Merger Rate Evolution for Dry, Wet, and Wet-Dry Mergers from DEEP2 Redshift Survey

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m~3 vs m~0 ?

assuming merger rate ~ $(1+z)^m$

- Theoretical Predictions
  - Rapid evolution:
    Governato et al. 2000;
    Gottlober et al. 2001
  - Mild evolution:
    Berrier et al. 2006

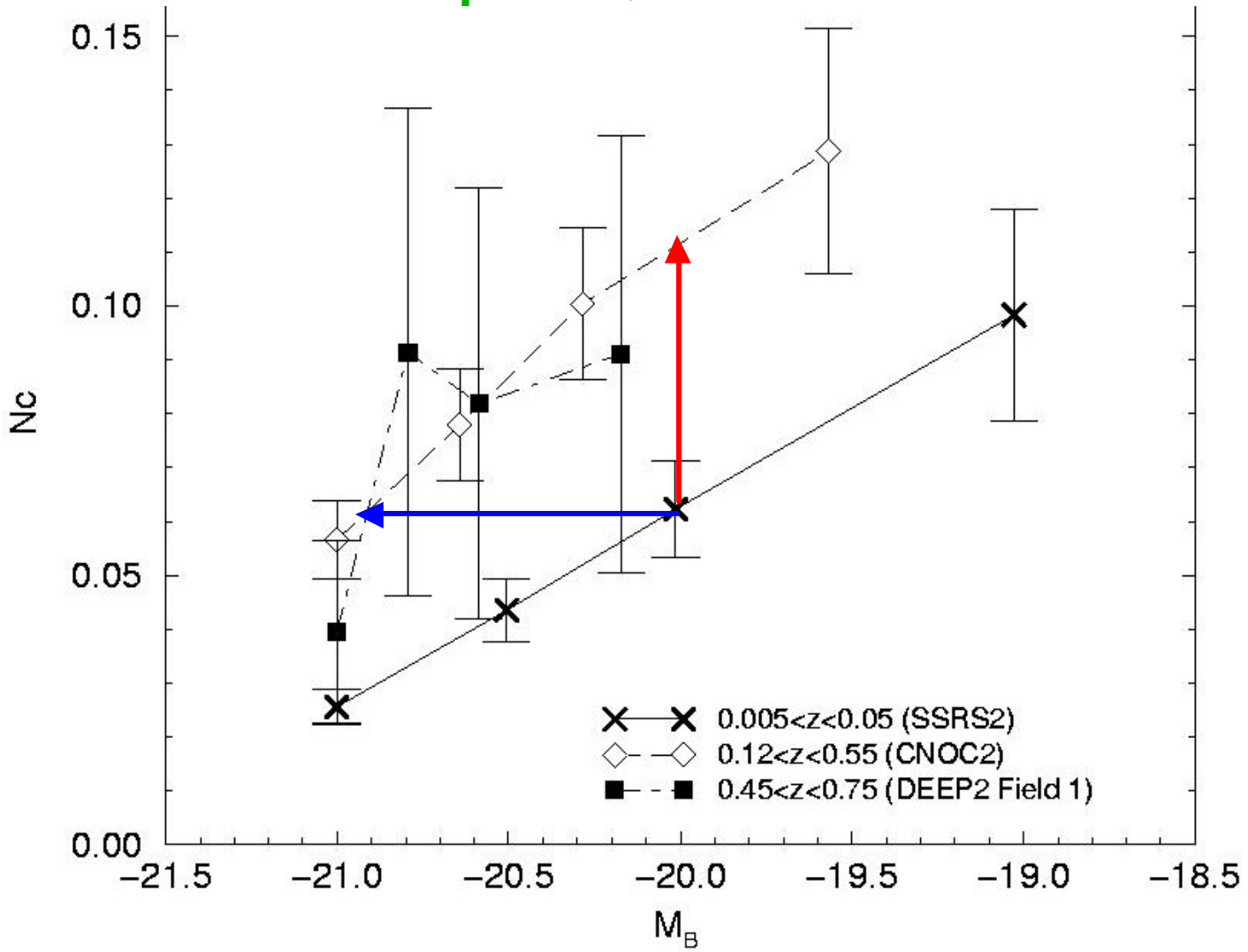
  =>consistent with Lin et al.2004

- Observational Results
  (**also see O. Le Fevre's talk**)
  - Rapid evolution:
    Zept & Koo 89; Burkey et al. 94; Yee & Ellinson 95; Le Fevre et al. 0 Patton et al. 02; Conselice et al. 03 Cassata et al. 05; Kampczyk et al. 07; Kartaltepe et al. 07
  - Constant/Mild evolution:
    Carlberg et al. 00; Bundy et al. 04; Lin et al. 04; Lotz et al. 06

