Prospects for galaxy surveys beyond $z=10$

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Cosmic dawn

One of the most important themes in modern astronomy and astrophysics is to understand the galaxy formation. The current frontier redshift is about $z=10$ and our observations will reach the Universe beyond $z=10$, the pre-reionization epoch, in near future.
Highest emission line redshift object

Hashimoto+AKI+18, Nature

[OIII] 88 μm line at z=9.1096
Formation at z~15

Hashimoto+AKI+18, Nature

Balmer break $\rightarrow$ Age of a few 100 Myrs $\rightarrow$ Formation at z~15!

SFR~10 Msun/yr at z~12-15
$\rightarrow$ $m$~26-27 AB
Very easy to be detected with JWST.
Massive BBGs at z~6

Mawatari, AKI+19, submitted

Balmer break galaxy (BBG) candidates at 5<z<8 selected by using the deepest wide NIR imaging data.
Cosmic SFRD at $z>14$

Mawatari, AKI+19, submitted

The stellar mass density requires a significant star formation rate density in an earlier epoch, that is, $z>14$.

99.7% confidence area
Observed UV luminosity functions

UV luminosity functions (LFs) of Lyman break galaxies (LBGs) have been observed up to $z \sim 10$.

Possible redshift evolutions of the number density ($\phi^*$) and the faint-end slope ($\alpha$).

Bouwens+15
\[ \log_{10} \phi_* [\text{Mpc}^{-3}\text{mag}^{-1}] = -0.25(1 + z) - 1.5 \] (for \( z > 3 \); solid)

\[ \log_{10} \phi_* [\text{Mpc}^{-3}\text{mag}^{-1}] = -0.6(1 + z) + 1.65 \] (for \( z > 8 \); dashed)

\[ M_{UV}^* = -20.5 \text{ (fixed)} \]

\[ \alpha = \begin{cases} -2.0 & (z < 9) \\ -2.3 & (z \geq 9) \end{cases} \text{ (fixed)} \]
UV luminosity functions at $z \sim 8$

Filled circles & thin solid line: Bouwens+15
Filled triangles: Stefanon+19
UV luminosity functions at z~9

Filled circles: Bouwens+16
Open circles: Oesch+13
Filled triangles: Stefanon+19
Five-pointed stars: Morishita+18
UV luminosity functions at $z \approx 10$

- Filled circles & thin solid line: Oesch+18
- Five-pointed stars: Morishita+18
- Red bars: Finkelstein+19
Bright-end of UV LFs at z>8
A time-independent excess???

Filled circles & thin solid line: Oesch+18
Filled triangles & open squares: Stefanon+19
Five-pointed stars: Morishita+18
Red bars: Finkelstein+19
Small crosses: Matsuoka+18
Expected surface number density

- Dark/light shades: ULTIMATE Subaru surveys
- Dotted lines: JWST surveys
- Solid lines: Smooth density evolution models
- Dashed lines: Rapid density evolution models
Expected surface number density

- Dark/light shades: ULTIMATE Subaru surveys
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- Dashed lines: Rapid density evolution models

\[ \lambda(Ly\alpha) = 1.95 \mu m \quad @ \quad z = 15 \]

WFIRST HLS 2000deg\(^2\), H<26.7

WFIRST SN Deep 5deg\(^2\), H<28.2

Euclid Deep 40deg\(^2\), H<26.0
Expected surface number density
The case with a time-independent bright-end excess

\[ \lambda(\text{Ly}\alpha) = 1.95 \mu m \]
@ \( z = 15 \)

2019/7/1
Expected surface number density
The case with a time-independent bright-end excess

\[ \lambda(\text{Ly} \alpha) = 1.95 \, \mu m \]
@ \( z = 15 \)
Expected surface number density

The case with a time-independent bright-end excess

\[ \lambda(Ly\alpha) = 1.95 \mu m \]

\[ @ z = 15 \]

(JWST)

(WFIRST)

(Euclid)

z~6 BBGs' progenitors

2019/7/1
Summary

- Expected UV luminosity functions of galaxies up to z=15 were presented, assuming an empirical galaxy number density evolution.
- Expected detectability of galaxies at z=10 to 15 in JWST, ULTIMATE-Subaru, Euclid and WFIRST surveys was presented.
- There may be a bright-end excess in UV luminosity functions, which was inferred from recent z=8-10 LBG and z=6 BBG observations.