# The Three Point Correlation Function for the EDR of the Sloan Digital Sky Survey

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# Outline

- Introduction
- Correlation functions
- Theoretical Predictions
- Results from SDSS
- Simulations
- Color dependence
- Time evolution
- Conclusions

# Correlation Functions

Two point correlations

$$dP_{12} = \bar{n}^2(1 + \xi(r_{12}))dV_1 dV_2$$

Three point function

$$dP_{123} = \bar{n}^3(1 + \xi(r_{12}) + \xi(r_{23}) + \xi(r_{31}) + \zeta(r_{12}, r_{23}, r_{31}))\, dV_1 dV_2 dV_3$$

Hierarchical ansatz

$$\zeta(r_{12}, r_{23}, r_{31}) = Q\ (\xi(r_{12})\xi(r_{23}) + \xi(r_{23})\xi(r_{31}) + \xi(r_{31})\xi(r_{12})).$$

Prediction of second order perturbation theory (Fry 1984)

$$\zeta = \left( \frac{10}{7} - \frac{\gamma}{3-\gamma} \cos\theta_1 \left( \frac{r_{12}}{r_{31}} + \frac{r_{31}}{r_{12}} \right) + \frac{4}{7} \frac{(3 - 2\gamma + \gamma^2 \cos^2\theta_1)}{(3-\gamma)^2} \right) \xi_{12}\xi_{31} + cyc.(1,2,3)$$

for $\xi(r) \sim r^{-\gamma}$ with $\gamma = 3 + n$
this result is hierarchical in the sense that
for $r \to \lambda r$ we have $\xi \to \lambda^{-\gamma}\xi$ and $\zeta \to \lambda^{-2\gamma}\zeta$

Effects which distort the correlation function

- Redshift distorsions
- Bias of galaxies $\xi_{gg} = b^2 \xi_{dm}$
- Nonlinear clustering at small scales

Halo model: combine the result of perturbation theory with halo profiles (NFW)

# Method to determine the correlations

Determination of the luminosity function

Weight every galaxy with the inverse of the selection function

Distribute random points in the observed volume according to the selection function

Two point correlations

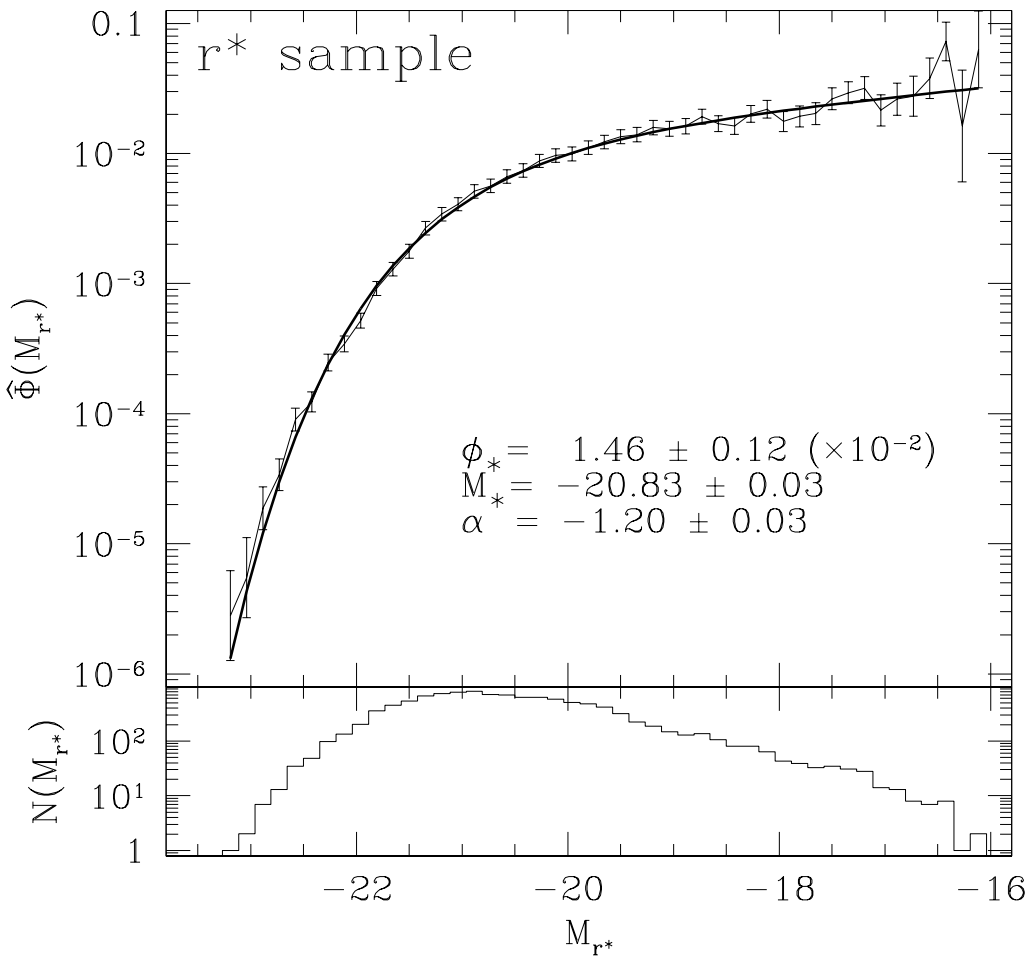
$$\xi = \frac{DD\ RR}{DR^2} - 1$$

Three point correlations

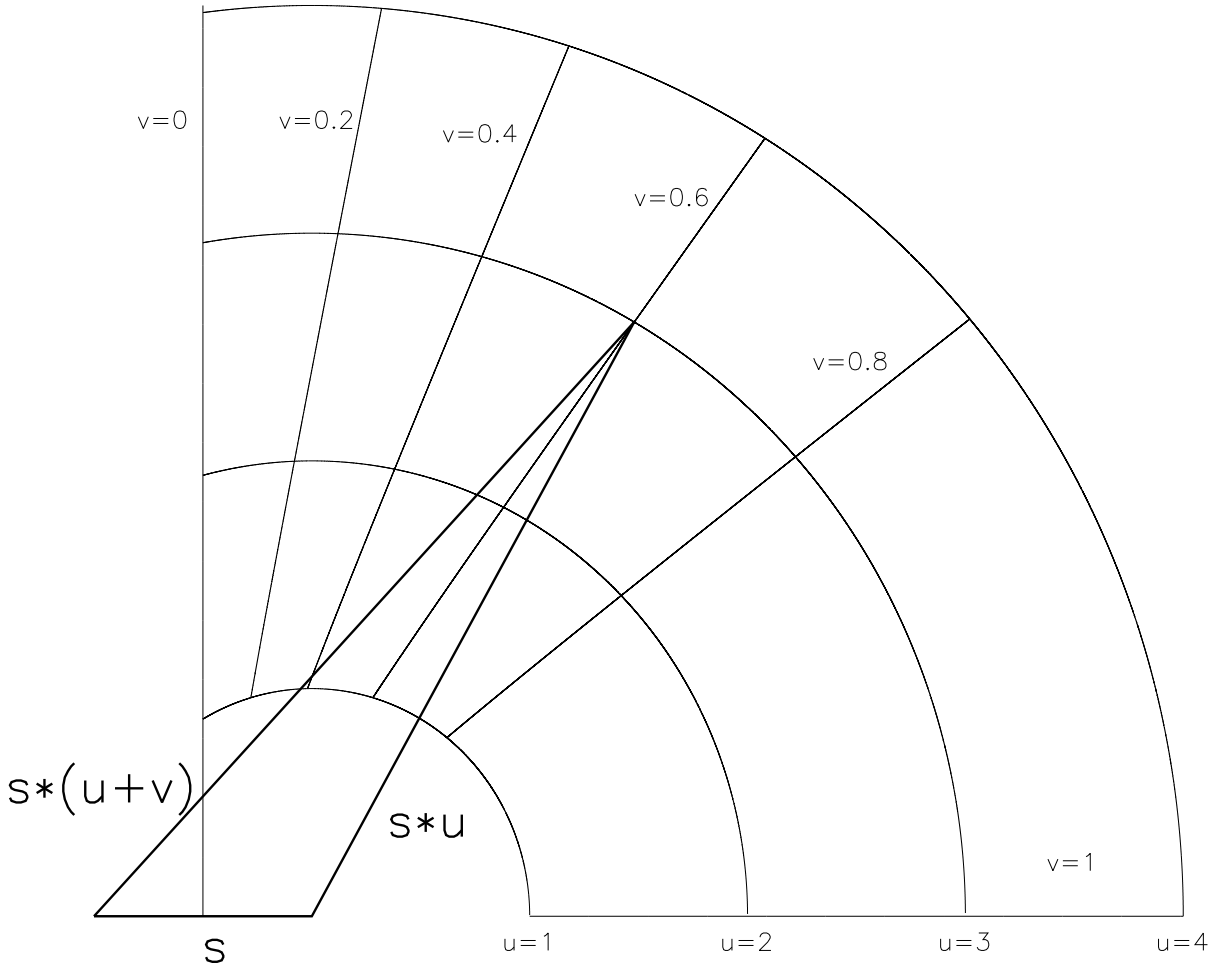
$$\zeta = \frac{27RRR^2\ DDD}{DRR^3} - \frac{9RRR\ DDR}{DRR^2} + 2$$

# Luminosity Function of Galaxies in the r-band

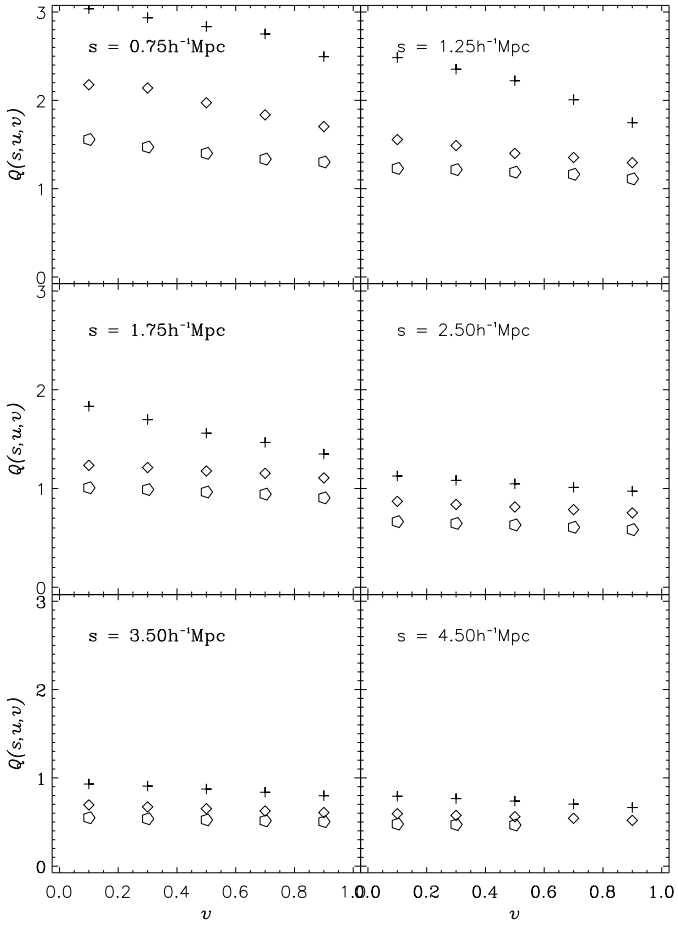
Blanton et al. (2001)



