

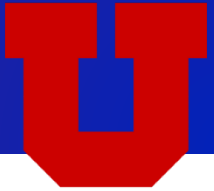
中国科学院上海天文台
Shanghai Astronomical Observatory, Chinese Academy of Sciences



上海交通大学
SHANGHAI JIAO TONG UNIVERSITY



物理与天文学院
School of Physics and Astronomy



The **C**onditional **C**olour-**M**agnitude **D**istribution (CCMD) of present-day Galaxies

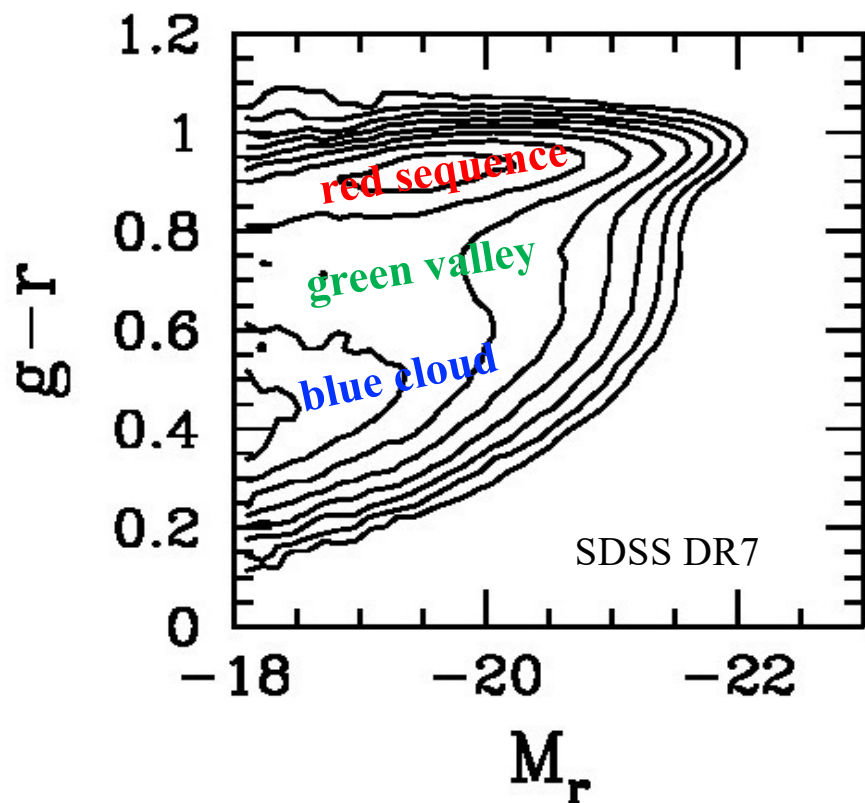
Xu+ 2018 (arXiv: 1801.07272)
Xu+ 2023 to be submitted

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Ying Zu (SJTU), Idit Zehavi (CWRU), David Weinberg (OSU)**

The 2nd Shanghai Assembly, Nov. 1st, 2023

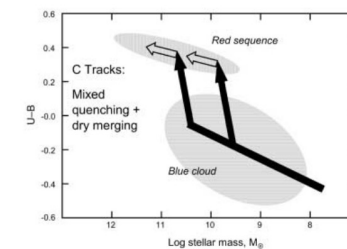
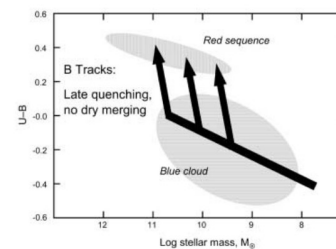
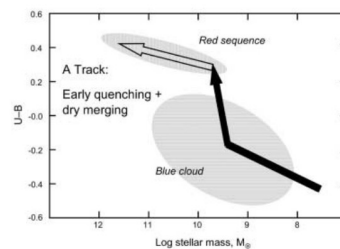
Color-Magnitude Diagram (CMD) of Galaxies



Bimodal color distribution

Emerge since $z \sim 1$

How do the **young active blue** galaxies transform to **old passive red** ones (quenching)?



Centrals/Satellites?

Mass of host halos?

Strateva+2001, Blanton+2006, Faber+ 2007

At a given halo mass, what does the Color-Magnitude Distribution of its member galaxies look like?

Conditional Color-Magnitude Distribution (CCMD)

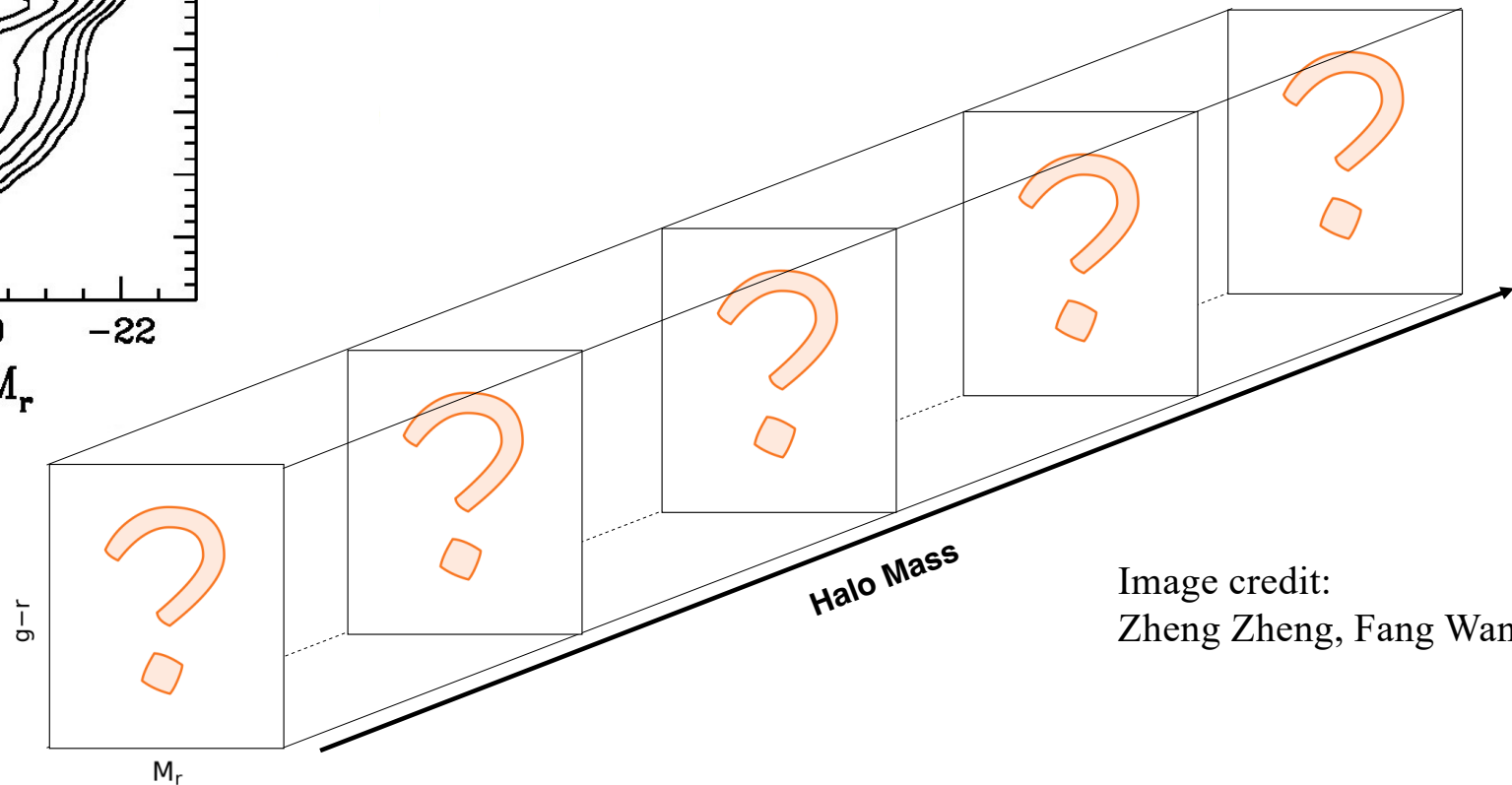
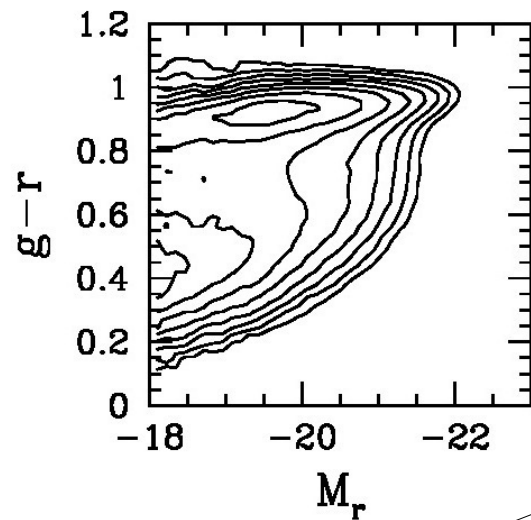
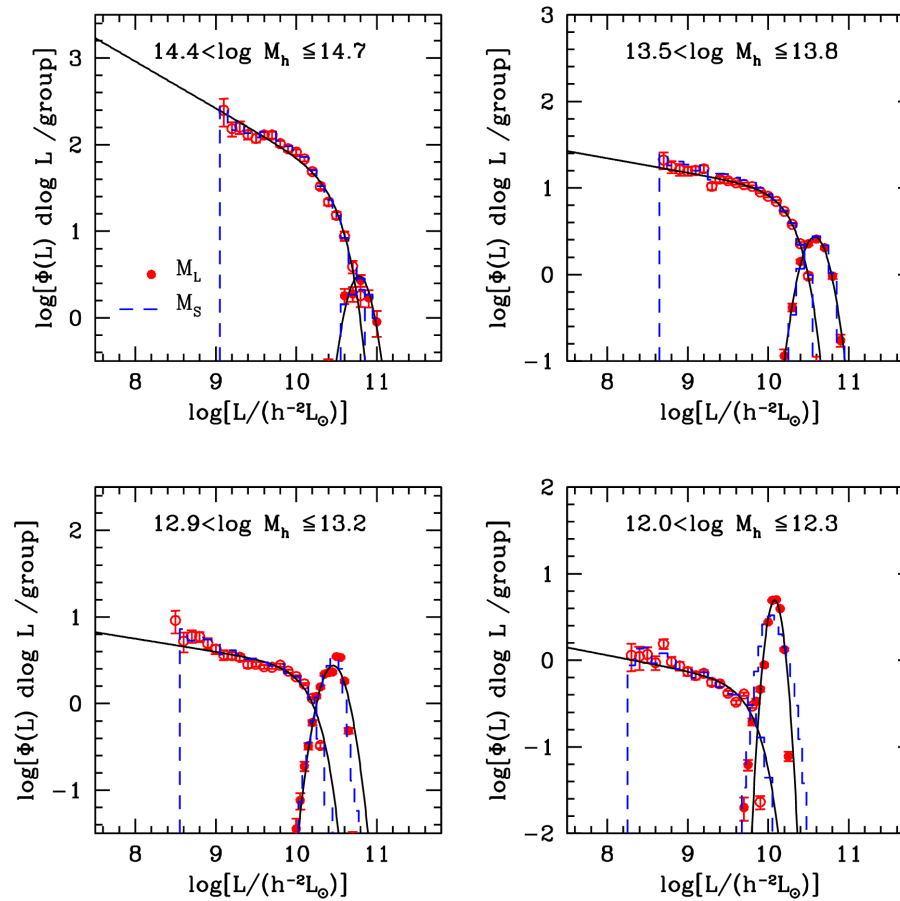


