Dust Attenuation & Star Formation Rate Density @ 0 < z < 4 and Integral Field Spectroscopy onboard the WISH wide-field, 1-5μm, Space Telescope
VLT/VVDS + Herschel/PEP+HerMES

(Burgarella, Buat, Gruppioni, Cucciati, Heinis et al. A&A avril 2013)

Two astrophysical quantities are deduced:

- **Dust Attenuation**
- **Star Formation Rate Density**

Two measurements are used:

- $L_{\text{IR}}$
- $L_{\text{UV}}$

Two measurements are used:

- $\log(\frac{L_{\text{IR}}}{L_{\text{UV}}})$
- $A_{\text{FUV}}$

**SUM**
The dust attenuation of the Universe reached a maximum at \( z \sim 1.2 \)
The very high redshift universe might experience a low dust attenuation. Statistically, this means that the very high-redshift universe \((z > 4)\) would be better studied in the rest-frame Far-UV.

**Figure 0.** The "age-metallicity" relation in our model, which is given by an absorption cross section weighted average of gas phase metallicity of all mass bins. Red crosses are measurements of a sample of 241 DLAs by Rafelski et al. (2012). The blue points are mean values in different redshift bins, as presented by Rafelski et al. (2012). Vertical error bars on the blue points represent 1\(\sigma\) error bars.

**Figure 7.** Metallicity as a function of Hubble time (lower x-axis) or redshift (upper x-axis) derived for GRB-DLAs (← as in figure 5), and the mean value derived for a sample of \(z < 1\) GRB hosts (↑, vertical and horizontal bars are the 1\(\sigma\) dispersion and the redshift interval of the sample, respectively). The curves are predictions from the empirical model of [19], for different total stellar masses. The shaded area indicates the range of stellar masses more favourable for the observed metallicities.
The Wide-field Imaging Surveyor for High-redshift (WISH)
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 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 French institutes (IRAP, Paris Obs. identified so far).

"I'll come back to this point later on"
What is WISH?

- **Launch**: ~2020
- **Lifetime**: 5 years
- **Optics**:
  - M1: $\varnothing 1.5m \times L2$
  - Passively cooled to 100K
  - Diffraction limited (0.2’’ @ 1µm)
- **$\lambda$ range**: 1 – 5 µm
- **Imaging**: 900 arcmin$^2$, 0.155’’/pixel
- **Spectroscopy**: Two options:
  - Priority 1: IFU, $\varnothing 1’$ (TBC), $R \sim 1000$, parallel observ.
  - Priority 2: Slitless, 900 arcmin$^2$, $R \sim 100$
- **Photometry (900 arcmin$^2$)**:
  - UDS: $m_{AB} = 28$ over 100 deg$^2$
  - UWS: $m_{AB} = 24-25$ over 1000 deg$^2$
  - ES: $m_{AB} = 29-30$ over 0.25 deg$^2$

1) Over 100 deg$^2$

**WISH will detect photometrically:**

- $\sim 10^2$ galaxies at $z=14-17$
- $\sim 10^{3-4}$ galaxies at $z=11-12$
- $\sim 10^{4-5}$ galaxies at $z=8-9$

2) Over 1 deg$^2$

**WISH will detect spectroscopically:**

- $\sim 10^{4-5}$ galaxies at $z=3-9$

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**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, ...)**

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*WISH*: We Invent a Stairway to Heaven

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


*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)

Dashed lines: no evolution from z=8

1 deg$^2$ to build a sample of $10^2$ galaxies at z $\sim$ 13.

ELTs’ spectroscopic limited mag
The need for WISH-Spec

- 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 => metallicities.

- Moreover, if an IFU option is selected, we will be able to:
  - detect serendipitously galaxies in the deep spectroscopic observations.
  - study the kinematics of distant galaxies.

Two simulations by V. Perret of the same modelled galaxy corresponding to an isolated disk.
If we assume an IFU spectrograph, it will observe in a parallel mode.

Translated into exposure 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: \([\text{OII}]\lambda3727, [\text{OIII}]\lambda4959, 5007, H\beta, [\text{NII}]\lambda6584 and H\alpha\) 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 \(\sim 1 \times 1 \text{arcmin}^2\) 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.

