Measuring the conditional luminosity and stellar mass functions of galaxies by combining the DESI LS DR9, SV3 and Y1 data

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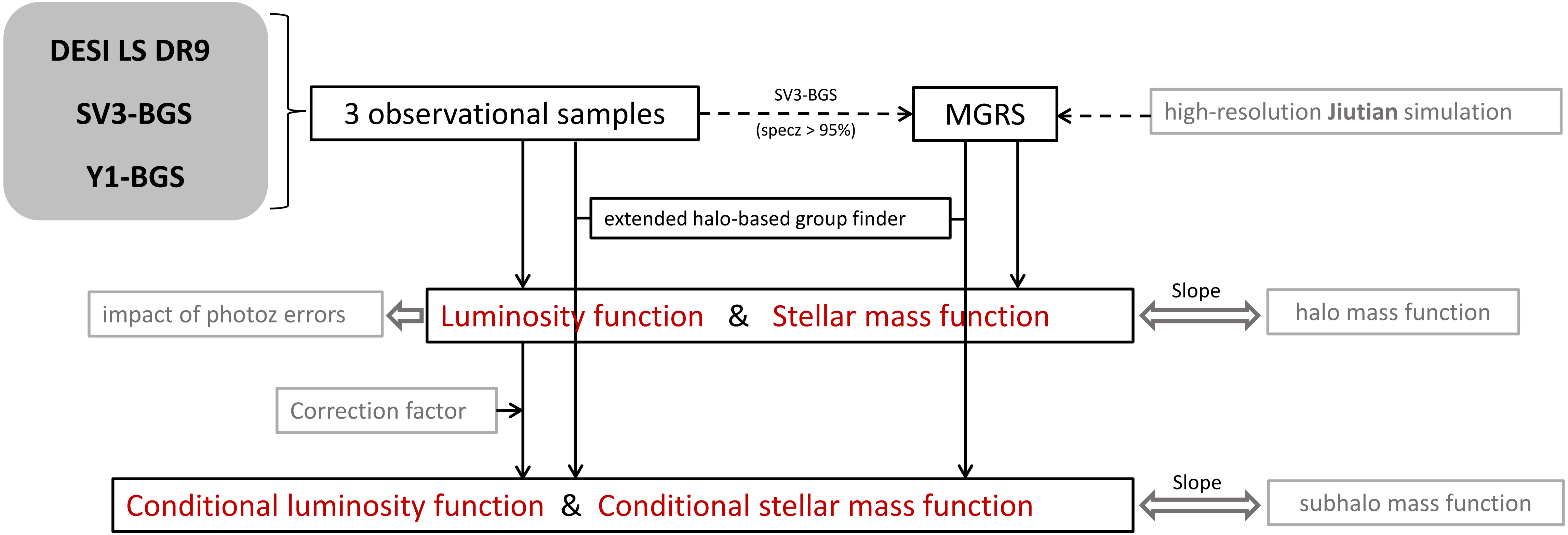
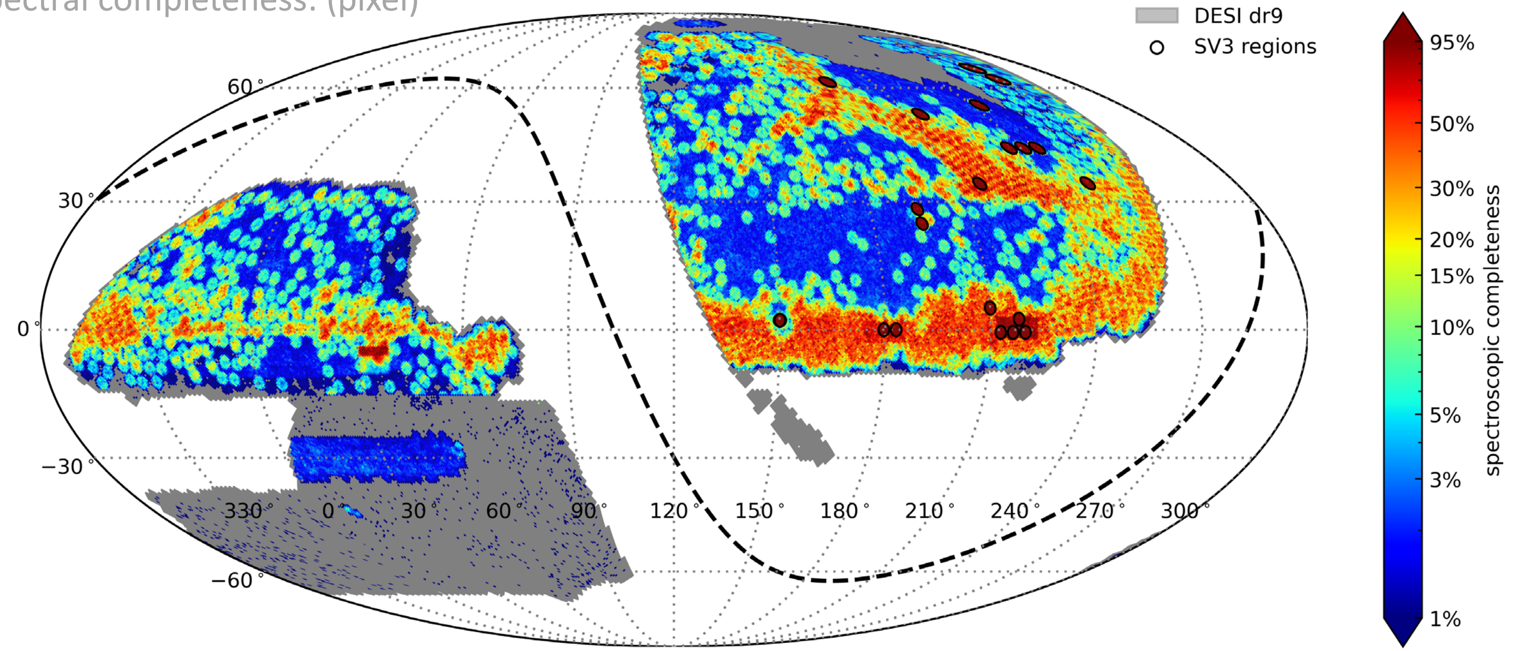
Framework