Image credit:
Zheng Zheng, Fang Wang

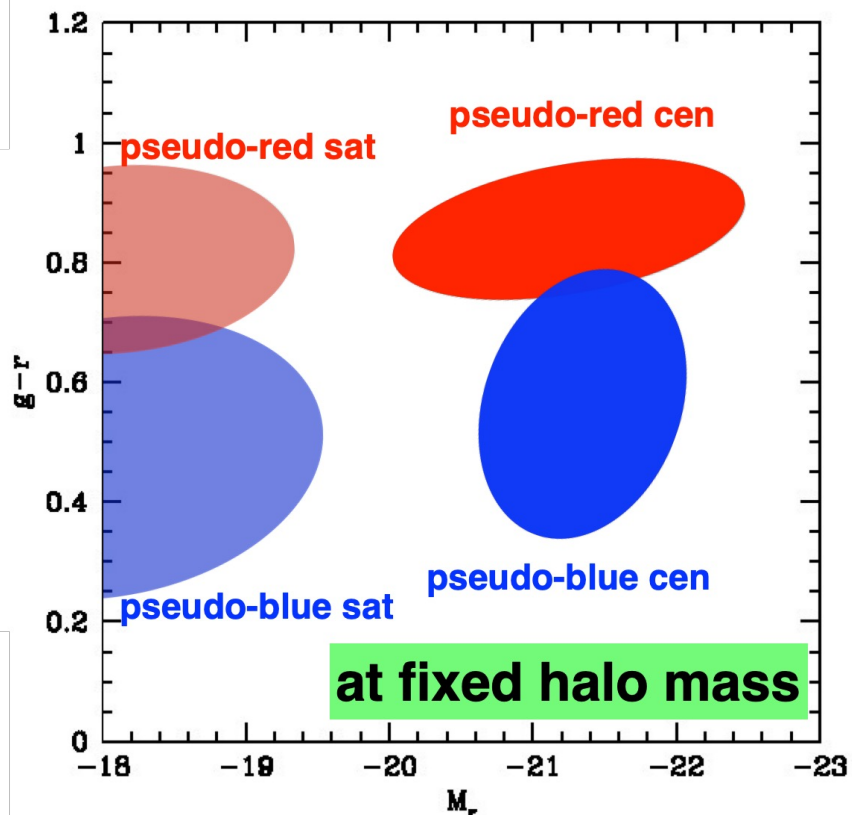
Conditional Color-Magnitude Distribution (CCMD)

= Conditional Luminosity Function + Color

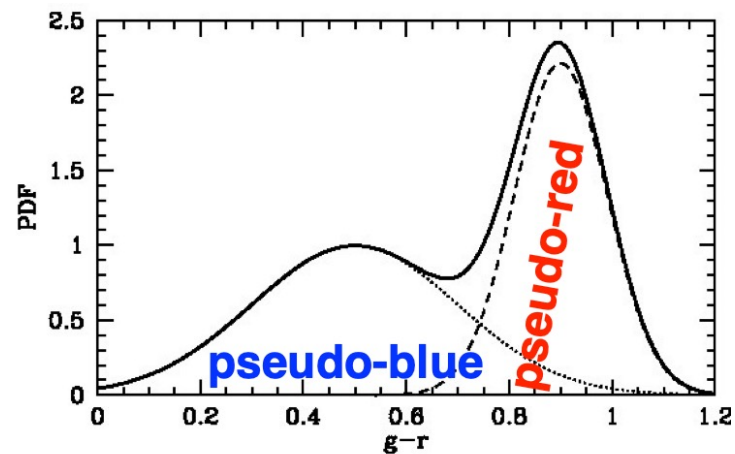


Yang+2003, Yang+2005, Yang+2008

CCMD Parameterization



Motivated by the bimodal distribution of color and previous HOD/CLF/Group results



CCMD centrals:

2D Gaussian

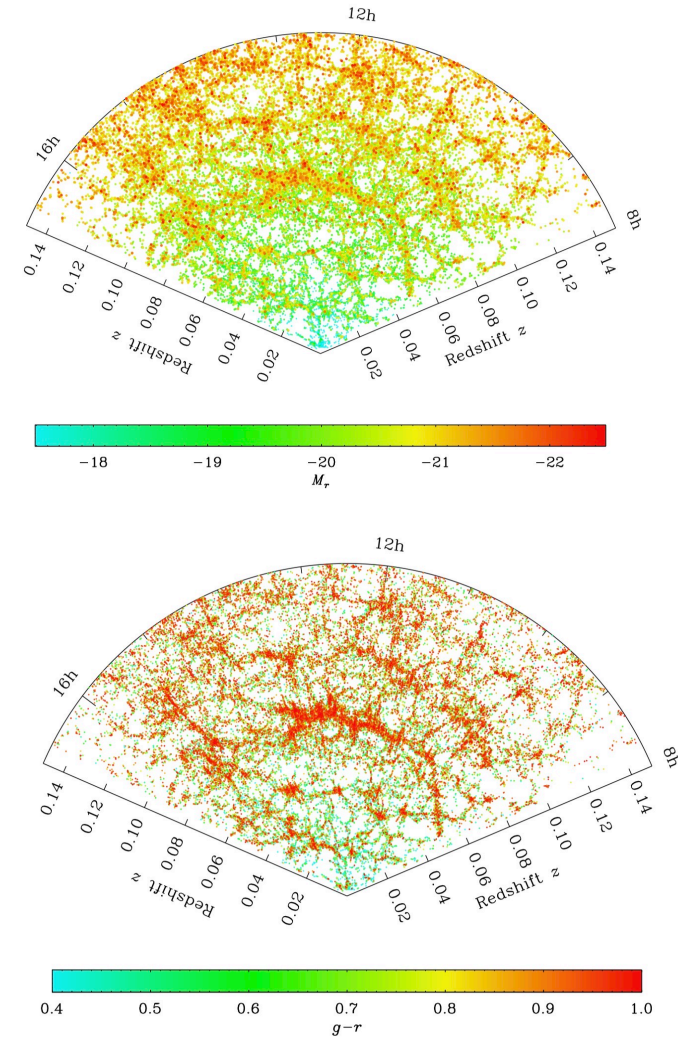
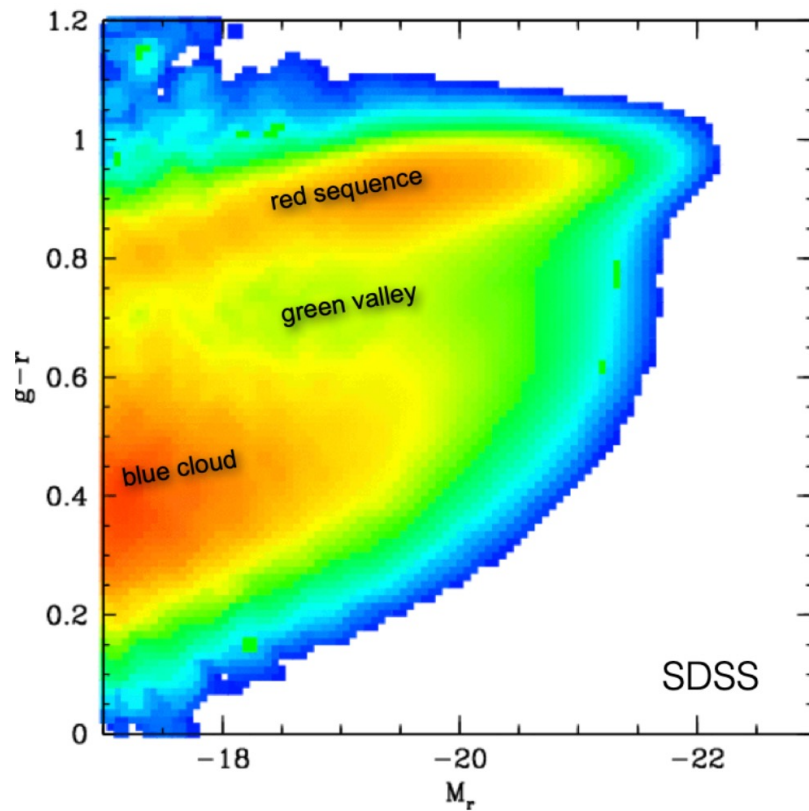
CCMD satellites:

Schechter-like CLF + Gaussian color

CCMD parameters all as a function of M_h

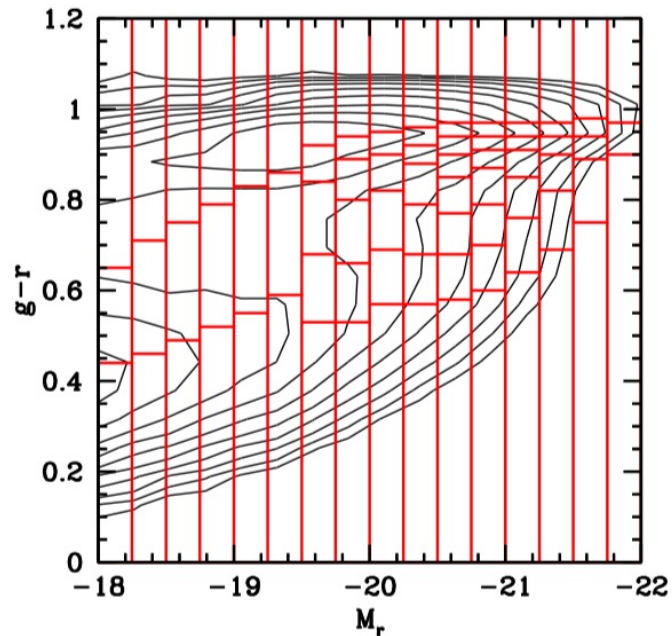
No assembly bias!