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Table valid for the optical lines \([\text{OII}]\lambda3727, [\text{OIII}]\lambda4959, 5007, H\beta, [\text{NII}]\lambda6584 and H\alpha\)
How many galaxies for WISHSpec surveys?
For each $3.0 \times 10^4$ sec on a 30’x30’ sub-field of the UDSPhot, we dither the field of view by ± 1’ => the UDSSpec FOV amounts to $9 \times (1’ \times 1’)$ 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 $3.0 \times 10^4$ sec

The exposure time per 1’x1’ field for the UDSPhot/Spec is $3.0 \times 10^4$ sec * $9 \times 400 = 1.1 \times 10^8$ sec

The total area covered by the UDSPhot is ~100 deg$^2$

=> the total area covered by the UDSSpec is ~1 deg$^2$

For UWS, the total area covered by the WDSSpec is ~10 deg$^2$

Ultra Deep Spectroscopic Survey

Spectroscopic instantaneous FOV = 1’x1’

UDS = Ultra Deep Survey

UDSS = Ultra Deep Spectroscopic Survey
Spectroscopic Survey – Option 1 over 1 deg²

Number of galaxies detected in 3x10^4 sec @ R=1000 and S/N=10

\[ N_{\text{gal}} \text{ [unit redshift}^{-1}] \text{ per deg}^2 \]

\[ f_{\text{lines}} [\text{erg/s/cm}^2] \]

**EUCLID NISP Survey**

R = 250
Number of galaxies detected in 200 sec @ R=1000 and S/N=10

Spectroscopic Survey – Option 1 over 10 deg²

$N_{gal}$ [unit redshift⁻¹] per 10 deg²

$f_{lines}[erg/s/cm^2]$

7/07/14 10:16 pm
http://www.mpa-garching.mpg.de/galform/virgo/millennium/

$z = 5.7, H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}, \Omega_M = 0.3 & \Omega_{\Lambda} = 0.7$

COSMOS HST IMAGING
$1.4 \times 1.4 = 2 \text{ deg}^2$

WISH/IFU SPECTROSCOPIC SURVEY
(NON CONTIGUOUS) $1.0 \text{ deg}^2$

WISH UDS PHOTOMETRIC SURVEY $100 \text{ deg}^2$

WISH UWS PHOTOMETRIC SURVEY $1000 \text{ deg}^2$ (FRAME NOT PLOTTED HERE)
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 => pre-phase A
Which team to study and develop WISHSpec?

• The French space agency (CNES) defined as one of its priorities: “Understanding the end of the Dark Ages and study the formation of the first objects” in the Near-IR through a mission of opportunity. This would match the requirements for an IFU spectrograph for the Japan-led WISH project.

• However, it is certainly interesting to open up the project to a wider community (Europe, USA, Canada and more?).

• Specifically for Europe, we envisage to apply to ESA « Collaborative Missions » (no AO announced, yet) like for AKARI, Suzaka, Hinode, ASTRO-H => enlarge the team in Europe (denis.burgarella@lam.fr)
WISH + First Galaxies
International Workshop
September 22 - 24, 2014
Laboratoire d'Astrophysique de Marseille, France
http://people.lam.fr/burgarella.denis/denis/WISH.html

- WISH is a space science mission concept whose primary goal is to study the first galaxies in the early universe in the λ range 1-5 μm.
- WISH will conduct unique ultra-deep and wide-area (900 arcmin²) photometric surveys.
- A spectroscopic parallel-mode spectrograph (IFU ~1arcmin²) is also planned.

The WISH + First Galaxies International Workshop will be divided in several sessions allowing people to present talks related to cosmology, extragalactic studies, stars, (exo-)planets and Solar system bodies but also to instrumentation:
- Day 1: The WISH project (scientific objectives, simulations, instrumentation).
- Days 2 and 3: The galaxies in the re-ionization era and the first galaxies (models, observational constraints, simulations).

Scientific Organizing Committee:
Denis BURGARELLA, co-chair (LAM, France)
Toru YAMADA, co-chair (Tohoku Univ., Japan)
Médéric BOQUIN (IoA, UK)
Jean-Claude BOURET (LAM, France)
Véronique BUAT (LAM, France)
Giovanni FAZIO (CFA, USA)
Ikuru IWATA (SUBARU Telescope, NAOJ, USA)
Akio INOUE (Osaka Sangyo University, Japan)
Barbara LO FARO (LAM, France)
Roser PELLO (IRAP, France)
Marcin SAWICKI (Saint Mary’s Univ., Canada)
Daniel SCHAEFER (Obs. de Genève, Switzerland)
If you wish to study the emission (continuum, lines, AGN, dust emission) of galaxies (resolved or not from the FUV to the FIR) at all redshifts with Complex Star Formation histories, please have a look at: http://cigale.lam.fr