DESI LS DR9
SV3-BGS
Y1-BGS
3 observational samples
SV3-BGS
(specz > 95%)
MGRS
high-resolution **Jiutian** simulation
extended halo-based group finder
impact of photoz errors
Luminosity function & Stellar mass function
Slope
halo mass function
Correction factor
Conditional luminosity function & Conditional stellar mass function
Slope
subhalo mass function

Three observational samples: DESI LS DR9, SV3-BGS, Y1-BGS

spectral completeness: (pixel)



138 million galaxies → (5 band requirement; z < 1; dec > -10 (NGC)) → 125 million galaxies

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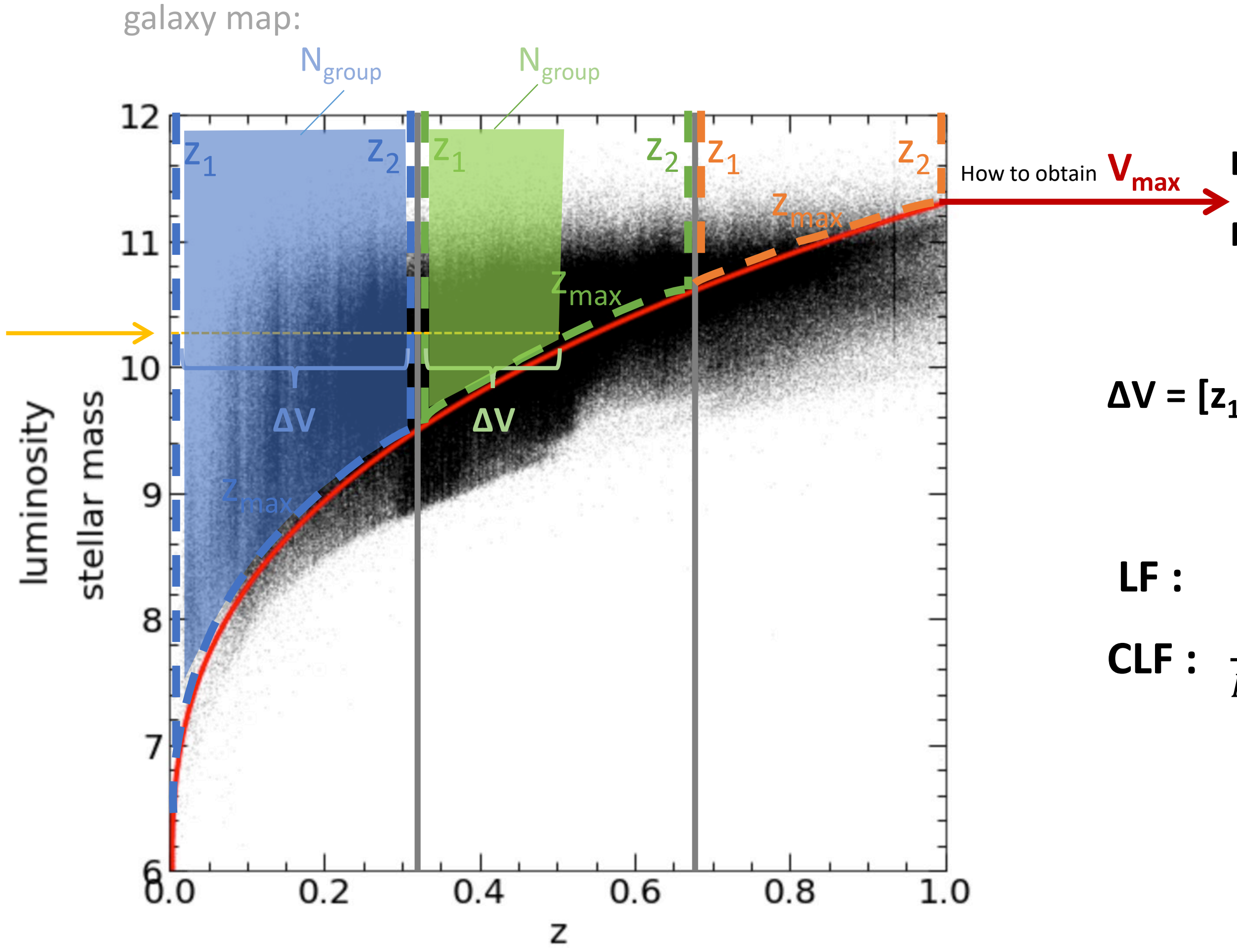
$1/f_{comp}(m_z)$
<selection incompleteness>

Sample ID	sky coverage (deg^2)	magnitude cut (mag)	total	central	satellite	specz percent
DESIDR9-NGC	9622	$m_z \leq 21.0$	66231350	48839245	17392105	4.2%
DESIDR9-SGC	8601	$m_z \leq 21.0$	59066483	42899992	16166491	1.3%
Y1-z19.0	12276	$m_z \leq 19.0$	10911254	8423566	2487688	44.4%
Y1-r19.5	12276	$m_r \leq 19.5$	8463396	6483000	1980396	46.5%
SV3-z19.0	124	$m_z \leq 19.0$	127939	102080	25859	95.2%
SV3-r19.5	124	$m_r \leq 19.5$	100151	78783	21368	99.3%

