End of 2016 of <=3 (TBC) of proposals for a study phase (~ 18 months, TBC), later down-selection to 1.

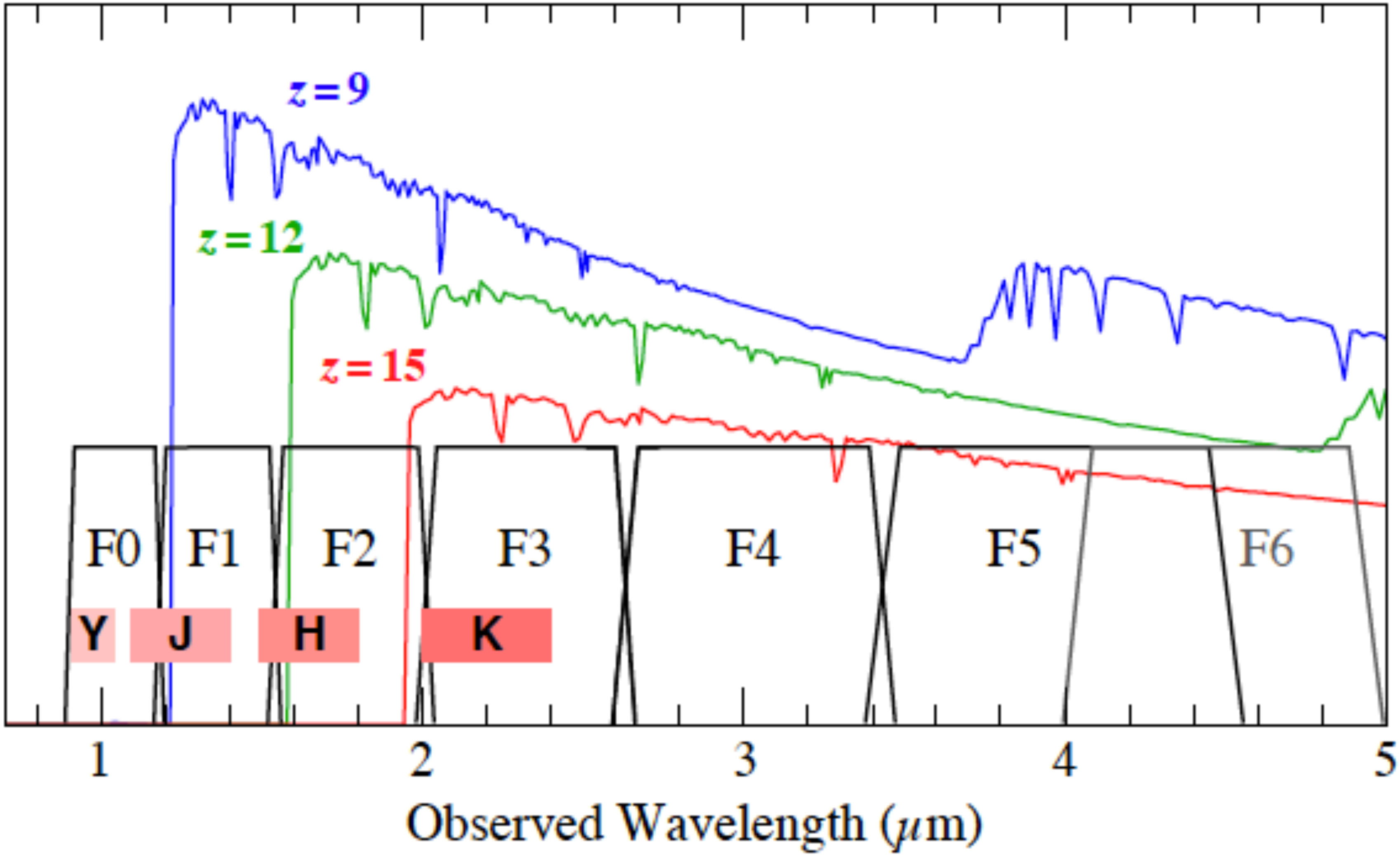
http://sci.esa.int/cosmic-vision/56198-announcement-of-the-plans-for-the-issuing-of-a-call-for-a-medium-size-mission-for-launch-in-2029-2030-m5/

Main Science Objectives

I. FLARE: First Light And Reionization Explorer (~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. »*

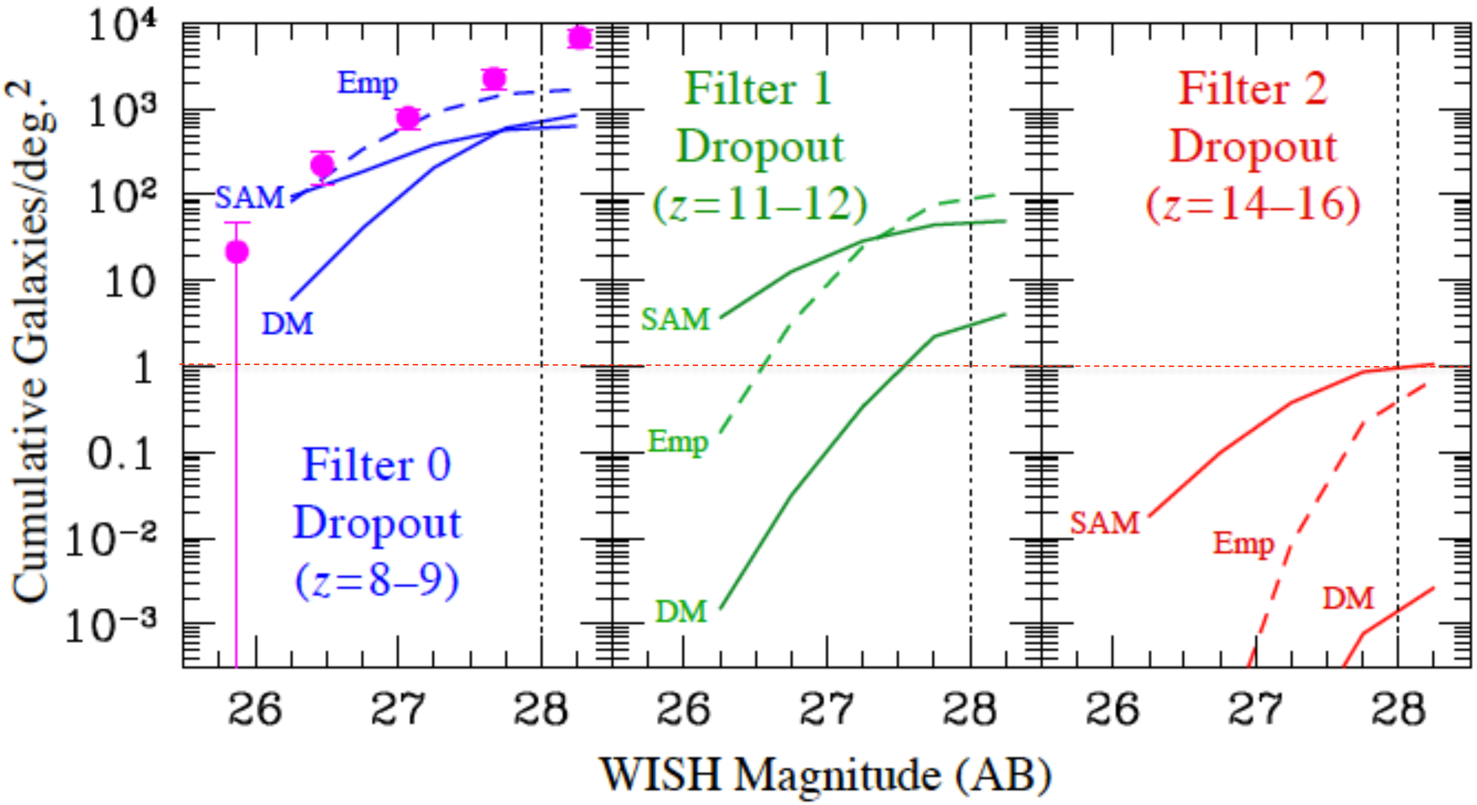
Passbands for the FLARE Filters
(same filters than JWST/NIRCam)