Halo merger rates vs Subhalo merger rates

Different Modeling, Redshift range; Sample selectio

The luminosity dependence of the pair fraction



Lin et al. 04, ApJ, 617, L9

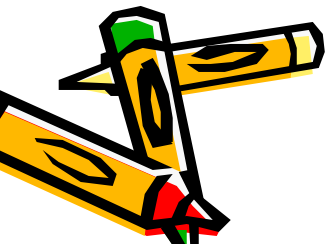
$M_B^e = M_B + Q*z$
--Fixing luminosity range $-22<M_B<-20$ at z~1

Model	M_B^e Range	m
Q=0	-22 ~ -20	1.60 ± 0.29
Q=0.5	-21.5 ~ -19.5	0.86 ±0.29
Q=1.0	-21 ~ -19	0.41 ± 0.30
Q=2.0	-20 ~ -18	-0.24 ± 0.35

Lin et al. 04, ApJ, 617, L9

Dry Mergers; Wet Mergers; Dry-Wet Mergers

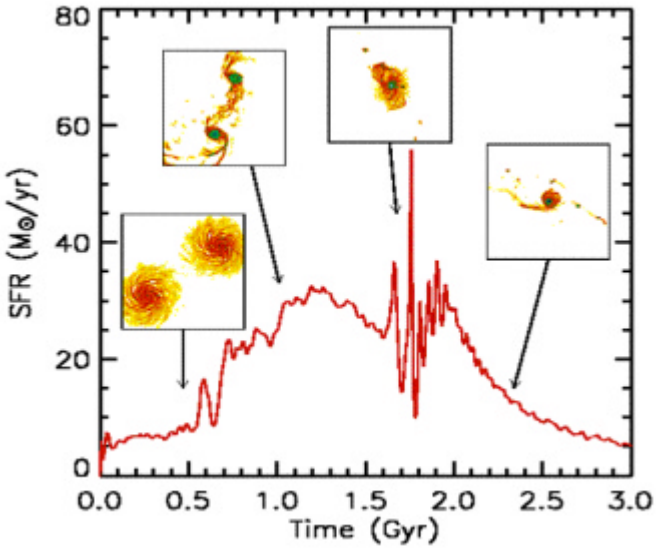
- Different types of mergers result in different star formation histories, stellar mass buildup, and morphologies in the remnants



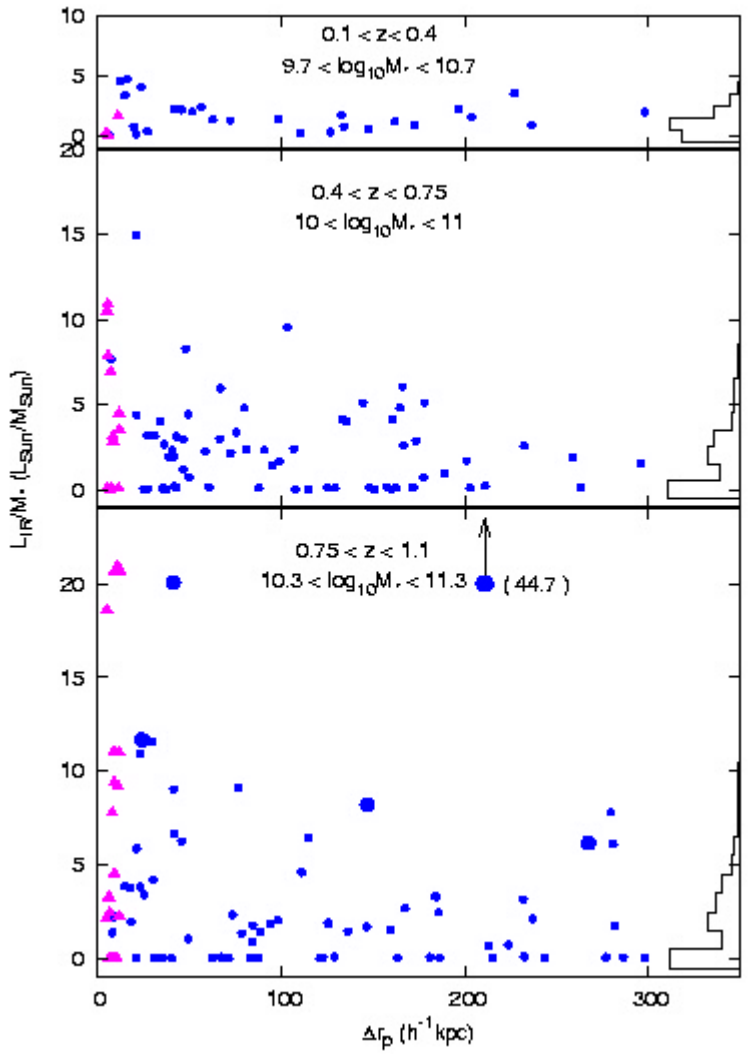
Wet Mergers (Gas Rich Mergers)

