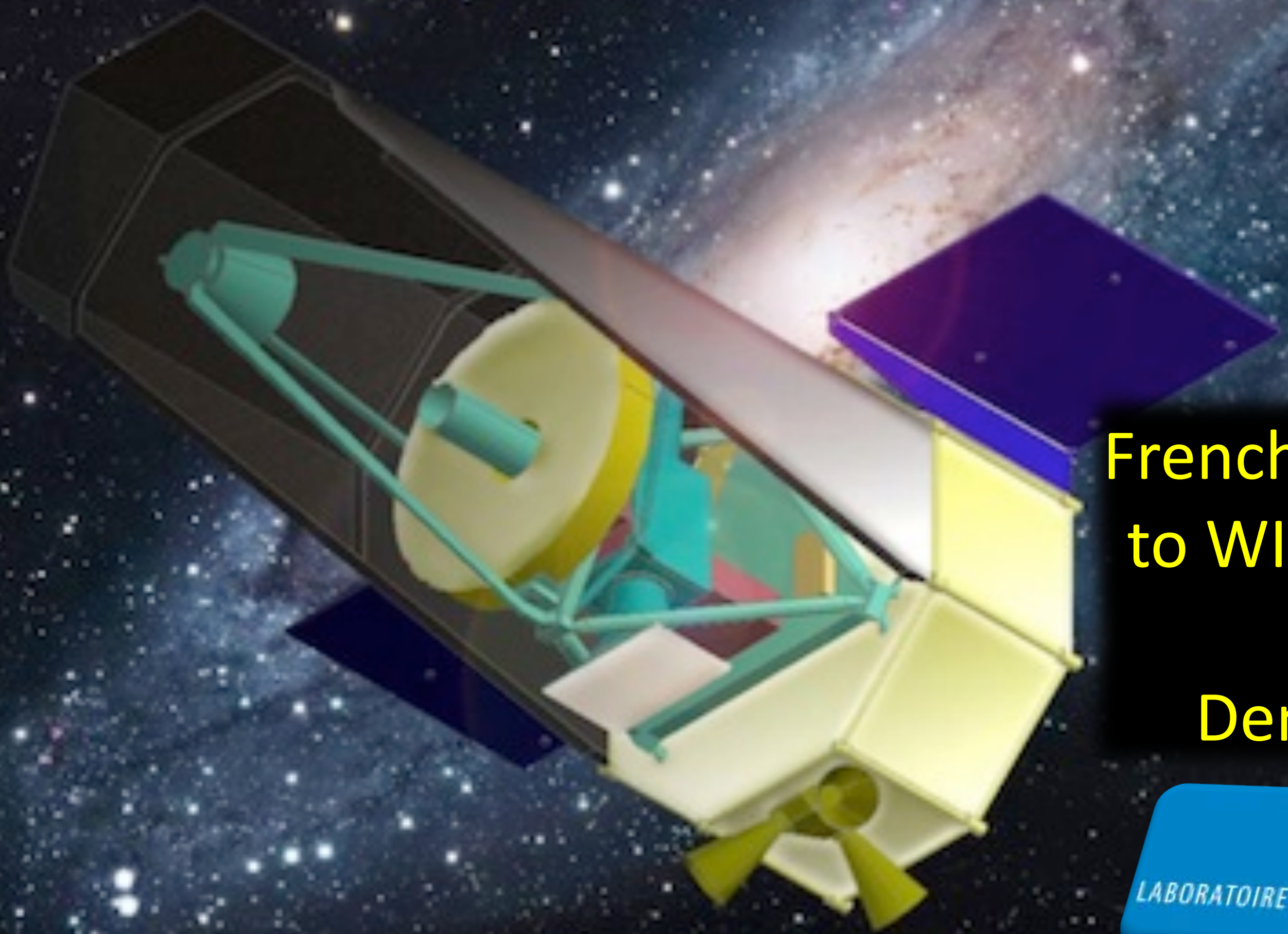
Wide-field Imaging Surveyor for High-redshift

WISH space telescope project



French Contribution(s) to WISH as proposed to CNES

Denis Burgarella

LAM
LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

Context

- The Wide-field Imaging Surveyor for High-redshift (WISH) is a proposed mission concept now being developed by the WISH Working Group in Japan under the Science Committee of Institute of Space and Astronautical Science (ISAS) and the Japan Aerospace Exploration Agency (JAXA).

- We (France) propose to contribute (*mission of opportunity frame*) to this project both scientifically and instrumentally under the coordination of the Laboratoire d'Astrophysique de Marseille in cooperation with other French institutes: IRAP (R. Pello et al.) and Paris Obs. identified so far.

WISH's main objectives

- WISH will dedicate ~80% of its observing time to studying the first galaxies and the very early formation of stars and elements.
- This directly addresses two of the main questions of ESA Cosmic Vision 2015-2025 programme: "4 ». How did the Universe originate and what is it made of" and more specifically:
- *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* (4.2 The Universe taking shape)
- *Trace the formation and evolution of the super-massive black holes at galactic centres – in relation to galaxy and star formation – and trace the life cycles of chemical elements through cosmic history* (4.3 The evolving violent Universe).

What is WISH?	
Launch	~ 2020
Lifetime	5 years
Optics	• M1: ⃠1.5m @ L2 • Passively cooled to 100K • Diffract. limited (0.2''@ 1µm)
λ range	1 – 5 µm
Imaging	900 arcmin², 0.155''/pixel
Spectro	Two options: Priority 1: IFU, ⃠ 1'(TBC), R~1000, parallel observ. Priority 2: Slitless, 900arcmin², R~100

Photometry (900 arcmin²)

- UDS: m_{AB} = 28 over 100deg²
- UWS: m_{AB} = 24-25 over 1000deg²
- ES: m_{AB} = 29-30 over 0.25deg²

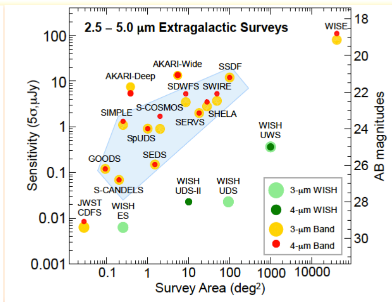
Spectroscopy (1' x 1' IFU):

- UDSS: 8x10^{-17} erg cm^{-2} s^{-1} over ~ 1deg²
- UWSS: 8x10^{-16} erg cm^{-2} s^{-1} over ~10deg²

Table D2. Prime WISH Surveys

	Depth (5σ) (AB Mag.)	Area (deg²)	Center Wavelengths (µm)	Survey Time[a] (years)	Proposal Section
Ultra-Deep Survey (UDS)	28	100	1.0, 1.4, 1.8, 2.3, 3.0	3.48	D2.1
Ultra-Deep Survey, 4µm (UDS-II)	28	10[b]	UDS + 4.0	0.24	D2.2
Ultra-Wide Survey (UWS)	25	1,000	1.0, 1.4, 1.8, 2.3, 3.0, 4.0	0.24	D2.3
Extreme Survey (ES)	29.5	0.24	1.0, 1.4, 1.8, 2.3, 3.0	0.13	D2.4

[a] Assumes 85% observing efficiency toward the ecliptic pole, a QE of 70%, a dark current of 0.05 e^-/s, a read noise of 15 e^- (for N=1, CDS), a throughput of 74%, and Fowler 4 sampling (see Section E1.3); [b] Within the UDS field.



Imaging

1) Over 100 deg²
WISH will detect photometrically:

~10² galaxies at z=14-17

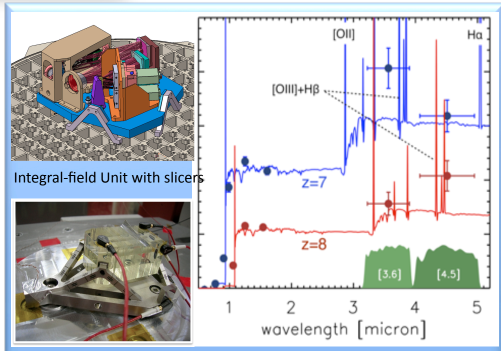
~10³⁻⁴ galaxies at z=11-12

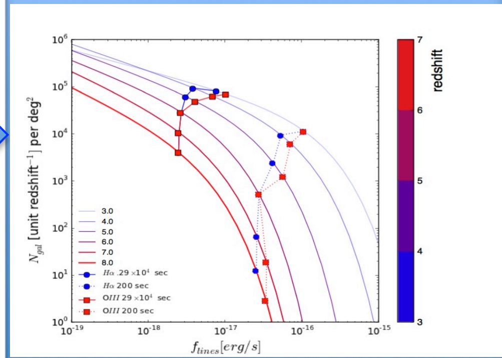
~10⁴⁻⁵ galaxies at z=8-9

2) Over 1 deg²
WISH will detect spectroscopically:

~10⁴⁻⁵ galaxies at z=3-9

Spectroscopy





http://people.lam.fr/burgarella.denis/denis/WISH.html

What is WISH?