Fuji, Guadalupe and Iron

Vmax method



L : maximum redshift for a galaxy with given luminosity

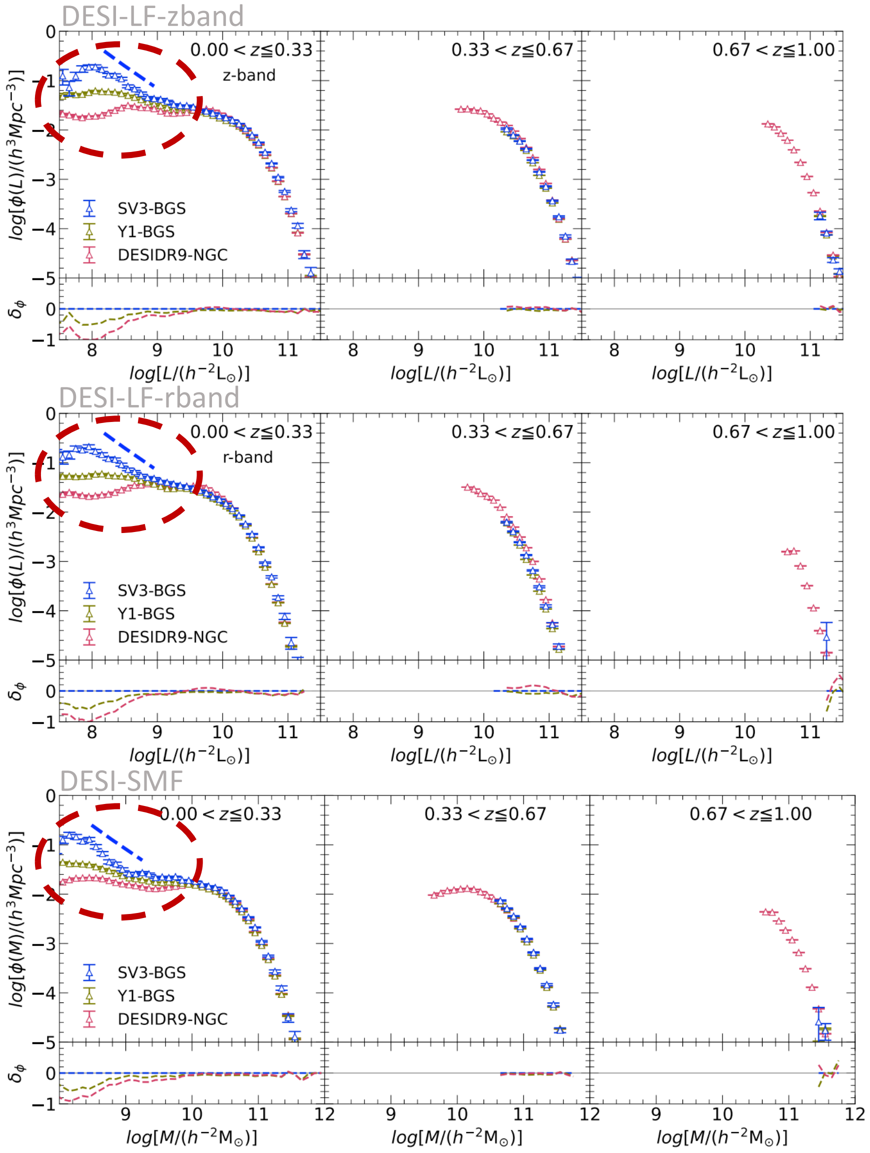
M_*: peak line of the < stellar mass vs. z > number density map

$\Delta V = [z_1, \min(z_2, z_{max})]$.

LF : $\frac{1}{\Delta V}$

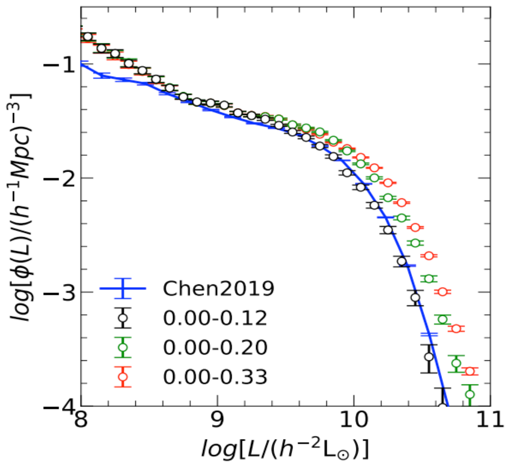
CLF : $\frac{1}{N_{group}(\Delta V)}$

Luminosity / Stellar mass function LF & SMF (observation)



- photometric redshift samples can induce a significant reduction in the faint end measurements of the LFs and SMFs in the lowest redshift bin.
- spectroscopic redshift SV3-BGS sample provides a clear upturn in the LFs and SMFs below $10^9\,h^{-2}L_\odot$ (or $h^{-2}M_\odot$), with a slope that is in nice agreement with that of halo mass function at the low mass end, which indicates that the galaxy formation efficiency in very small halo could be very efficient.
- Obtain Correction factor from LFs/SMFs reduction with respect to the SV3-BGS sample.

LF (our work vs. SDSS)



Jiutian Simulation

dark-matter-only simulation
particle number: **6144^3**
box size: **1Gpc/h**
cosmology: **Planck-2018**
($\Omega_M = 0.3111$, $\Omega_\Lambda = 0.6889$, $\Omega_b = 0.0490$, $\sigma_8 = 0.8102$ and $n_s = 0.9665$)
particle mass: $\mathbf{m_p = 3.723 \times 10^8\ h^{-1} M_\odot}$
redshift range: **127-0 (128 snapshots)**
identify halo: Friends-of-Friends algorithm
identify subhalo: HBT+ code