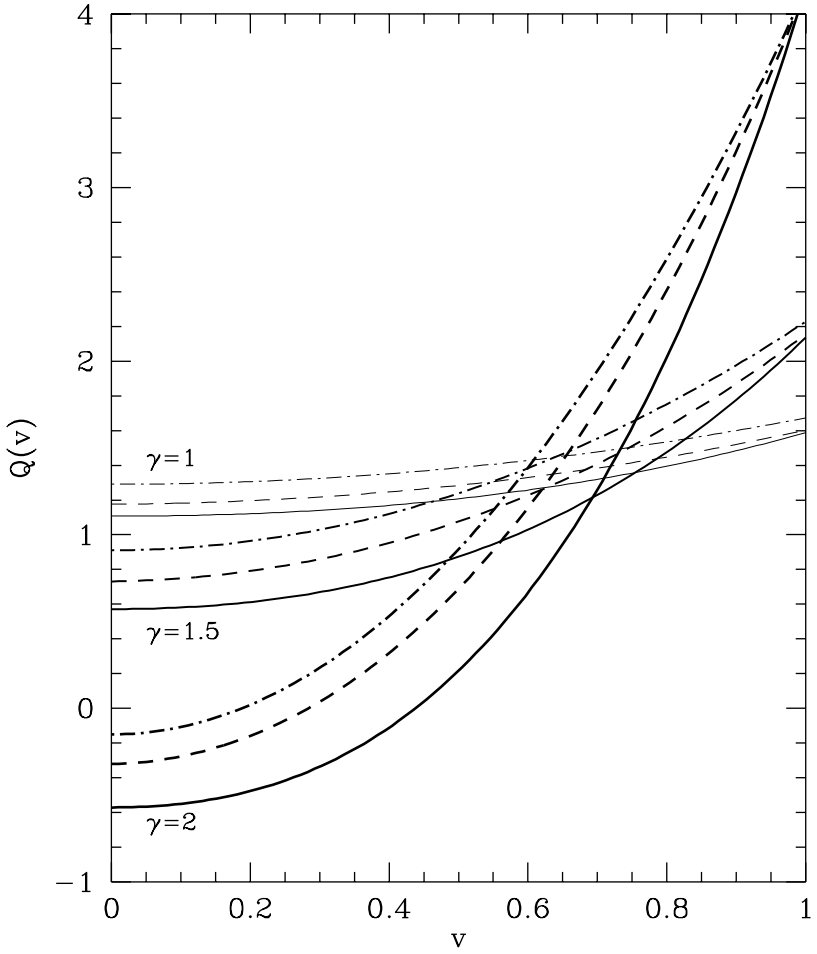
# Parametrisation of the Triangles



# 3PCF for a spherical halo with isothermal density profile

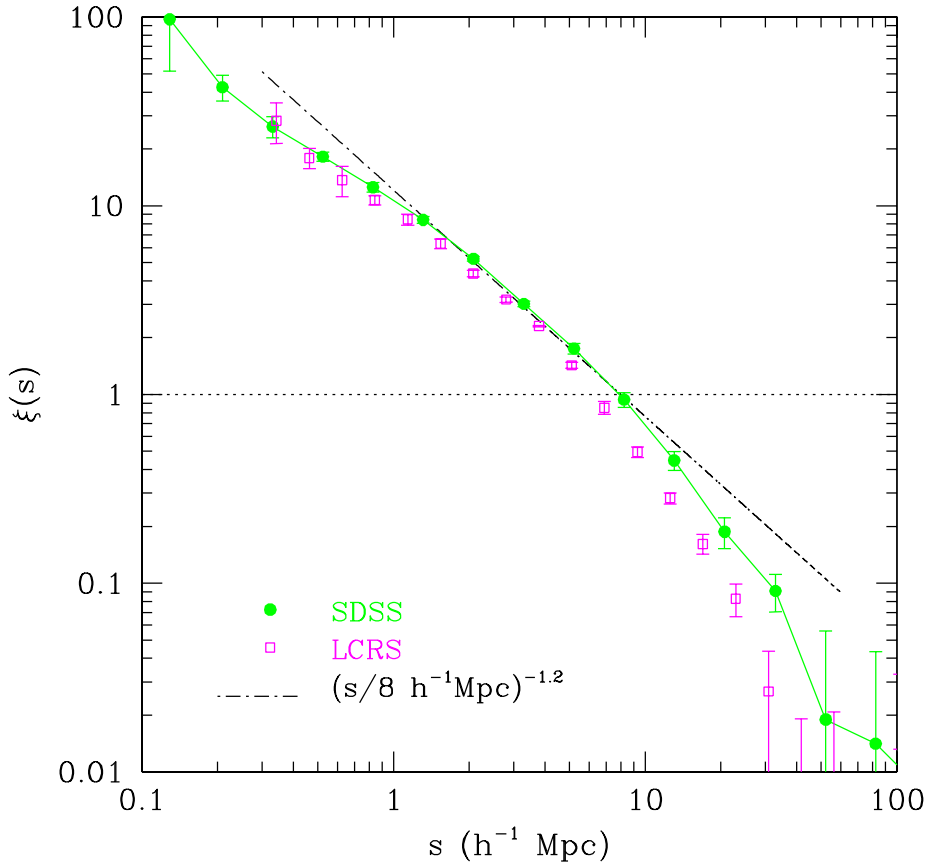


# Prediction of Perturbation Theory (Jing & Boerner 1997)

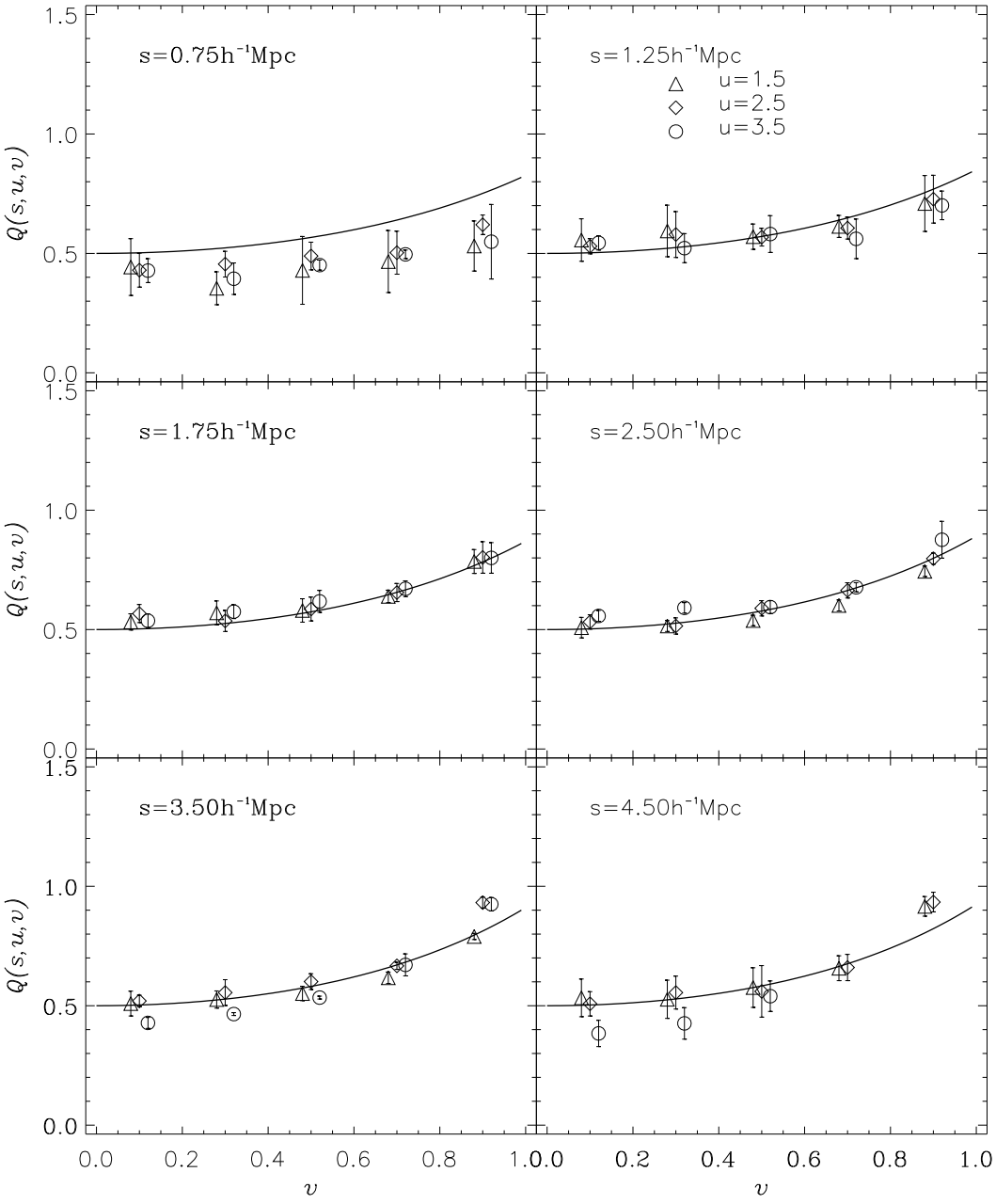


# Redshift Space Correlation Function of Galaxies in the SDSS

Zehavi et al. (2002)