- *WISH is an M Japan-led project (PI: T. Yamada).*
- WISH-Spec A spectrograph (IFU, D. Burgarella et al.)
- SAO (G. Fazio et aL.) & Canada (M. Sawicki et al.) involved
- Main science objective: first galaxies in the Universe… but not only (Solar system, ISM, galaxies, ...)

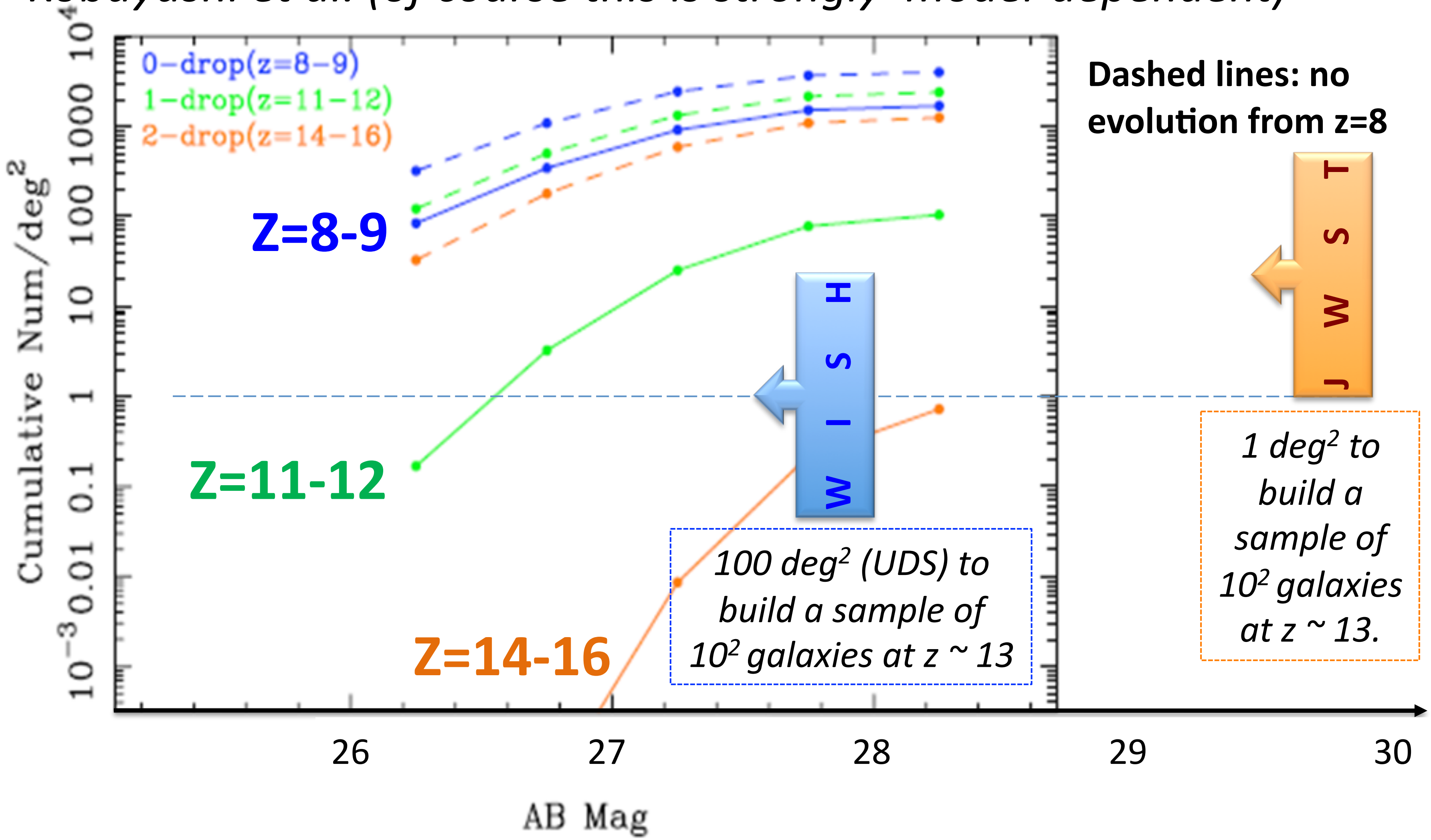
The Wide-field Infrared Surveyor for High-redshift (WISH)

Burgarella D., Pello R., Combes F., Schaerer D., Adami C., Amram P., Bacon R., Boissier S., Boquien M., Boselli A., Braine J., Buat V., Charlot S., Contini T., Cuby J.G., E. Daddi, Delsanti A., Dole H., Epinat B., Ferrari C., Flores H., Groussin O., Hammer F., Heinis S., Ilbert O., Lagache G., Lançon A., Leborgne J.F., Marcelin M., Maurogordato S., Perret V., Pointecouteau E., Prieto E., Puech M., Puy D., Reylé C., Slezak E., Surace C., Vernazza P., Wozniak H., etc.

(French team only).

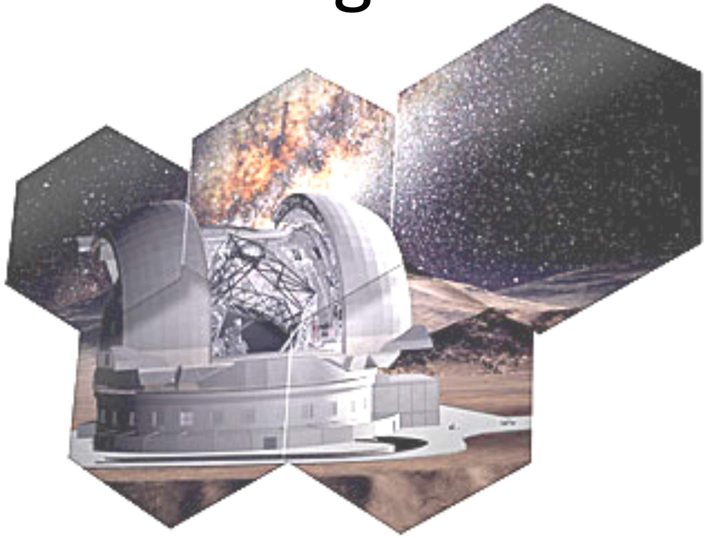
Expected Number of Galaxies in 1deg^2

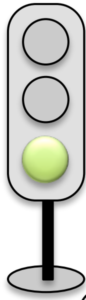
Extrapolation of z=6-8 UV LF by Semianalytic Model by Kobayashi et al. (of course this is strongly model-dependent)



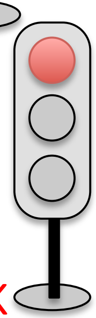
OCEVU Montpellier, 27 mai 2014, denis.burgarella@lam.fr

Ground-based spectroscopic follow-up of candidate primordial galaxies with the E-ELT





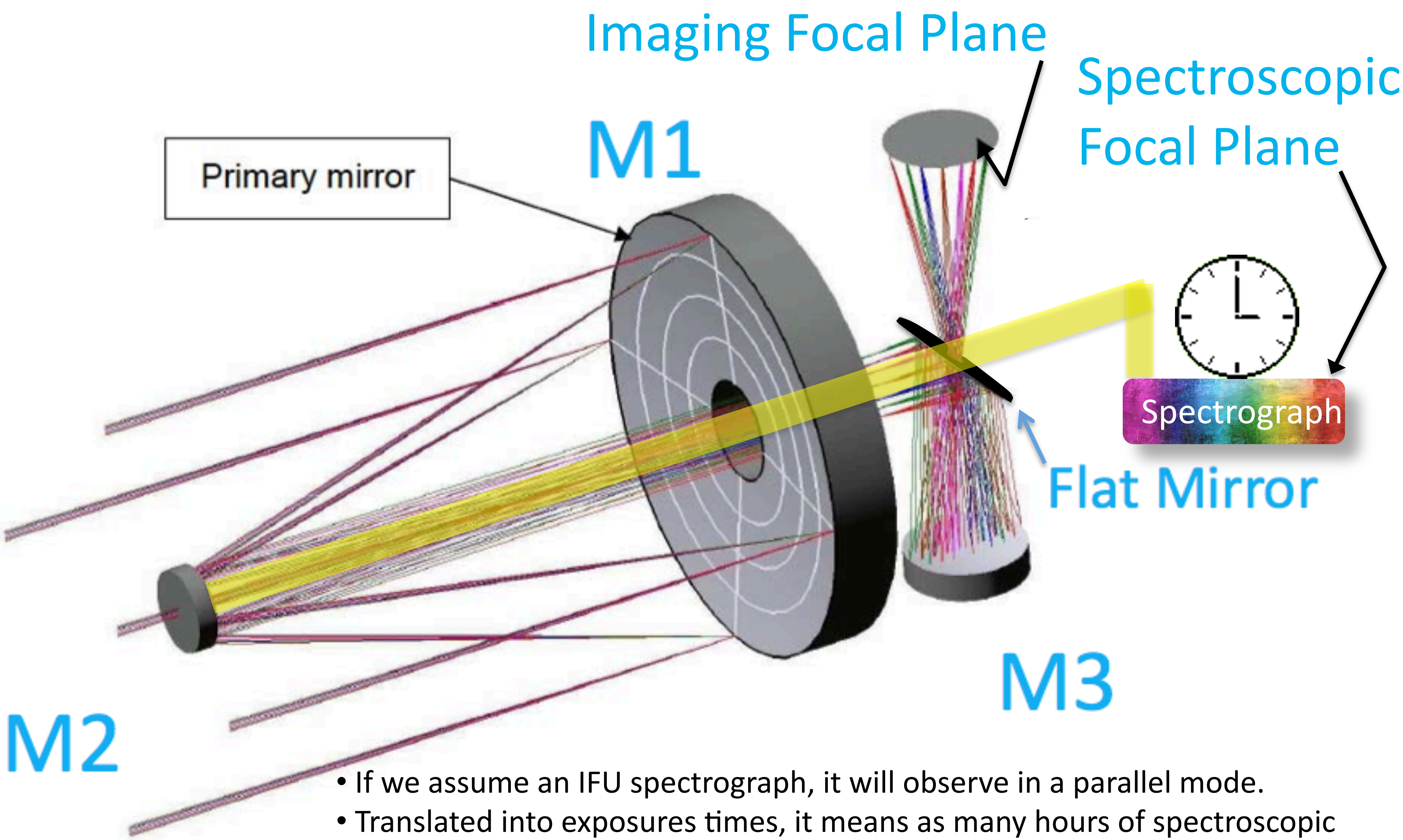
Limiting magnitude for WISH UDS (m_{AB} ~ 27 – 28) to build a sample of 100 galaxies at z > 13 in agreement with limiting magnitude for ELT's AO Multi-Objects spectrographs (m_{AB} ~ 27 – 28):
....ground-based follow-ups OK