Main Science Objectives

I. FLARE: First Light And Reionization Explorer (~80%)

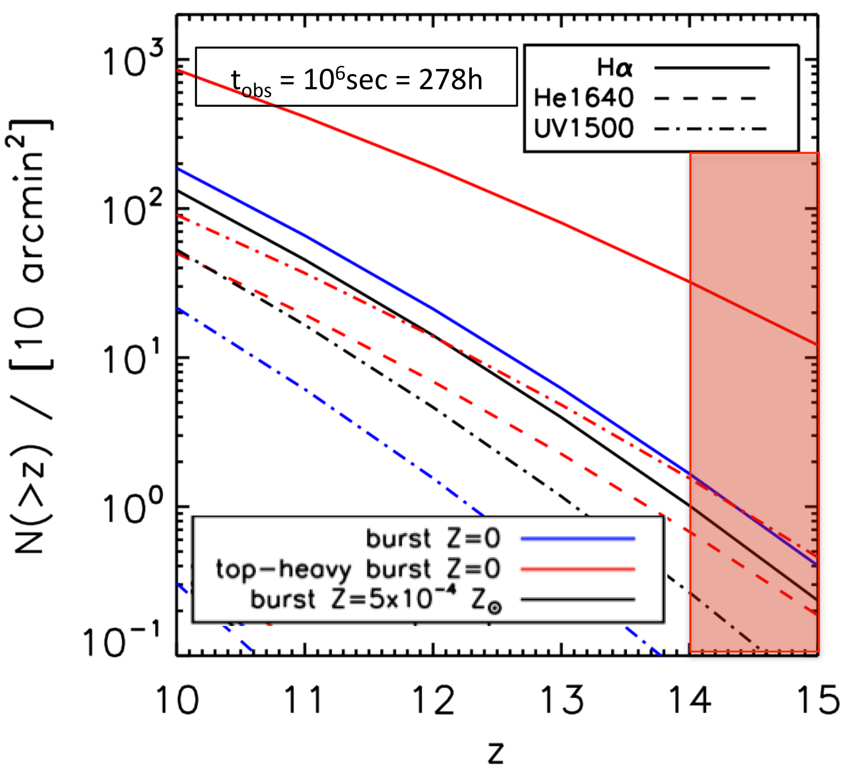
- Aim#1: detection of a large enough sample, i.e. $N_{sources}$ ~ 100, sources at z ~ 14-16



Main Science Objectives

I. FLARE: First Light And Reionization Explorer (~80%)

JWST NIRSpec Spectroscopy



Pawlik, Milosavljevic, and Bromm (2010) http://arxiv.org/abs/1011.0438)

The Science Case for Multi-Object Spectroscopy on the European ELT Jan. 2015, http://arxiv.org/pdf/1501.04726v2.pdf

For the E-ELT, integrated magnitudes of **m_{AB} ~ 28** and emission-line fluxes of a few 10^{-20} erg s^{-1} cm^{-2} should be reached within ~24 hr of integration time (with an average S/N per spaxel of 5).

The E-ETL will be able to follow-up, spectroscopically the candidate First-Light from FLARE at m_{AB} ~ 28 but not those from JWST at m_{AB} ~ 30.

Main Science Objectives

I. FLARE: First Light And Reionization Explorer (~80%)

- Aim#1: detection of a large enough, i.e. a sample of $N_{sources}$ ~ 100, sources at z ~ 15

Expected number of sources at 8 < z < 16 from the previous assumptions

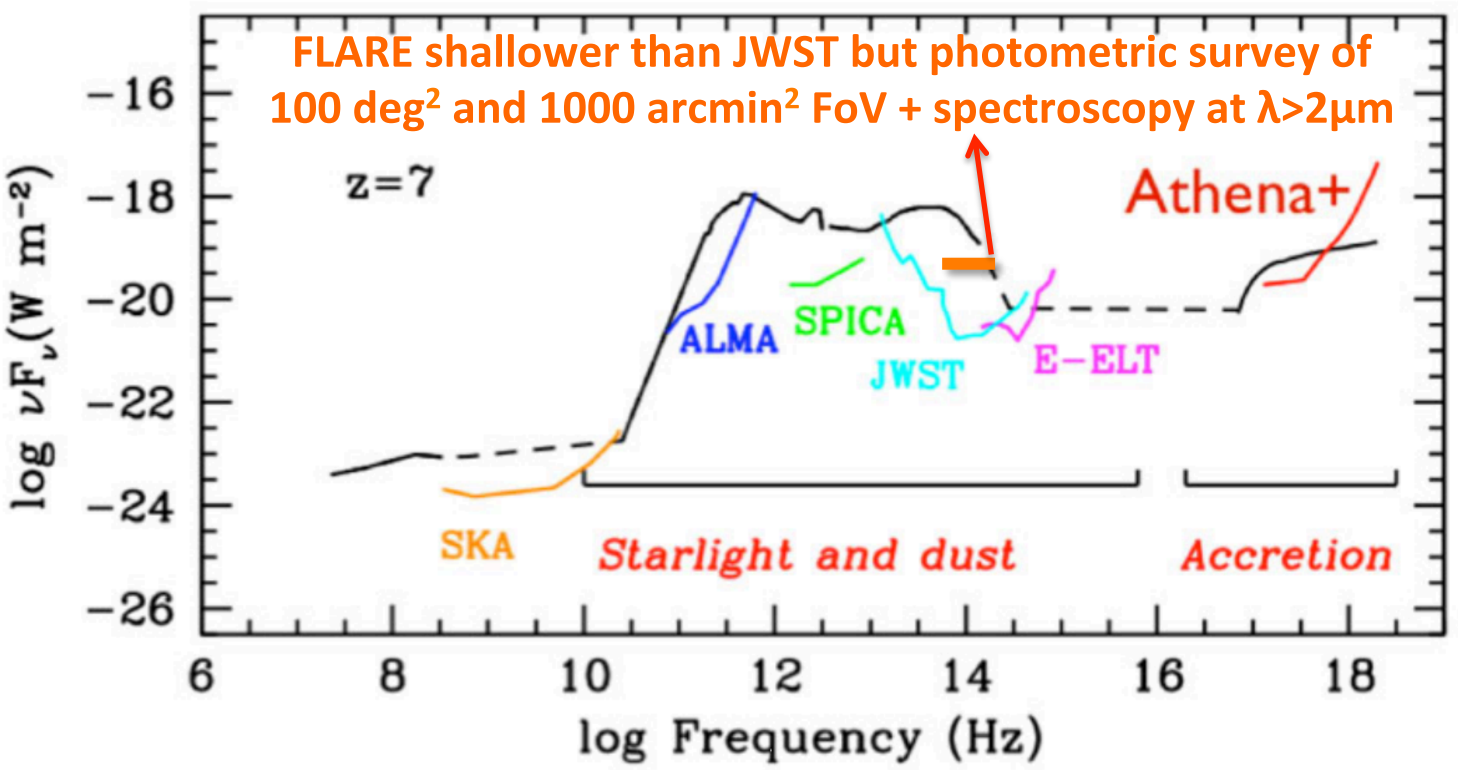
	Redshift	Empirical LF	DM Evolution	SAM
Filter 0-Dropout	8–9	170,000	85,000	63,000
Filter 1-Dropout	11–12	10,000	410	5000
Filter 2-Dropout	14–16	72	0.3	110