Three Point Function of the SDSS−EDR
with Fit of Jing & Boerner to the LCRS



# Numerical simulations

ART (Adaptive Refinement Tree) code (A. Klypin, A. Kravtsov, A. Khokhlov)

refinement (and derefinement) criterion is the local overdensity

time step refinement according to the spatial refinement

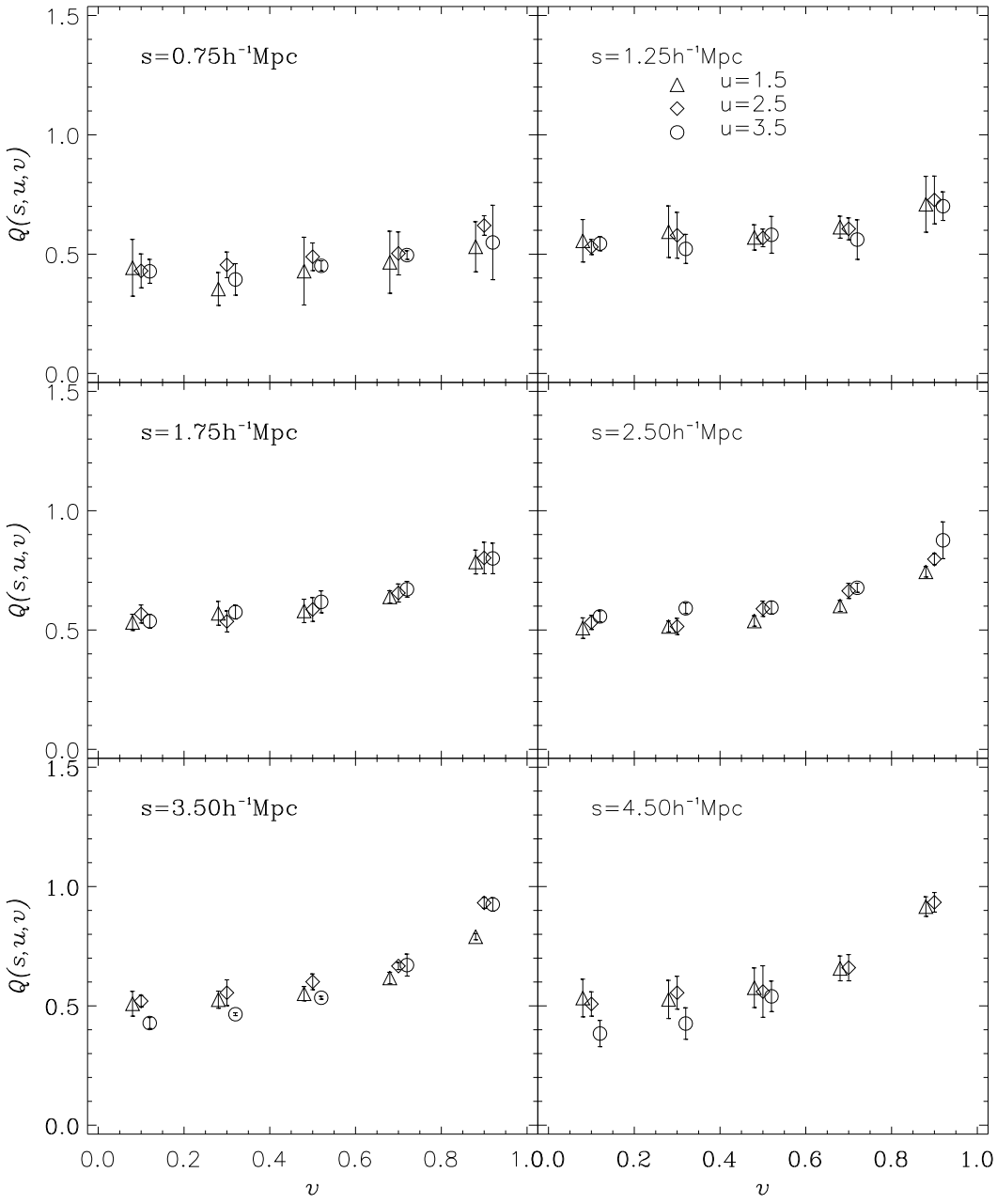
Halos are found by the Bound Density Maxima algorithm ($v_{circ} \geq 120 km/s$)

Parameters of the simulation:

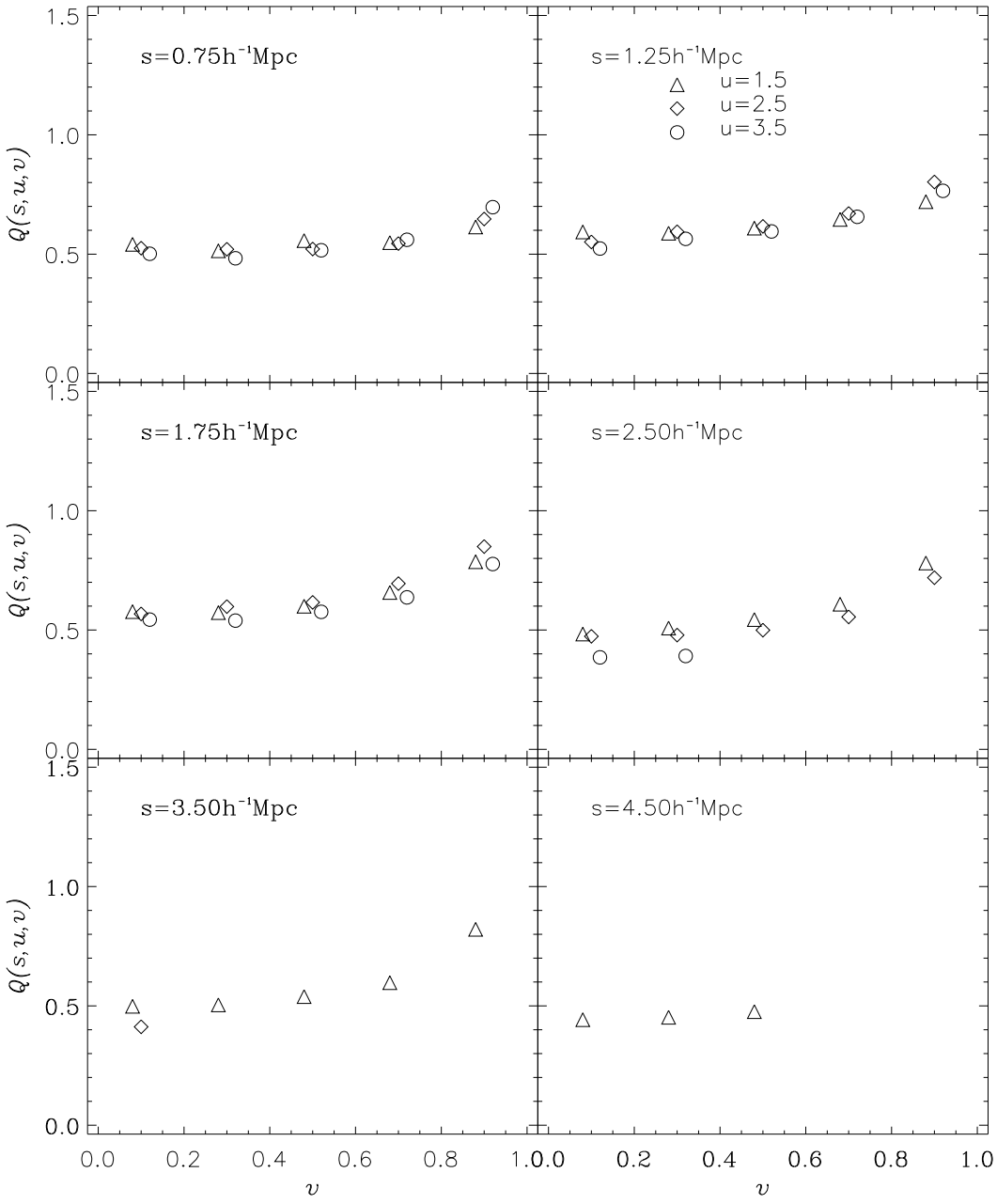
ΛCDM cosmology: $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, $h = 0.7$ and $\sigma_8 = 1.0$

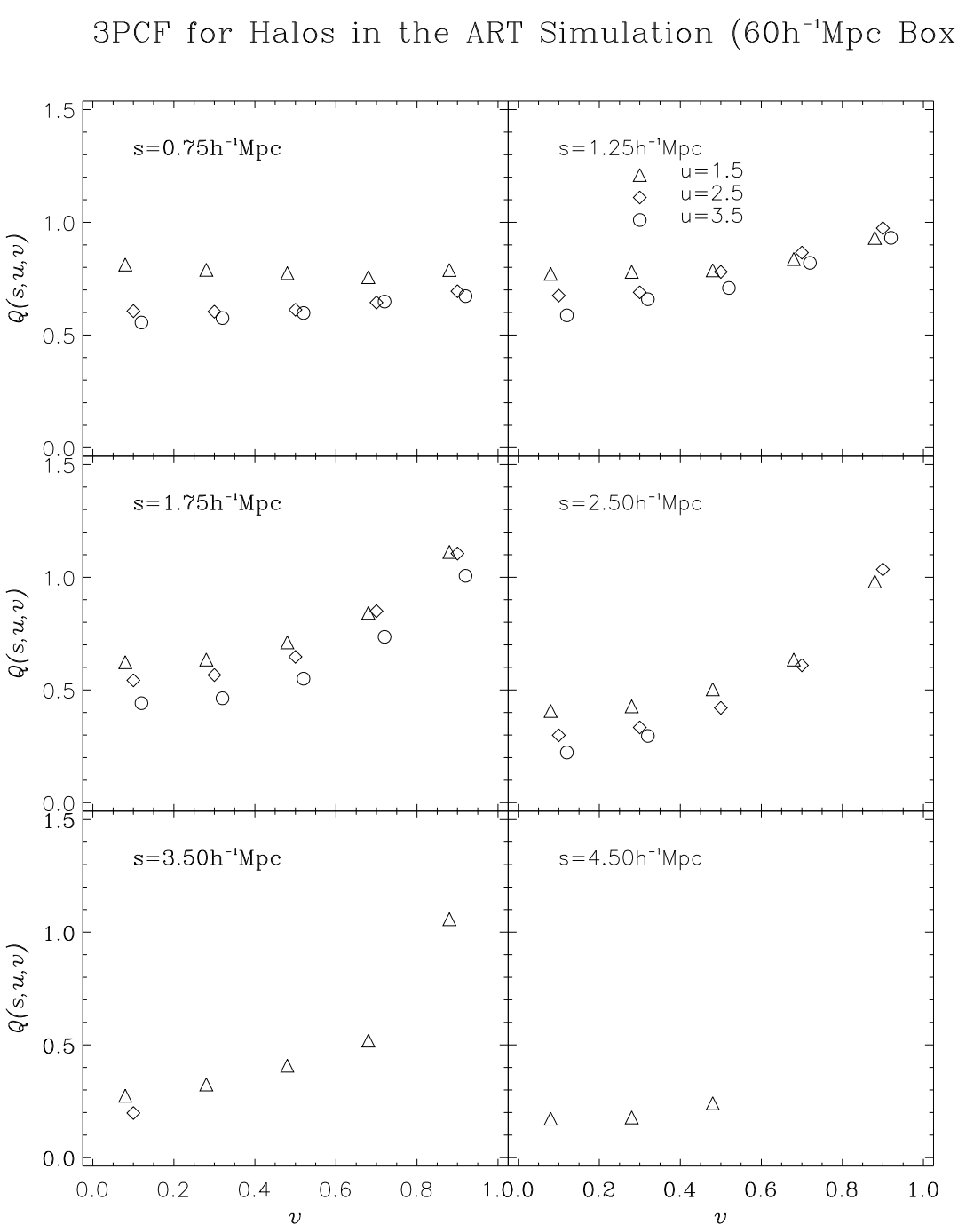
Box: $L = 60 Mpc/h$ with $256^3$ particles $M_p = 1.1 \times 10^9 M_\odot$

