UV & U-band luminosity functions from CLAUDS and HSC-SSP – I. Using four million galaxies to simultaneously constrain the very faint and bright regimes to z ~ 3

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ABSTRACT

We constrain the rest-frame FUV (1546Å), NUV (2345Å) and U-band (3690Å) luminosity functions (LFs) and luminosity densities (LDs) with unprecedented precision from $z \sim 0.2$ to $z \sim 3$ (FUV, NUV) and $z \sim 2$ (U-band). Our sample of over 4.3 million galaxies, selected from the CFHT Large Area *U*-band Deep Survey (CLAUDS) and HyperSuprime-Cam Subaru Strategic Program (HSC-SSP) data lets us probe the very faint regime (down to $M_{\rm FUV}, M_{\rm NUV}, M_{\rm U} \simeq -15$ at low redshift) while simultaneously detecting very rare galaxies at the bright end down to comoving densities $< 10^{-5}$ Mpc^{-3}. Our FUV and NUV LFs are well fitted by single Schechter functions, with faint-end slopes that are very stable up to $z \sim 2$. We confirm, but self-consistently and with much better precision than previous studies, that the LDs at all three wavelengths increase rapidly with lookback time to $z \sim 1$, and then much more slowly at $1 < z < 2$–3. Evolution of the FUV and NUV LFs and LDs at $z < 1$ is driven almost entirely by the fading of the characteristic magnitude, $M^\star_{UV}$, while at $z > 1$ it is due to the evolution of both $M^\star_{UV}$ and the characteristic number density $\phi^\star_{UV}$. In contrast, the U-band LF has an excess of faint galaxies and is fitted with a double-Schechter form; $M^\star_{\rm U}$, both $\phi^\star_{\rm U}$ components, and the bright-end slope evolve throughout $0.2 < z < 2$, while the faint-end slope is constant over at least the measurable $0.05 < z < 0.6$. We present tables of our Schechter parameters and LD measurements that can be used for testing theoretical galaxy evolution models and forecasting future observations.

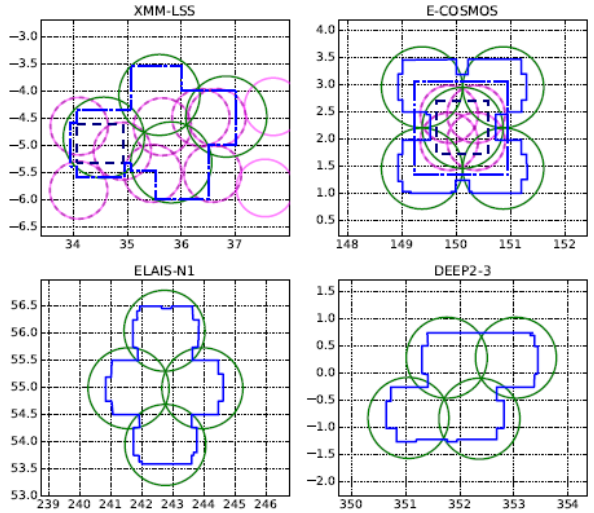
Data:

U CFHT-CLADUS $U_{AB} = 27.1(18.60\ \deg^2), 27.7(1.36\ \deg^2)$ 0.92" (Sawicki 2019, release: 2020)

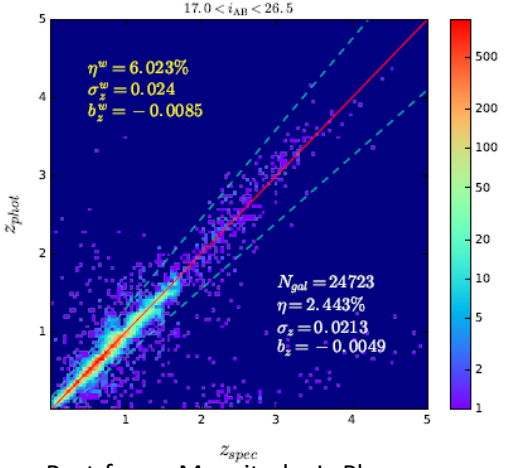
g,r,i,z,y HSC-SSP-PDR1 (public) 26.6(g) to 24.2(y) best seeing: 0.62"(i) (Data merging with PDR1, maybe PDR2 better?)

NUV FUV GALEX (low-z) (Only for Verification)

Blue: CLAUDS-DEEP
Dark-Blue: CLAUDS-UltraDeep
Green: HSC-SSP
Magenta: GALEX



Z_{photo}: KNN (machine learning) + LePhare (template-fitting)



