Fewer small clumps in radiation pressure simulations

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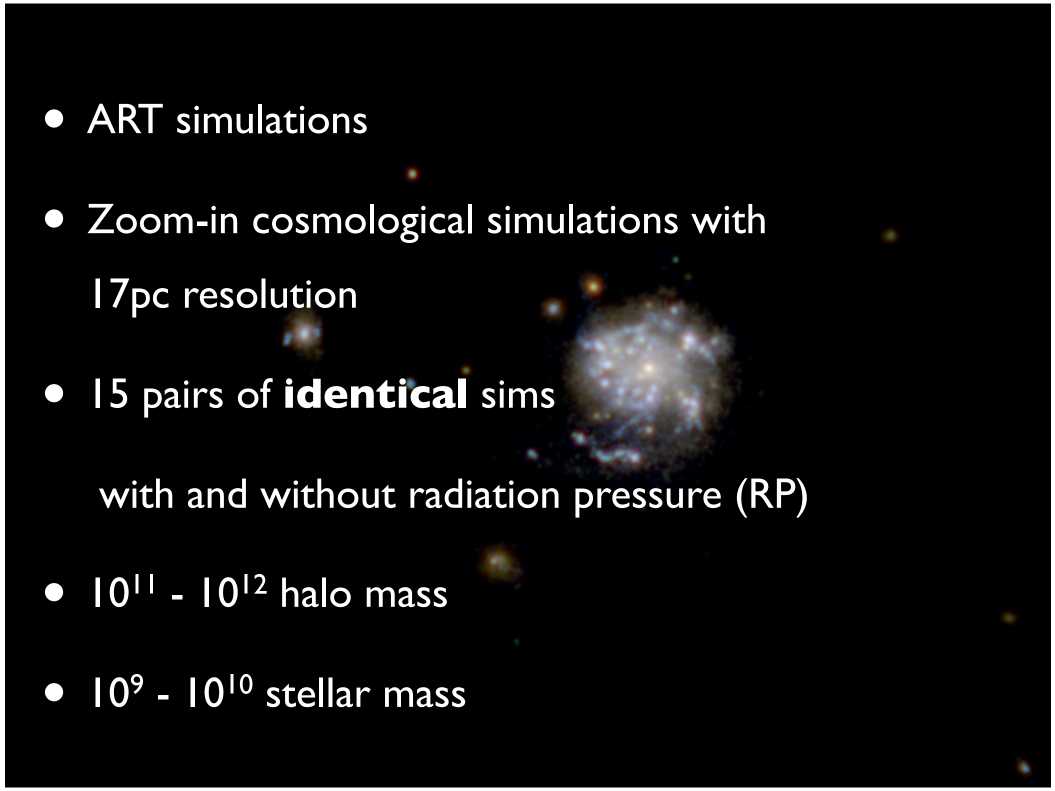


Starting point is a series of simulations that Daniel Ceverino has created using ART Code

Not isolated

Zoom-in, which is demonstrated in the gas density animation. Zoom-in means we don’t resolve the full 40Mpc box, but just turn on physics in the inner 1-2Mpc