- Enhanced star formation rates are shown during mergers of gas-rich systems :
  - Barton et al. 00 (CfA2)
  - Lambas et al. 03 (2dF)
  - Nikolic et al. 2004 (SDSS)
  - Lin et al. 07 (DEEP2)

- Continuous SF post mergers



Jonsson et al. 05



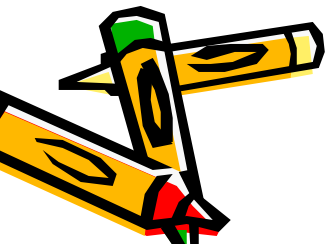
Lin et al. 07, ApJ, 660, L51

Dry Mergers

- Little SF going on before, during, or post mergers
- They are likely responsible for the growth of massive ellipticals in the present day (Van Dokkum et al. 05)

Wet-Dry Mergers

•Unclear about their behavior---need model predictions



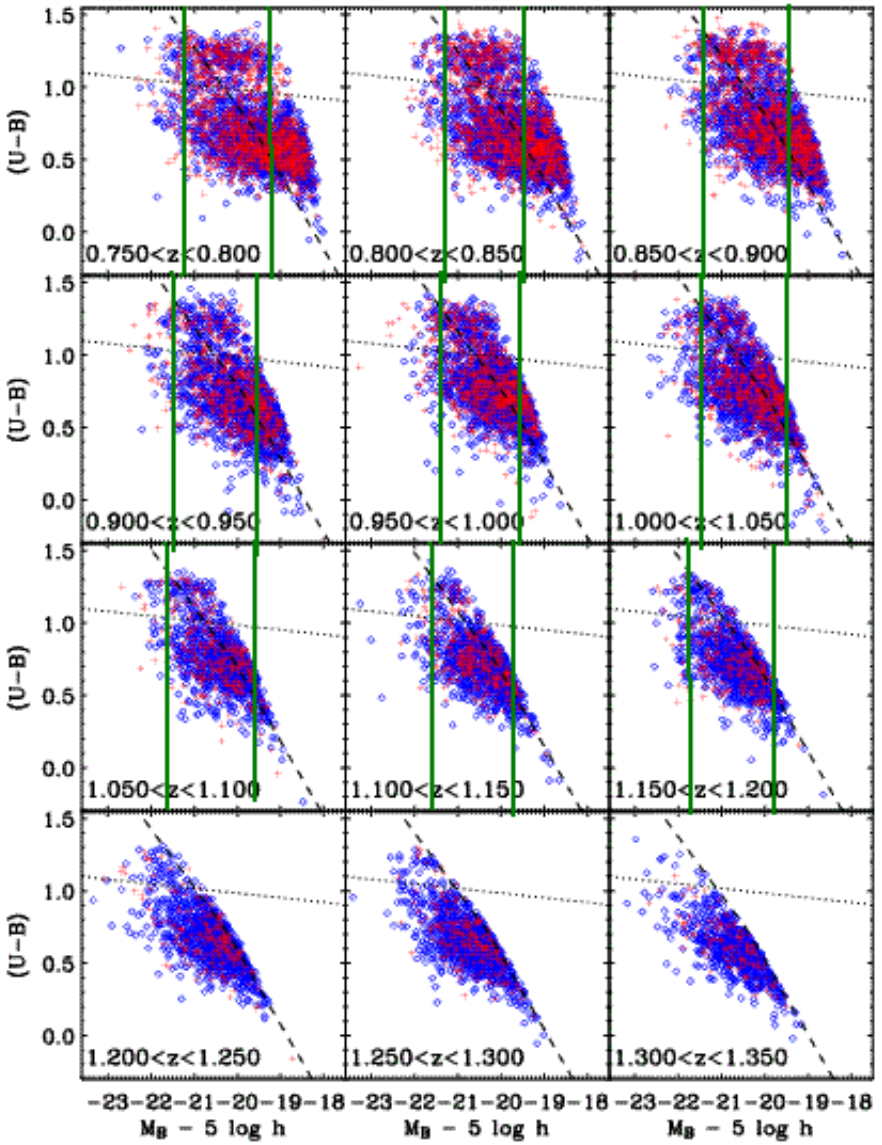
Samples

- 0.4 < z < 1.2
  - DEEP2 Redshift Survey
    - 4 Fields: each 30'by 120' (15'by 120' for EGS)
      - 1417 +5230 (EGS)
      - 1652 +3455
      - 2330 0000
      - 0230 0000
    - Sample size: ~ 50,000 galaxies at 0.2<z<1.4
    - Grating and Spectra: 1200/mm
    - 6000A~9000A
    - [OII] doublet is visible at 0.7<z<1.4
    - Resolution: 1.0" slits; FWHM=1.7A~68/(1+z) km/s (R=5000)
  - Supplemented by TKRS in GOODS-N
- 0.05 < z < 0.4