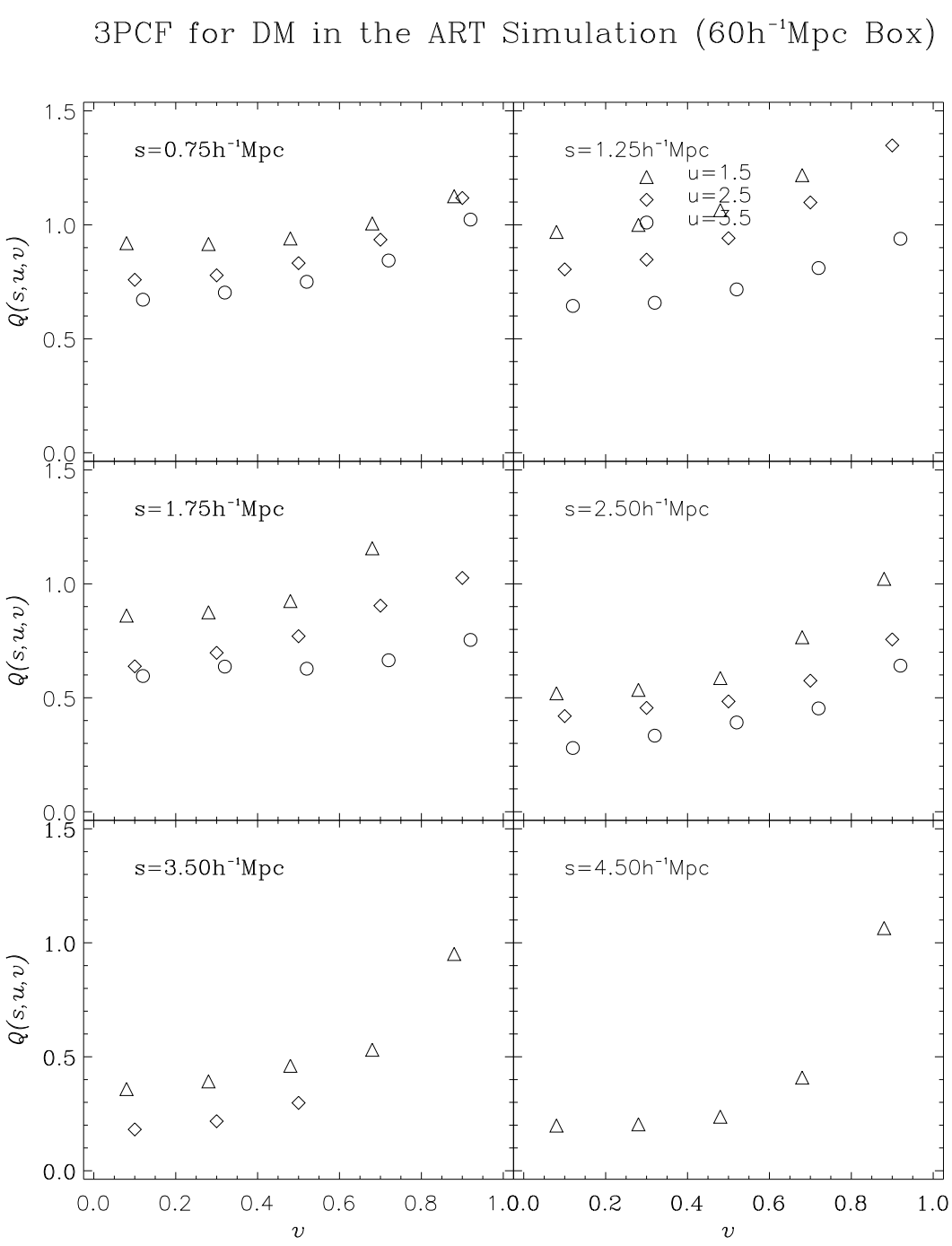
# Three Point Function of the SDSS-EDR



3PCF for Halos in the ART Simulation ($60h^{-1}$Mpc Box) in Redshift Space




3PCF for Halos in the ART Simulation (60h⁻¹Mpc Box)
s=0.75h⁻¹Mpc
s=1.25h⁻¹Mpc
u=1.5
u=2.5
u=3.5
s=1.75h⁻¹Mpc
s=2.50h⁻¹Mpc
s=3.50h⁻¹Mpc
s=4.50h⁻¹Mpc
Q(s,u,v)
v
0.0
0.5
1.0
1.5
0.2
0.4
0.6
0.8

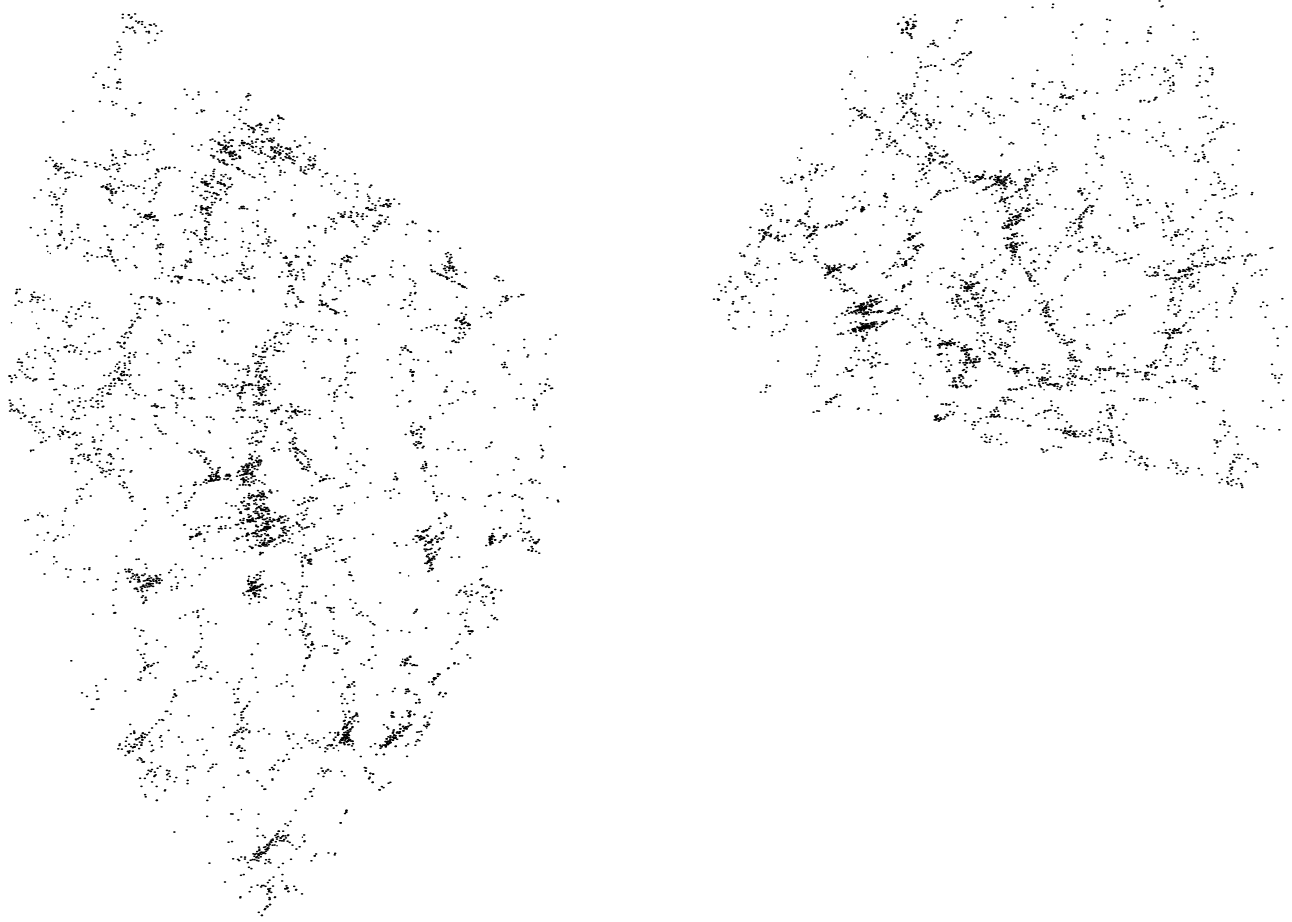

3PCF for DM in the ART Simulation (60h⁻¹Mpc Box)
s=0.75h⁻¹Mpc
s=1.25h⁻¹Mpc
u=1.5
u=2.5
u=3.5
s=1.75h⁻¹Mpc
s=2.50h⁻¹Mpc
s=3.50h⁻¹Mpc
s=4.50h⁻¹Mpc
Q(s,u,v)
v
0.0
0.5
1.0
1.5
0.2
0.4
0.6
0.8