Rest-frame Magnitude: LePhare

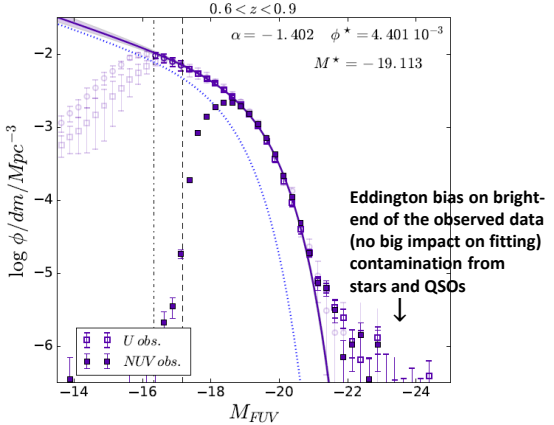
Number of galaxies

Redshift bin	Deep [a]	Ultra-Deep [b]	Overlap [c]	Total used [d]
$0.05 < z < 0.3$	201,617	(18,073)	—	201,617
$0.3 < z < 0.45$	296,940	(30,590)	—	296,940
$0.45 < z < 0.6$	331,144	(31,291)	—	331,144
$0.6 < z < 0.9$	735,345	84,059	63,473	755,931
$0.9 < z < 1.3$	1,142,045	143,771	93,381	1,192,435
$1.3 < z < 1.8$	830,481	134,570	68,037	897,014
$1.8 < z < 2.5$	566,007	102,226	58,784	609,449
$2.5 < z < 3.5$	(277,050)	54,977	—	54,977
	(277,050)	(79,962)		
$0.05 < z < 3.5$	4,103,579	519,603	283,675	4,339,507

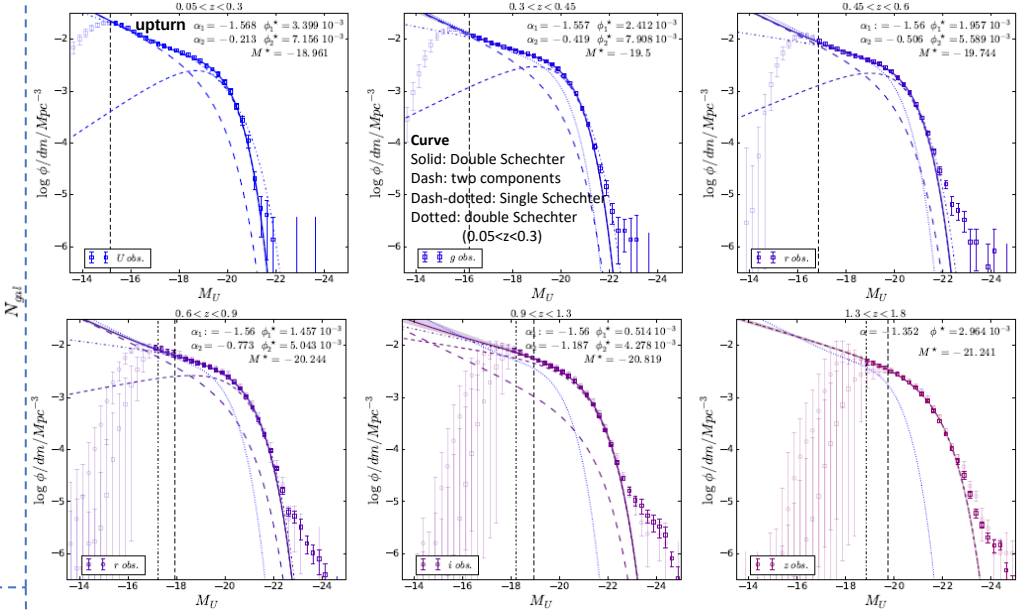
Cosmic Variance

Limited depth

A sample LF of FUV (Solid curve: fitting, Dotted: fitting at $0.06 < z < 3$)
U obs: CLAUDS (□: Deep ○: Ultra Deep) Dash(-dotted) : Completeness limits
NUV obs: GALEX (Verification the extrapolation blueward at low z)

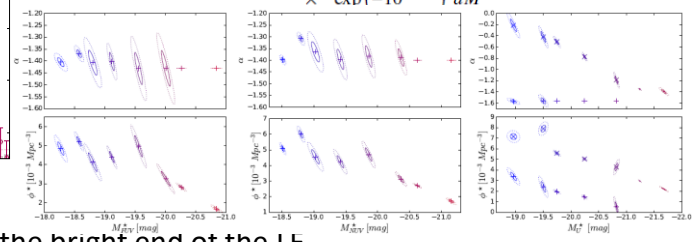


Eddington bias on bright-end of the observed data (no big impact on fitting) contamination from stars and QSOs



FUV, NUV, U (high-z): Single Schechter α, Φ, M
U (low-z): Double Schechter α1, Φ1, α2, Φ2, M

$$\phi(M)\,dM = \frac{\ln 10}{2.5}\left[\phi_1^\star \left(10^{0.4\Delta M}\right)^{\alpha_1+1} + \phi_2^\star \left(10^{0.4\Delta M}\right)^{\alpha_2+1}\right] \times \exp\left(-10^{0.4\Delta M}\right) dM \qquad \Delta M = M^\star - M$$



Fitting Conclusion:

1. The evolution of the bright end of the LF
2. **U:** the location of the upturn is preserved with cosmic time
3. **UV:** The slope α is stable, The normalization Φ drops at z > 1.3

FUV, NUV LF are in overall agreement with the literature, but show a remarkably steady (less noisy) progression with cosmic time.

Luminosity density:

$$\rho(L) = \int_L^\infty L'\,\phi(L')\,dL'$$

FUV:
Increase until z ~ 1, then become stable