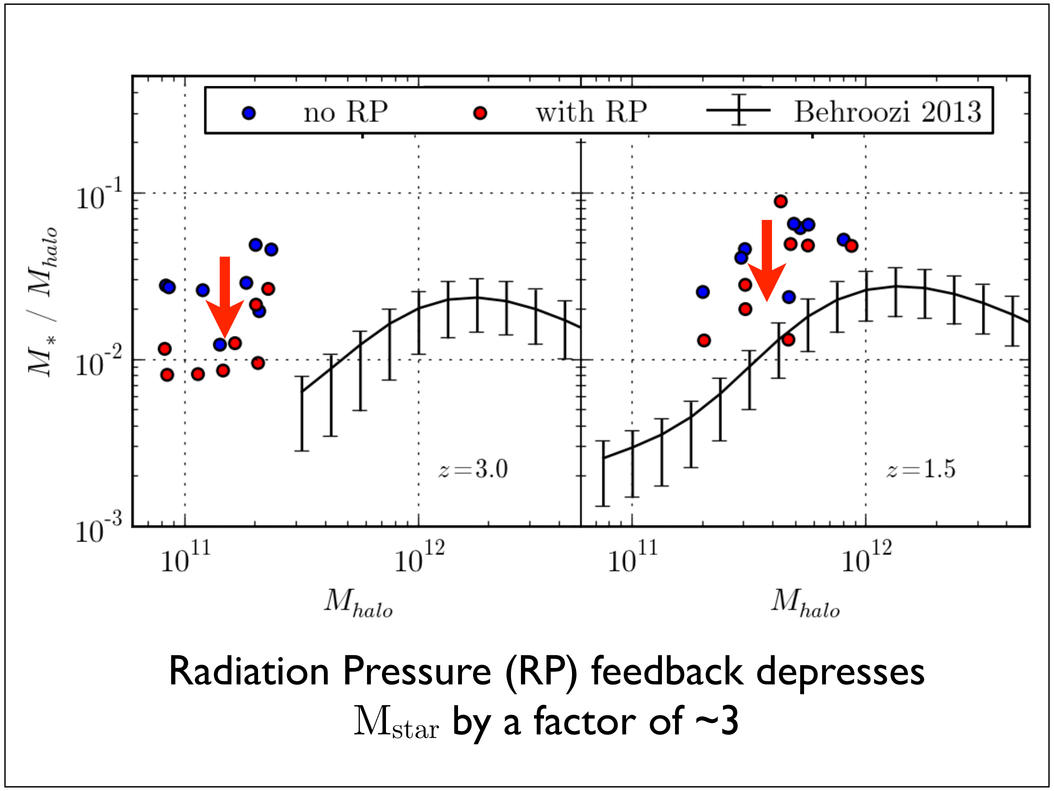
17pc resolution

15 pairs of simulations
tau ~ 1

1e11-1e12 halo masses

Most carried down to z=1

Point is: state of the art simulations, with realistic physics.



Why do we care about RP? Historically, simulations...

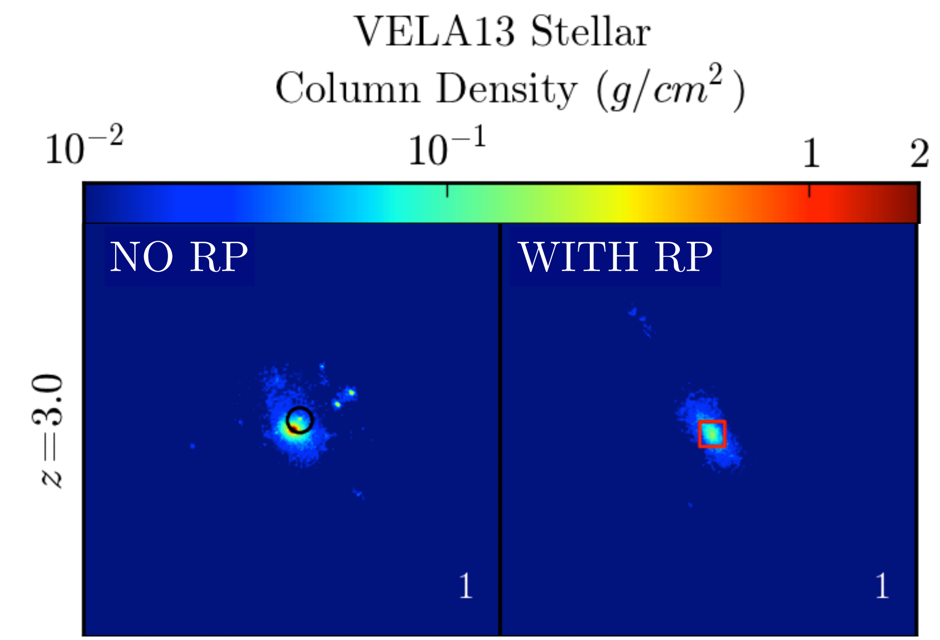
The stellar mass to halo mass ratio as a function of halo mass is plotted of RP and no-RP simulations at redshifts of z = 3, and z = 1.5.