Construction of the light-cone of the halos/subhalos

Use halos in different snapshots, at the location of their redshifts

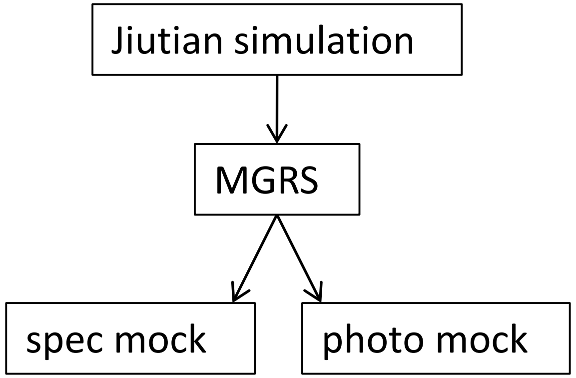
Observer is placed at the center

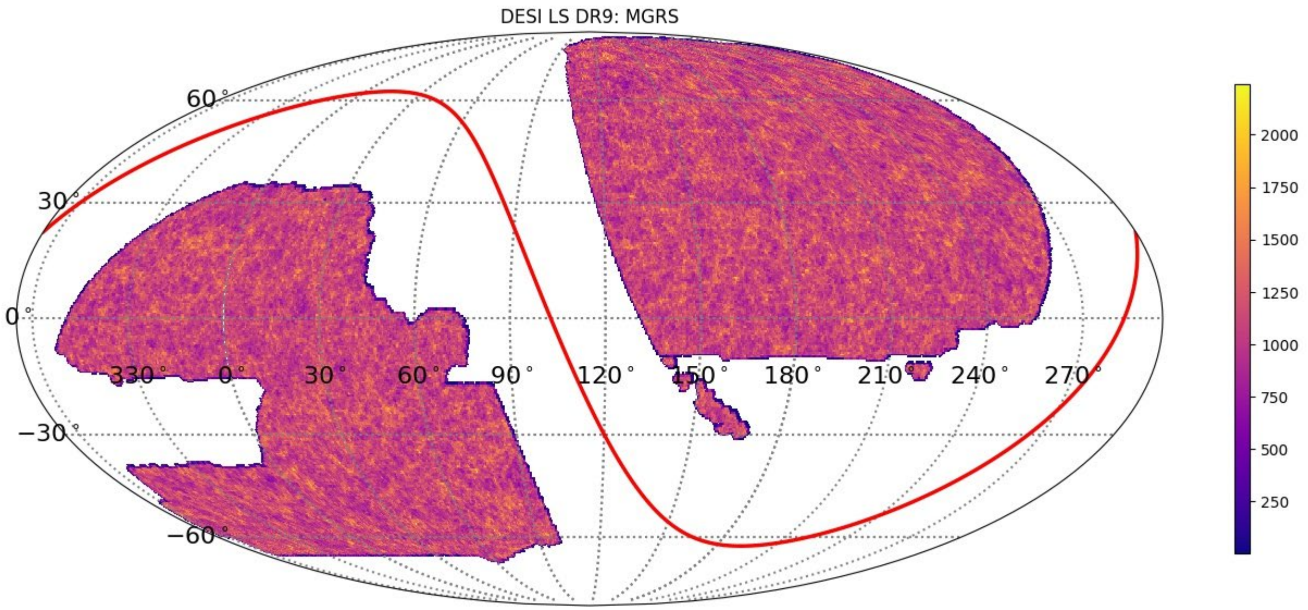
Jiutian Simulation

MGRS:

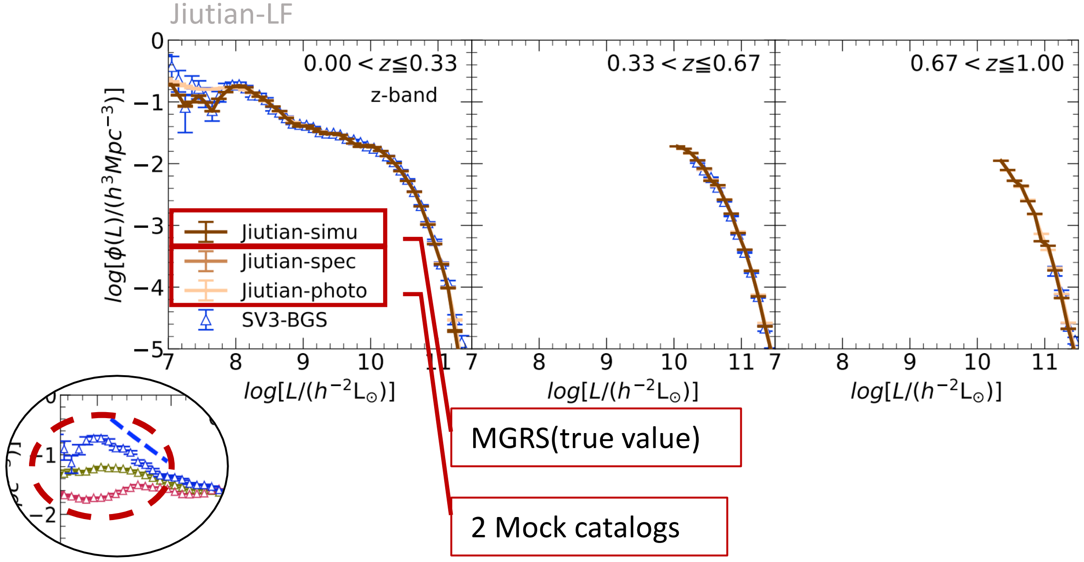
sky coverage: same as DESIDR9
apparent magnitude limit cut: **z ≤ 21.0**
redshift range: **[0.0, 1.0]**
specz: with RSD and spectroredshift error 35km/s
photoz: \sigma_z=0.01+0.015(1+z)