Limiting magnitude for JWST (m_{AB} ~ 29 – 30) to build a sample of 100 galaxies at z > 13 not in agreement with limiting magnitude for ELTs' AO Multi-Objects spectrographs (m_{AB} ~ 27 – 28):
....ground-based follow-ups not OK

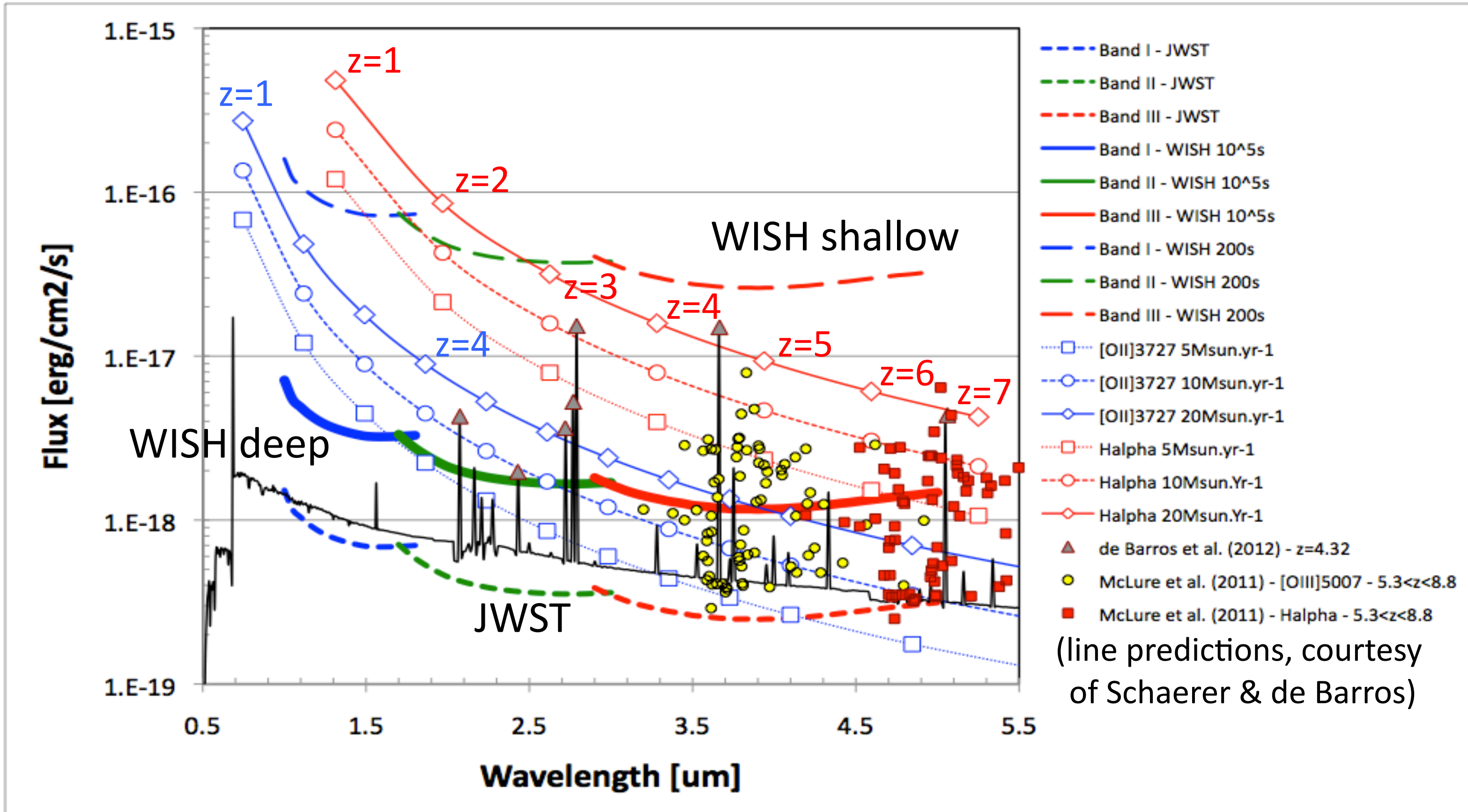
The need for WISHSpec

- A spectrograph onboard WISH will help estimating redshifts for galaxies up to and beyond the re-ionization.
- With a spectrograph onboard WISH, we will be able to detect emission lines, especially [OIII] and Hα for about half of the high-redshift galaxies (say $5 < z < 8$) samples. Spectral resolutions $500 < R < 1000$.
- Moreover, if an IFU option is selected, that means that we will be able to detect serendipitously galaxies in the deep spectroscopic observations.



- If we assume an IFU spectrograph, it will observe in a parallel mode.
- Translated into exposures times, it means as many hours of spectroscopic observation as we observe a single photometric field over 5 years, but of course, only for the central part of the field.
- Very deep observations (exposure time) without confusion (IFU).

A spectroscopic mode for WISH



Expected lines fluxes and sensitivity of WISH 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).*

- 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, WISHSpec and JWST/NIRSpec are much more adapted to the very high redshift (i.e. z > 3).

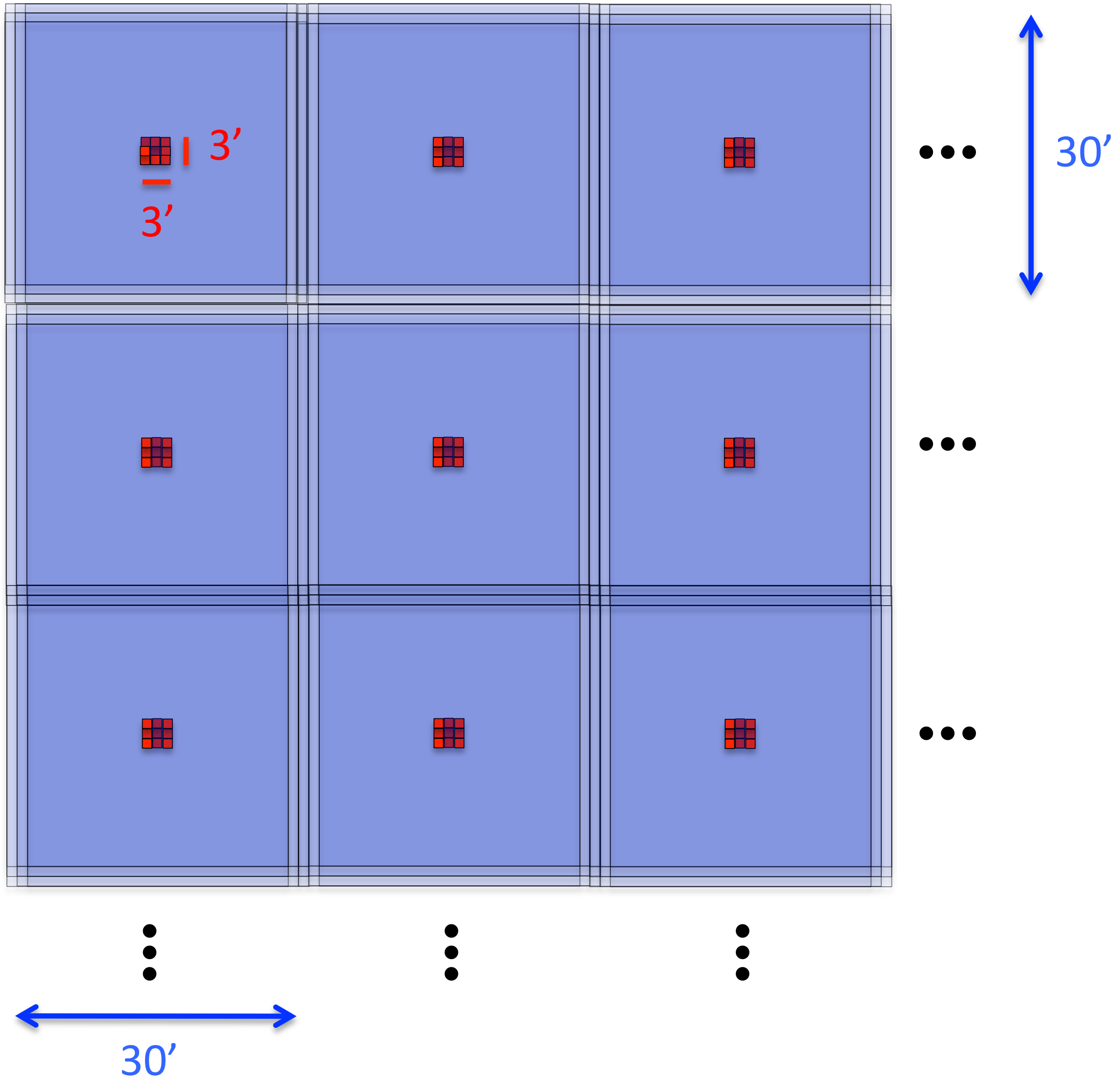
- On the spectroscopic side, assuming ~ 1 x 1 $arcmin^2$ field of view, WISHSpec **should observe more spectra than NIRSpec**. JWST would collect 10^5 galaxies down to AB=25 (R=100) to calibrate the photometric redshifts. NIRSpec would collect 10^4 galaxies (Franx 2011) over JWST lifetime (100 simultaneously,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

