The physical nature of submm source multiplicity

The first three rows show mock observed-frame 850-µm continuum images (assuming $z = 2$) of the merger from H11 near apocentre (first row; time $t = 0.28$ Gyr; nuclear separation $d_{BH} = 71 h^{-1}$ kpc; quiescently star forming), during the final approach (second row; $t = 0.63$ Gyr; $d_{BH} = 13 h^{-1}$ kpc; quiescently star forming) and at the peak of the starburst (third row; $t = 0.7$ Gyr; $d_{BH} = 0.1 h^{-1}$ kpc; starburst). The fourth row shows the isolated disc at $t = 0.28$ Gyr (quiescently star forming). The simulated images have been convolved with a Gaussian filter in order to mimic the intrinsic simulation resolution (first column; FWHM = $0.2 h^{-1}$ kpc) and the resolution achievable with various telescopes/interferometers. The second column has FWHM = 0.5 arcsec ($3 h^{-1}$ kpc at $z = 2$), the resolution roughly characteristic of (sub)mm interferometers such as the SMA, the IRAM Plateau de Bure Interferometer and ALMA. (Note that we have not made any attempt to model the interferometric process.) See Fig. 2 for zoom-ins of the boxed regions. Third column: FWHM = 7 arcsec ($42 h^{-1}$ kpc), representative of the resolution available with, for example, Herschel PACS and the current configuration of the LMT. Fourth column: FWHM = 15 arcsec ($89 h^{-1}$ kpc), representative of, for example, Herschel SPIRE and the JCMT. The fields of view are 23.5 arcsec ($140 h^{-1}$ kpc) for the first three columns and 59 arcsec ($351 h^{-1}$ kpc) for the last. For all but the first column, Gaussian noise with realistic amplitude has been added. The same noise map is used for all images in a given column. When present, scale bars show the beam FWHM, and contours correspond to 3σ, 4σ, 5σ, 10σ and 20σ. The first column has logarithmic scaling; all others are linear. Units are arbitrary.

To constrain the relative contributions of starbursts and quiescently star-forming galaxies to the SMG population, thereby testing the bimodality we claim exists.

The rest of the paper is organized as follows. We describe our simulation methodology in Section 2. Section 3 presents multiple observational diagnostics that can be used to distinguish between quiescently star-forming galaxies and starbursts from integrated data alone, including the luminosity–effective dust temperature relation (Section 3.1), SFE (Section 3.2), IR excess (IRX; Section 3.3) and the SFR–$M_\star$ relation (Section 3.4). In Section 4 we discuss...
Possibility of blended sources noted from the start

“at least some of the apparent sources in the map could consist of emission from more than one object… confusion is only a serious problem when there is a blend of one or more sources of similar flux”

Hughes+98, Nature
Mergers result in blended sources

$2.3S_{1.1} \approx S_{850} \text{ (mJy)}$

CCH, Narayanan+13; also CCH+11, 12
Chance projections also possible

Wang+11

z=3.46

z=3.157

z=2.914

z=3.11

z=2.095
Pre-2013, chance projections not treated by any models
Model details

- Start with Bolshoi N-body sim
- Generate lightcones
- Assign properties such as $M_{\text{star}}$ and SFR via abundance matching and other empirically calibrated relations
- Compute submm flux using scaling relations based on results of performing dust RT on hydro sims
- Blend mock SMGs
- See CCH, Behroozi+13 for details; also Cowley+15ab for similar analysis with very different model
Real vs. projected multiples

CCH, Behroozi+13
Real vs. projected multiples
Why chance projections should be common in submm
Model predicts chance projections

CCH, Behroozi+13

associated

projections
Also predicted by subsequent models

Muñoz Arancibia+14

Cowley+15
But what about the real Universe?
“You’re at Caltech. You should put in a Keck proposal.”
— Nick Scoville
“If you see an observational paper with a theorist as lead author be very afraid.”
— Ian’s Fifth Rule of Observational Cosmology
Examples: association (but not merger)

CCH, Chapman, Steidel+, in prep
Examples: projection

CCH, Chapman, Steidel+, in prep
Examples: ambiguous (but likely projection)

$z = 1.6324$

$\text{SFR}_{850} \sim 500 \text{ M}_\odot/\text{yr}$

$\text{SFR}_{H\alpha} = (5.6+/-0.2) \text{ M}_\odot/\text{yr}$

$z_{\text{phot}} = 0.90+/-0.05$

$\text{SFR}_{H\alpha} < 0.5 \text{ M}_\odot/\text{yr} \ (3\sigma)$

CCH, Chapman, Steidel+, in prep
How common are chance projections?

Majority of our submm sources contain at least one unassociated SMG; more consistent with CCH, Behroozi+13 than Cowley+15 (but small sample)
Multiple very different theoretical models predict chance projections should be common

Reasons: (1) large beam, (2) negative K-correction, & (3) mergers only weakly submm boost flux

Spectroscopic followup of resolved submm sources indicates that majority are comprised of at least one unassociated SMG, in qualitative agreement with model predictions

Open question: our sample is small and likely biased; what chance projection fraction will larger, unbiased studies find? How does it depend on e.g. single-dish submm flux?