For comparison, the Behroozi data and limits are shown. RP simulations depress the stellar mass by a factor of ~ 2 – 3 at all redshifts.

At high redshifts the simulations are offset from the modeled relations, but become less discrepant at z = 1.5

M* reduced by ~3.

Naive interpretation: need more feedback?



Radiation Pressure sims lack small clumps!

So what's happening visually - morphologically and qualitatively?

The projected stellar mass densities of two pairs of RP and no-RP simulations are plotted above at a series of redshifts between $z=1.3$ and z=3.0.

In the first and second columns the no-RP and RP versions of an example simulation are plotted. 20kpc on a side.

We find stellar clumps in the 2D projected image using a method similar to contour finding.

Also do halo finding with Rockstar HF, throw out 'clumps' if they are really minor mergers

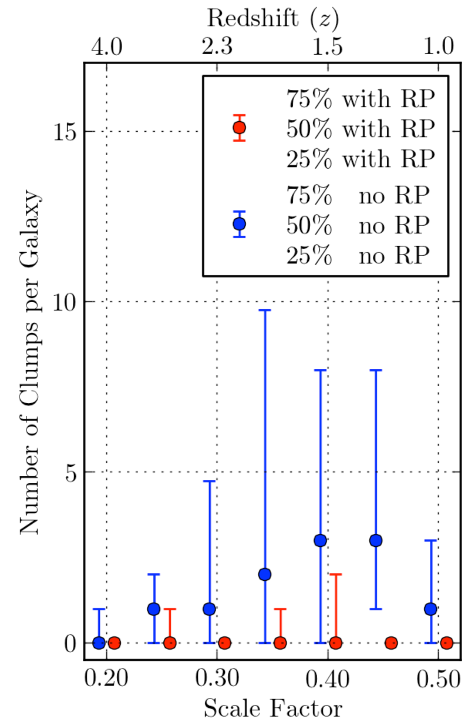
Detected clumps (black circles) and minor mergers are marked (red squares) and the total number of clumps is inlaid (bottom right white text).

Can't tell if they are prevented or disrupted!

Peak in clump # at z~1.5

Median # of clumps at peak is ~3

For RP simulations, at any given redshift, 50% of snapshots have zero clumps.



That's the qualitative picture - let me quantify this in some way.

Explain plot.

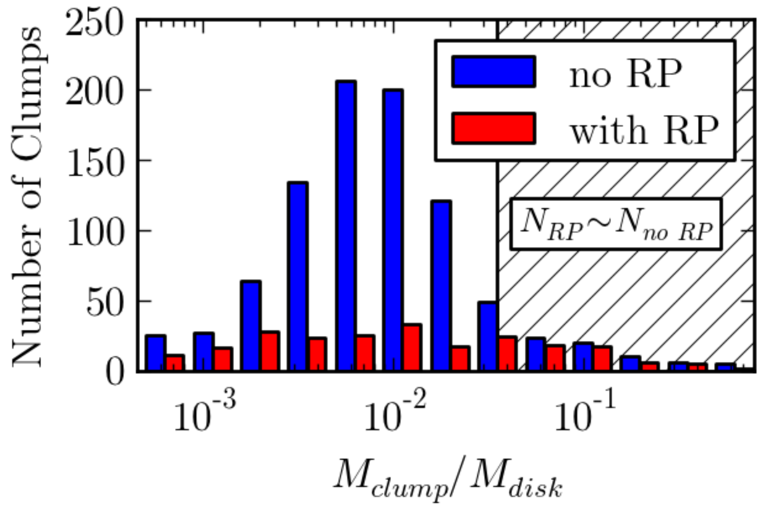
The number of clumps per galaxy is computed for each bin in scale factor, for both RP and no-RP simulations.