Galaxy CMD and Clustering of SDSS Galaxies



Inferring CCMD parameters

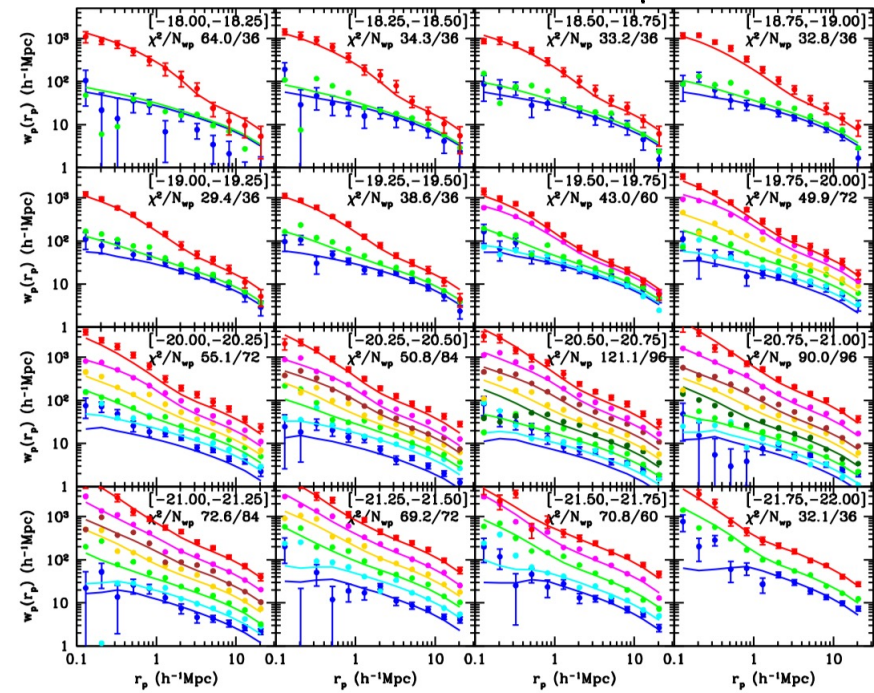
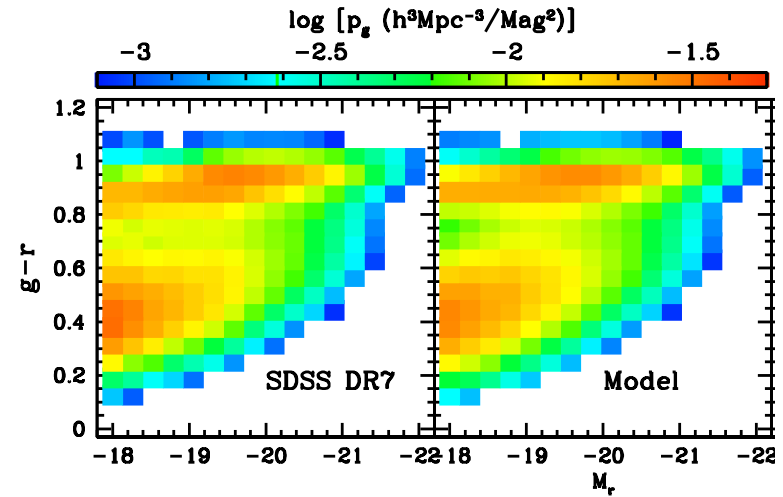
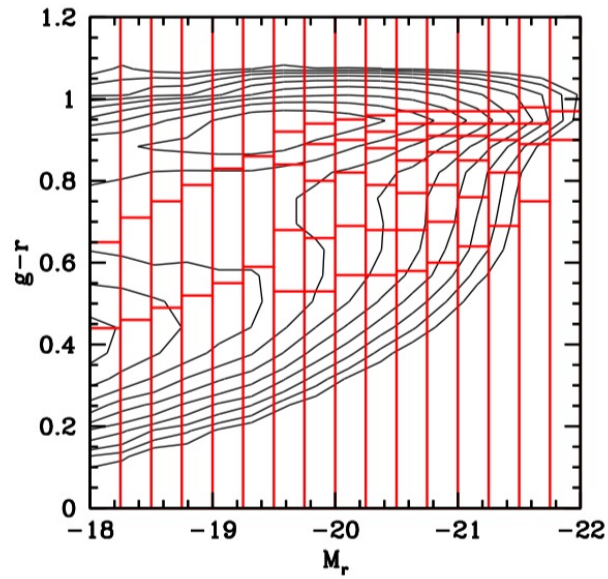
from simultaneously fitting the **space number densities** and **2-point auto-correlation functions** of 79 SDSS galaxy samples defined in fine bins in the CMD



simulation-based, accurate and efficient method for the 2PCFs (Zheng & Guo 2016)

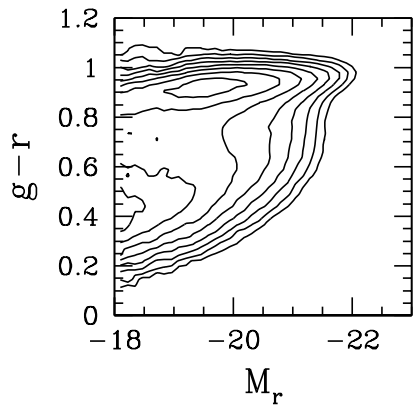
[equivalent to populating mocks and using the mock-based 2PCFs as model prediction, but much more efficient]

CCMD modeling results

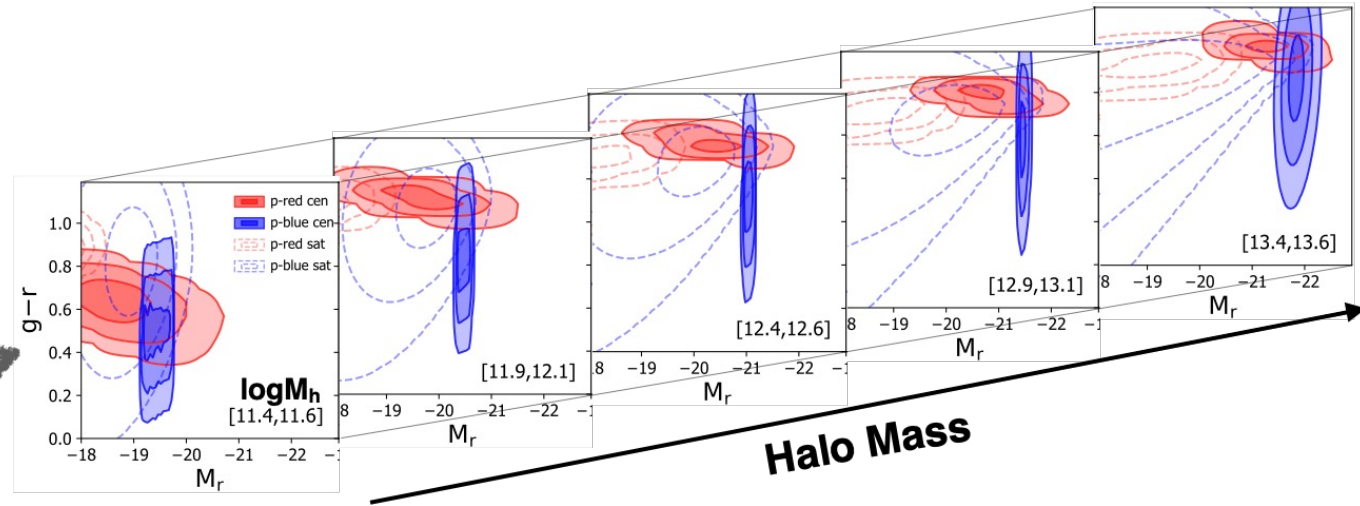


Xu+, MNRAS 2018, arXiv:1801.07272

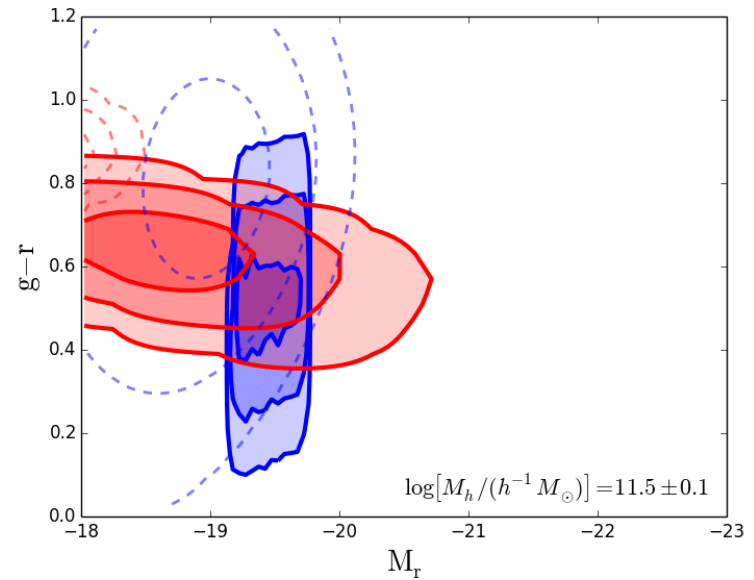
Inferred CCMD



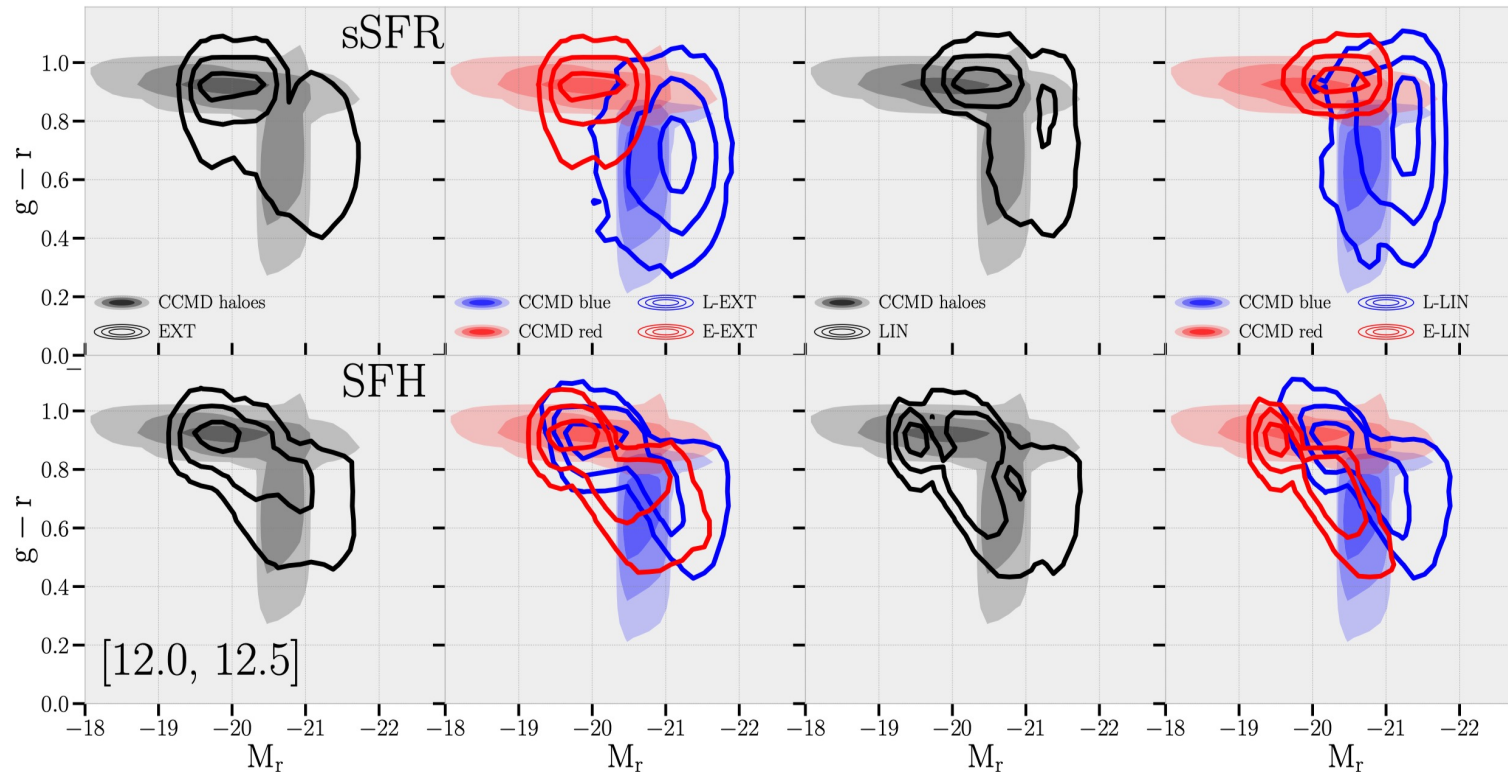
parameterized halo
mass dependent
color-magnitude
distribution
+
galaxy abundances
+
color/magnitude
dependent clustering