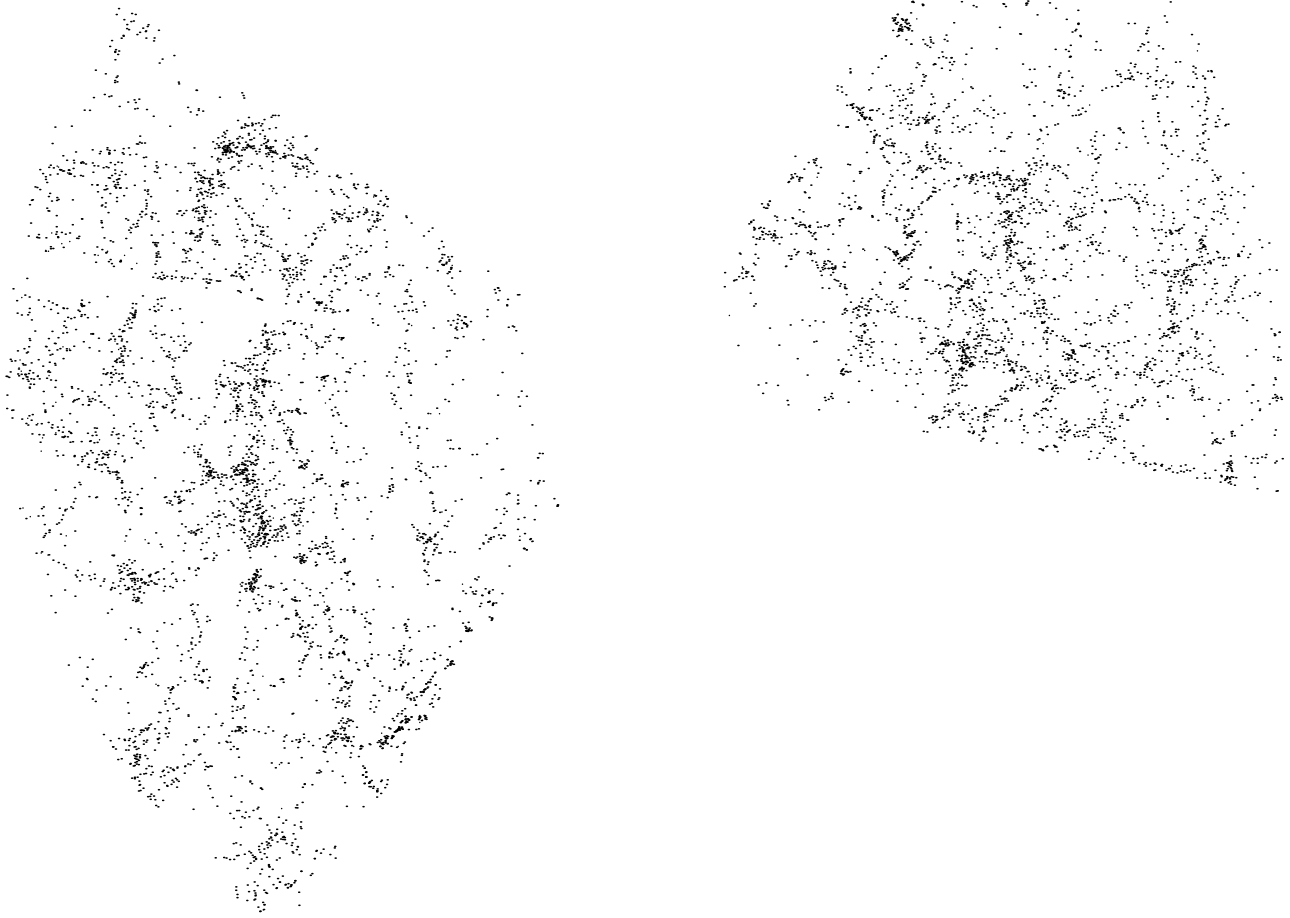
# Color separation

Clustering is a function of galaxy properties such as:

- morphological type
- color
- luminosity
- concentration

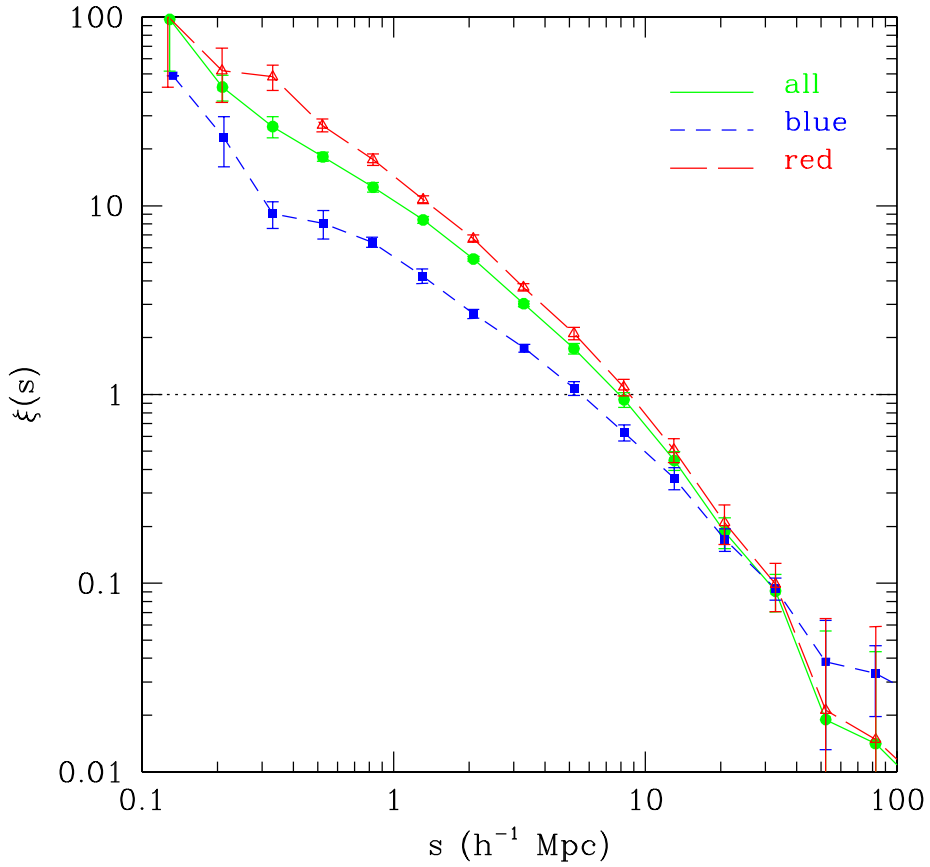
Here we have investigated the difference in clustering for red and blue galaxies. There are two populations of galaxies (Strateva et al. 2001) which can be separated by the color $u^* - r^* = 1.8$.
As can be seen in the following two slides the red galaxies reside mainly in big galaxy clusters whereas the blue galaxies are more smoothly distributed and trace the large filaments of the dark matter distribution. This difference can be seen in the three point correlation function for large triangles ($s = 4.5$).