  - Millennium Galaxy Catalog
  - CNOC2 Redshift Survey

DEEP2 Sample

- Galaxies on average are brighter by 1.3 mag per redshift unit (Faber et al. 07) => Q=1.3

- Color Separation:
  U-B = 0.032*(M_B+21.62)+1.035



Pair Selection Criterion

1. Magnitude range:

Galaxy luminosity evolution

$$M^*(z) = M^*(z=0) - Qz$$

$$M_B^e \equiv M_B + Qz \,, \quad \text{with } Q=1.3 \text{ (Patton 2002)}$$

$$-21 < M_B^e < -19$$

to select galaxies of the same type

2. 3D separation:

$$10\ h^{-1}\text{kpc} < \Delta r < r_{max} \,, \text{ with } r_{max} = 30, 50, \text{ and } 100\ h^{-1}\text{kpc}$$

$$\Delta v <= 500 \text{ km/s}$$

reduce the line of sight projection effect

Pair Fraction

Definition:
(averaged number of companion per galaxy)

$$N_c \equiv \frac{\sum_{i=1}^{N_{sam}} n_i}{N_{sam}}$$

weighting of each spectral-companion through the selection function

Selection function

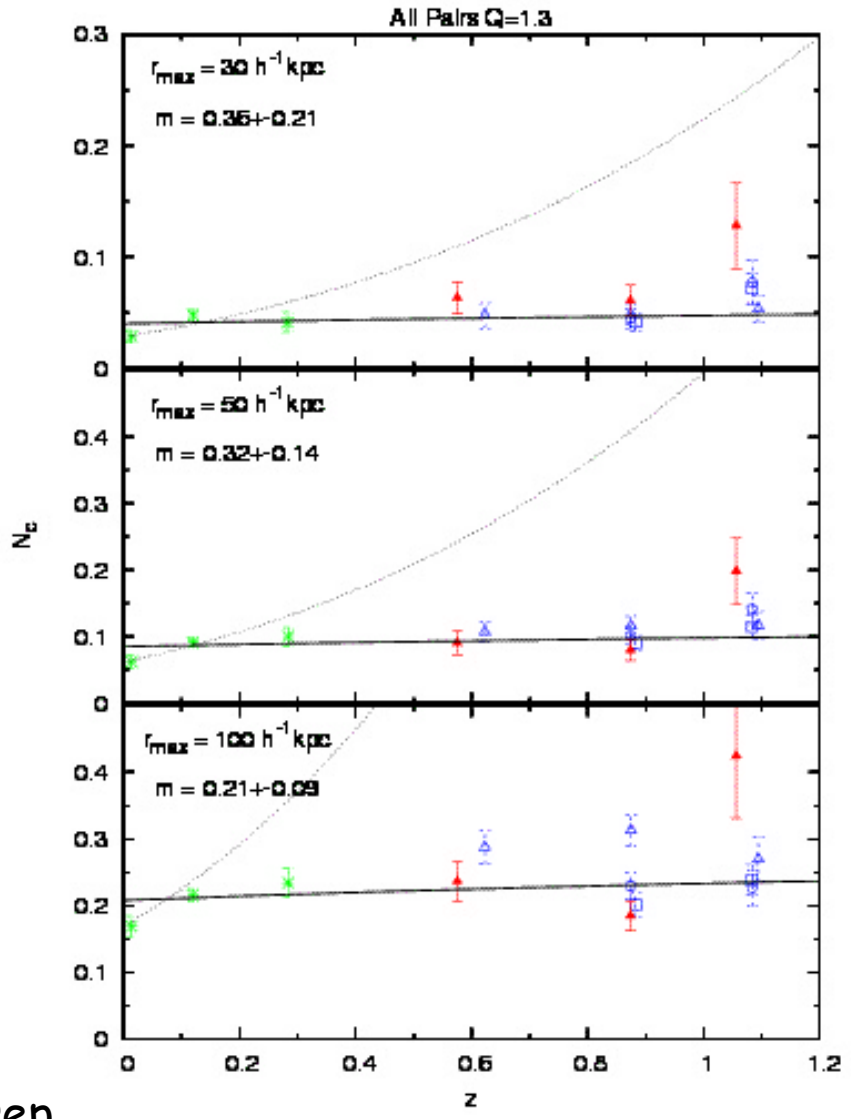
weighting with angular separation of each pair
⇒ refine the weighting of density fluctuation (cosmic variance).