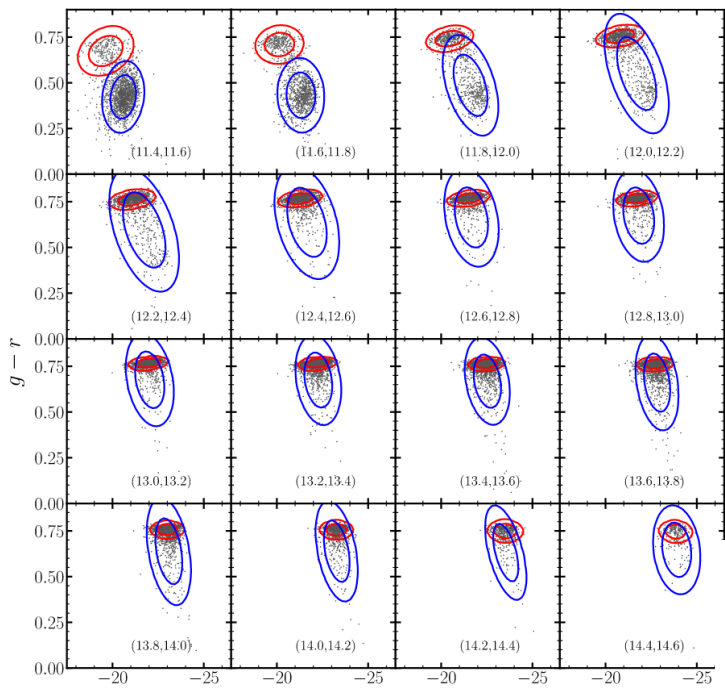
pseudo-blue cen and
pseudo-red cen
distinct and orthogonal



Direct CCMD features from observations

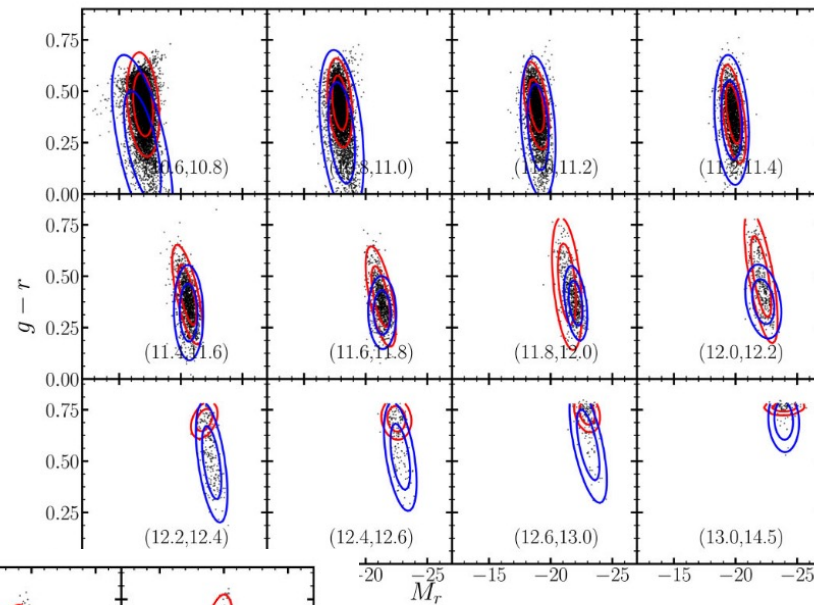


- External two collections of central galaxies: LIN & EXT *thanks to Yen-Ting Lin and Kevin S. McCarthy for supplying their collections of central galaxies
- Halo mass calibrated by weak-lensing measurements
- Divided into star-forming/quenched by sSFR and SFH

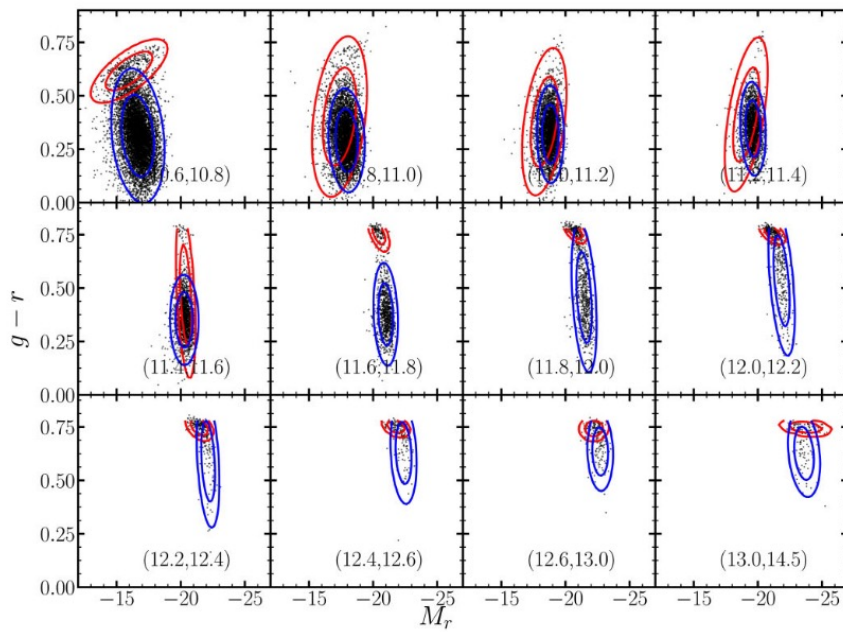


Q.Guo+2011 SAM

Xiaoju Xu+2022

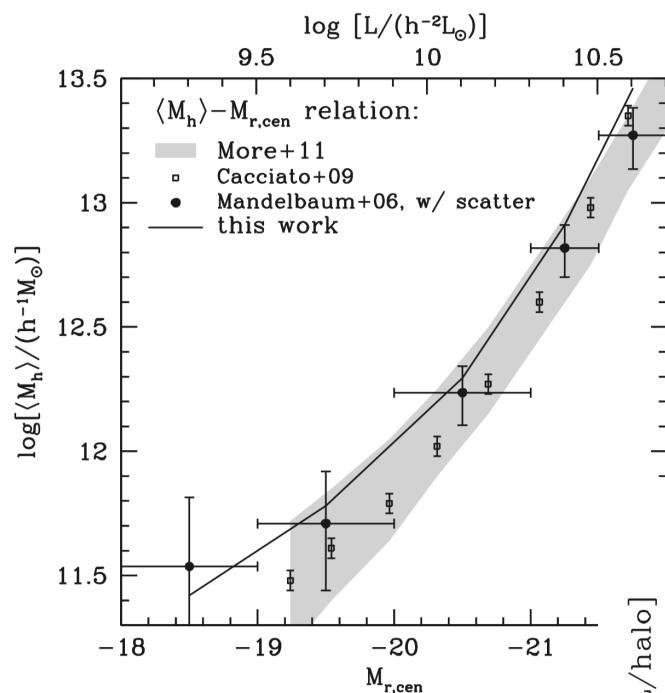


Illustris



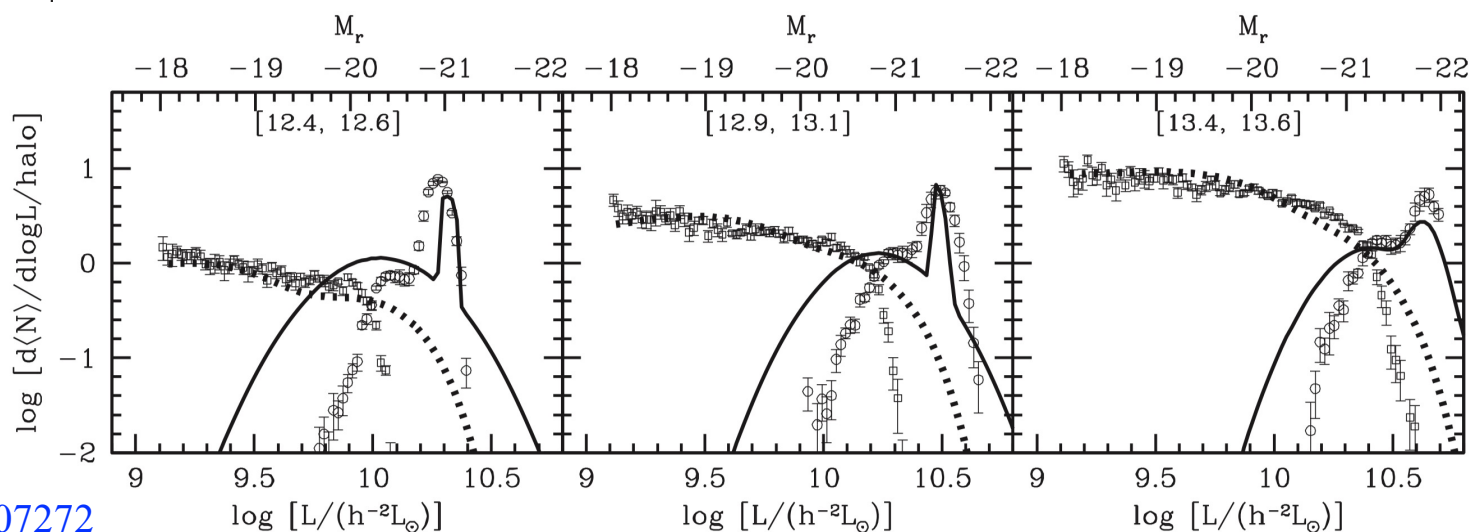
TNG100

Galaxy-halo connections (CCMD VS. previous work)