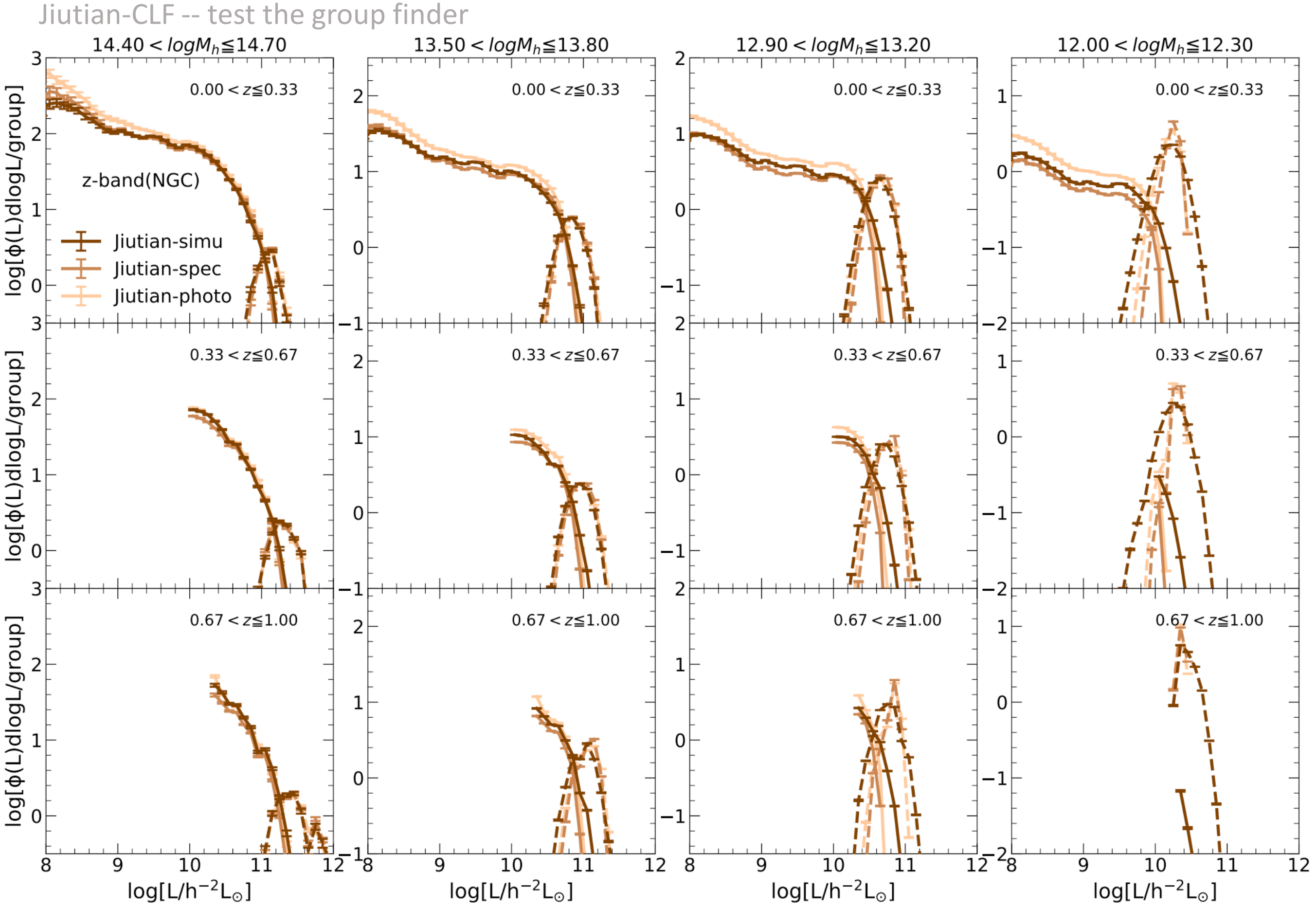
Matched with DESI galaxy properties, color, stellar mass, etc.