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

Physics OK   Redshift OK   BAD

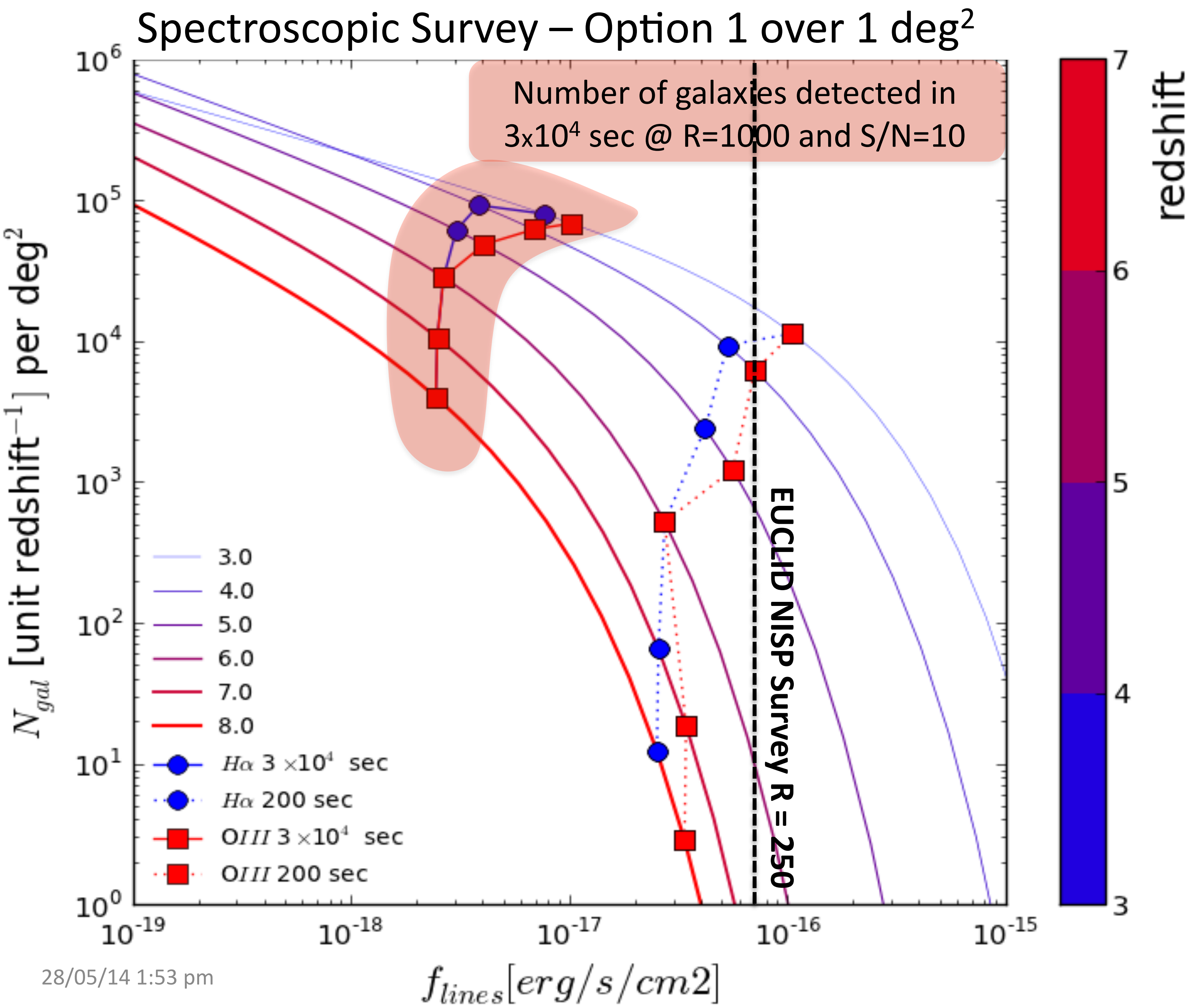
How many galaxies for WISHSpec surveys?



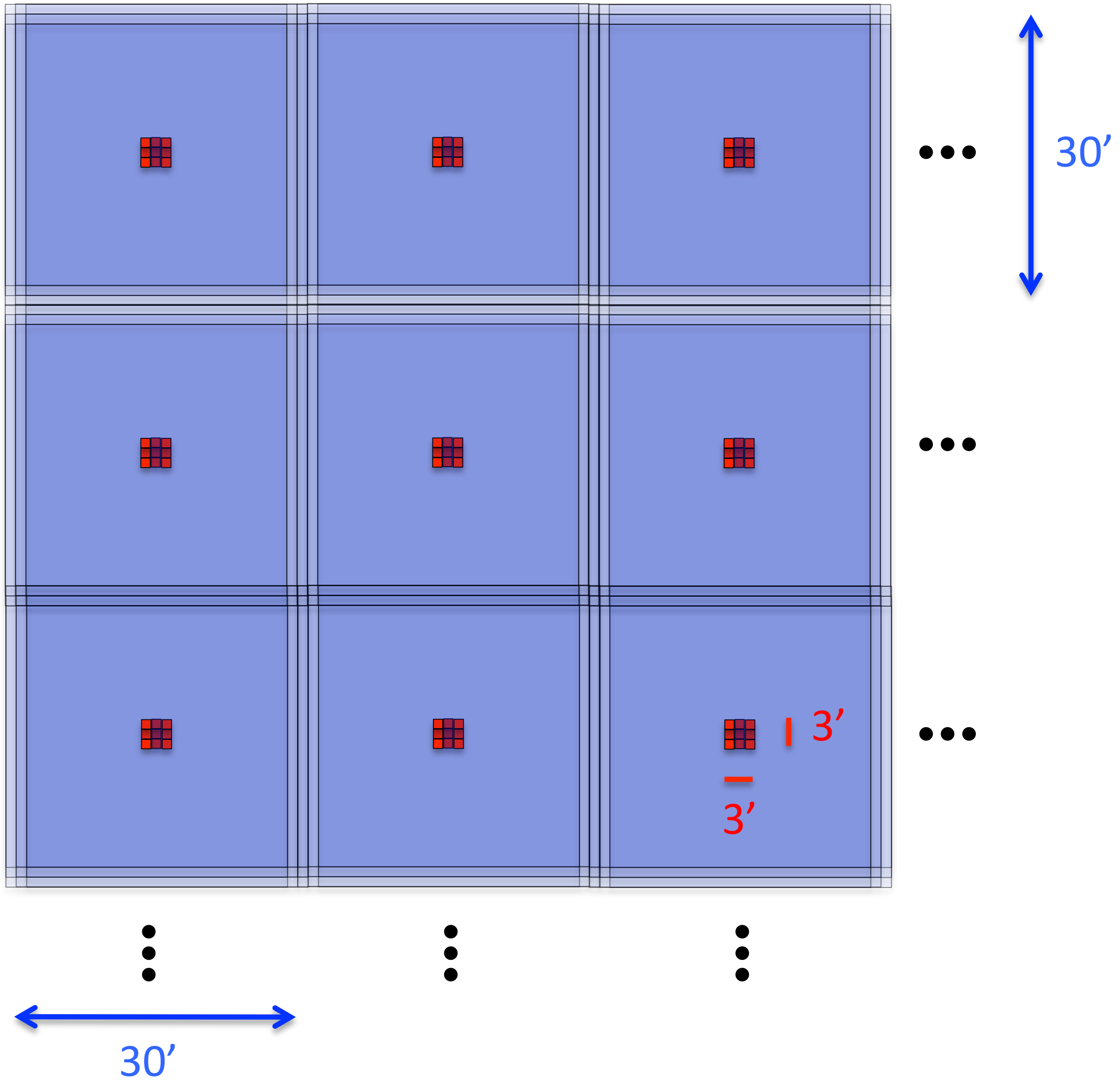
Ultra Deep Spectroscopic Survey

- For each $3.0x10^4$ sec on a 30’x30’ sub-field of the UDSPhot, we dither the field of view by ± 1’ => the UDSSpec FOV amounts to 9*(1’x1’) per each UDSPhot FoV
- That means that $9’^2/900’^2$ = 1/100 of the UDSPhot area will be covered by the UDSSpec
- The UDSSpec is observed in parallel to the UDSPhot => no additional time required.
- The exposure time for each UDSSpec FOV is $3.0x10^4$ sec
- The exposure time per 1’x1’ field for the UDSPhot/Spec is $3.0x10^4$ sec * 9 * 400 = $1.1x10^8$ sec
- The total area covered by the UDSPhot is ~$100deg^2$
- **=> the total area covered by the UDSSpec is ~$1deg^2$**
- **For UWS, the total area covered by the WDSSpec is ~$10deg^2$**