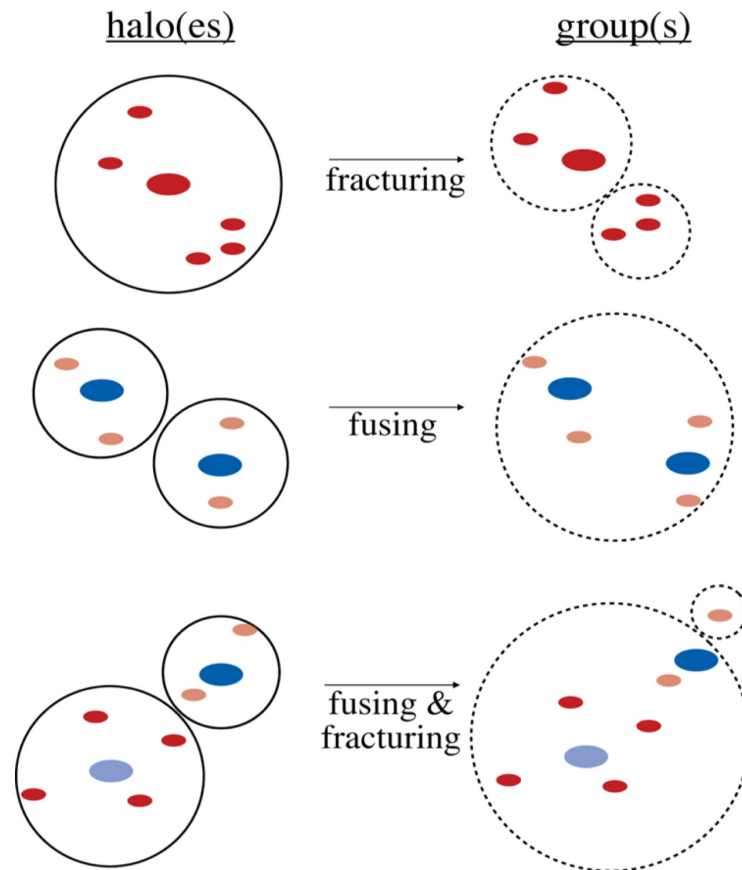


- $L_{\text{cen}} - M_h$ relation :
 - satellite dynamics (More+2011)
 - CLF (Cacciato+2009)
 - galaxy-galaxy weak lensing (Mandelbaum+2006)

- CLF from group catalogues
 - Lines: **CCMD**;
 - Symbols: SDSS DR7 group catalogues (Yang+2008)



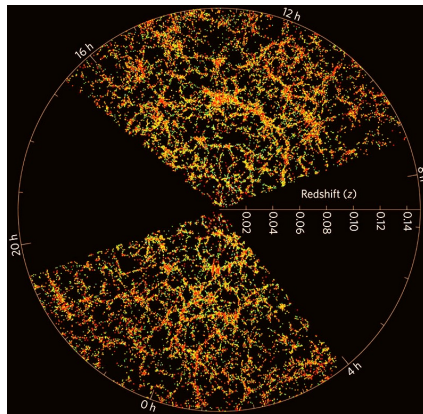
Not a apples-to-apples comparison



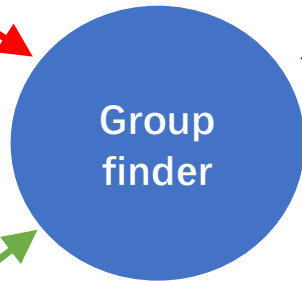
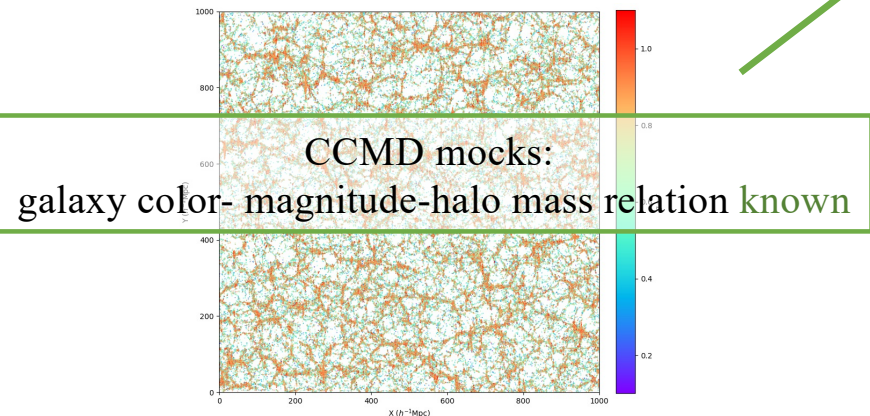
- ❑ membership allocation errors
- ❑ central/satellite designation errors
- ❑ halo mass estimation errors

Assess CCMD by group finders

SDSS:
galaxy color- magnitude-halo mass relation **unknown**



||

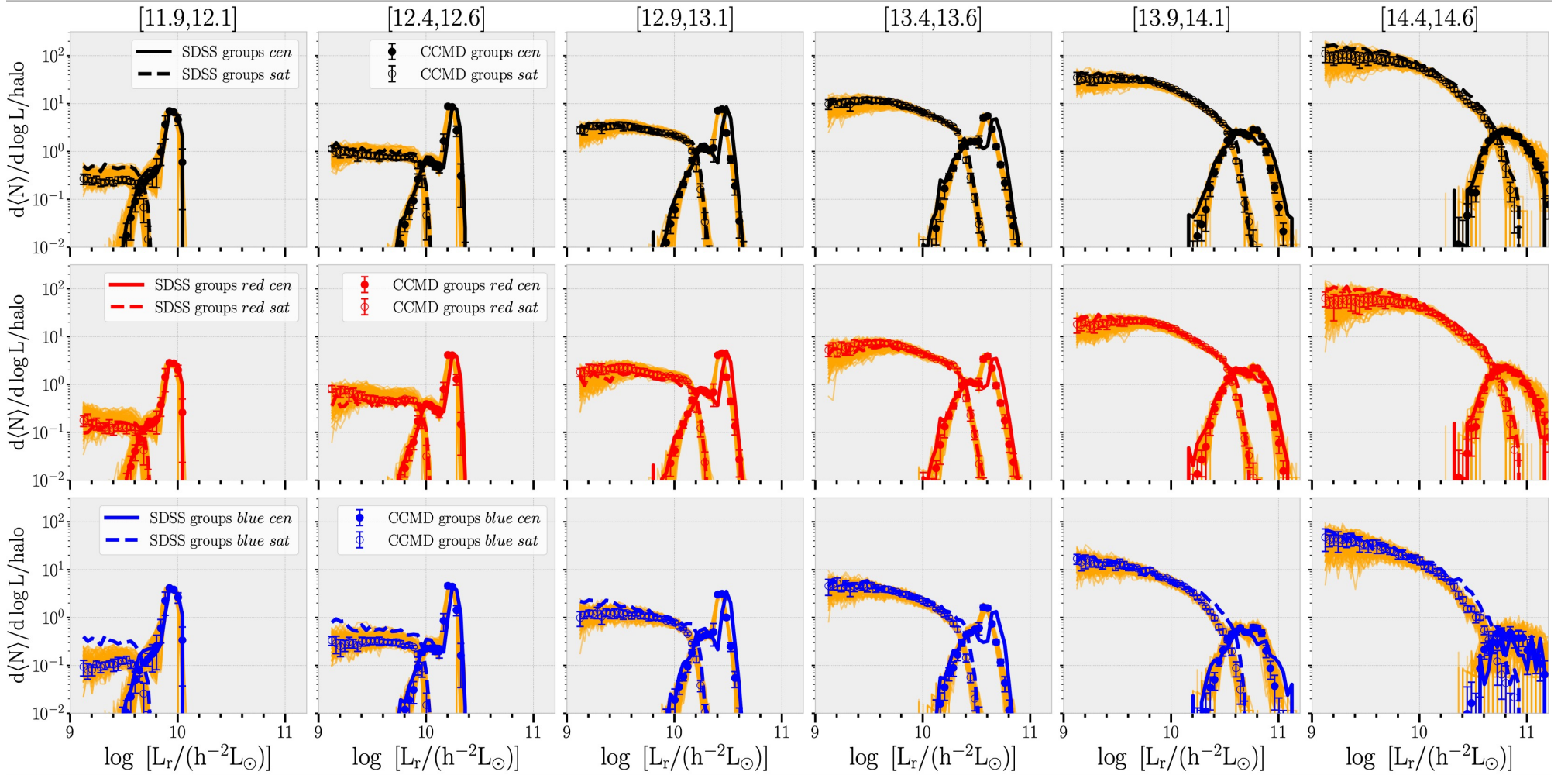


- SDSS group catalog:
1. conditional luminosity function
 2. conditional color function
 3. conditional color-magnitude distribution

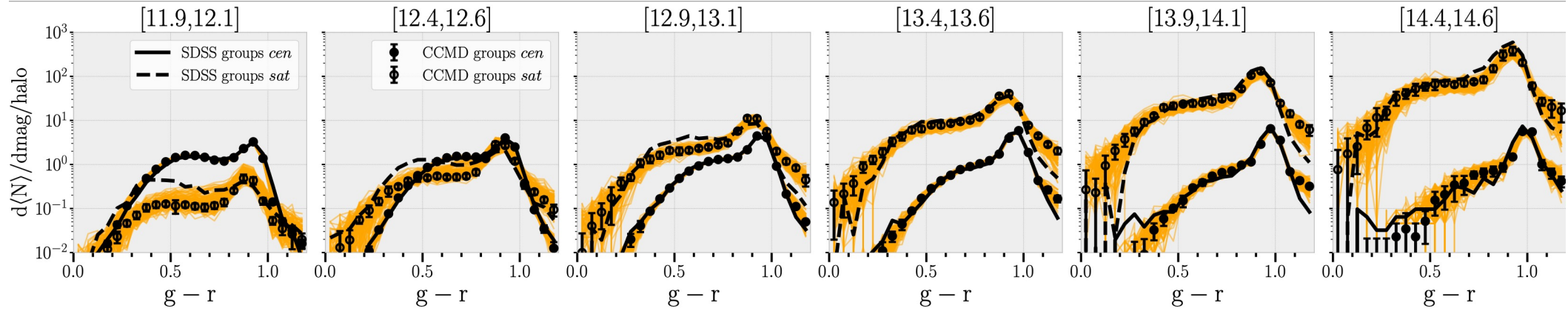
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- CCMD group catalog:
1. conditional luminosity function
 2. conditional color function
 3. conditional color-magnitude distribution