Testing the reliability of CLF measurements using MGRS

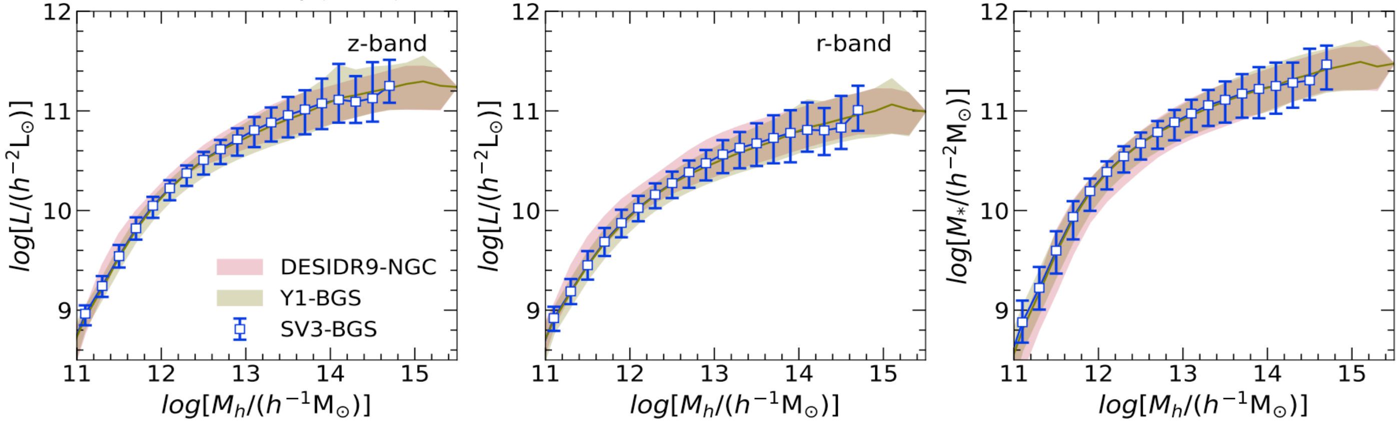




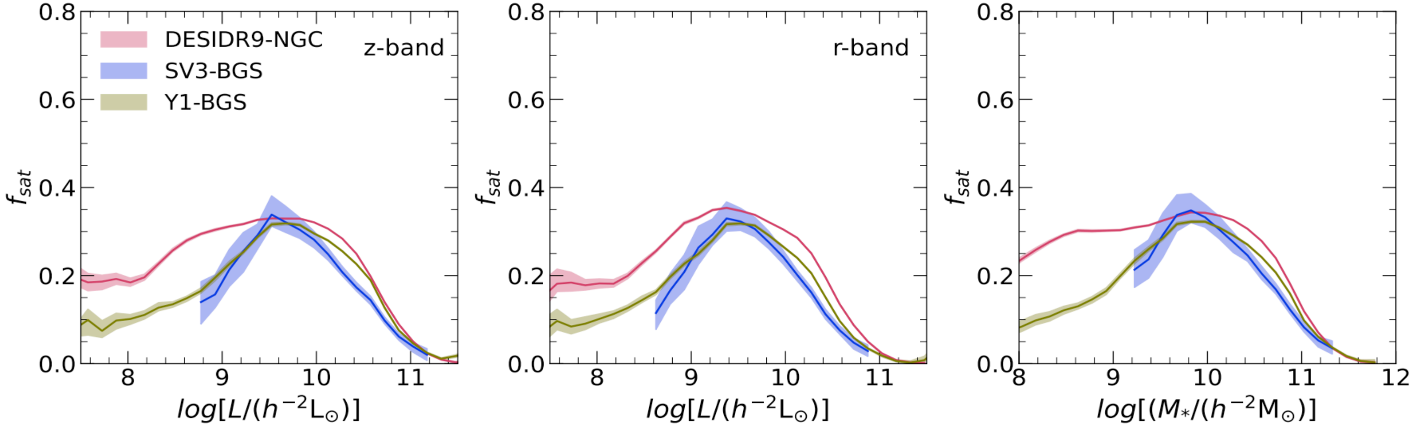
- The smoothed trend of Jiutian-photo at the faint end in the lowest redshift bin indicates that the significant reduction in the faint end LFs of DESIDR9 must be explained by some photoz systematics.
- Central CLFs in both Jiutian-spec and Jiutian-photo are extremely well recovered in halos with mass $\gtrsim 10^{13}\ h^{-1}M_{\odot}$, and independent of redshift.
- Jiutian-spec slightly underestimates(0.1dex) the satellite CLFs at certain luminosity ranges. While for the Jiutian-photo sample, the situation is reversed(overestimates 0.1-0.2dex).

Global properties (observation)