Spectroscopic instantanenous FOV = 1’x1’
UDS = Ultra Deep Survey
UDSS = Ultra Deep Spectroscopic Survey



28/05/14 1:53 pm

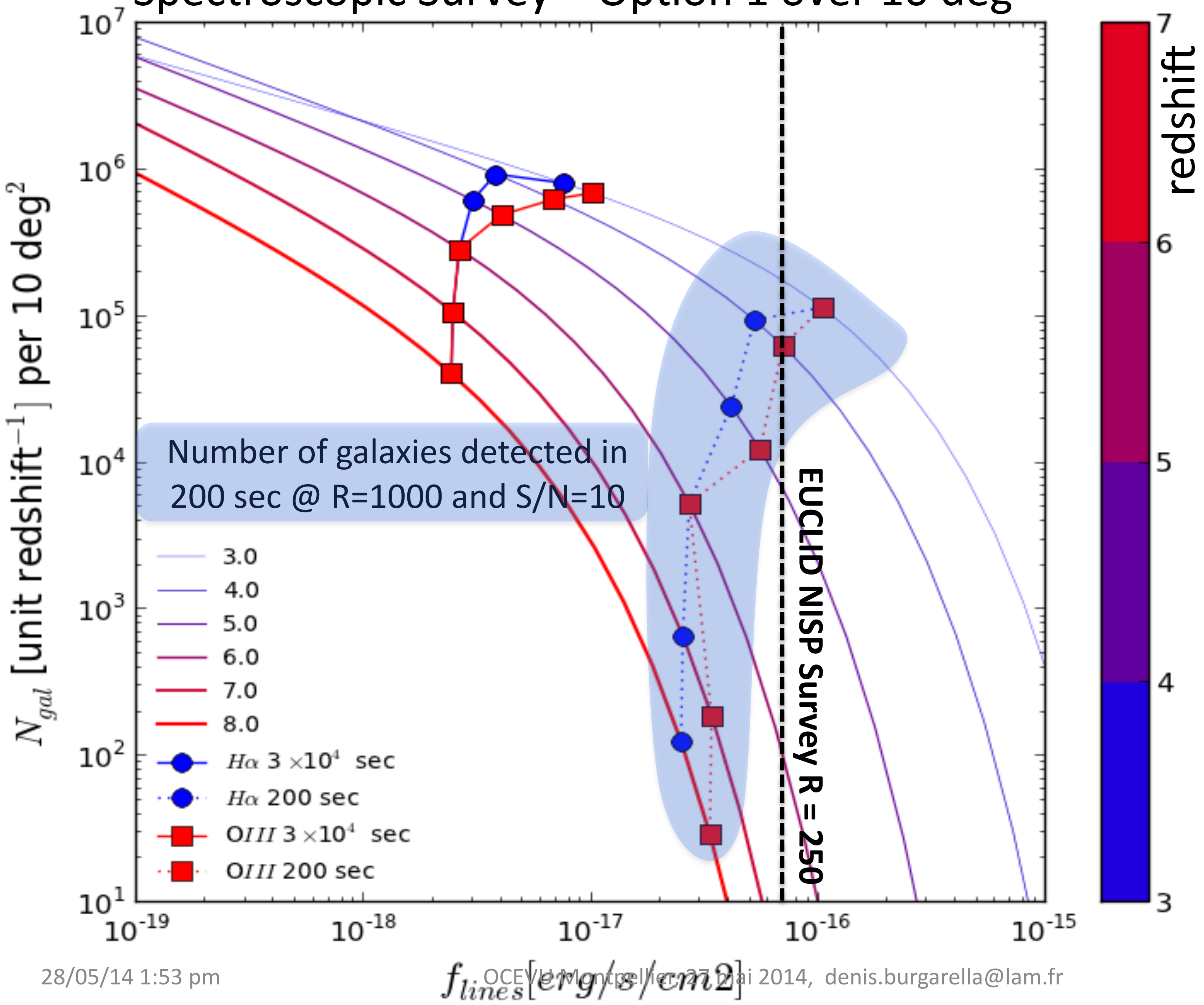


- For each 200 sec on a 30'x30' sub-field of the WDSPhot, we dither the field of view by ± 1'
  => the WDSpec FOV amounts to 9*(1'x1') per each WDSPhot FoV
- That means that $9'^2/900'^2$ = 1/100 of the WDSPhot area will be covered by the WDSSpec
- The WDSSpec is observed in parallel to the WDSPhot
  => no additional time required.
- The exposure time for each WDSSpec FOV is 200 sec
- The total exposure time for the WDSPhot/Spec is 200 sec * 9 * 4000 = 7.6×10^6 sec
- The total area covered by the photometric WDS is ~$1000 deg^2$
- => the total area covered by the WDSS is ~$10 deg^2$

Ultra Wide Spectroscopic Survey

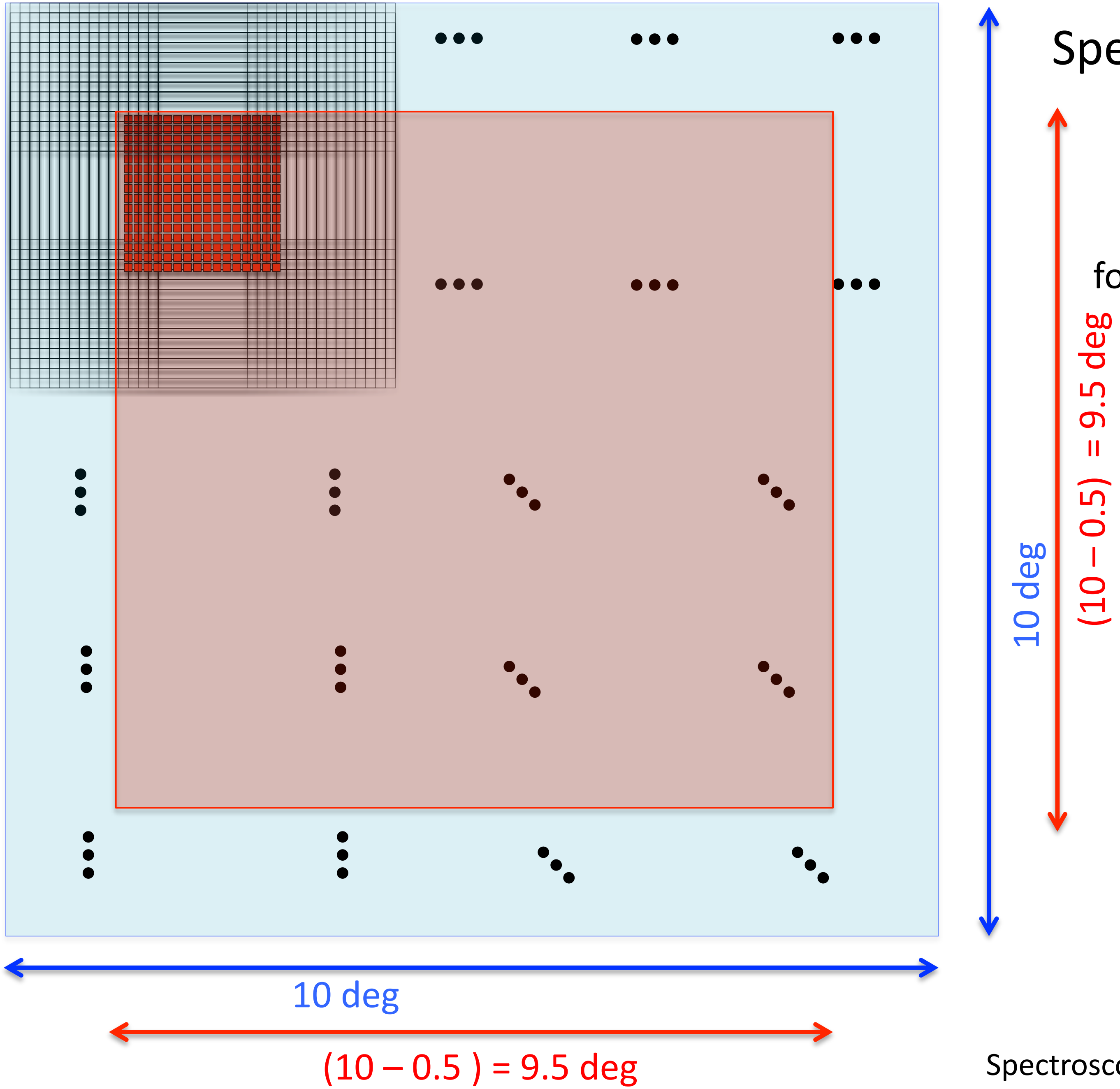
Spectroscopic instantanenous FOV = 1'x1'
WDS = Ultra Wide Survey
WDSS = Ultra Wide Spectroscopic Survey