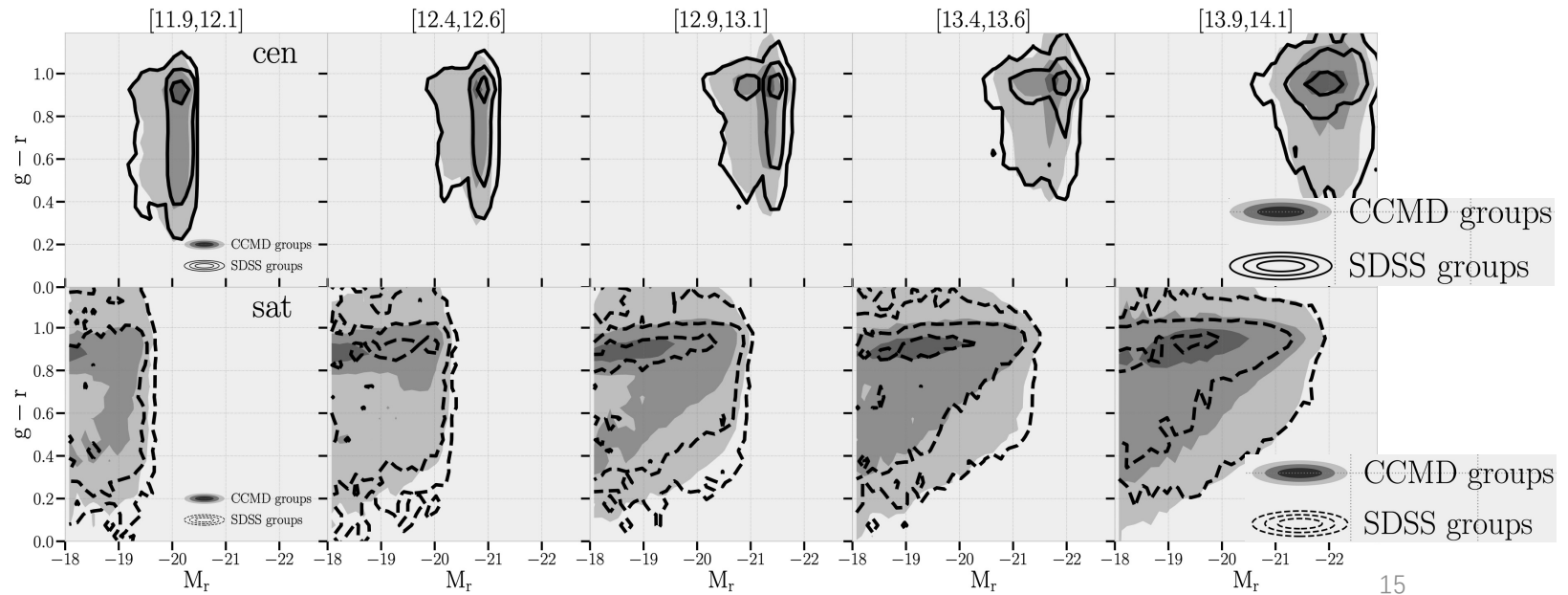
➤ Conditional Luminosity Function



➤ Conditional Color Function

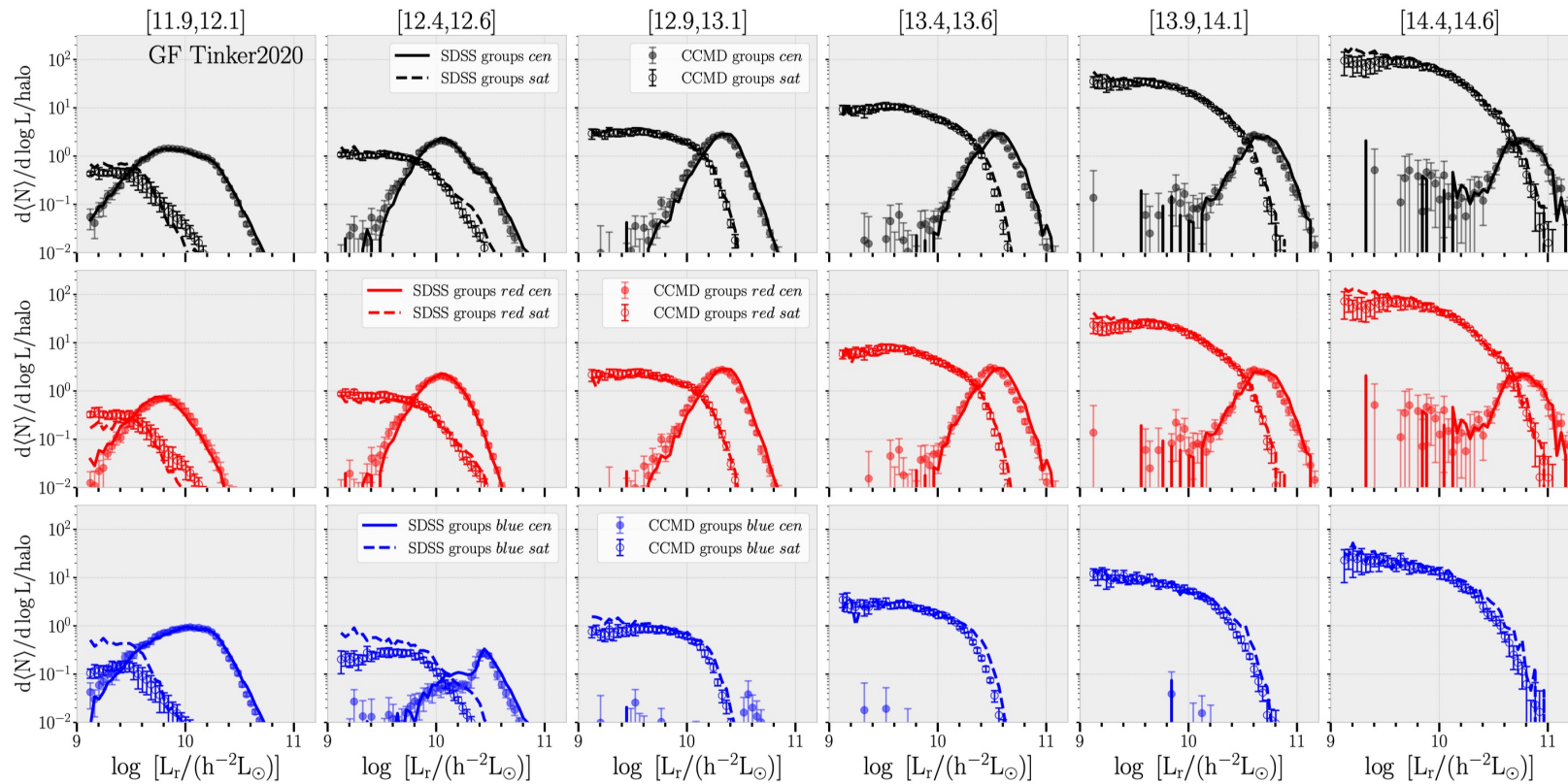


➤ Conditional Color Magnitude Distribution

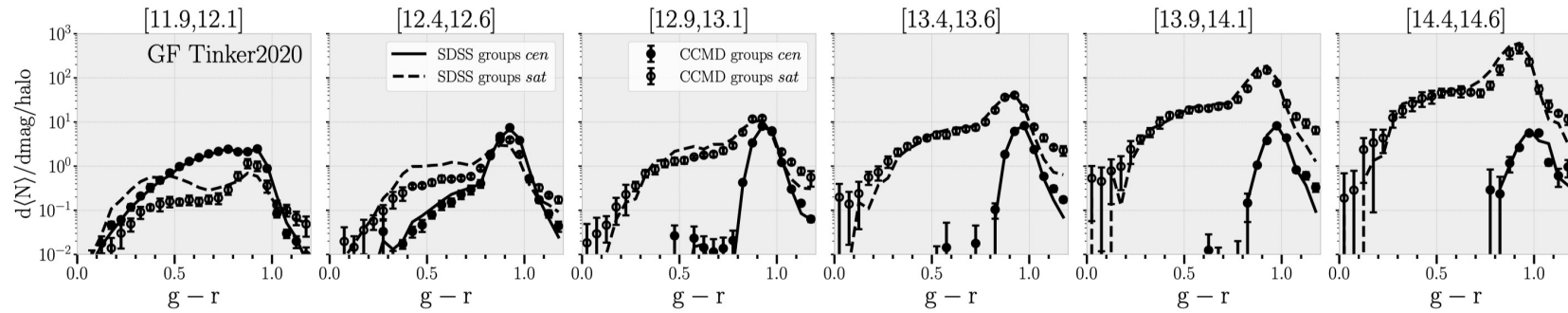


Tinker2020 Group finder

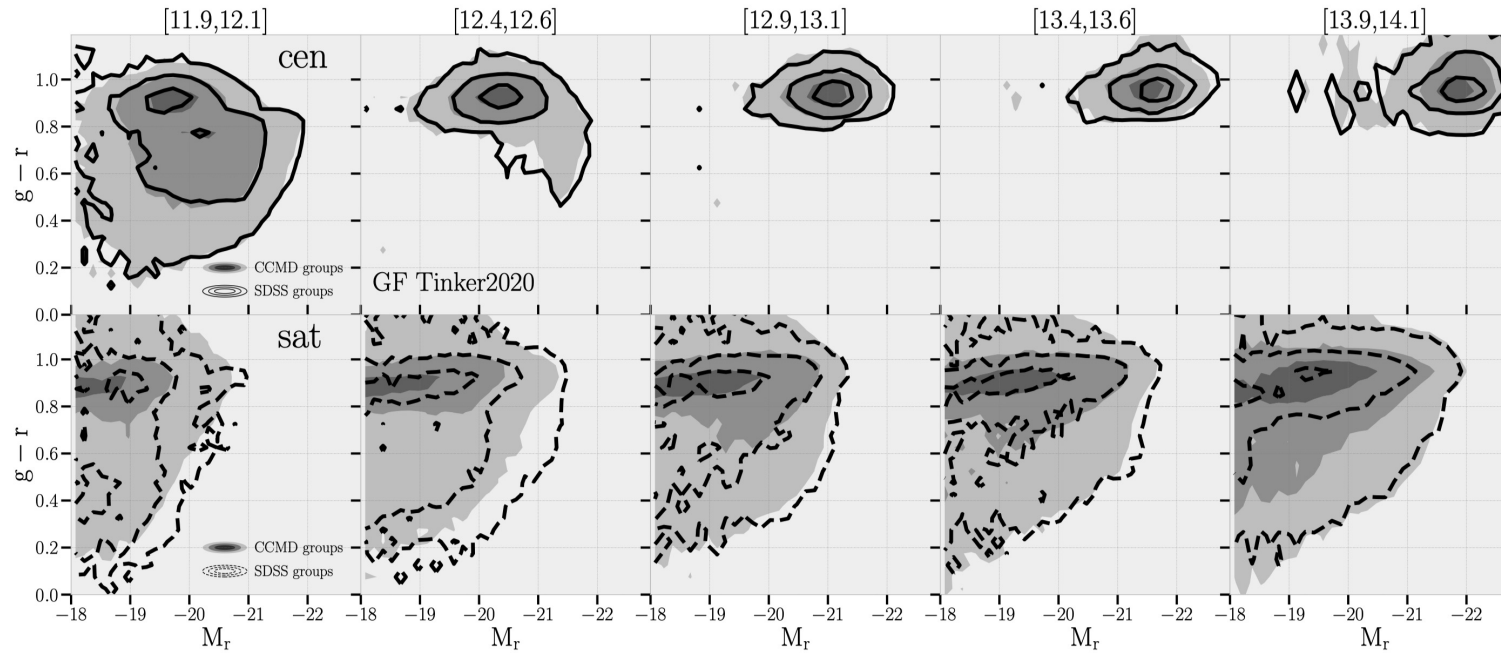
➤ Conditional Luminosity Function



➤ Conditional Color Function (Tinker2020 Group Finder)