Note: this is bad for FLARE, but, very bad for JWST

Main Science Objectives

I. FLARE: First Light And Reionization Explorer (~80%)

- Aim#2: follow-up (lines) and study of z > 6 quasars identified by ATHENA

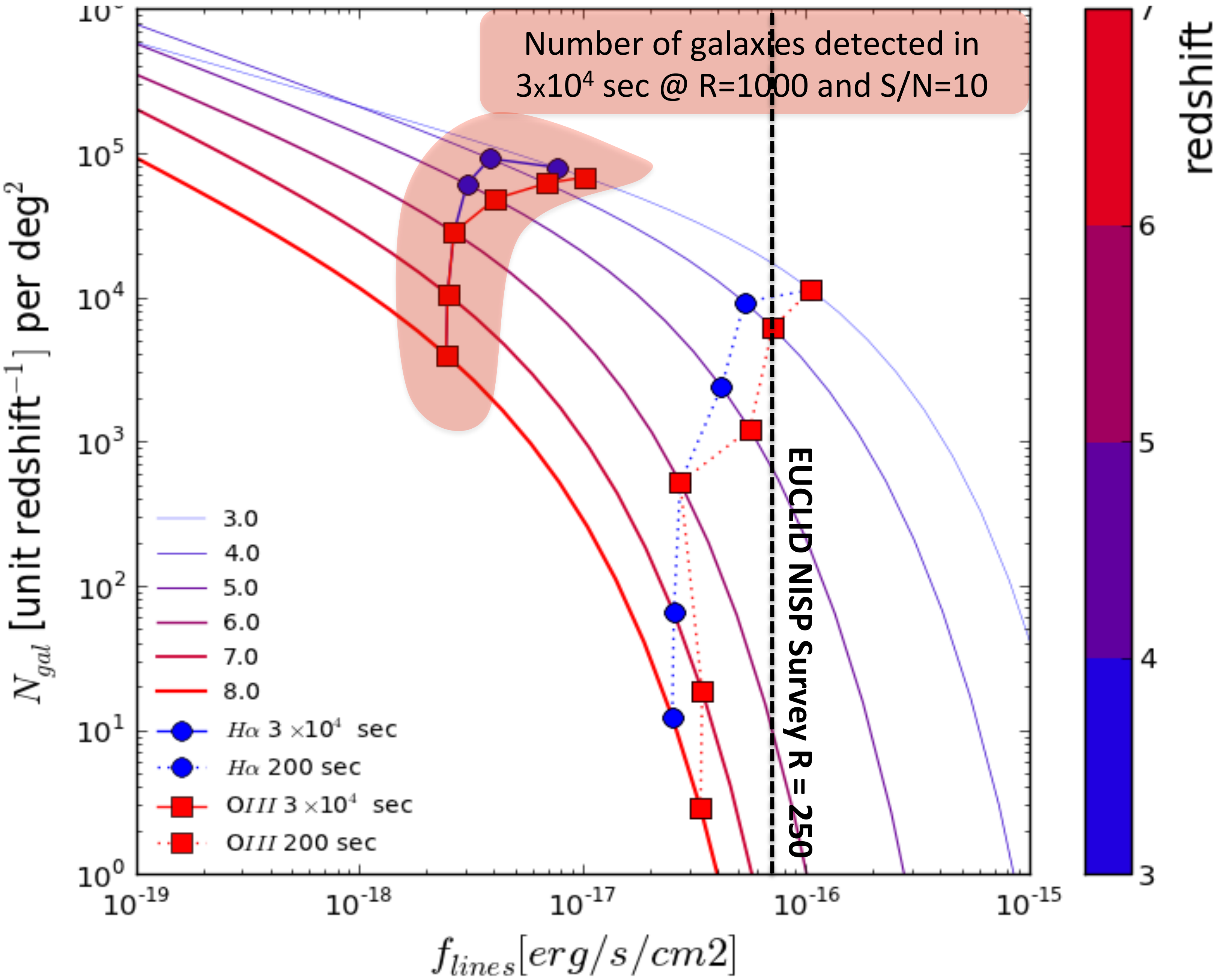


Main Science Objectives

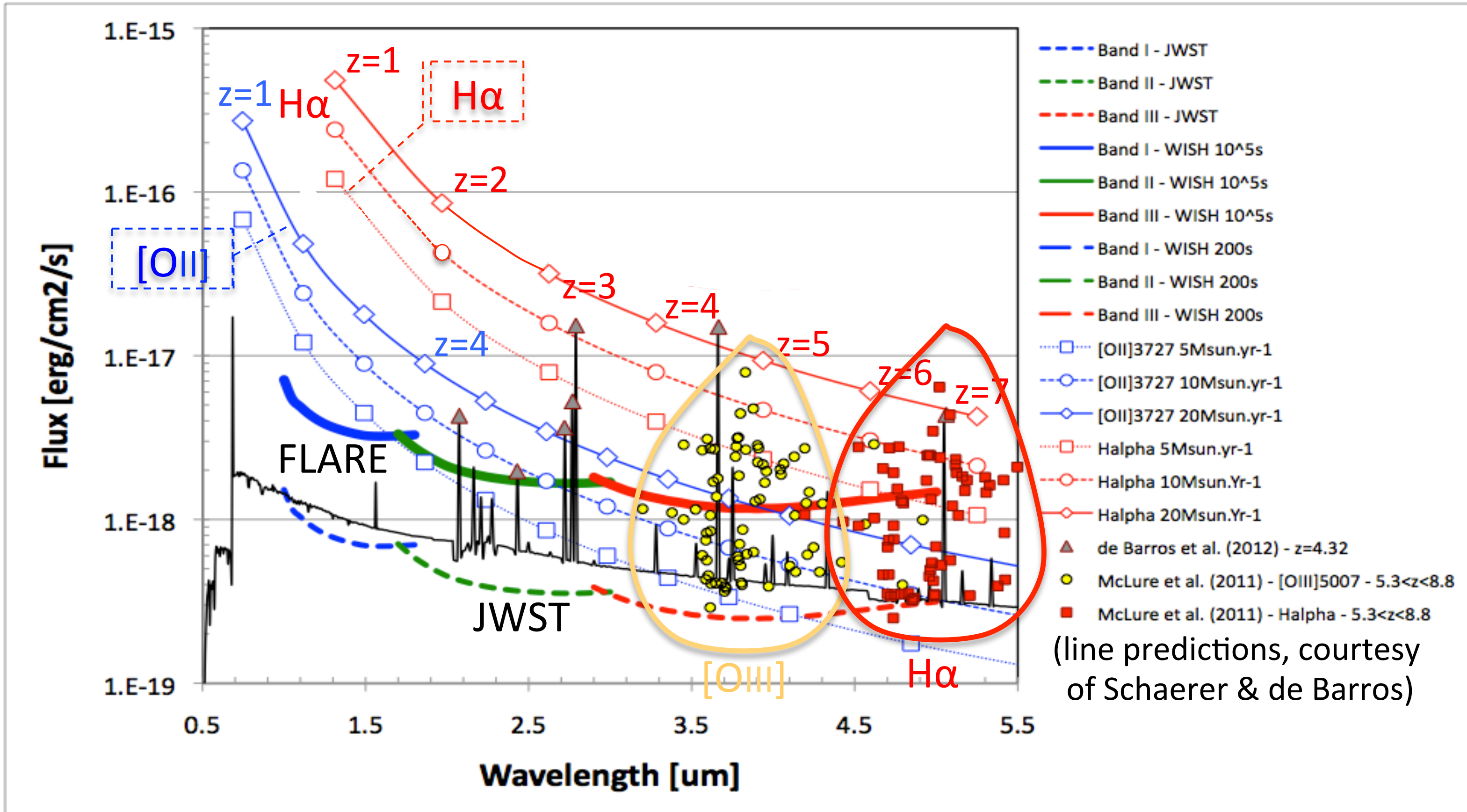
I. FLARE: First Light And Reionization Explorer (~80%)

- Aim#3: Formation of metals at $3 < z < 8$ from Integral-field spectroscopy of large galaxy and quasar sample.