Central luminosity (mass) - Halo mass relation



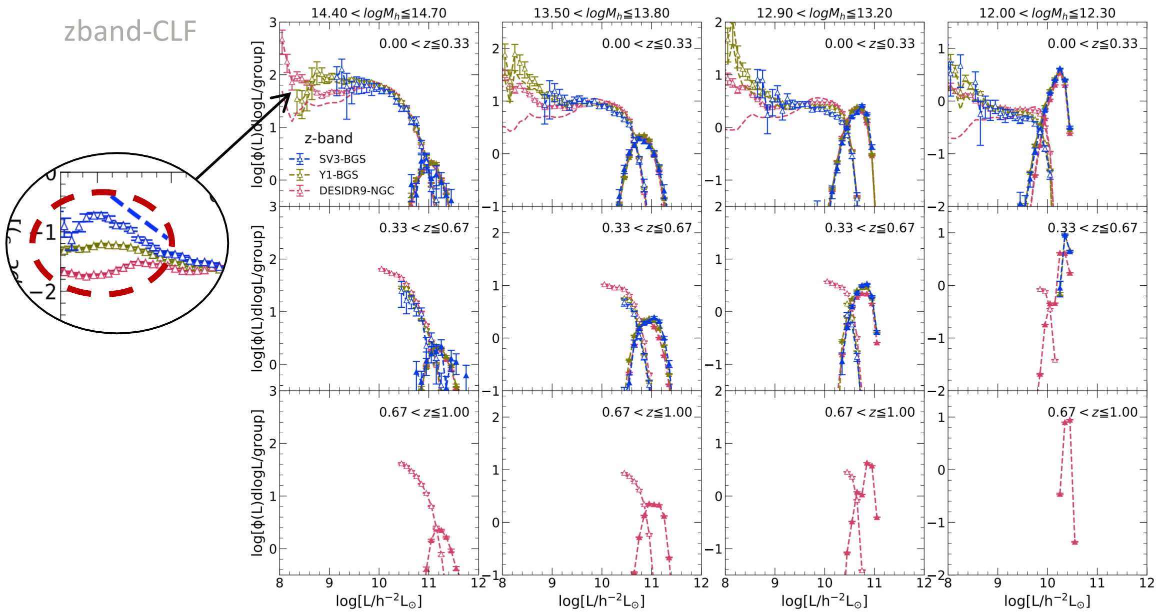
Satellite fraction



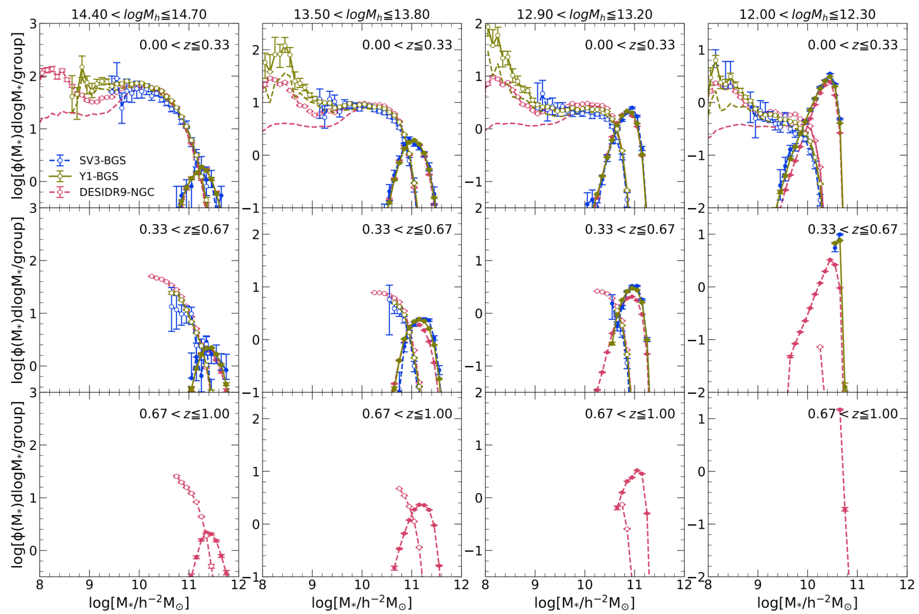
- The luminosity (stellar mass) of centrals increases but the slope of the relationship decreases significantly with increasing halo mass. (AGN feedback, changes in the efficiencies of radiative cooling and dynamical friction)
- The 10% level satellite fraction in the faint (low mass) end is in nice agreement with the sub to total halo fraction at the low mass end in theory or simulations.
- f_{sat} for photoz sample is overall somewhat overestimated.
- We obtain these two measurements down to a luminosity or stellar mass $\lesssim 10^8\ h^{-2}L_\odot$ (or $h^{-2}M_\odot$)

Conditional luminosity / stellar mass function CLF & CSMF (observation)

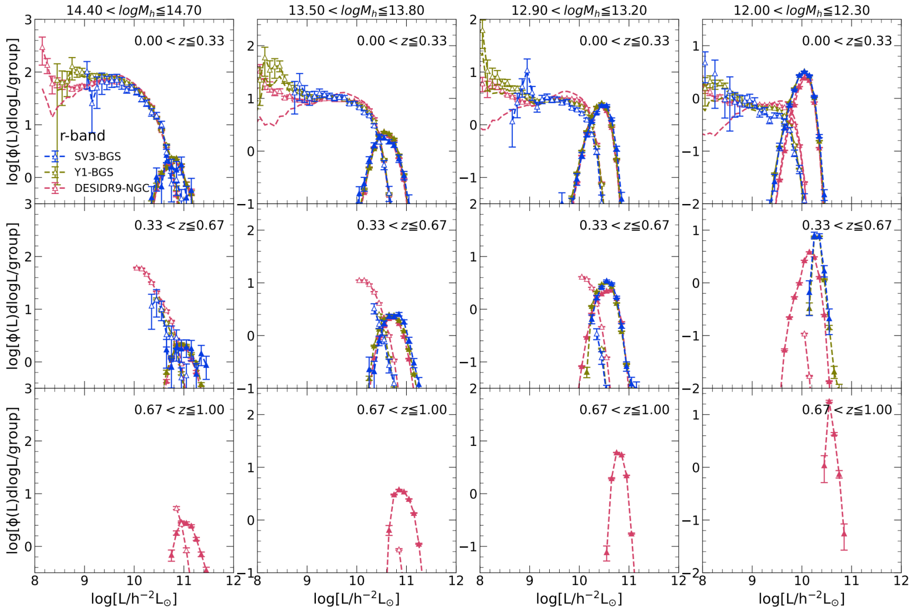
zband-CLF



CSMF



rband-CLF



SV3:

the most specz completeness(>95%); a tiny sky coverage about 124 deg^2.

DESIDR9:

a large sky area with 9600 deg^2 and deep; just 4.5% spectrum completeness.

Y1:

over 40% specz completeness; a sufficiently large sky area with >12000 deg^2.