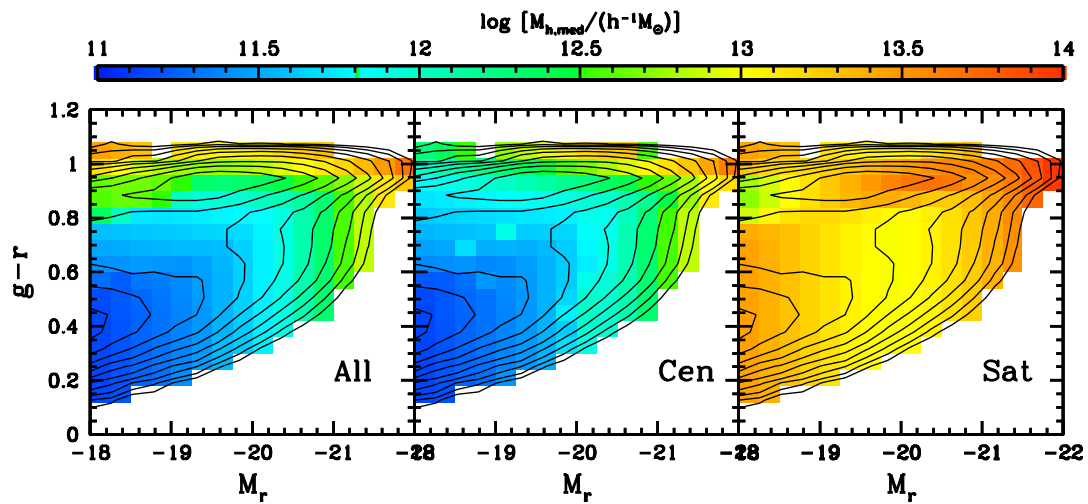


➤ Conditional Color Magnitude Distribution (Tinker2020 Group Finder)

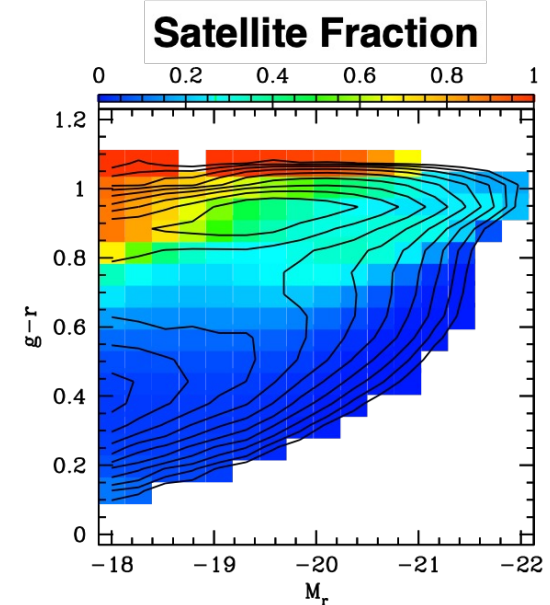


CCMD derived quantities

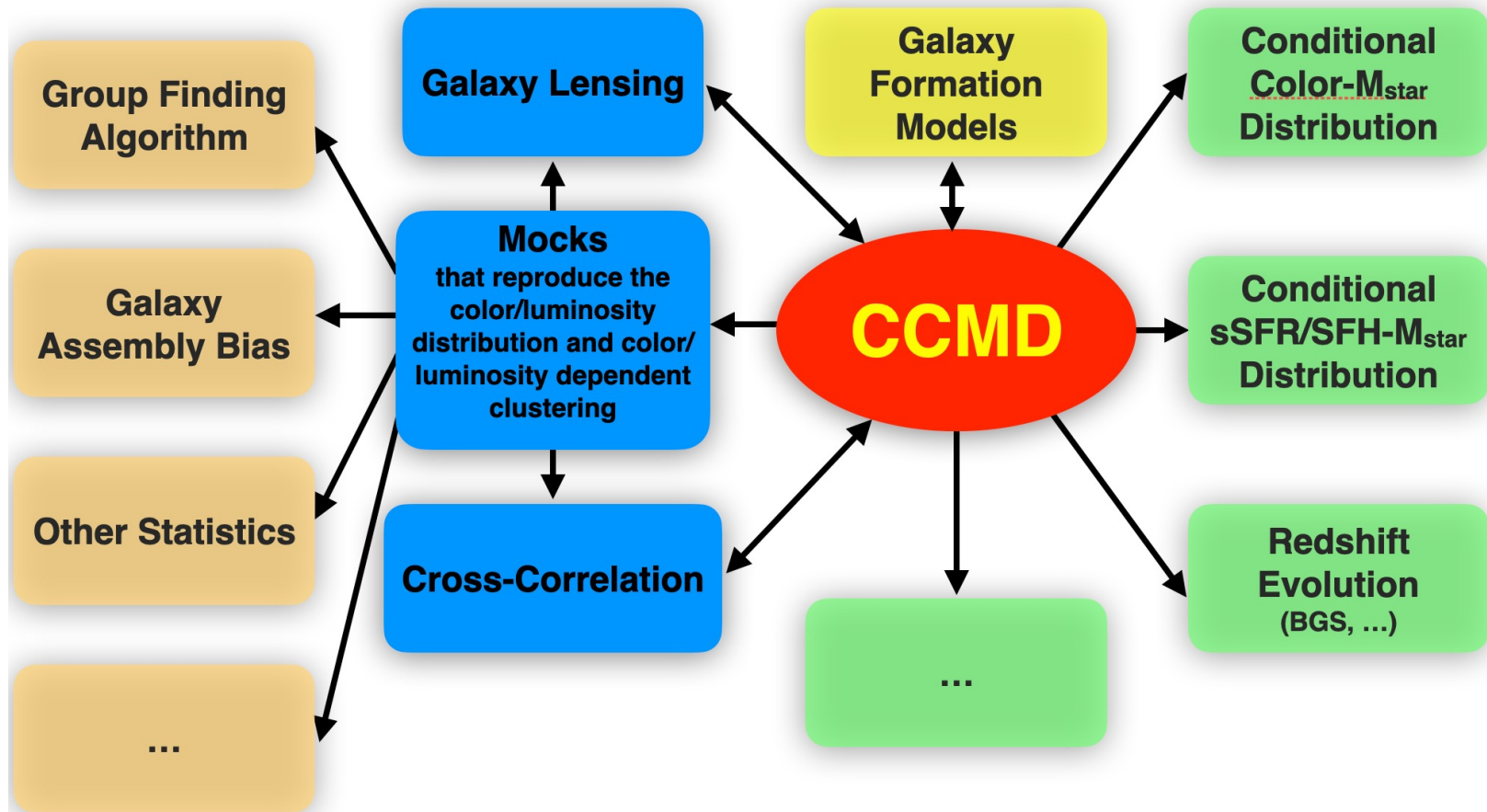
- Host halo mass (color, luminosity, and cen/sat)



- Satellite fraction (color and luminosity)



What's Next?

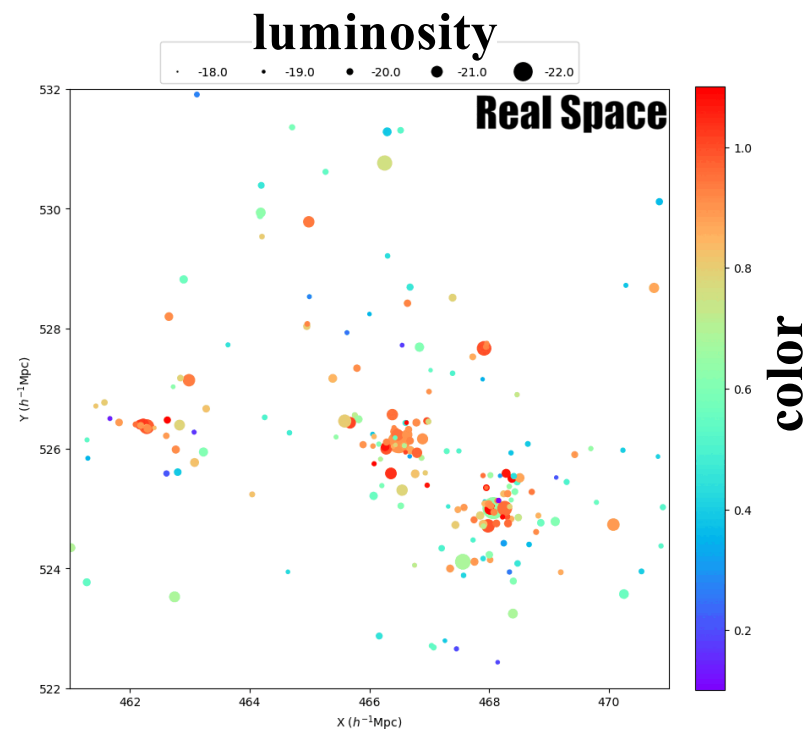
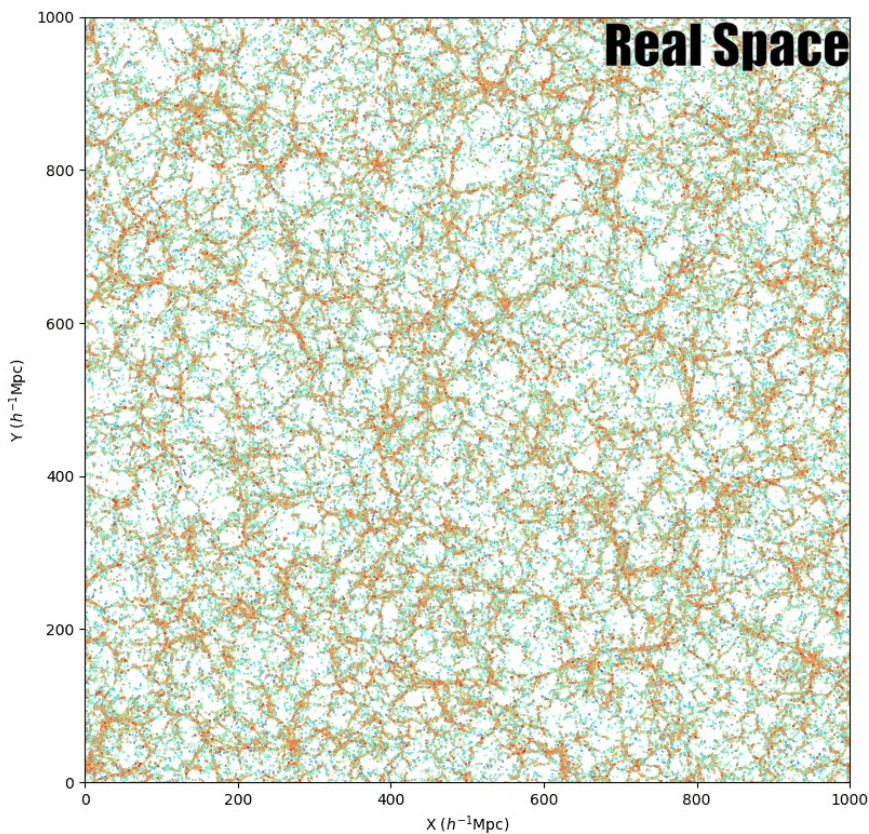