Time goes from z=4 to z=1, left to right.

The median, 25th and 75th percentiles are shown. Not indicative of the uncertainty so much as the spread in the measured number of clumps.

For no-RP simulations, few clumps form at redshifts above z>4.0, but the number of clumps found in any single snapshot peaks at z=1.5 and steadily declines afterwards.

For RP simulations, more than 50% of snapshots contain zero clumps, and therefore median number of clumps is always at zero.



Most clumps are gone with RP, but
large clumps (M_{clump}/M_{disk} > 8%) are preserved

But the story gets more interesting. Let's seperate big clumps from small clumps.

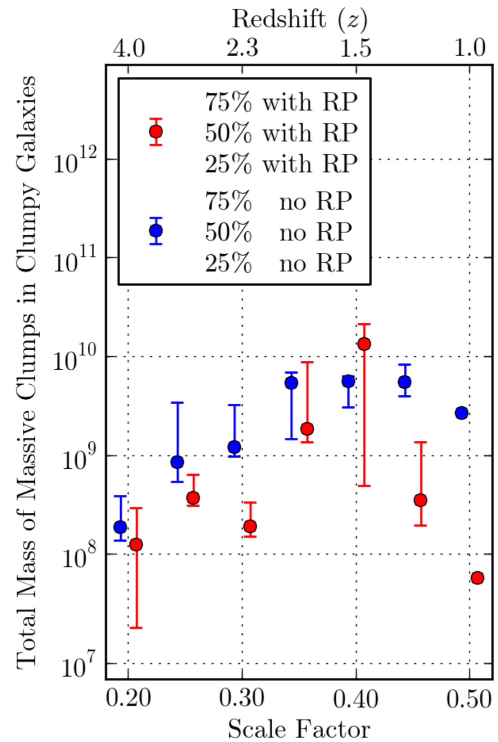
Explain plot.

Dramatic difference in the number of clumps between RP and no-RP for low-mass clumps!

But massive clumps are preserved!

Halo mass is typically 5e11, baryon mass is 1-3% of that, 1e10. Giant clumps are ~1e9 .

Selecting galaxies with at least one big clump gives similar trends between RP and no-RP, although total clump mass is slightly depressed with RP.