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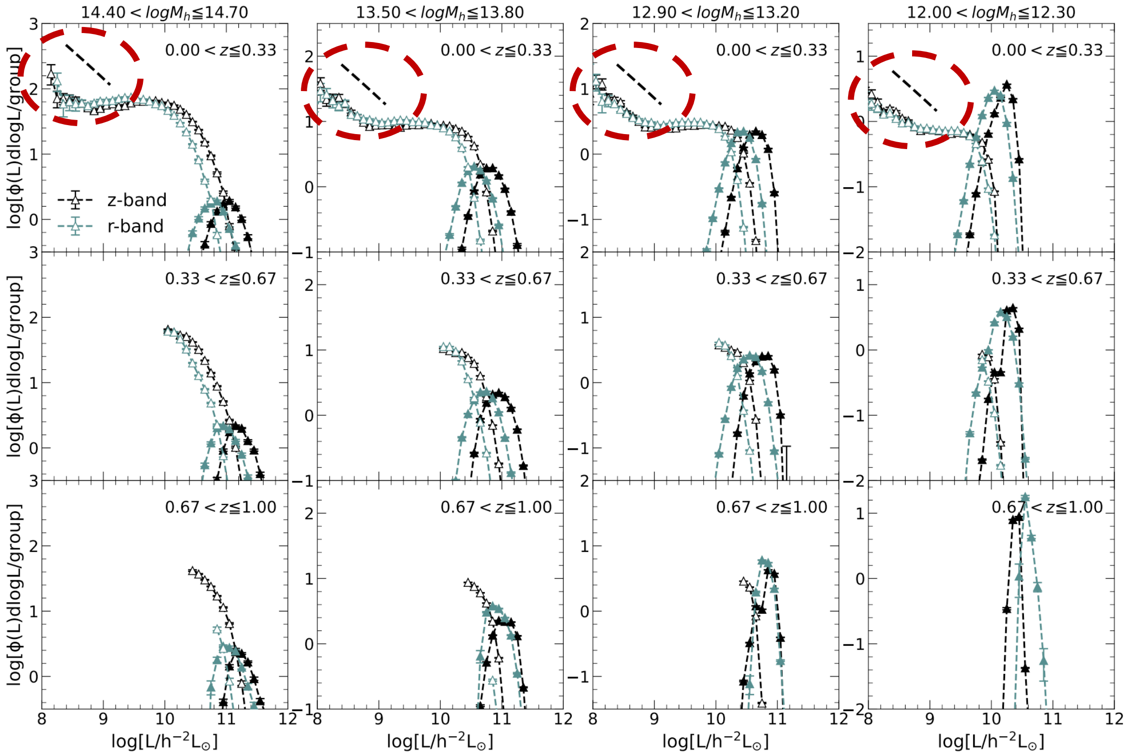
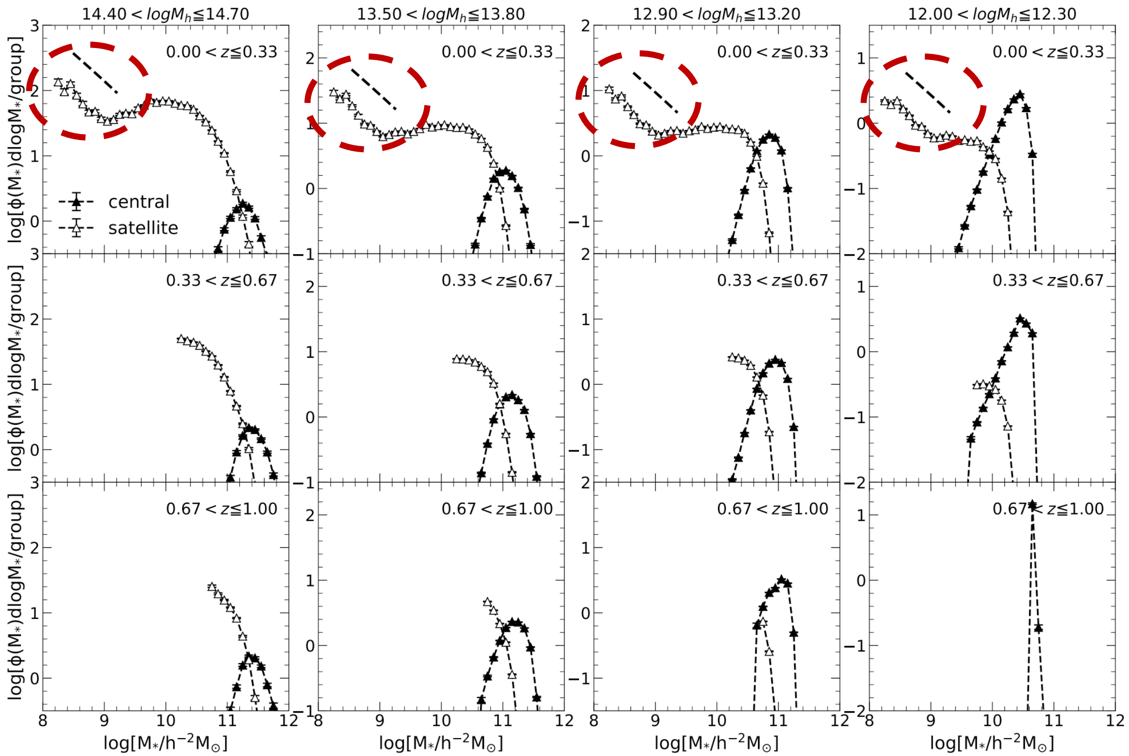
combining three sets of results (weighted average method)

Combining CLF & CSMF (observation)

CLF z-band & r-band



CSMF



- By properly correcting the reduction of the faint end LFs and SMFs caused by the photometric systematics, we obtain the CLFs and CSMFs in wide halo mass ranges and in three redshift bins.
- They have a upturn at the faint and low mass end below $10^9\ h^{-2}L_\odot$ (or $h^{-2}M_\odot$) which was not detected in SDSS.
- The slope of CLF and CSMF at the faint is in nice agreement with that of the subhalo mass functions, which shows galaxies do have similar star formation efficiency in the very small halos.

Summary

- We measure the galaxy LFs and SMFs from three galaxy samples in different redshift ranges, and find photometric redshift samples can induce a significant reduction in the faint end measurements of the LFs and SMFs in the lowest redshift bin.
- Based on the LFs and SMFs obtained from the spectroscopic redshift SV3-BGS sample, we find there is a clear upturn in the LFs and SMFs below $10^9 h^{-2} L_\odot$ (or $h^{-2} M_\odot$), with a slope that is in nice agreement with that of halo mass function at the low mass end.
- We constructed MGRS and the corresponding mock group catalogs from Jiutian simulation based on the LFs of SV3-BGS. The smoothed trend of Jiutian-photo at the faint end in the lowest redshift bin indicates that the significant reduction in the faint end LFs of DESIDR9 must be explained by some photoz systematics.
- Jiutian mock proves that, without photoz systematics, the central galaxy CLFs can be well recovered in all redshift and halo mass bins, while the satellite galaxy CLFs can be fairly well recovered from the spectroscopic redshift data, and are somewhat overestimated from the photometric redshift data.
- Based on the group catalogs constructed from the three DESI observational samples, we obtained the central luminosity (stellar mass) - host halo mass relations, as well as the satellite fraction measurements down to a luminosity or stellar mass $10^8 h^{-2} L_\odot$ (or $h^{-2} M_\odot$).
- By properly correcting the reduction of the faint end LFs and SMFs caused by the photometric systematics, we obtain the CLFs and CSMFs in wide halo mass ranges and in three redshift bins.
- Similar to the total LFs and SMFs, we also find that the CLFs and CSMFs have a upturn at the faint and low mass end below $10^9 h^{-2} L_\odot$ (or $h^{-2} M_\odot$), and the slope is in nice agreement with that of the subhalo mass functions, which strongly surport the high galaxy formation efficiency at very low mass halos.

Thanks !