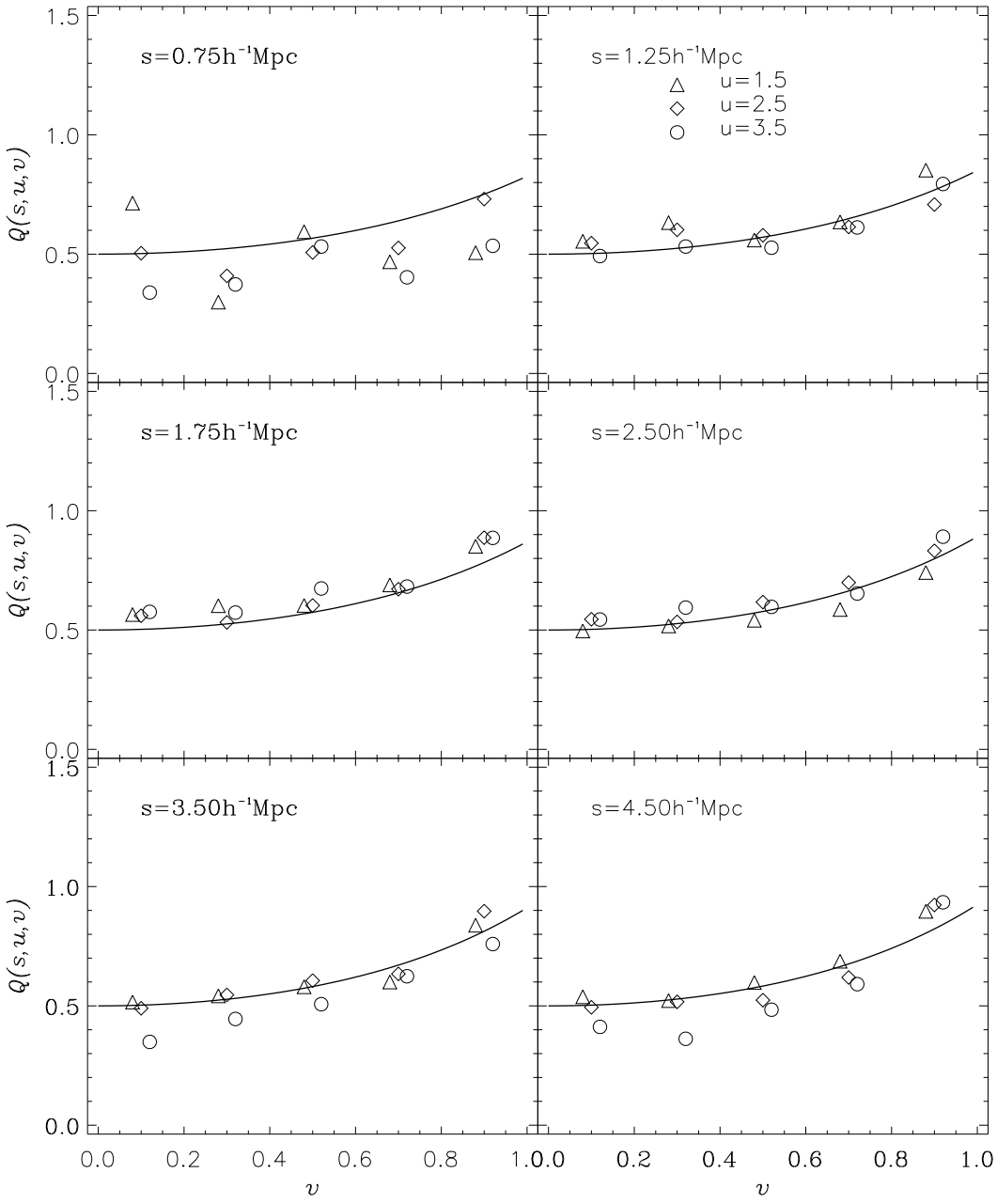


# Correlation Function of Red and Blue Galaxies in the SDSS

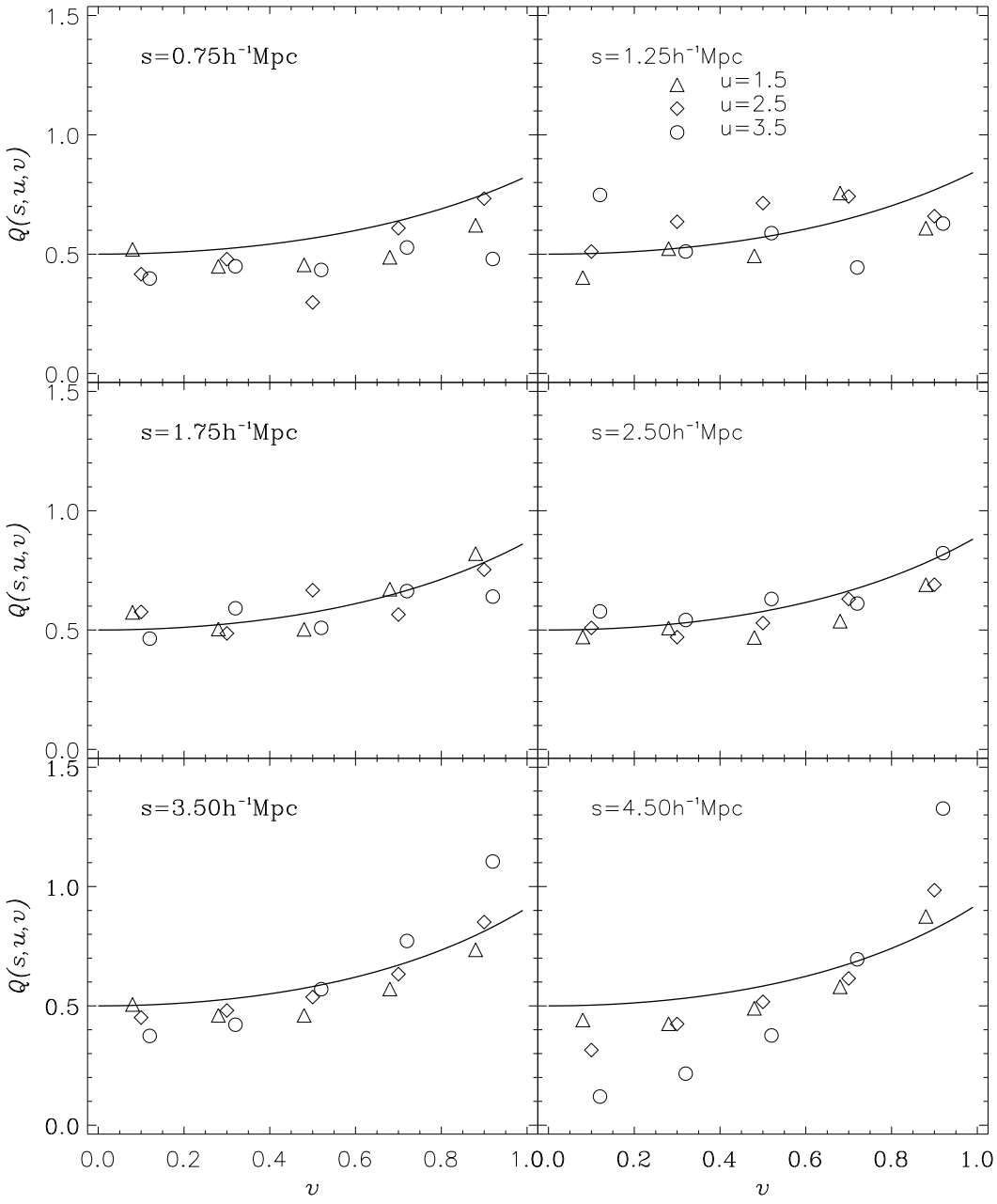
Zehavi et al. (2002)



## Three Point Function of Red Galaxies



# Three Point Function of Blue Galaxies



# Time evolution of the correlation functions

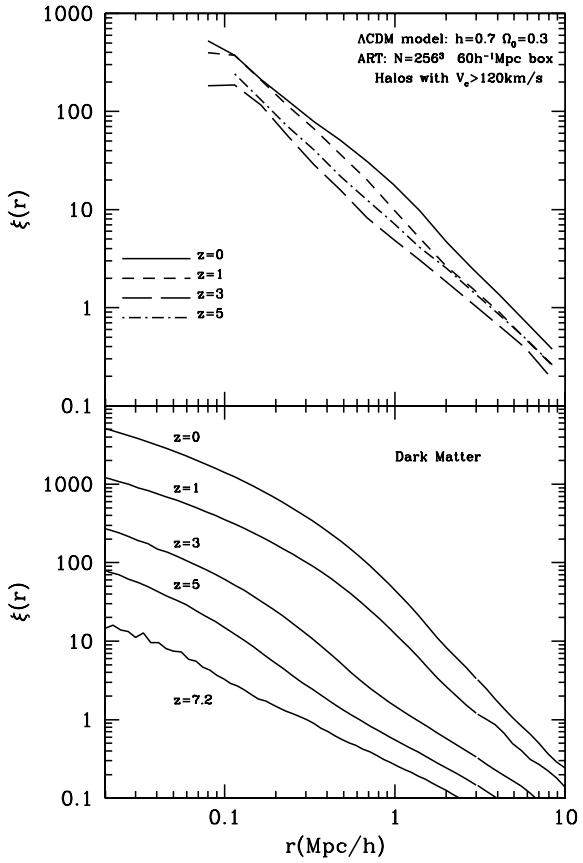
Dark matter particles and halos of the VIRGO/GIF-simulation (P3M-code):

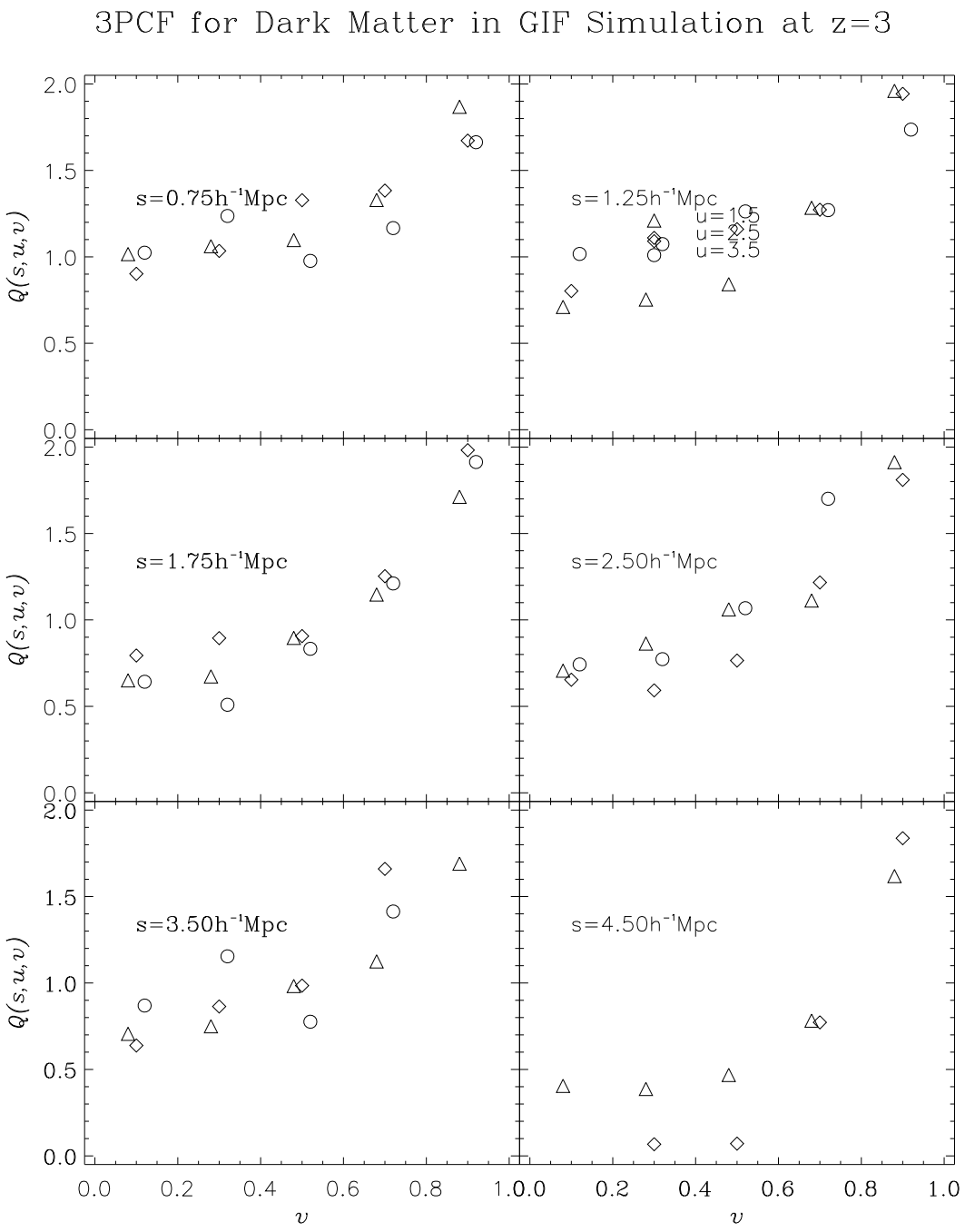
- $\Lambda$CDM cosmology: $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, $h = 0.7$ $\sigma_8 = 0.9$ and $\Gamma = 0.21$
- Box: $L = 141.3 Mpc/h$ with $256^3$ particles $M_p = 1.4 \times 10^{10} M_\odot$
- Halos are found by the friends-of-friends algorithm with more than 9 particles