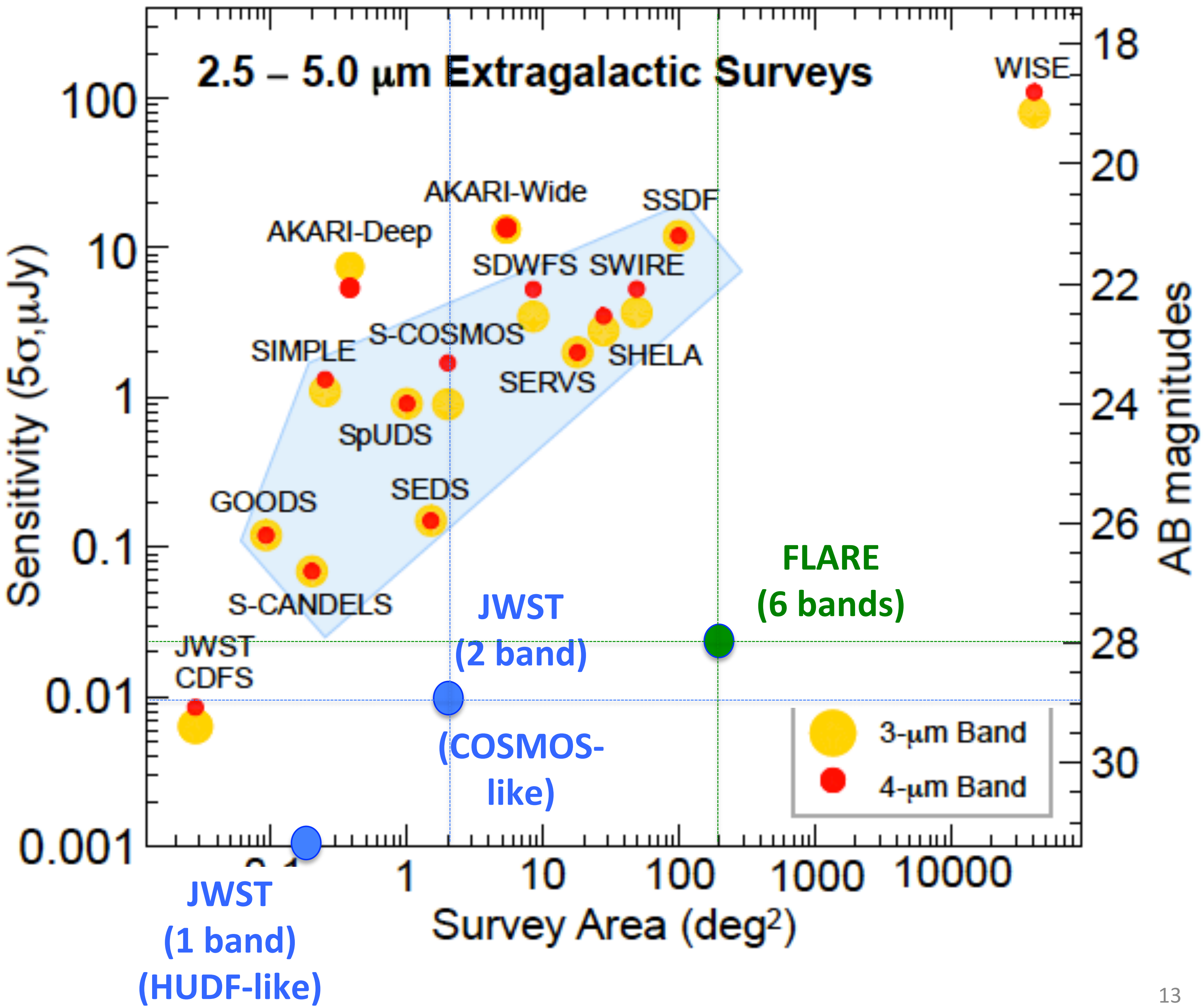
Spectroscopic Survey over 1.7 deg^2 from well-calibrated rest-frame optical lines



FLARE Integral Field Specroscopy



Expected lines fluxes and sensitivity of FLARE and JWST. We overplot a spectrum of a sub-L LBG (M_{UV} = -20.) at z = 4.32 from de Barros et al. (2012, black). The **main lines in the rest-frame optical range can be detected at S/N=10**. Yellow dots and red boxes correspond to [OIII]5007 and Hα lines from McLure et al. (2011) at 5.3 < z < 8.8. Almost half of them can be detected showing that we are able to confirm the redshift of these objects and to measure in detail the strength of these lines. Thin blue lines (continuous, dashed, dotted for 20 M_{Sun}/yr, 10 M_{Sun}/yr & 5 M_{Sun}/yr) correspond to [OII]3727 from z = 1 to z = 11 while the thin red lines (same as blue but from z = 1 to z = 7) correspond to Hα. Both are computed assuming Kennicutt (1998).*


2.5 – 5.0 μm Extragalactic Surveys
Sensitivity (5σ,μJy)
AB magnitudes
Survey Area (deg²)
100
10
1
0.1
0.01
0.001
18
20
22
24
26
28
30
1
10
100
1000
10000
WISE
AKARI-Wide
SSDF
AKARI-Deep
SDWFS SWIRE
S-COSMOS
SIMPLE
SHELA
SERVS
SpUDS
GOODS
SEDS
S-CANDELS
JWST
CDFS
FLARE
(6 bands)
JWST
(2 band)
(COSMOS-
like)
JWST
(1 band)
(HUDF-like)
3-μm Band
4-μm Band

Main Science Objectives

II. Formation of Stars (and Planets) in the Milky Way

- 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. »*

Main Science Objectives

II. Formation of Stars (and Planets) in the Milky Way

- For the nearest star-forming clouds of the Galaxy observed at submillimeter wavelengths with the Herschel Space Observatory, we obtain unprecedented images of the initial conditions and early phases of the star formation process.
- The Herschel images revealed an intricate network of filamentary structure in every interstellar cloud. Interestingly, the width of these filaments are remarkably similar, about 0.1 pc, in the densest ones.
- We can detect prestellar cores that are the seeds of future stars.
- The angular resolution is a key parameter to resolve the small structure of the star formation regions.
- The dust attenuation at wavelengths beyond 2 µm is negligible compared to ultraviolet and optical ones.
- Moreover, onestrong PAHs features (3μm) lie in this spectral range.
- So, the FLARE wavelength range will to peep inside dusty nebulae and study the young phases of star formation.
- To map a large portion of the Milky Way over a few hundreds of deg^2 down to m_{AB} = 24, a wide instantaneous field of view is necessary.