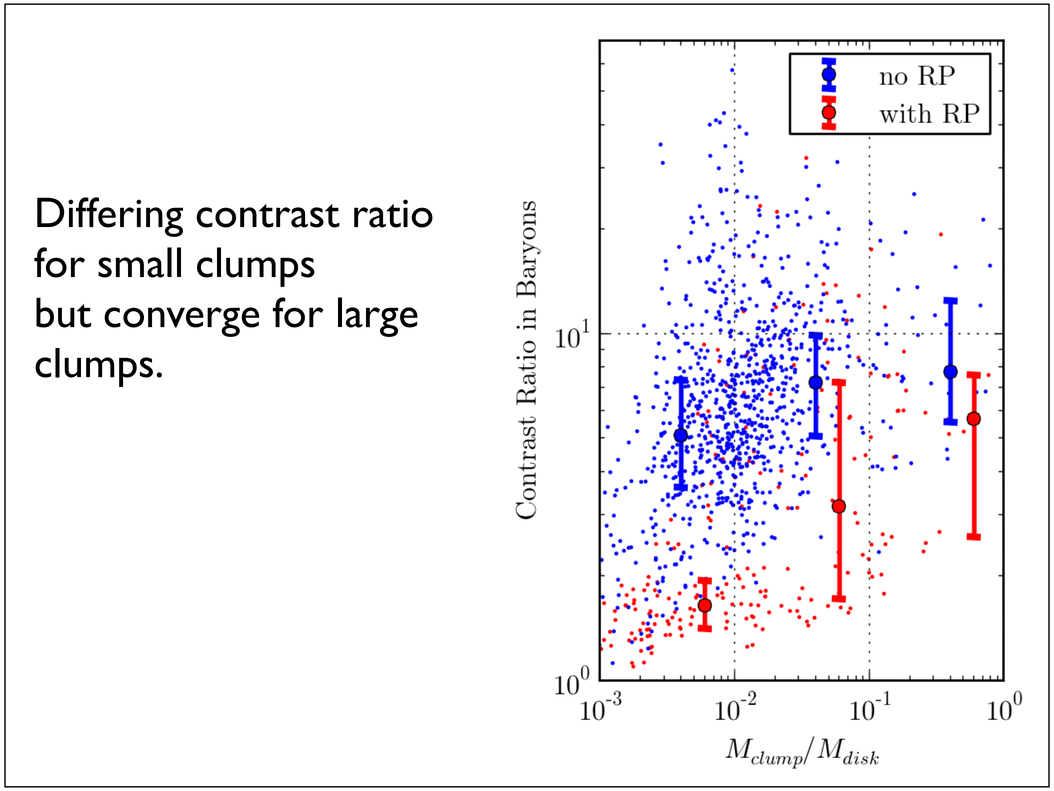


Let's look at the growth of the total mass of clumps in a galaxy.

Specifically select for clumpy galaxies by picking galaxies hosting at least one giant clump.

That means we throw out the majority of snapshots, and so by construction the median mass is no longer zero.

The trends are roughly similar between RP and no-RP, still peaking in total clump mass up to z~1.5 and declining afterwards. Similar to # of clumps.



Let’s look at the homogeneity of the clumps by measuring the contrast ratio.

Explain plot.

The clump finder is just contour finding.

From those contours get a region, and the pixels that are enclosed inside that region.

Contrast ratio of peak vs disk density, which we’re calling 95% most dense pixel / 5% most dense pixel in that region

With

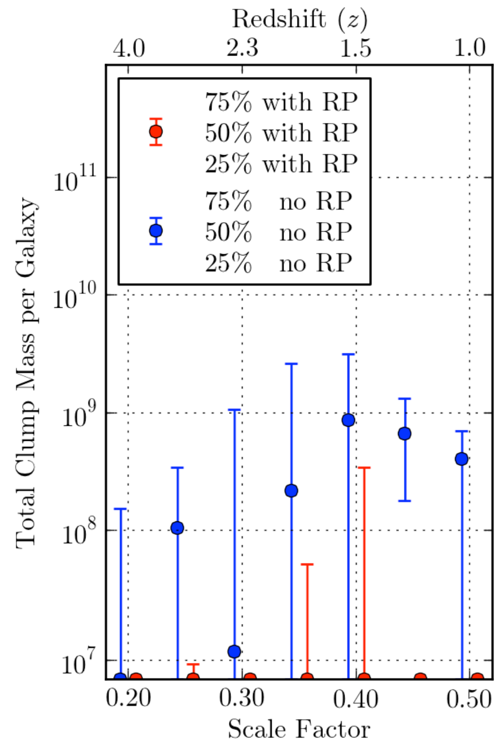
1. Radiation pressure is reducing $\mathrm{M}_{\mathrm{star}}$ by factor of ~3

2. RP removes small clumps with ($\mathrm{M}_{\mathrm{clump}}/\ \mathrm{M}_{\mathrm{disk}}$ < 8%)
   Can't tell if they never form, or are disrupted more quickly.

3. Trends clump #, mass, and contrast are similar in RP and no-RP cases *only* for massive clumps.

4. Future: test observability of these clumps via *Sunrise*.

Total clump mass also peaks at z~1.5



The total clump mass per galaxy is computed for each bin in scale factor, for both RP and no-RP simulations.

The median, 25th and 75th percentiles are shown.

The clump mass is defined as the sum of all of the clumps at any given time.

For no-RP simulations the clump mass peaks at z=1.5, and declines at lower redshifts.

Because the median number of clumps in RP simulations is zero, the median clump mass is also zero.

Because of the log-scale axis, these zero-mass points are drawn at the bottom of the axis.