Spectroscopic Survey – Option 1 over 10 deg^2



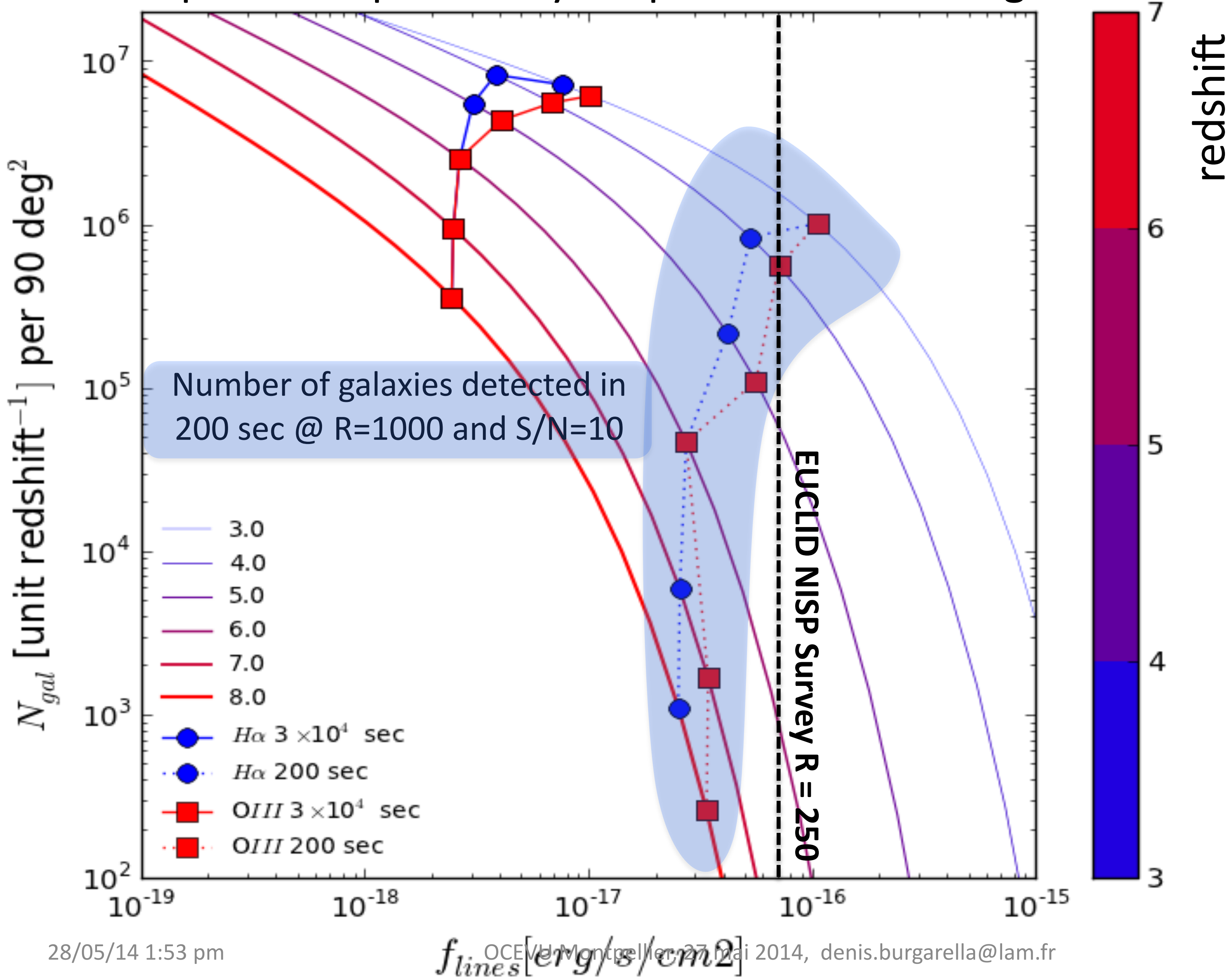
Spectroscopic Survey option 2 over ~ 90 deg^2

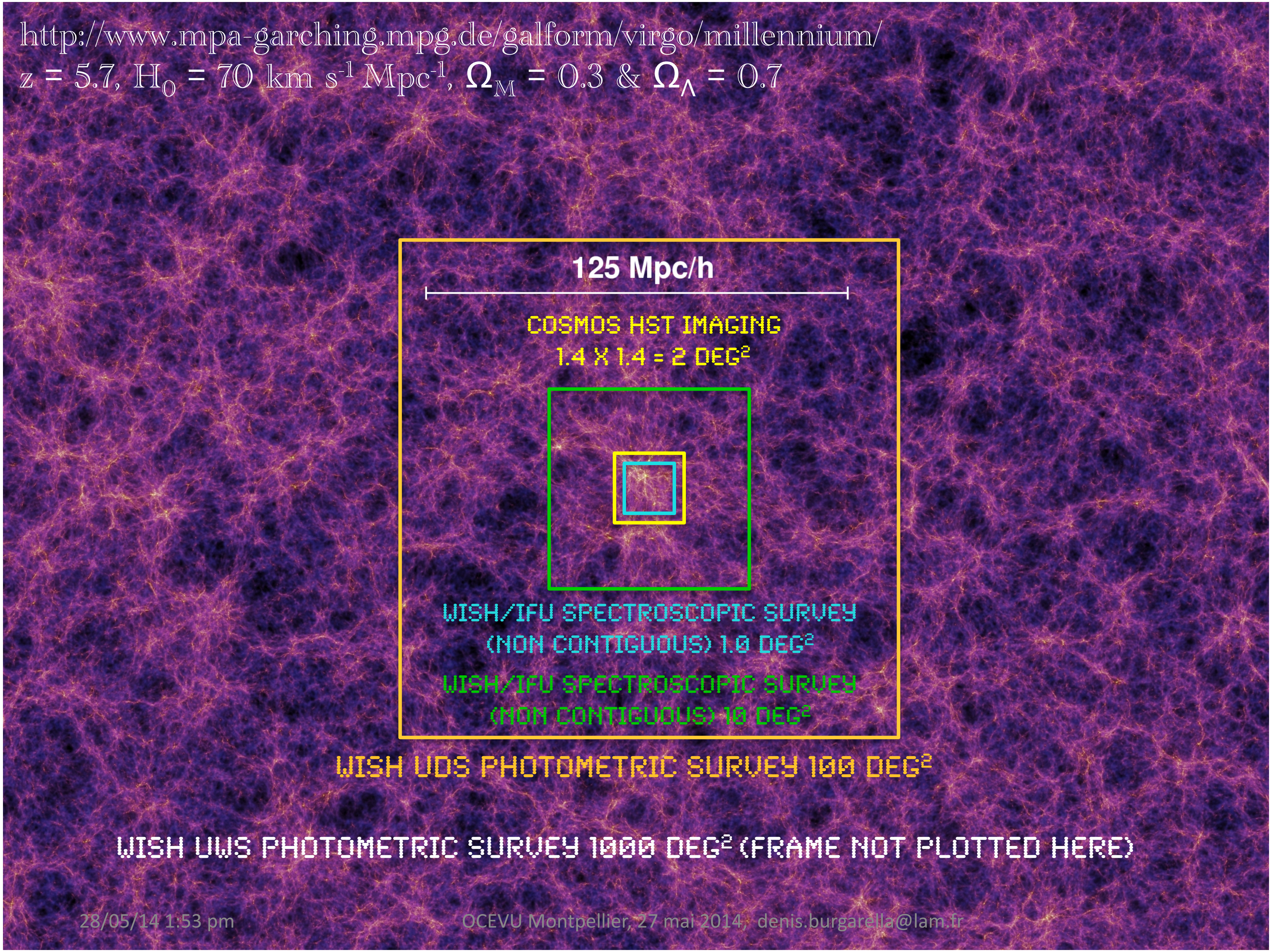
The exposure time for each FOV is 200 sec