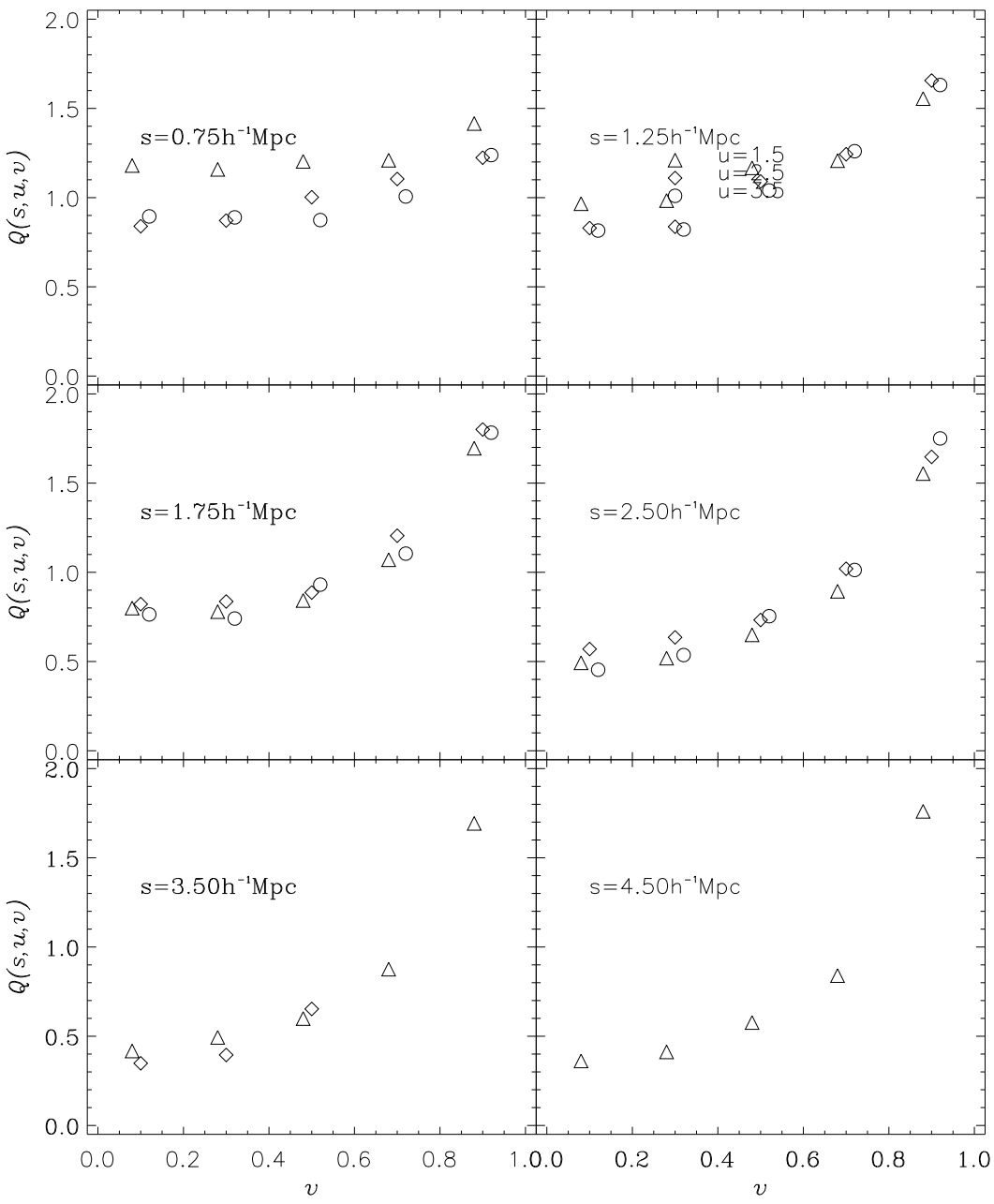
For the two point correlation function there is an evolution in the clustering of dark matter whereas the halo correlation function is almost independent of time. Here we find for the three point correlation function an evolution for both components.

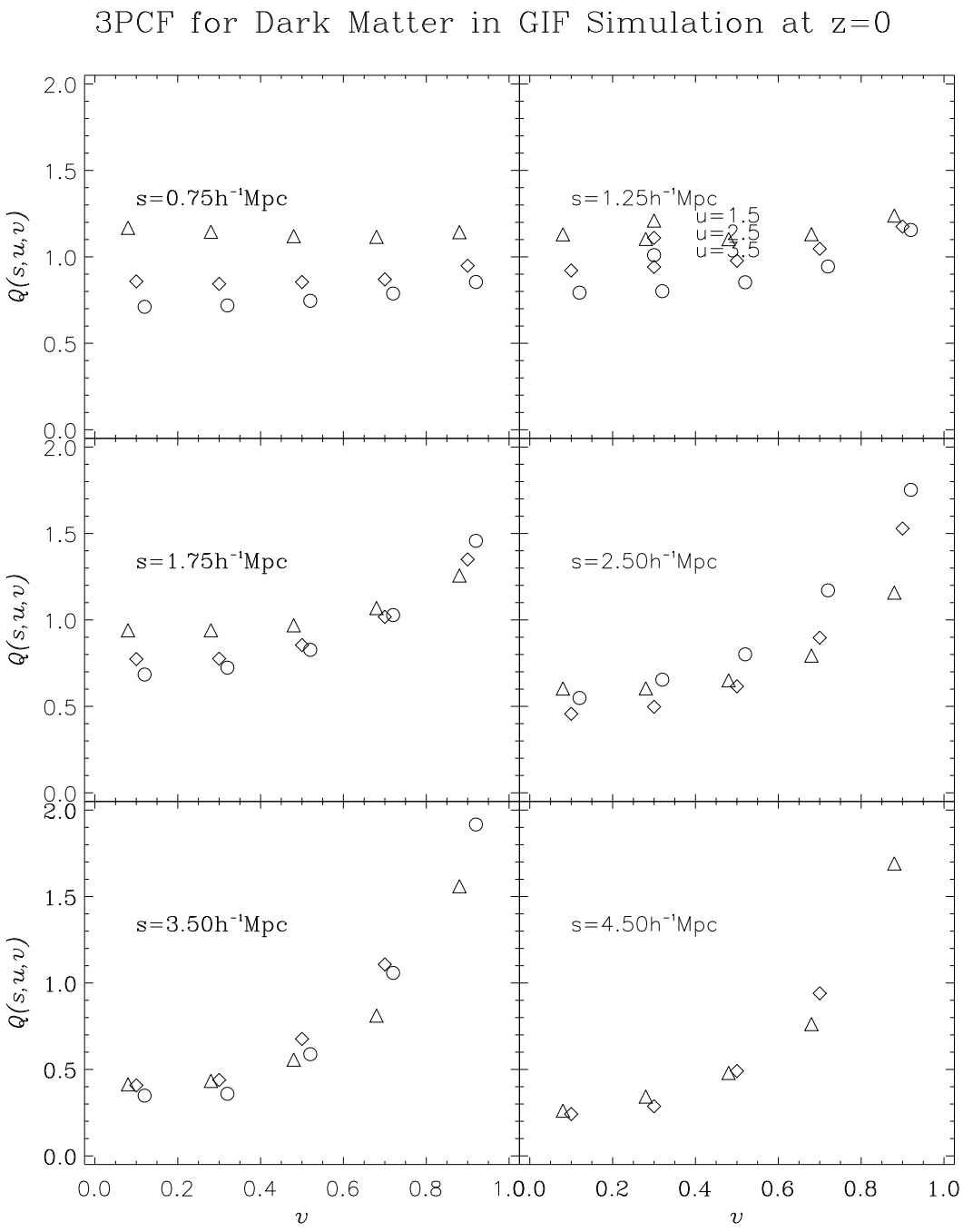
# Time evolution of the correlation function for dark matter and halos

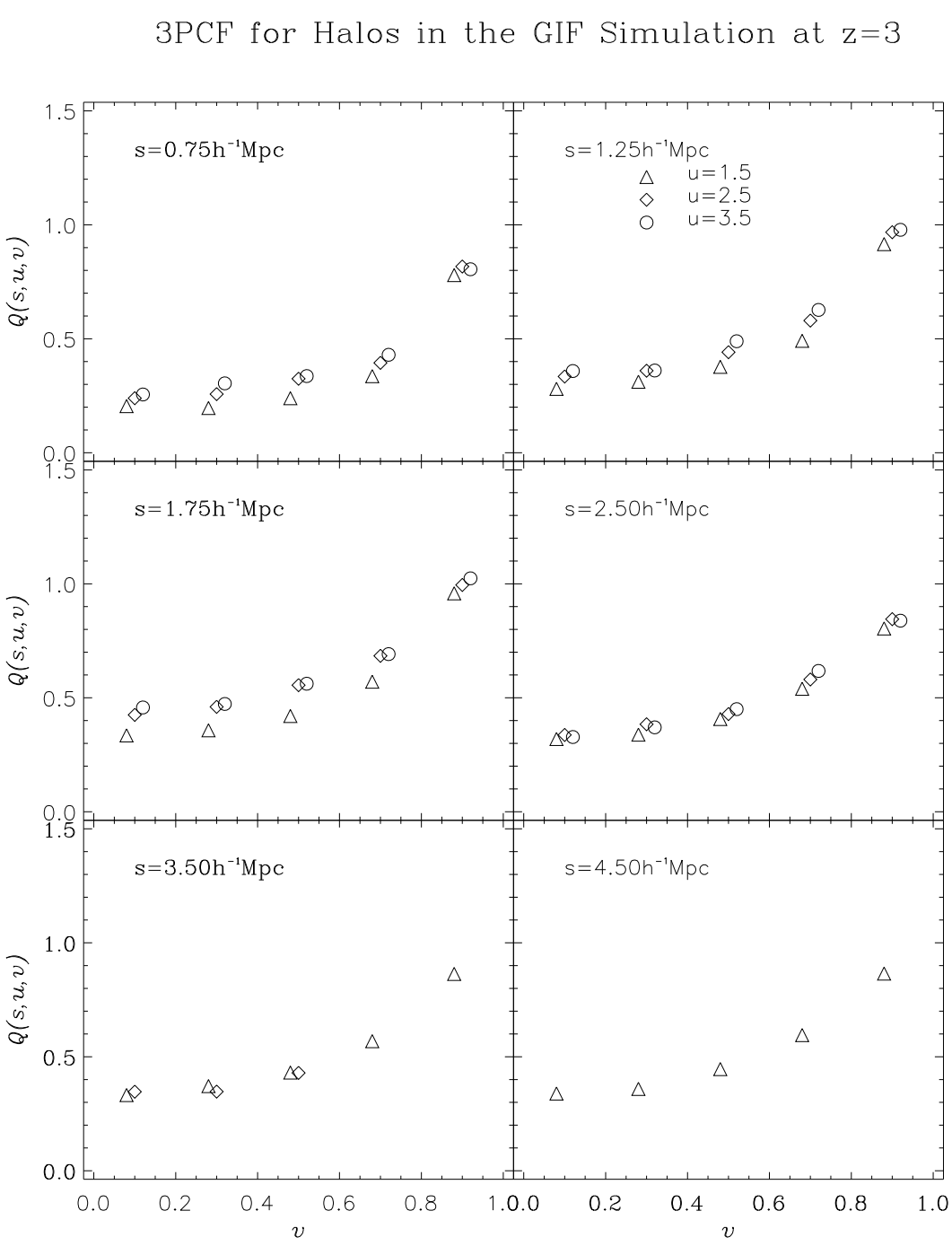
Colin et al. (1999)