CCMD-based Galaxy Mocks

- The mocks have realistic galaxy magnitude and color that reproduce the abundance, luminosity/color-dependent clustering, and CLF/CCF/CCMD of SDSS main galaxies sample.
- Based on the MDPL2 N-body simulation, $z \sim 0$, boxsize = 1 Gpc/h , Rockstar halos
- $M_r < -18$, ~ 29 million galaxies
Positions, velocities, colors, magnitudes, cen/sat, haloID etc
- Halo catalogs, ~ 32 million halos, $M_h > 10^{11} M_{\text{sun}}/h$

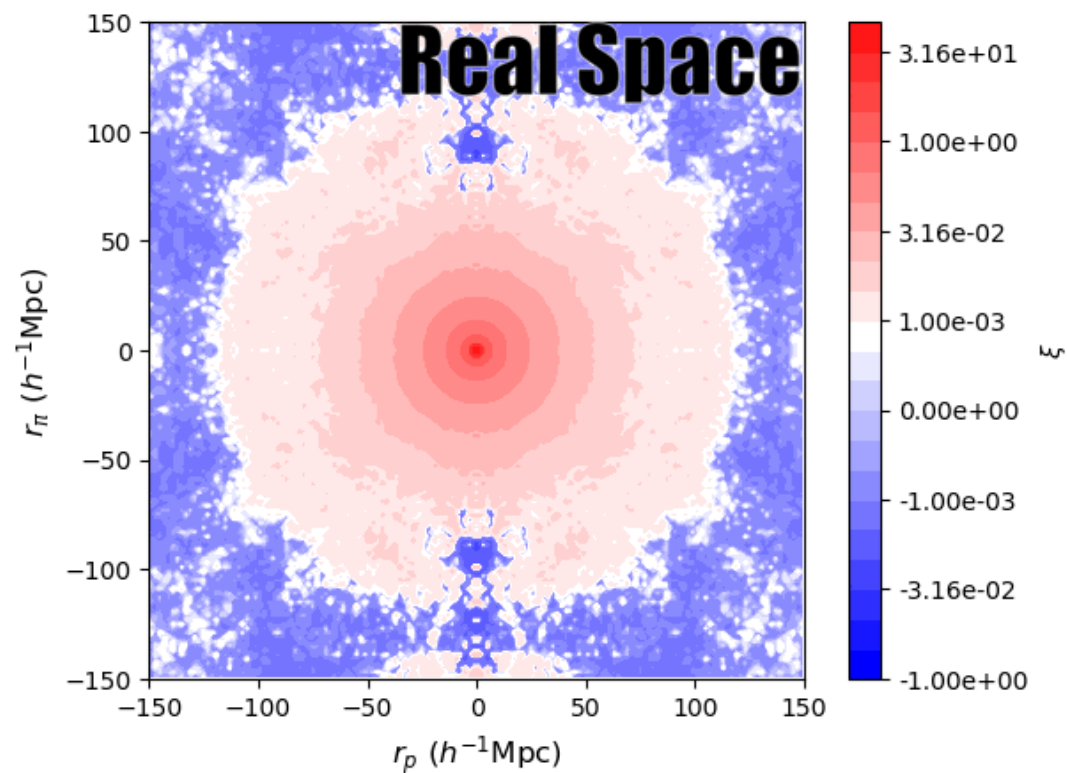
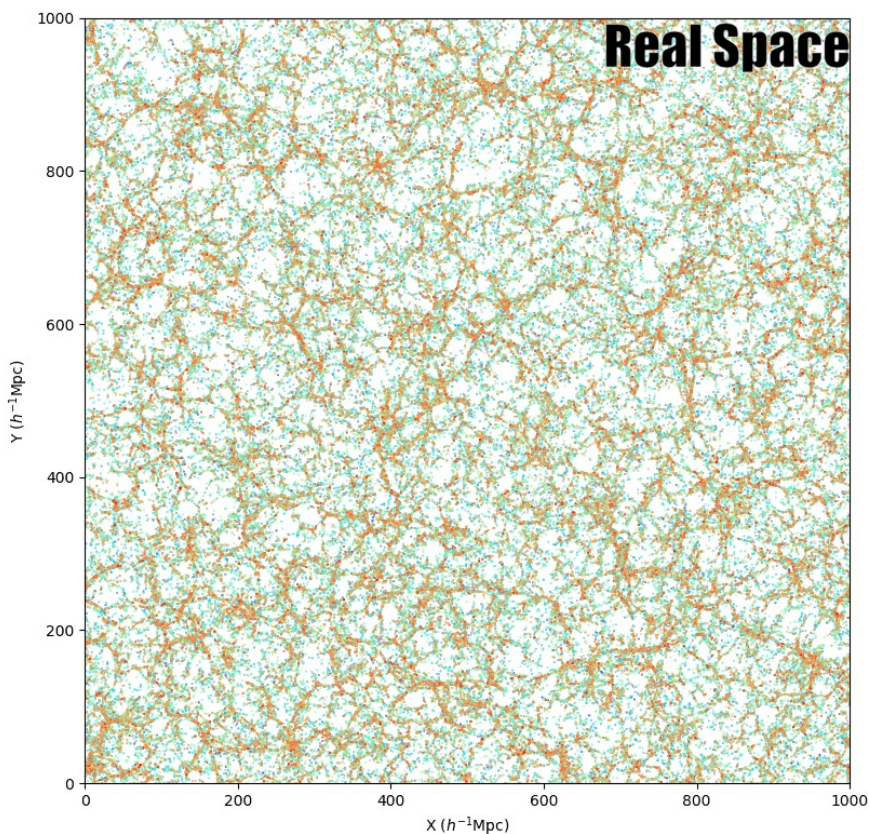
The CCMD mocks and halo catalogs are public available at <https://www.astro.utah.edu/~zhengzheng/data.html>

Scan the QR code to access the website



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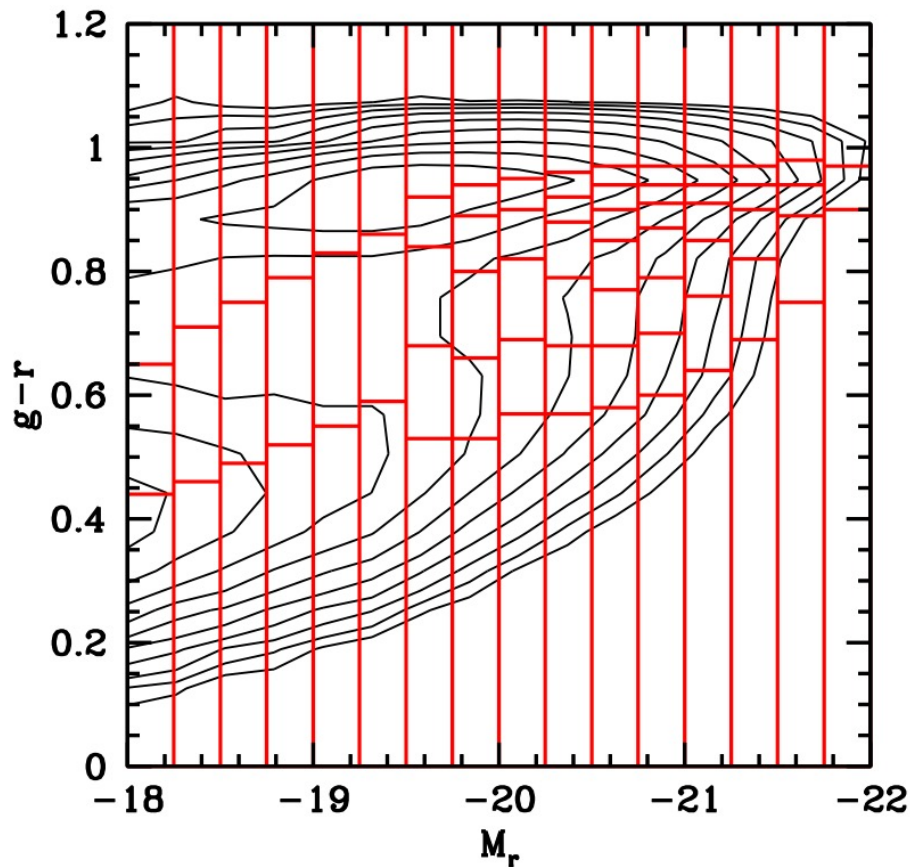


Summary:

- ❑ The CCMD model describes the galaxy luminosity and color as a function of halo mass. (conceptually = CLF + color)
- ❑ The CCMD parameters are inferred from simultaneously fitting **abundance** and **clustering** of ~80 SDSS galaxy samples defined by fine bins in the CMD.
- ❑ The color bimodality is driven by centrals at bright ends, and by the blue centrals and red satellites at faint ends.
- ❑ The CCMD predicts **two distinct and orthogonal** components for centrals in the CMD, which are also revealed in two external central galaxy catalogs.
- ❑ The satellites fraction is more sensitive to the **color** than luminosity.
- ❑ The comparison between SDSS and CCMD groups suggests that the CCMD mocks well represent the reality in terms of galaxy color and luminosity.

Back-up slides

Modeling Luminosity/Color-Dependent Clustering of SDSS Galaxies and Inferring CCMD Parameters



Xu et al. (2018)

HOD
Halo Properties

$$\bar{n}_g = \sum_i [\langle N_{\text{cen}}(M_i) \rangle + \langle N_{\text{sat}}(M_i) \rangle] \bar{n}_i \quad \text{Mass Function}$$

$$1 + \xi_{\text{gg}}^{\text{1h}}(\mathbf{r}) = \sum_i 2 \frac{\bar{n}_i}{\bar{n}_g^2} \langle N_{\text{cen}}(M_i) N_{\text{sat}}(M_i) \rangle f_{\text{cs}}(\mathbf{r}; M_i) + \sum_i \frac{\bar{n}_i}{\bar{n}_g^2} \langle N_{\text{sat}}(M_i) [N_{\text{sat}}(M_i) - 1] \rangle f_{\text{ss}}(\mathbf{r}; M_i) \quad \text{Profile}$$

$$\xi_{\text{gg}}^{\text{2h}}(\mathbf{r}) = \sum_{i \neq j} \frac{\bar{n}_i \bar{n}_j}{\bar{n}_g^2} \langle N_{\text{cen}}(M_i) \rangle \langle N_{\text{cen}}(M_j) \rangle \xi_{\text{hh,cc}}(\mathbf{r}; M_i, M_j) + \sum_{i \neq j} 2 \frac{\bar{n}_i \bar{n}_j}{\bar{n}_g^2} \langle N_{\text{cen}}(M_i) \rangle \langle N_{\text{sat}}(M_j) \rangle \xi_{\text{hh,cs}}(\mathbf{r}; M_i, M_j) + \sum_{i \neq j} \frac{\bar{n}_i \bar{n}_j}{\bar{n}_g^2} \langle N_{\text{sat}}(M_i) \rangle \langle N_{\text{sat}}(M_j) \rangle \xi_{\text{hh,ss}}(\mathbf{r}; M_i, M_j) \quad \text{Clustering}$$

Simulation-based, accurate and efficient method for the 2PCF (Zheng & Guo 2016)
 equivalent to measurements from an average mock
 but no mock construction, fast