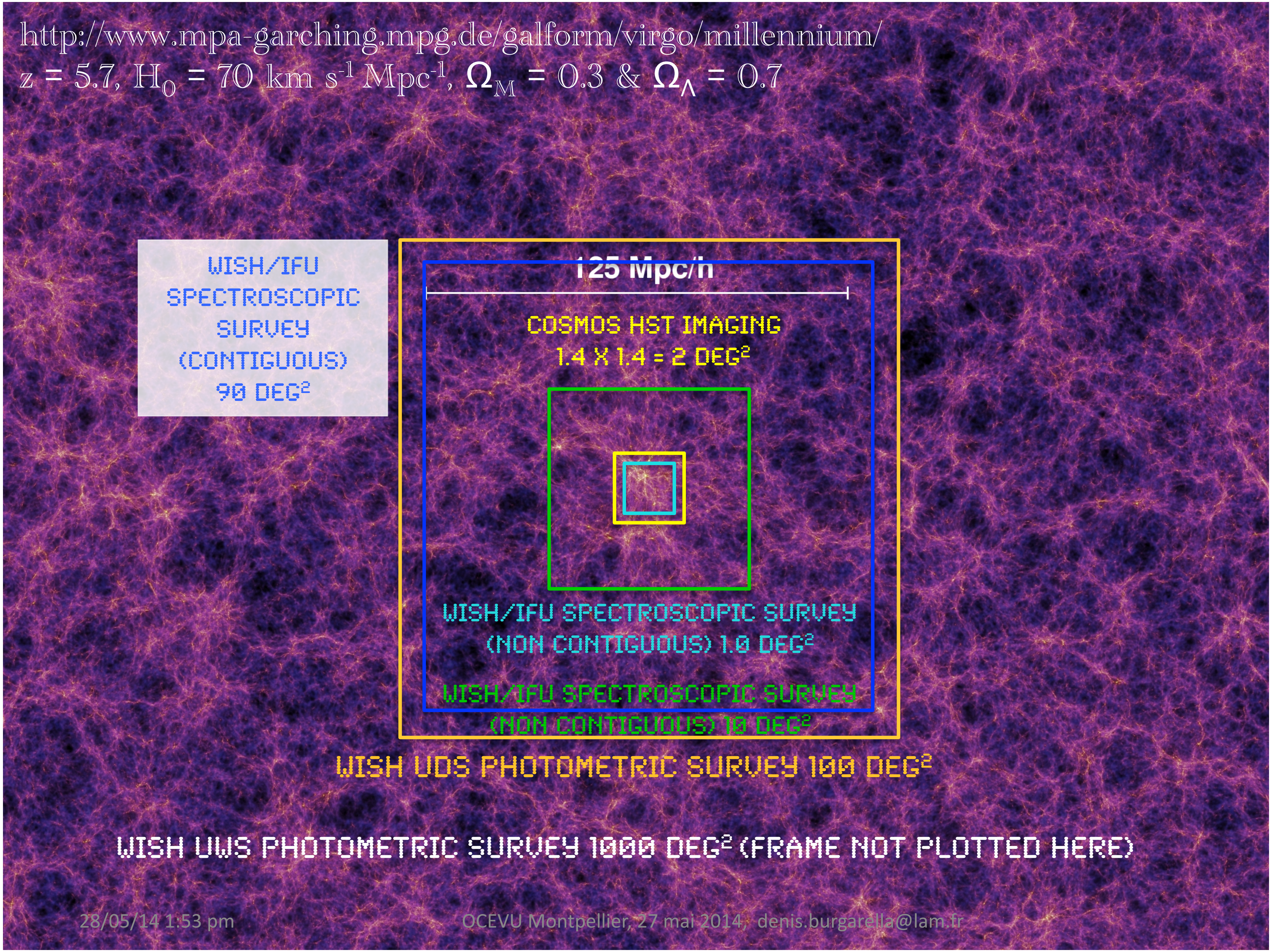


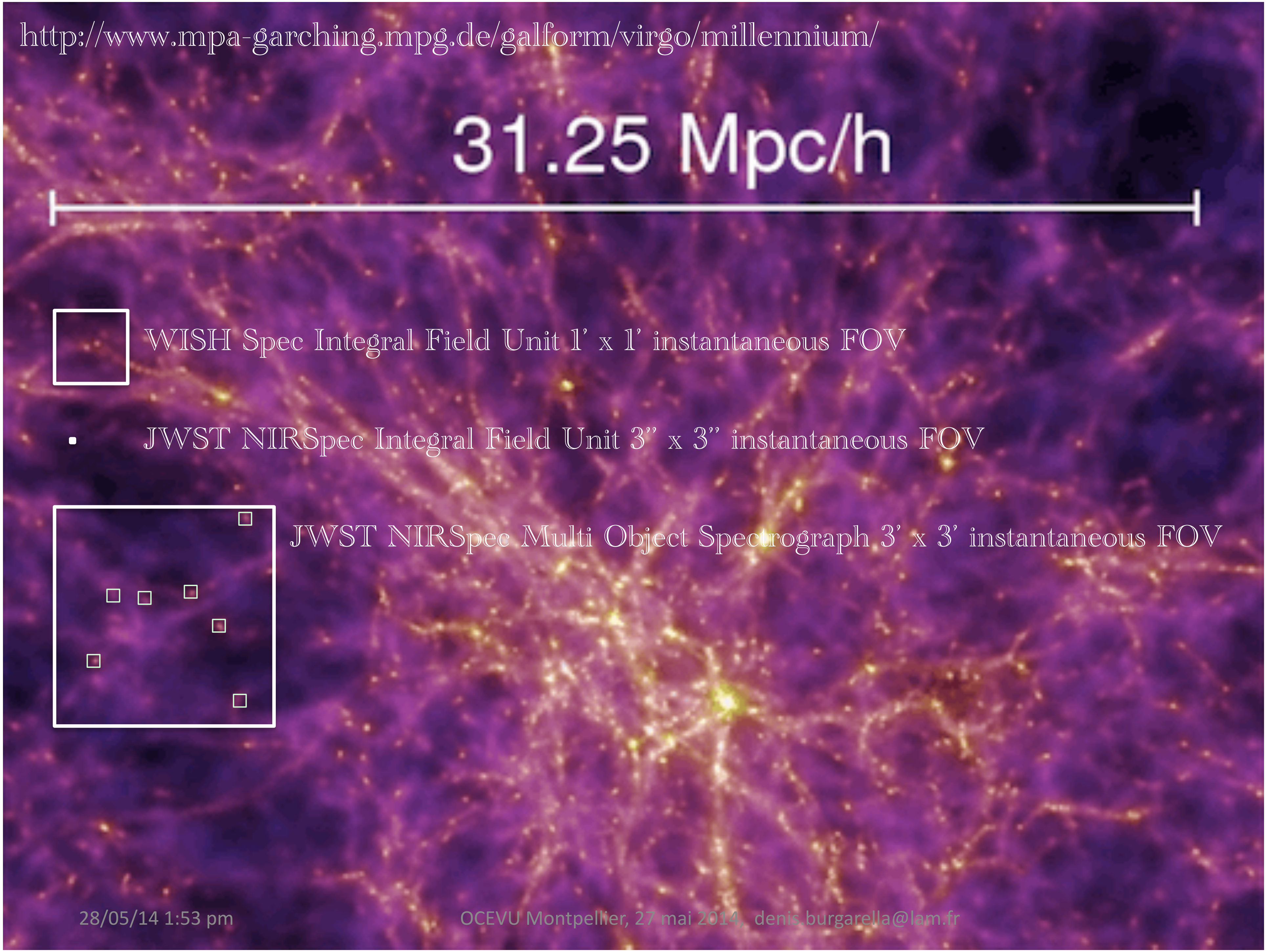
Spectroscopic instantanenous FOV = 1'x1'

Spectroscopic Survey – Option 2 over 90 deg^2




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
WISH/IFU SPECTROSCOPIC SURVEY
(NON CONTIGUOUS) 1.0 DEG^2
WISH/IFU SPECTROSCOPIC SURVEY
(NON CONTIGUOUS) 10 DEG^2
WISH UDS PHOTOMETRIC SURVEY 100 DEG^2
WISH UWS PHOTOMETRIC SURVEY 1000 DEG^2 (FRAME NOT PLOTTED HERE)


http://www.mpa-garching.mpg.de/galform/virgo/millennium/
$z = 5.7$, $H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_M = 0.3$ & $\Omega_\Lambda = 0.7$
WISH/IFU
SPECTROSCOPIC
SURVEY
(CONTIGUOUS)
90 DEG^2
125 Mpc/h
COSMOS HST IMAGING
1.4 X 1.4 = 2 DEG^2
WISH/IFU SPECTROSCOPIC SURVEY
(NON CONTIGUOUS) 1.0 DEG^2
WISH/IFU SPECTROSCOPIC SURVEY
(NON CONTIGUOUS) 10 DEG^2
WISH UDS PHOTOMETRIC SURVEY 100 DEG^2
WISH UWS PHOTOMETRIC SURVEY 1000 DEG^2 (FRAME NOT PLOTTED HERE)
28/05/14 1:53 pm
OCEVU Montpellier, 27 mai 2014 - denis.burgarella@lam.fr


http://www.mpa-garching.mpg.de/galform/virgo/millennium/
31.25 Mpc/h
WISH Spec Integral Field Unit 1' x 1' instantaneous FOV
JWST NIRSpec Integral Field Unit 3'' x 3'' instantaneous FOV
JWST NIRSpec Multi Object Spectrograph 3' x 3' instantaneous FOV