Number of gal with spectral-z

Pair Fraction vs Redshift

- Nc: averaged number of companion per galaxy
- m ~ 0.36+-0.21, consistent with mild evolution from Lin et al. 04

Blue: deep2;
red: TKRS;
green: MGC+CNOC2

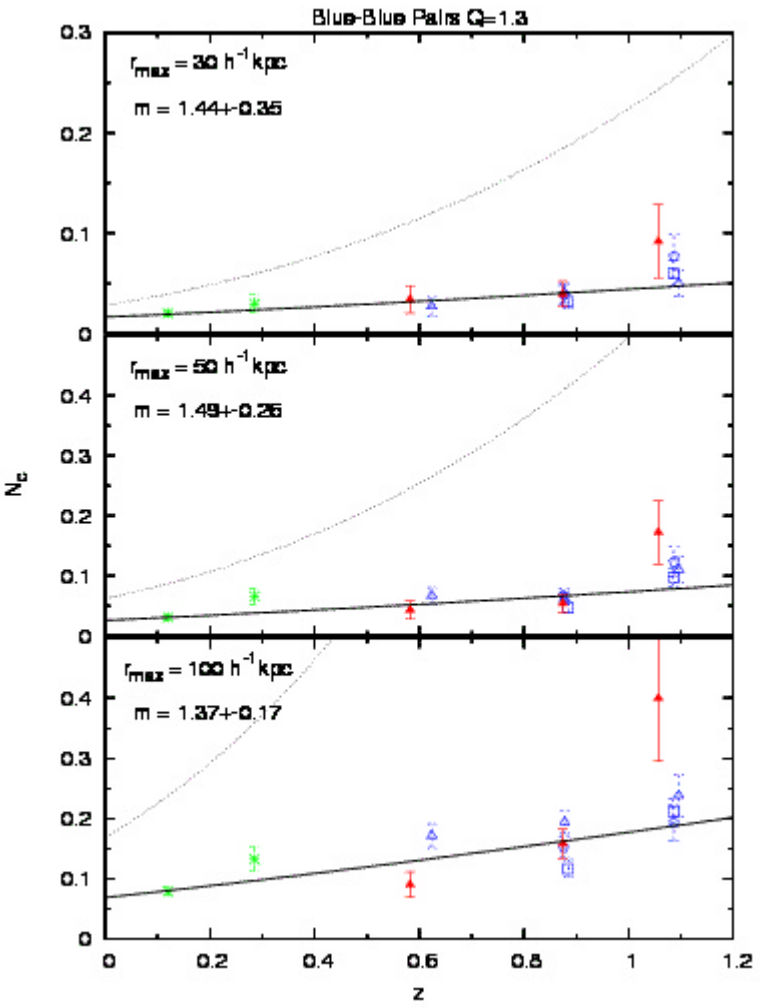


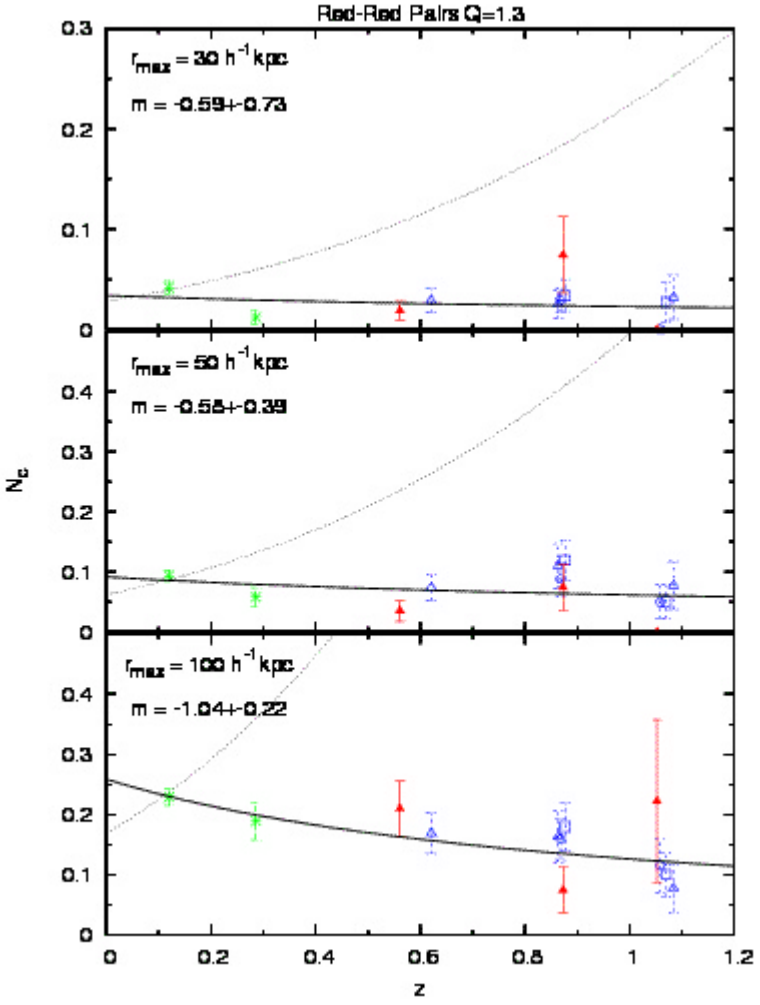
Lin et al. 07, in prep.