Main Science Objectives

II. Formation of Stars (and Planets) in the Milky Way

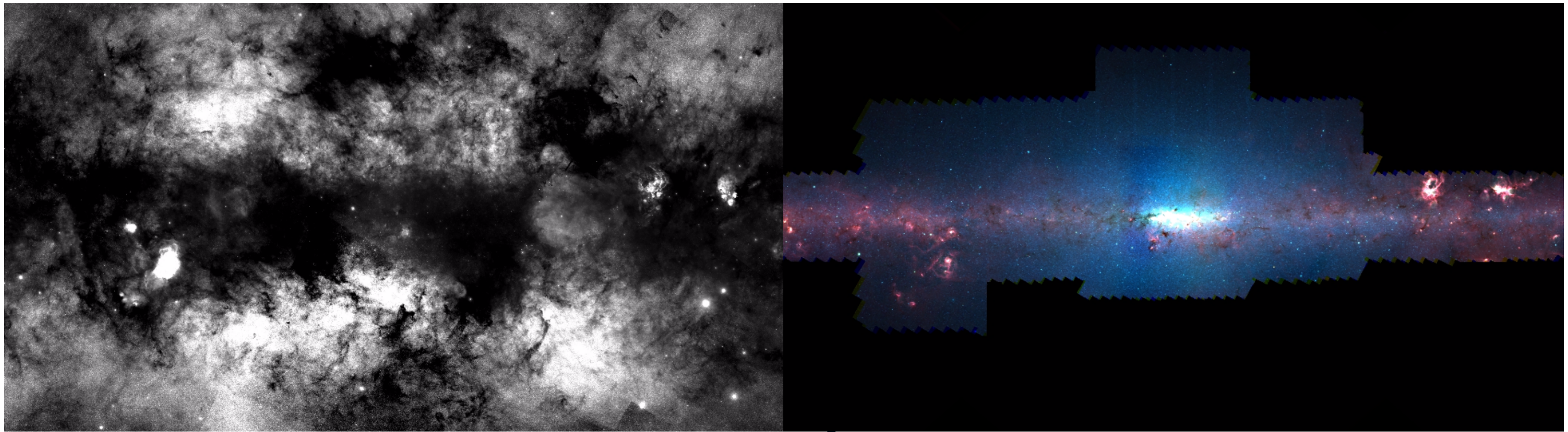


Figure 2: these two images show about 20 deg^2 of the center of the Milky Way from Left, optical image (DSS2 red). Right, near-infrared composite IRAC image from several programmes (GLIMPSE, SAGE, SAGE-SMC and SINGS). Two important points emerge : a) the near-infrared range clearly allows to study the 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.

FLARE's Science Working Group

- **First stars and reionization:**
  - **Andrea Ferrara (Italy),**
  - **Andrew Bunker (United Kingdom)**
  - **Rychard Bouwens (Netherlans)**
- **Building the elements and physics of galaxies:**
  - **Véronique Buat (France)**
  - **Daniel Schaerer (Switzerland / France)**
  - **David Sobral (United Kingdom / Portugal)**
- **First quasars:**
  - **Jose Afonso (Portugal)**
  - **David Alexander (United Kingdom)**
- **Milky Way science:**
  - **Laurent Pagani (France)**
  - **Sergio Molinari (Italy)**
  - **Laurent Cambresy (France)**
- **To the above list, we will likely add:**
  - **1 or 2 US scientists**
  - **1 Chilean scientist**
  - **1 or 2 Japanese scientists depending on their implication**

A list of Co-Investigators will also be defined but, this will also strongly depends on the sharing of technical work packages.

FLARE in a few numbers

FLARE (First Light And Reionization Explorer) – ESA M5 Proposal	
Primary Mirror	1.8 – 2.0m
Launch / lifetime	2028 – 2030 (after JWST) / 5 – 6 years
Limiting Photometric Magnitude	m_{AB} = 28
Photometric Wavelength Range	1 – 5 µm
Photometric Instantaneous FoV	0.25 x 0.75 deg^2
Size Photometric Survey	100 – 200 deg^2
Photometric angular resolution	~ 0.4 arcsec
Limiting Spectroscopic Flux	~ 3 10^{-18} $erg/cm^2/s$
Spectroscopic Instantaneous FoV	1 $arcmin^2$
Size Spectroscopic Survey	1 – 2 deg^2
Spectroscopic Wavelength Range	2 octaves: 1.25 – 2.50 µm 2.50 – 5.00
Spectral Resolution	$500 < R = \lambda / \Delta\lambda < 1000$
Spectroscopic angular resolution	~ 0.4 arcsec (size of slice)

How does FLARE compare with others incoming projects?

	Euclid[a]	WFIRST (DRM1)[b]	WFIRST (NRO)[c]	JWST	FLARE
Mirror	1.2m	1.3m	2.4m	6.5m	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]	100 – 200 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];

- 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).

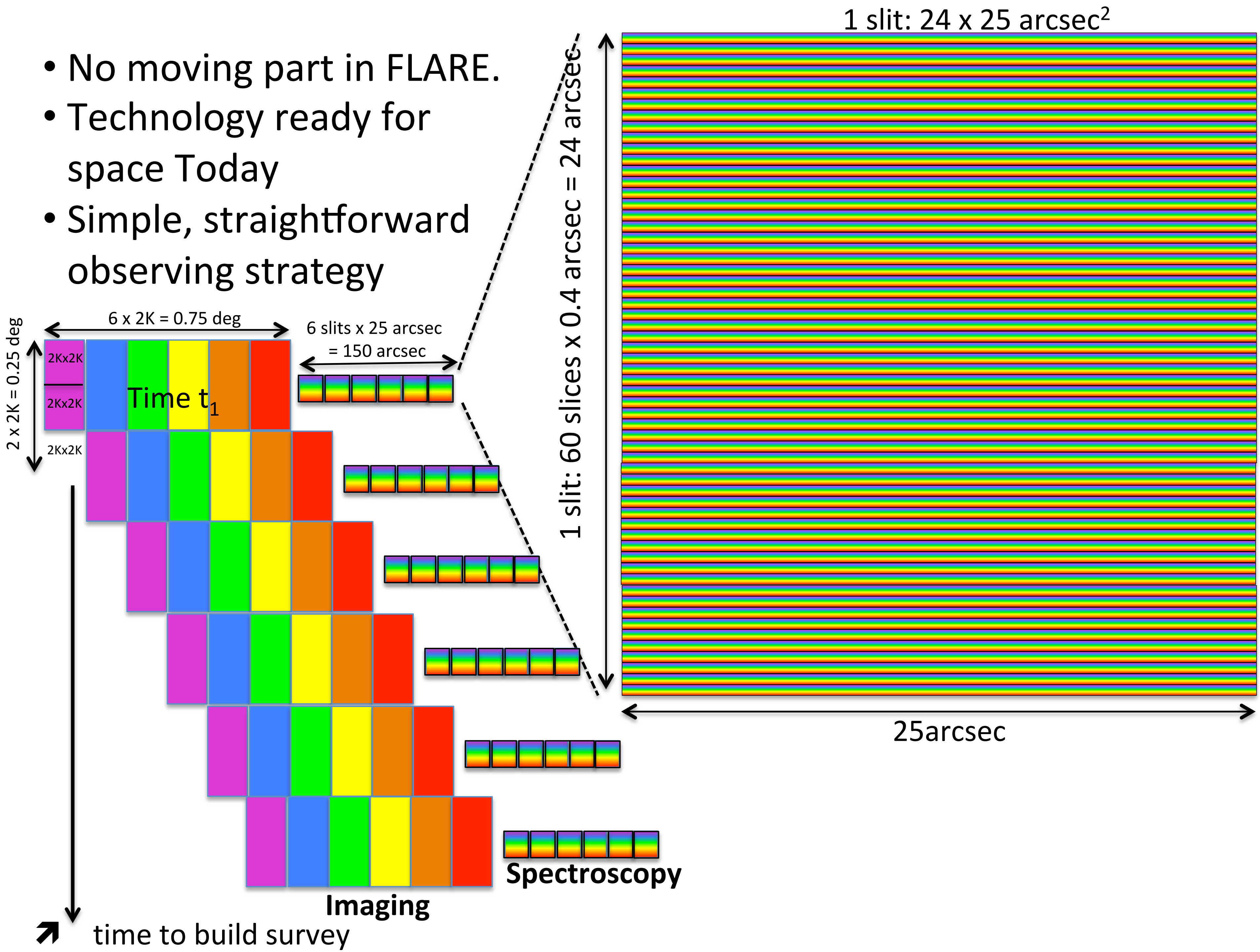
- On the spectroscopic side, assuming ~ 1 x 1 $arcmin^2$ field of view, FLARE **should observe more spectra than NIRSpec**. JWST would collect 10^5 galaxies down to AB=25 (R=100) to calibrate the photometric redshifts. NIRSpec would collect 10^4 galaxies (Franx 2011) over JWST lifetime (100 simultaneously, at all redshifts and part (how many?) at low R.