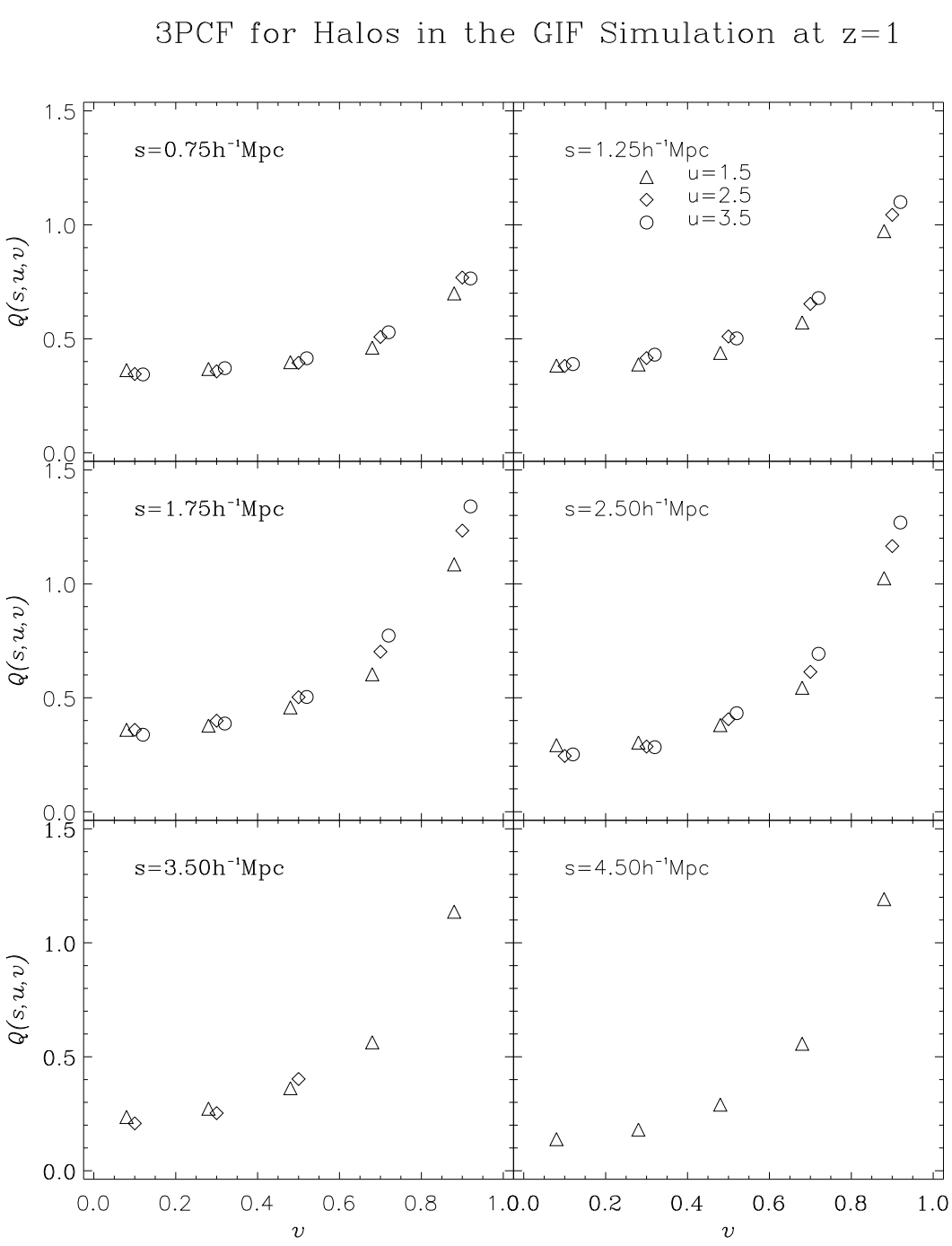


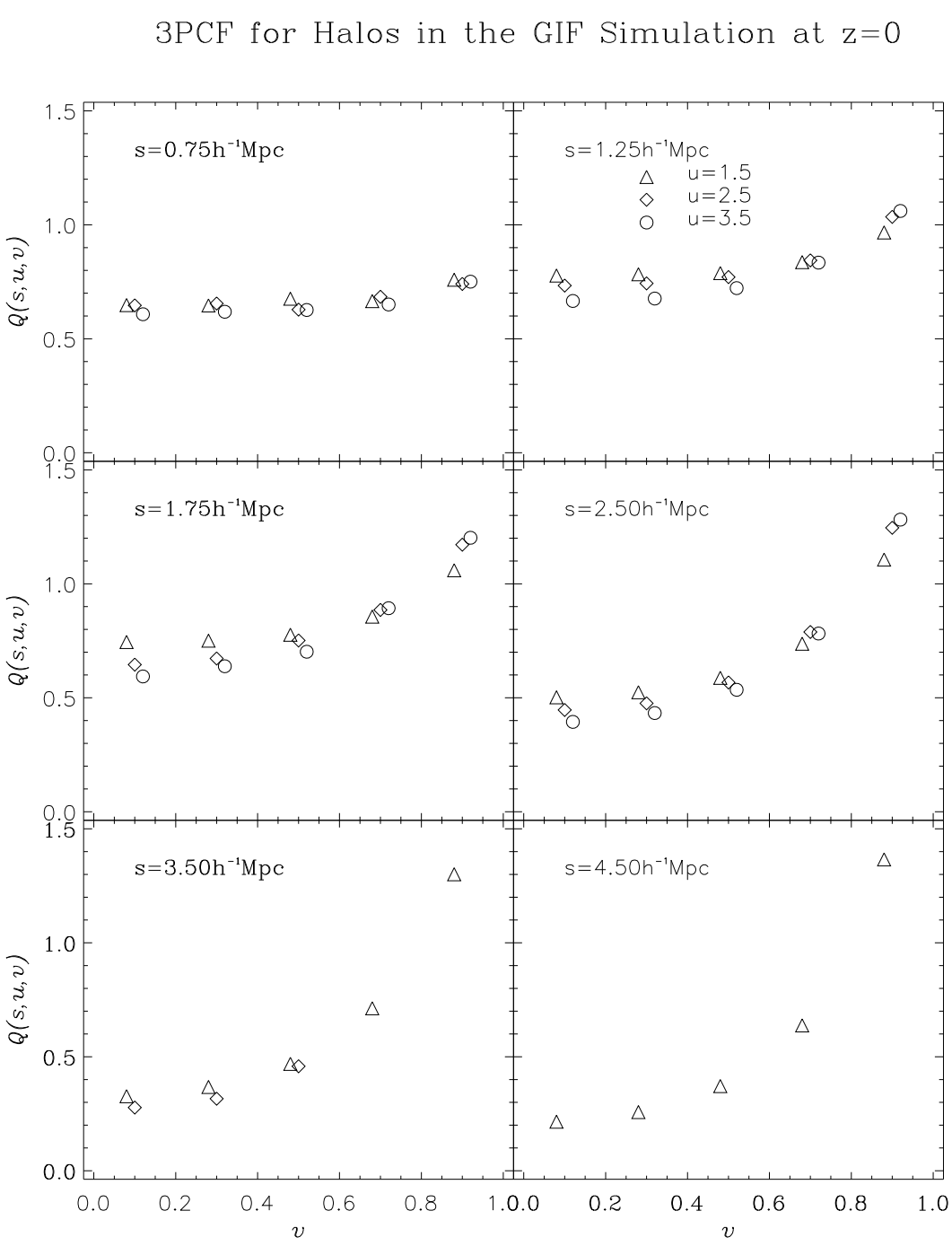

3PCF for Dark Matter in GIF Simulation at z=3
s=0.75h⁻¹Mpc
s=1.25h⁻¹Mpc
u=1.0
u=2.5
u=3.5
s=1.75h⁻¹Mpc
s=2.50h⁻¹Mpc
s=3.50h⁻¹Mpc
s=4.50h⁻¹Mpc
Q(s,u,v)
v
0.0
0.5
1.0
1.5
2.0
0.2
0.4
0.6
0.8


3PCF for Dark Matter in GIF Simulation at z=1
s=0.75h⁻¹Mpc
s=1.25h⁻¹Mpc
u=1.5
u=2.5
u=3.5
s=1.75h⁻¹Mpc
s=2.50h⁻¹Mpc
s=3.50h⁻¹Mpc
s=4.50h⁻¹Mpc
Q(s,u,v)
v
0.0
0.5
1.0
1.5
2.0
0.2
0.4
0.6
0.8


3PCF for Dark Matter in GIF Simulation at z=0
s=0.75h⁻¹Mpc
s=1.25h⁻¹Mpc
u=1.5
u=2.5
u=3.5
s=1.75h⁻¹Mpc
s=2.50h⁻¹Mpc
s=3.50h⁻¹Mpc
s=4.50h⁻¹Mpc
Q(s,u,v)
v
0.0
0.5
1.0
1.5
2.0
0.2
0.4
0.6
0.8


3PCF for Halos in the GIF Simulation at z=3
s=0.75h⁻¹Mpc
s=1.25h⁻¹Mpc
u=1.5
u=2.5
u=3.5
s=1.75h⁻¹Mpc
s=2.50h⁻¹Mpc
s=3.50h⁻¹Mpc
s=4.50h⁻¹Mpc
Q(s,u,v)
v
0.0
0.5
1.0
1.5
0.2
0.4
0.6
0.8


3PCF for Halos in the GIF Simulation at z=1
s=0.75h⁻¹Mpc
s=1.25h⁻¹Mpc
u=1.5
u=2.5
u=3.5
s=1.75h⁻¹Mpc
s=2.50h⁻¹Mpc
s=3.50h⁻¹Mpc
s=4.50h⁻¹Mpc
Q(s,u,v)
v
0.0
0.5
1.0
1.5
0.2
0.4
0.6
0.8


3PCF for Halos in the GIF Simulation at z=0
s=0.75h⁻¹Mpc
s=1.25h⁻¹Mpc
u=1.5
u=2.5
u=3.5
s=1.75h⁻¹Mpc
s=2.50h⁻¹Mpc
s=3.50h⁻¹Mpc
s=4.50h⁻¹Mpc
Q(s,u,v)
v
0.0
0.5
1.0
1.5
0.2
0.4
0.6
0.8

# Summary

We have determined the three point function of galaxies for the Sloan Digital Sky Survey in agreement with earlier measurements of the LCRS.

The agreement with the ART simulation for a concordance ΛCDM model is very good (however the small boxsize may affect the result).

Redshift and bias have similar effects on the 3PCF of dark matter.

Different clustering for red and blue galaxies is seen in the 3PCF.

There is an evolution of the three point correlations for the dark matter as well as for halos.