Conclusion (from CNES) Commentaires du groupe Astrophysique et Astrophysique du CNES 4 April 2014

- [CNES] noted that the addition of [Integral Field] spectroscopy [at R ~ 1000] to WISH would multiply the scientific possibilities of the mission.
- The large number of people who expressed an interest into WISH in France emphasizes its scientific merit and potential impact for our community.
- Moreover, this mission would ideally complement JWST [but also EUCLID, the ELTs, SPICA and ALMA]

Synthèse des priorités

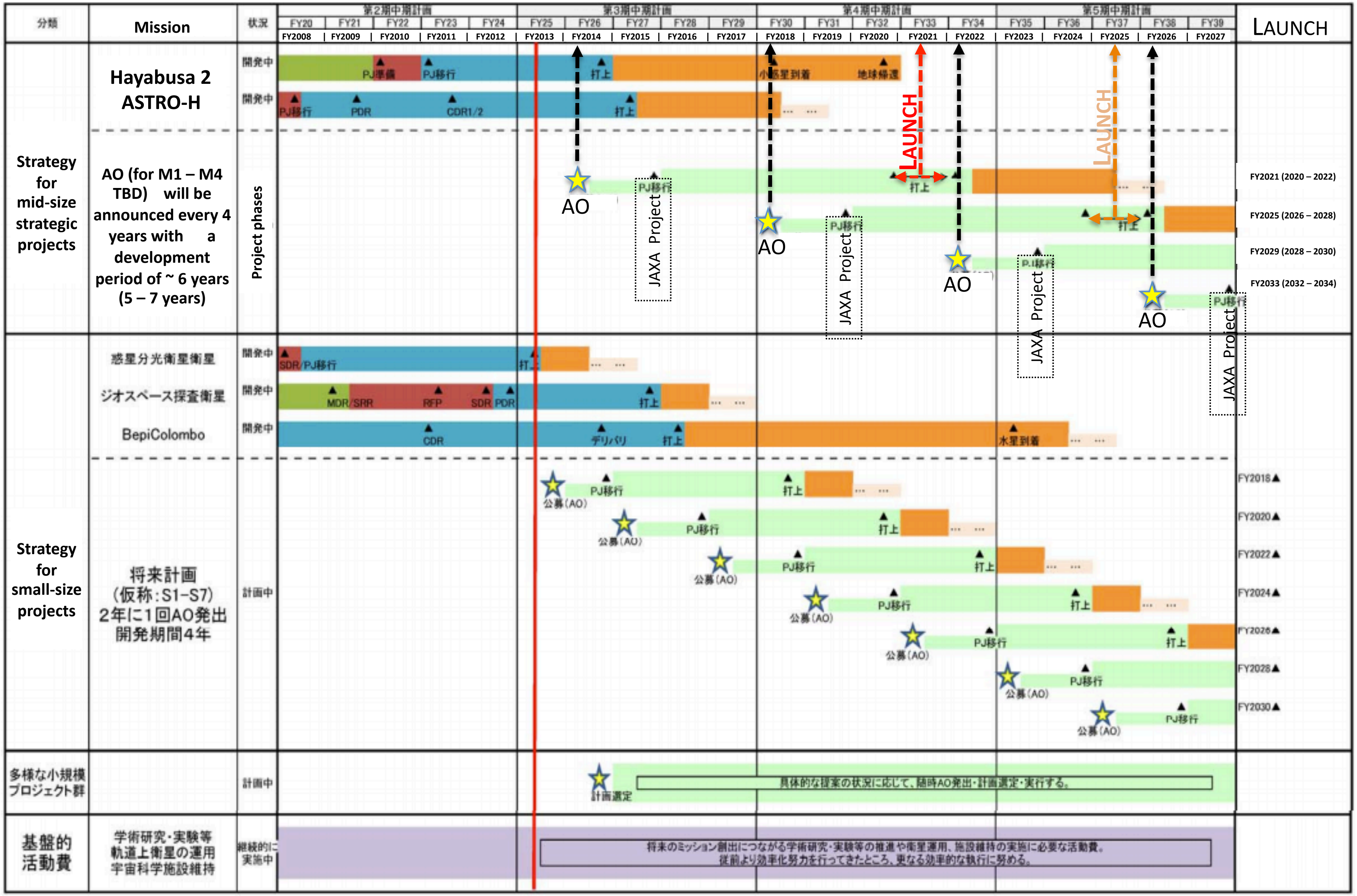
Colloque de prospective CNES, mars 2014)

Méthode d'observation	Cadre de réalisation	Priorité	R&T associée	Thème scientifique
Observer l'Univers dans le domaine des rayons X	L2 (ESA)	P0	Chaîne de détection et cryogénie	– Comprendre la fin des âges sombres et étudier la formation des premiers objets – Comprendre les mécanismes d'échange de matière et d'énergie aux différentes échelles, des étoiles aux trous noirs et aux galaxies
Observer les modes B de la polarisation du fond diffus cosmologique	M (ESA) ou Opportunité (NASA/JAXA)	P0	Chaîne de détection et cryogénie	– Comprendre la phase d'inflation de l'Univers primordial
Observer l'Univers lointain dans l'infrarouge lointain ou l'Univers proche dans l'ultraviolet	M (ESA) ou Opportunité (NASA)	P1		– Comprendre les mécanismes d'échange de matière et d'énergie aux différentes échelles, des étoiles aux trous noirs et aux galaxies
Observer par spectrophotométrie les atmosphères des exoplanètes	M (ESA) ou Opportunité	P1		– Caractériser les exoplanètes et chercher les biosignatures
Observer l'Univers dans le domaine du MeV	M (ESA) ou Opportunité	P2	Chaîne de détection	- Comprendre les explosions stellaires, la physique des objets compacts. - Comprendre l'origine des rayons cosmiques galactiques.
Observer les étoiles dans l'ultraviolet	M (ESA) ou Opportunité	P2	Spectro-polarimètre	– Comprendre la formation et l'évolution des étoiles et des planètes.
Observer l'univers lointain dans l'infrarouge proche	Opportunité	P2		– Comprendre la fin des âges sombres et étudier la formation des premiers objets

Phase 0 également demandée pour « Observer les étoiles dans l'ultraviolet ».

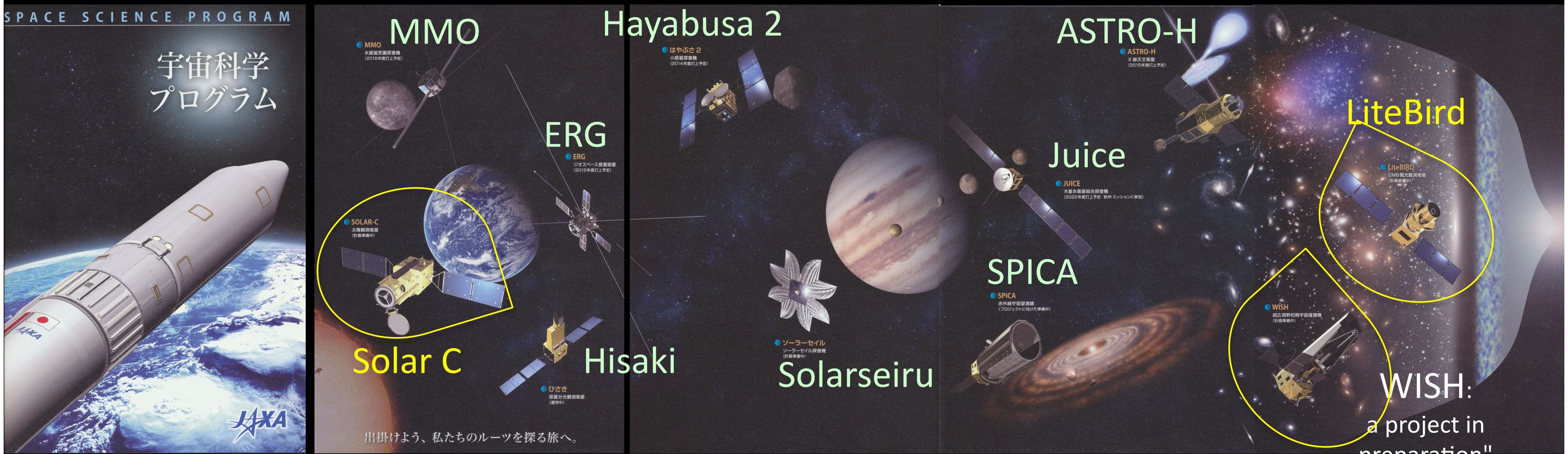
Translation Denis Burgarella...
Le précédent document en japonais fait référence

MEDIUM- AND LONG-TERM START-UP PLAN OF SPACE SCIENCE AND EXPLORATION PROGRAM (PRELIMINARY DRAFT)



The Three projects in competition in Japan

- Solar C : Moon
- Lite Bird: CMB Polarization
- WISH: First galaxies



Let's go, the travel to find our origins

Merci