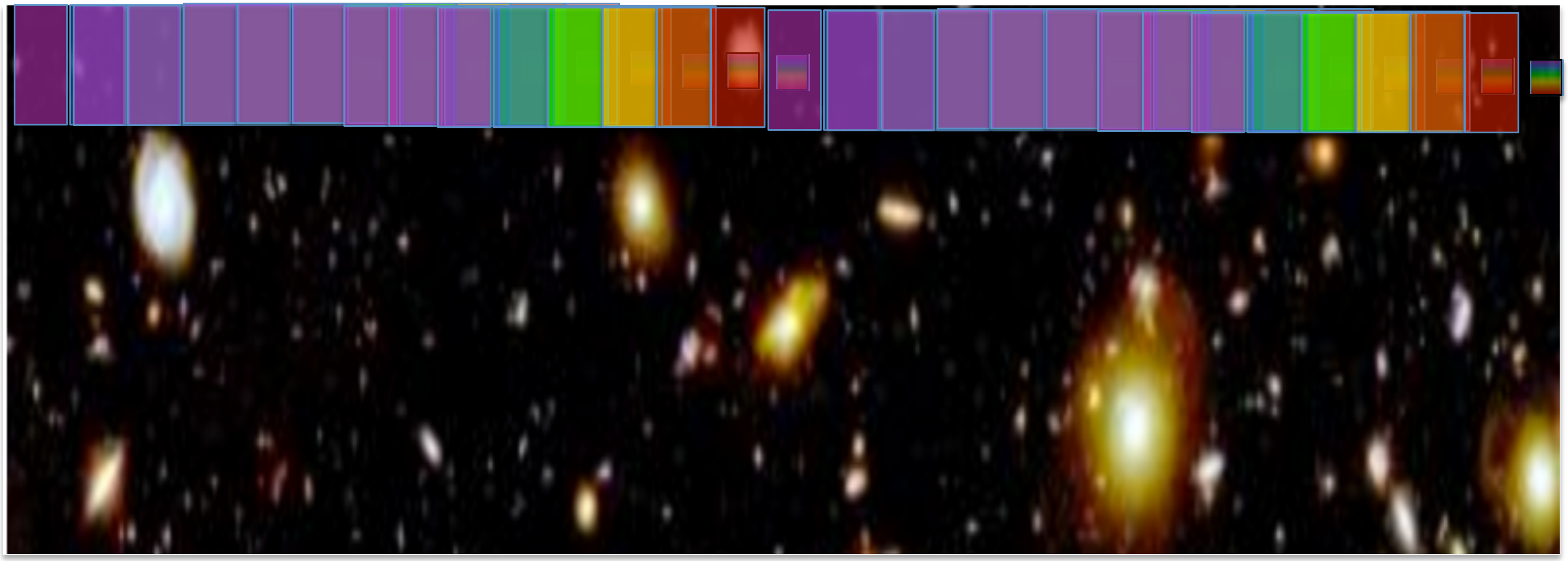
REDSHIFT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
WISH/SPEC	4	7	7	7	7	7	5	5	4	2	2	2	1	1	1
JWST/NIRSPEC	4	7	7	7	7	7	5	5	4	2	2	2	1	1	1
EUCLID/NISP	6	7	3	1	0	0	1	1	1	1	1	1	1	1	0
HST/WFC3IR	6	4	1	0	0	0	1	1	1	1	1	1	0	0	0
WFIRST	6	7	3	1	0	0	0	0	0	0	0	0	0	0	0
SPICA/MCS	0	0	0	0	0	0	3	3	4	6	6	6	7	7	7
JWST/MIRI	0	0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

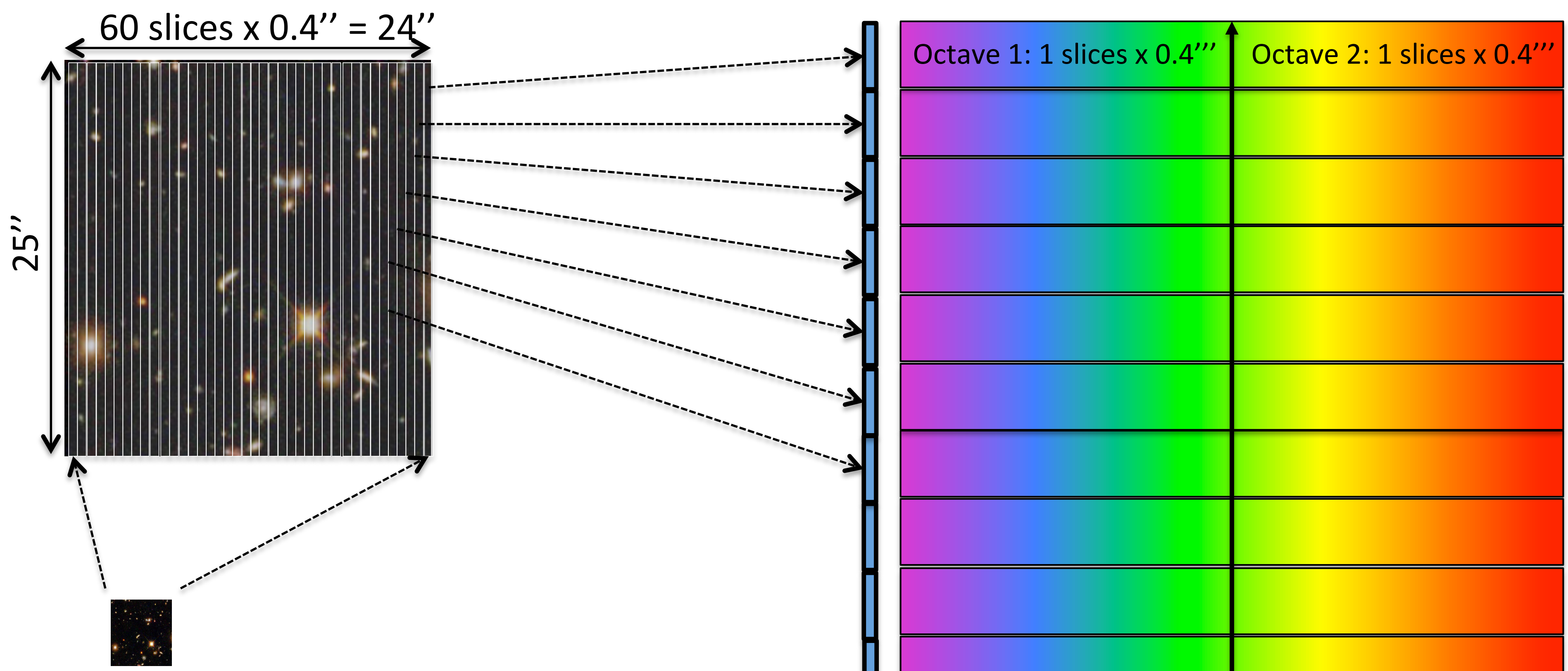
Physics OK Redshift OK BAD

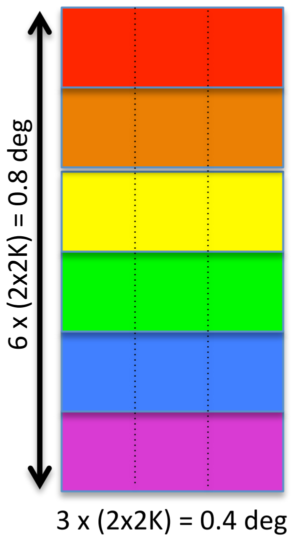
Table valid for the optical lines ***[OII]λ3727, [OIII]λ4959, 5007, Hβ***, ***[NII]λ6584*** and ***Hα***

- No moving part in FLARE.
- Technology ready for space Today
- Simple, straightforward observing strategy