Pair Fraction vs Redshift

Blue galaxies : m ~1.44+-0.36

Red galaxies have m<=0

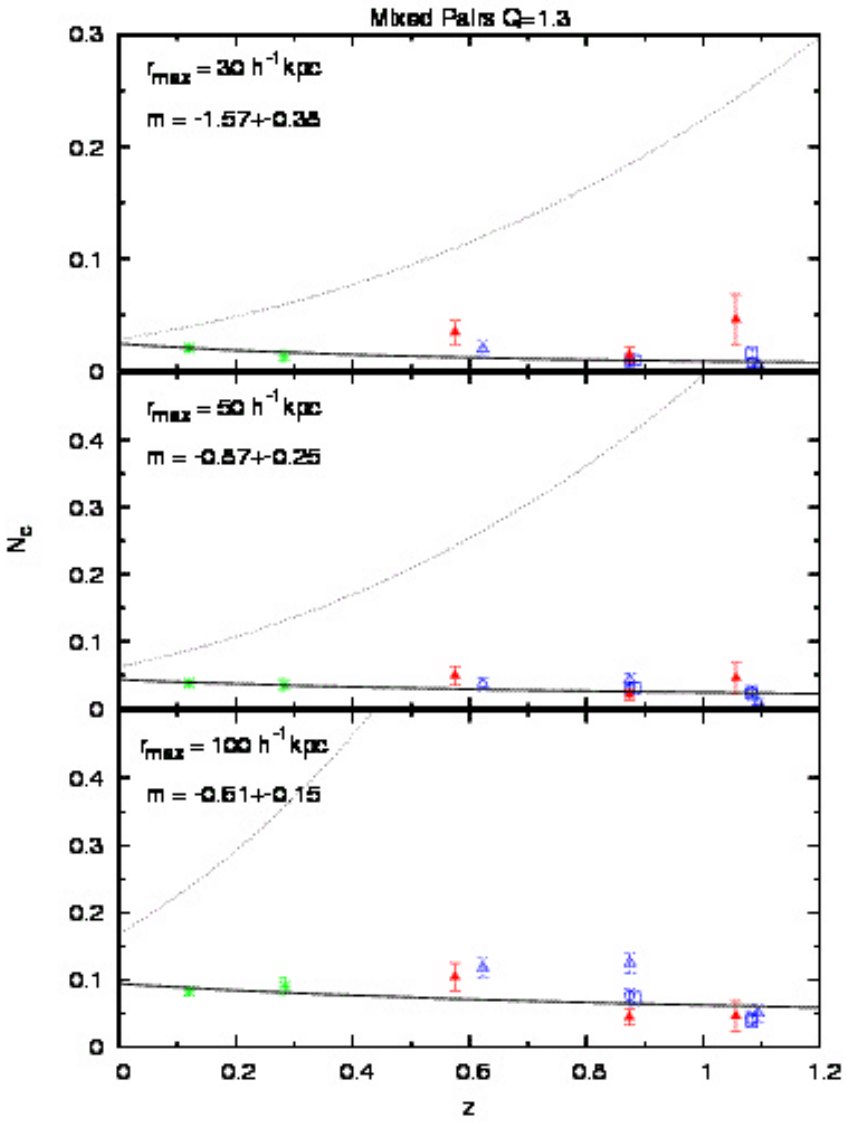




Lin et al. 07, in prep

Pair Fraction vs Redshift

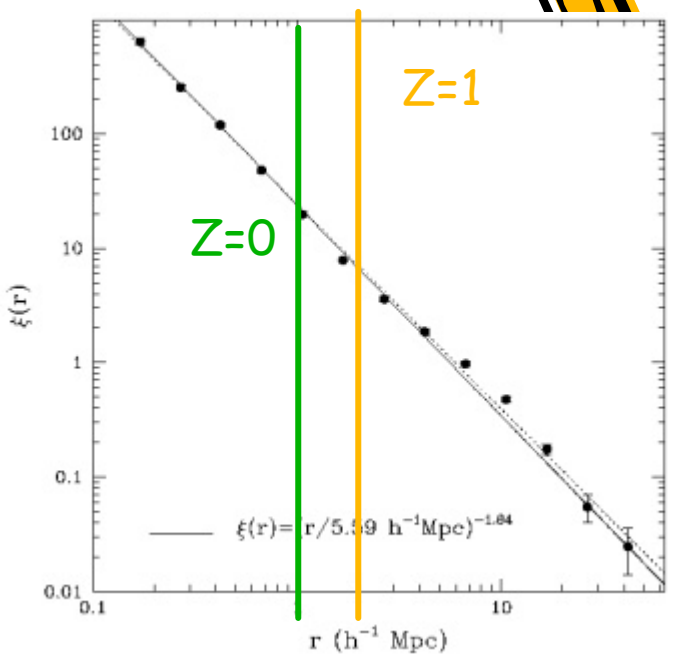
- The mixed pairs have -0.5<m<-1.57



Lin et al. 07, in prep.

Nc vs 2-point correlation function

$$?(r) = (\frac{r}{r_0})^{-?}$$



$$\text{r : comoving length } r = \frac{x}{a} = x(1+z)$$

$$\text{pair fraction} \sim n(z)\int_0^{R/a} ?(r)4\pi r^2 dr$$

$$= 4\pi n(z)\frac{r_0^{\gamma}}{3-\gamma}(\frac{R}{a})^{3-?} = 4\pi n(z)\frac{r_0^{\gamma}}{3-\gamma}R^{3-\gamma}(1+z)^{3-?}$$

For non-evolving galaxy number density, if clustering is fixed in comoving space and **?** = 1.8 => $\sim(1+z)^{1.2}$

Comoving Merger Rate

Definition:
(number of mergers per comoving volume per time period)

