Marked cross-correlation functions and merger trees: update
Geraint Harker
Marked correlation function: reminder!

- \( \xi(r) = \sum \frac{m_i m_j}{n(r)\bar{m}^2} \) for \( \{i,j|r_{ij}=r\} \)
- Assign a mark \( m_i \) to each halo (formation redshift here) and evaluate the above formula.
- \( \xi=1 \) indicates no environmental dependence.
Marked correlation function: disadvantages

- The halo environment as measured by the marked correlation function is only defined by haloes of the same mass as those being measured.
- Averaging over a large mass range to give a less noisy signal introduces problems:
  - Signal tends to be dominated by the more numerous, lower mass haloes in the range.
  - Signal from higher mass haloes only cuts in above some scale determined by halo exclusion.
  - Resulting marked correlation function is hard to interpret.
Marked cross-correlation function: definition

- Find the environmental dependence of the mark for some ‘marked’ population.
- Measure environment using some ‘tracer’ population.
- \( \xi \neq 1 \) still indicates environmental dependence.
- Marked cross-correlation function of a population with itself is not the marked autocorrelation function.
- Interchanging marked and tracer populations changes the marked cross-correlation function.

\[
\xi(r) = \sum_{\{i,j|r_{ij}=r\}} \frac{m_j}{n(r)\bar{m}} 
\]

\( i \) from tracer population
\( j \) from marked population
Marked cross-correlation function: results

- Choose a sufficiently abundant tracer population: \( \sim 6 \times 10^{13} h^{-1} M_{\text{sun}} \) here.
- Clearly >1 for low mass marked haloes; less significant signal for high mass haloes.
- Possible sign change for high mass marked population.
Tracer population less massive than marked population
Effect of changing merger trees

• Throwing away any subhaloes the centre of which are outside twice the half-mass radius of the parent halo, or which have retained more than 75% of the mass they had at the last time they were independent haloes.
Effect of changing merger trees

- Treating as separate haloes any subhaloes the centre of which are outside twice the half-mass radius of the parent halo, or which have retained more than 75% of the mass they had at the last time they were independent haloes.
Effect of changing merger trees

- Dashed line: oldest 10%.
- Dotted line: youngest 10%.
- Haloes with 100-200 particles
- Sign of age dependence changes in most extreme case.
Effect of changing merger trees

Munich trees

$500 \leq N_p \leq 2000$

$Z_{\text{form}}$

$\log_{10}(1 + \delta(2-5 \\text{h}^{-1} \text{Mpc}))$

FOF trees

$500 \leq N_p \leq 2000$

$Z_{\text{form}}$

$\log_{10}(1 + \delta(2-5 \\text{h}^{-1} \text{Mpc}))$
Not a problem case

Several possible ways to treat this situation, affecting the final halo catalogue and the merger trees: a choice, not a problem!
Problem cases: de-mergers
Conclusions

• For haloes with a wide range in mass, the Millennium Simulation enables us to determine well:
  – The marked correlation function;
  – The marked cross-correlation function (easier to interpret, and gives us additional information on good choices for tracers of environment);
  – Halo formation redshift as a function of local overdensity in dark matter.

All of these give secure detections of an environmental dependence of halo formation.

• The details of these statistics depend on choices made in merger tree construction. Whatever these choices, care must be taken that de-mergers, which become more important for environmentally weighted statistics are properly accounted for. FOF haloes do especially badly!