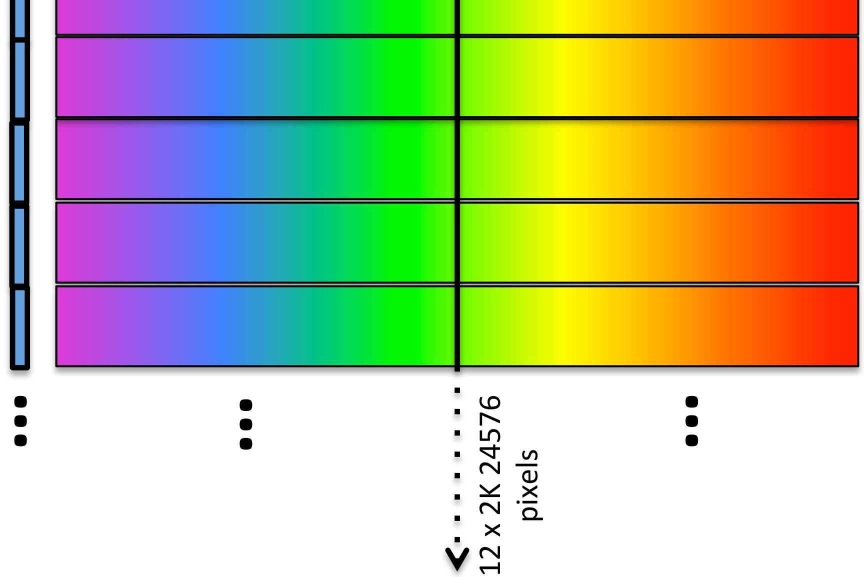




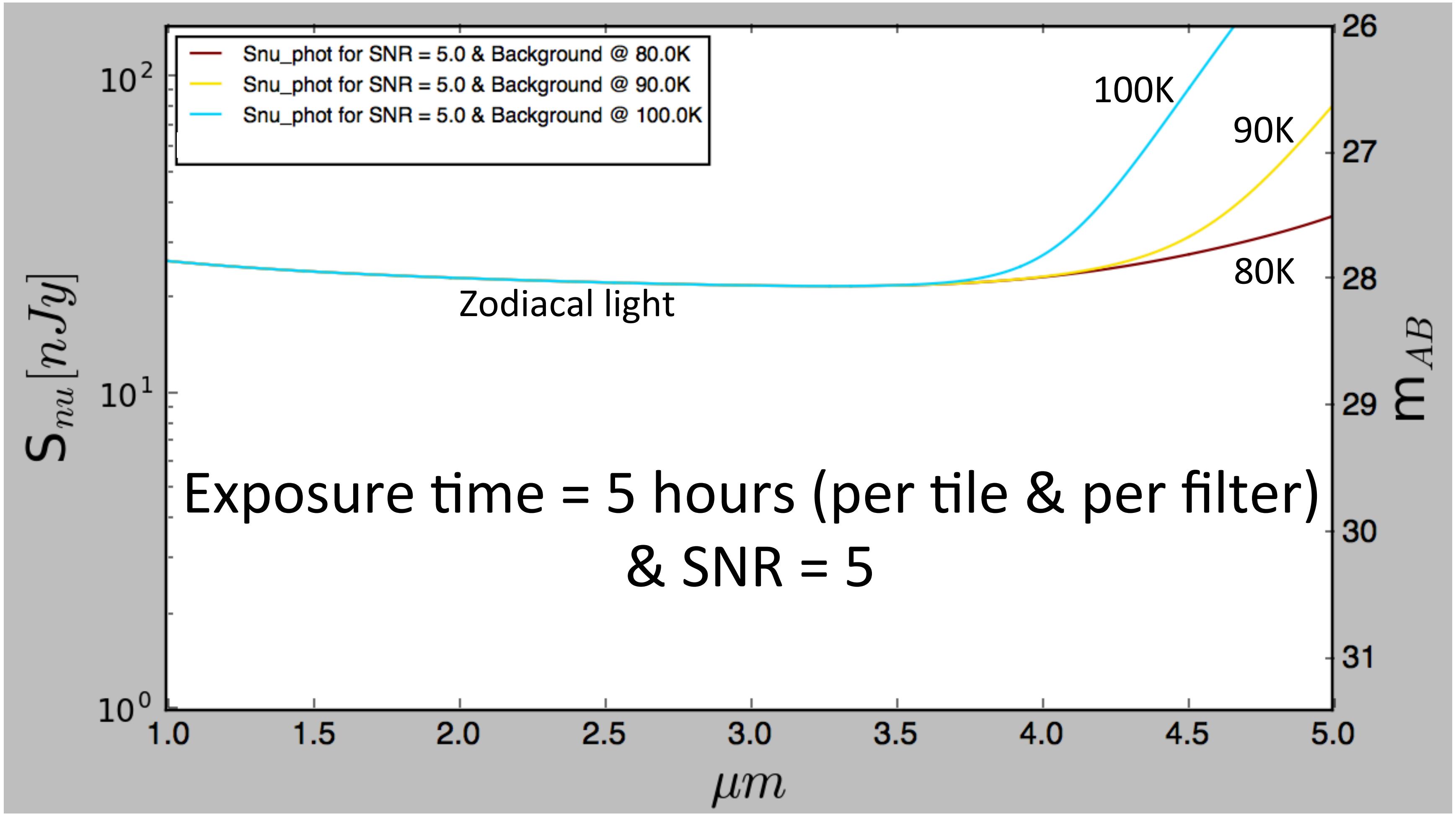


We can have 2 octaves on 2K:

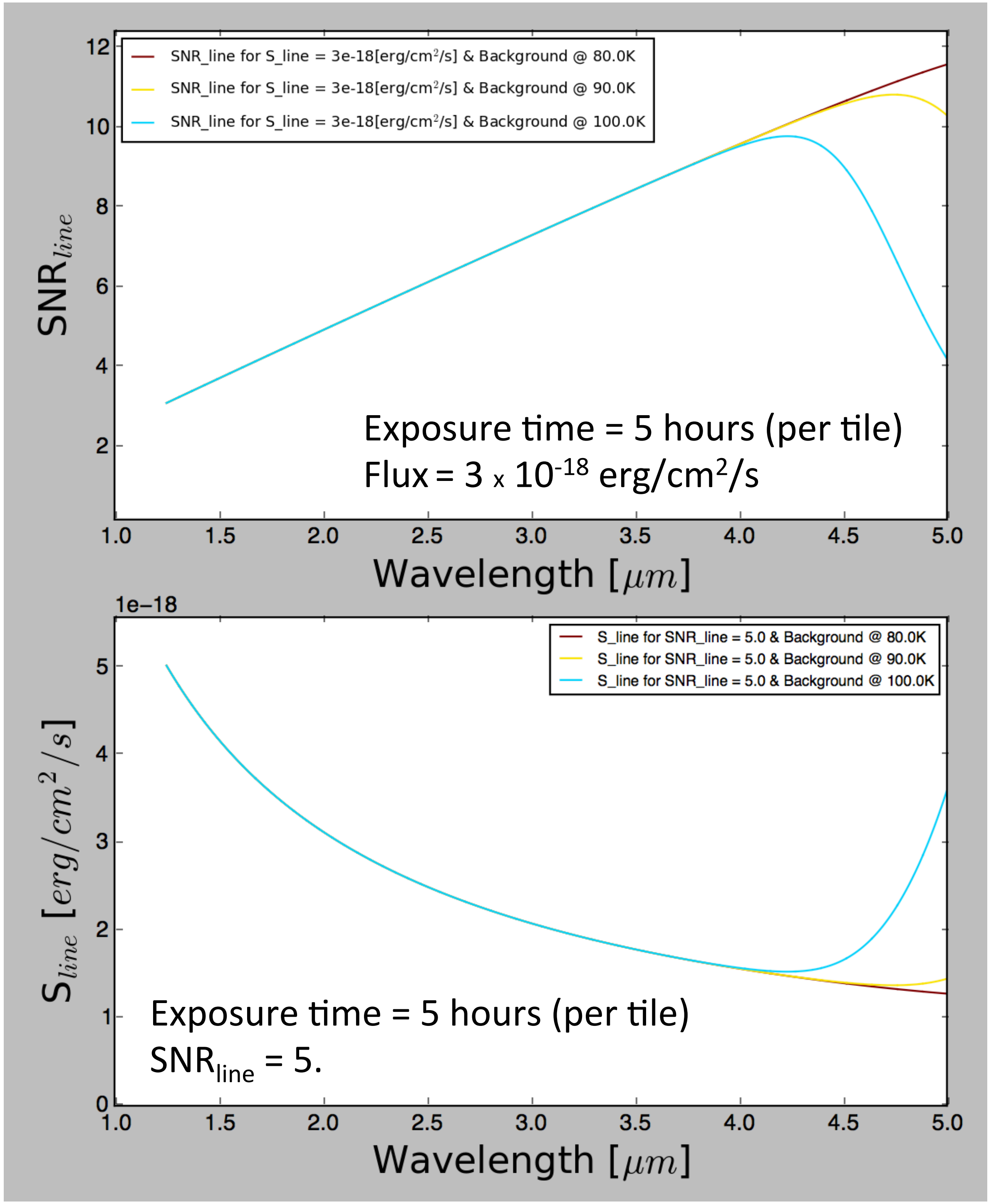
* **Octave 1:** 1.25 – 2.50 um with λ_{mean} = 1.875 um
  With R = λ_{mean} / $\Delta\lambda$ = 768, $\Delta\lambda$ = 0.00244 um.
  We need (with 2 pixels per spectral resolution element),
  1.25/(0.00244/2) = 1024 pixels.
* **Octave 2:** 2.50 – 5.00 um with λ_{mean} = 3.750 um
  With R = λ_{mean} / $\Delta\lambda$ = 768, $\Delta\lambda$ = 0.00488 um
  We need (with 2 pixels per spectral resolution element),
  2.50/(0.00488/2) = 1024 pixels.