fraction of pair to become actual merger

comoving number density of galaxies

Pair fraction = # of companion/galaxy

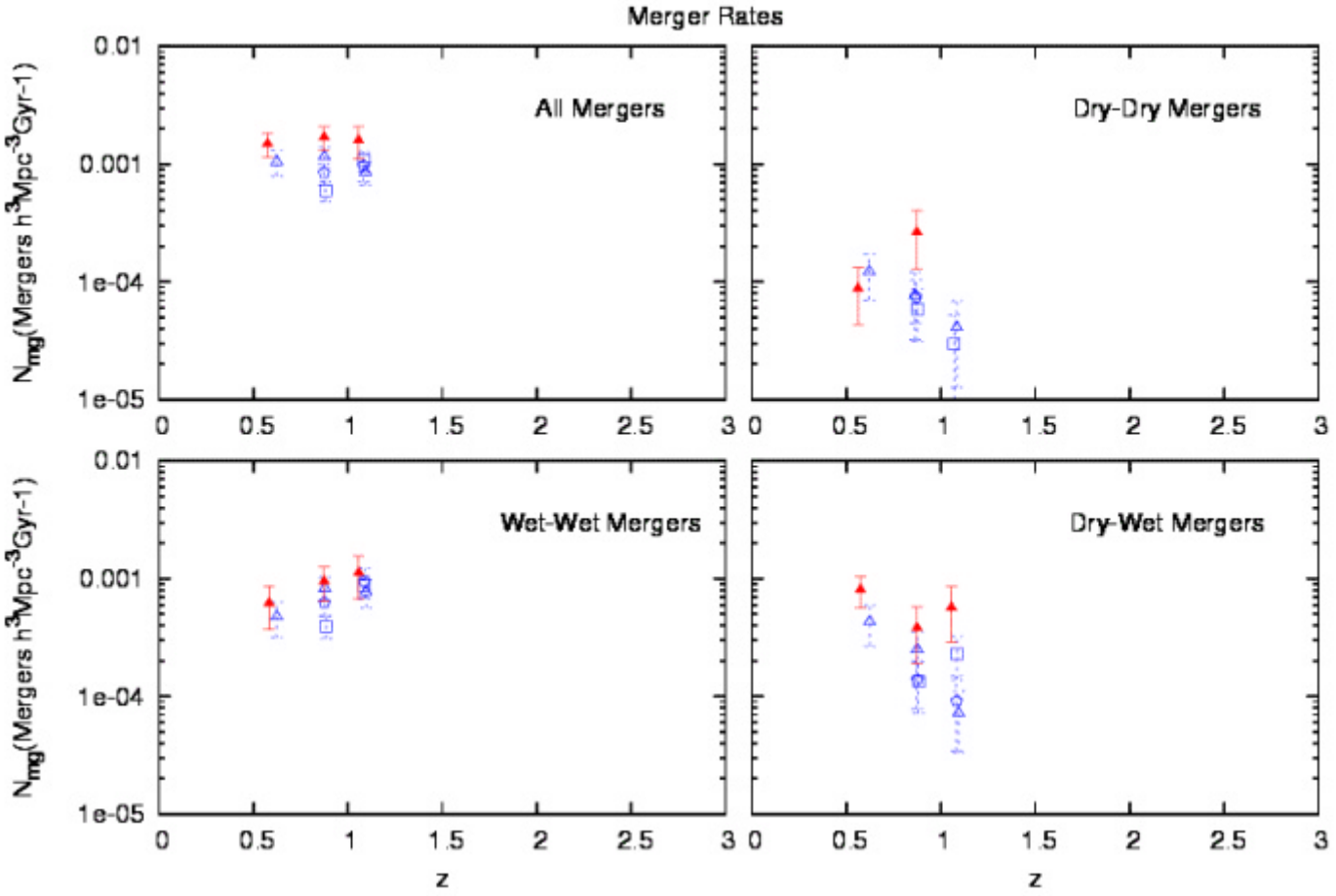
$$N_{mg}(z) = \frac{f_m n(z) N_c(z) * (0.5 + G)}{T_{mg}}$$

the time scale of being close pair

Assuming $f_m = 0.5$
$T_{mg} = 0.5$ Gy

Comoving Merger Rates

- Blue mergers : Red mergers: Blue-Red mergers
  ~ 6 : 1 : 2 at z~0.8



Lin et al. 07, in prep.

Summary

- The frequency of galaxy interactions depends on galaxy properties (luminosity/mass) at a given redshift, therefore it is crucial to specify clearly the sample selection when discussing the evolution of galaxy merger rates with redshifts.

- For galaxies brighter than 0.4L*, we find a mild increase of pair fraction as a function of redshift for all types of galaxies from DEEP2 Redshift Survey (+ CNOC2 + MGC Samples); The pair fraction from blue-blue pairs (wet mergers) has steeper slope while the the pair fraction from red-red pairs (dry mergers) has negative or constant evolution depending on how the correction of incompleteness is applied. Blue-red (wet-dry) pairs also give negative evolution:
  - m~ 0.4 for all types of pairs
  - m~ 1.4 for blue-blue pairs
  - M<=0 for red-red pairs
  - m< 0 for blue-red pairs

- The redshift evolution of pair fraction can be understood in the context of the evolution of two-point correlation function, although more carefully comparisons are required.

- The ratio of galaxy merger rates (# of merger events per unit comoving volume per unit time) for wet-wet, dry-dry, and wet-dry mergers ~ 6 : 1 : 2 at z~0.8 if assuming same merger time scale. But the relative fractions of dry mergers and wet-dry mergers become higher at low redshifts. Suggestions of more careful modeling of merger time scale are welcome!

Thank You