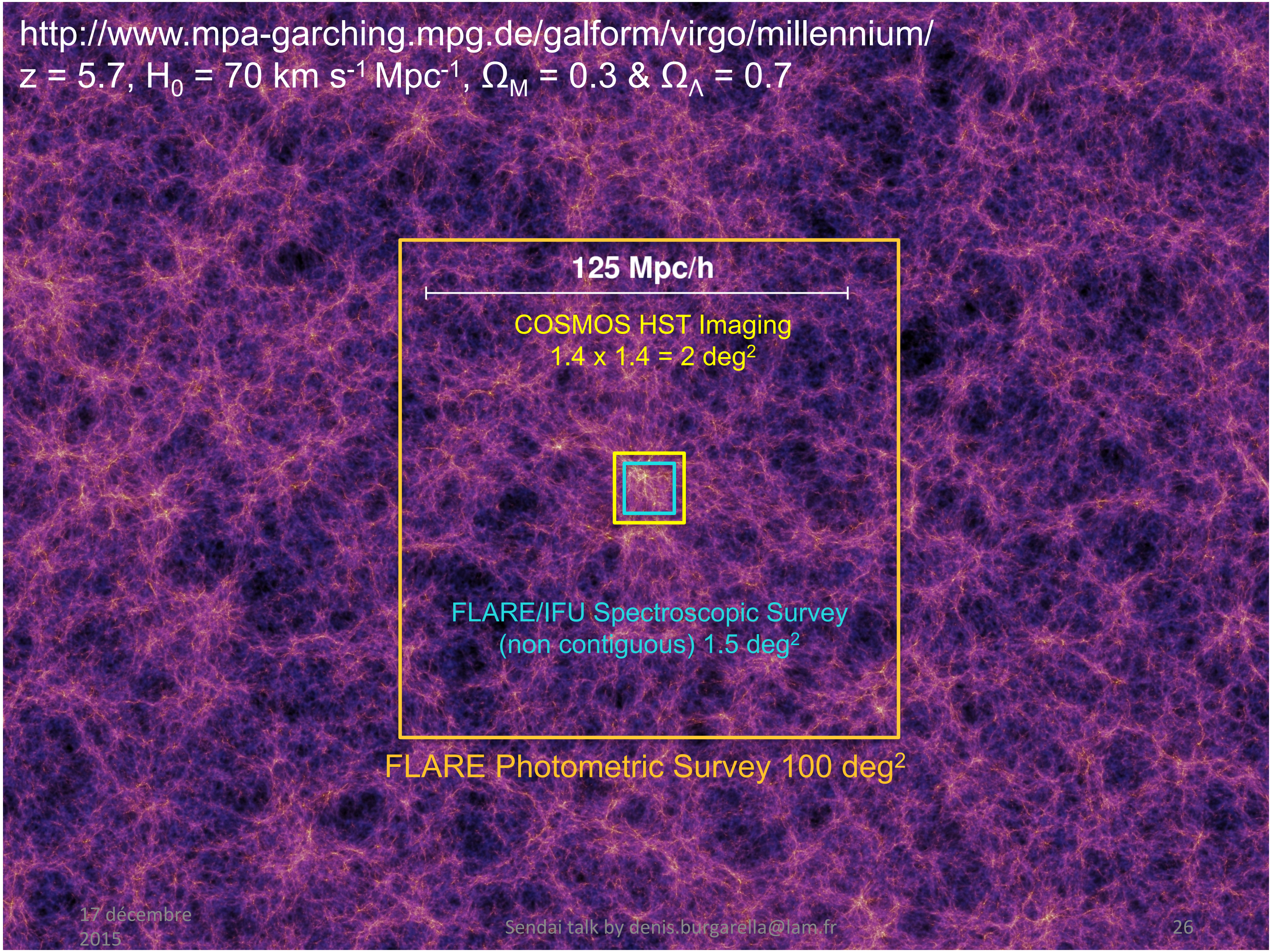


Photometric performances of FLARE



Line sensitivity for FLARE's spectroscopic survey




http://www.mpa-garching.mpg.de/galform/virgo/millennium/
$z = 5.7$, $H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_M = 0.3$ & $\Omega_\Lambda = 0.7$
125 Mpc/h
COSMOS HST Imaging
1.4 x 1.4 = 2 deg^2
FLARE/IFU Spectroscopic Survey
(non contiguous) 1.5 deg^2
FLARE Photometric Survey 100 deg^2

What consortium to build FLARE?

- We have started to discuss with industrials.
- We will need their help to work on the telescope itself and other non-instrumental aspects of FLARE.

What consortium to build FLARE?

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

Do You Wish to Get Involved?

- That's very easy: let me know and we will discuss how and where.
- A meeting will be held early 2016 to work on the proposal, both scientifically and technically (2 workshops co-funded by PNCG in 2013 and 2014)

PNCG's support is crucial because of PNCG's support but also because CNES listens to PNCG. Thank You!

If you also think that FLARE is important, it is crucial to ensure that people and institutions around you know it.

Conclusion

- **FLARE' wavelength range is different from either EUCLID, WFIRST or E-ELT**. While all these facilities observe at $\lambda \leq 2\mu m$, FLARE's **wavelength range is 1.0 µm λ ≤ 5.0 µm**. This range is necessary and sufficient if we are to observe the first stellar light in the universe: 0.36µm at z = 6 is at 2.5µm. We can therefore follow the rest-frame U-band emission to z = 13 at 5.0µm. EUCLID, WFIRST or E-ELT cannot.
- **FLARE does share a common wavelength range with JWST NIRCam and NIRSpec**. Wide fields is the key-word, here.
  - **JWST NIRCam** field of view is 2.2 x 2.2 $arcmin^2$ while **FLARE features a 675 $arcmin^2$ field of view (about 150 times NIRCAM's).**
  - **NIRSpec IFU is 3 x 3 $arcsec^2$, FLARE will feature a 1 $acrmin^2$ IFU (more than 400 times JWST's)**.
- Contacts established with other projects' teams: ATHENA, SKA and E-ELT to work on the synergy with FLARE
- **International Conference Early 2016 to be announced (by PNCG)**

First Light And Reionization Explorer

FLARE