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Dark matter cores in massive high-z galaxies formed by baryonic clumps

Go Ogiya[1,2,3]★ and Daisuke Nagai[4]
[1]*Waterloo Centre for Astrophysics, University of Waterloo, Waterloo, ON N2L 3G1, Canada*
[2]*Department of Physics and Astronomy, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada*
[3]*Institute for Astronomy, School of Physics, Zhejiang University, Hangzhou 310027, China*
[4]*Department of Physics, Yale University, New Haven, CT 06520, U.S.A.*

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ABSTRACT
The rotation curves of some star forming massive galaxies at redshift two decline over the radial range of a few times the effective radius, indicating a significant deficit of dark matter (DM) mass in the galaxy centre. The DM mass deficit is interpreted as the existence of a DM density core rather than the cuspy structure predicted by the standard cosmological model. A recent study proposed that a galaxy merger, in which the smaller satellite galaxy is significantly compacted by dissipative contraction of the galactic gas, can heat the centre of the host galaxy and help make a large DM core. By using an N-body simulation, we find that a large amount of DM mass is imported to the centre by the merging satellite, making this scenario an unlikely solution for the DM mass deficit. In this work, we consider giant baryonic clumps in high redshift galaxies as alternative heating source for creating the baryon dominated galaxies with a DM core. Due to dynamical friction, the orbit of clumps decays in a few Gyr and the baryons condensate at the galactic centre. As a back-reaction, the halo centre is heated up and the density cusp is flattened out. The combination of the baryon condensation and core formation makes the galaxy baryon dominated in the central 2-5 kpc, comparable to the effective radius of the observed galaxies. Thus, the dynamical heating by giant baryonic clumps is a viable mechanism for explaining the observed dearth of DM in high redshift galaxies.

Моделируется динамическое трение – чистое N-body

- Хозяйская галактика – только темная материя, NFW(ini)
- Спутник – темная материя и звезды, более концентрированный, чем host
- Сгусток – только звезды, менее концентрированный, ρ ~ 1/r

In all simulations, the virial mass of the host system is $M_{200,\mathrm{host}} = 3 \times 10^{12} M_{\odot}$ which yields $r_{200,\mathrm{host}} = 146$ kpc at $z = 2$ and its concentration is $c_{\mathrm{host}} = 5$. Note that smooth baryonic components, such as the central bulge and stellar and gas disks, of the host system are approximated as part of the NFW halo. The setup is the same as those employed in Dekel et al. (2021). In this study, we employ the approximated model for simplicity and leave the inclusion of the baryonic components for future studies. The host system is modelled with 67,108,864 particles, and each particle has a mass of $m_{\mathrm{p}} \approx 4.5 \times 10^{4} M_{\odot}$. Employing the large number of particles, we have the

Поглощение спутника

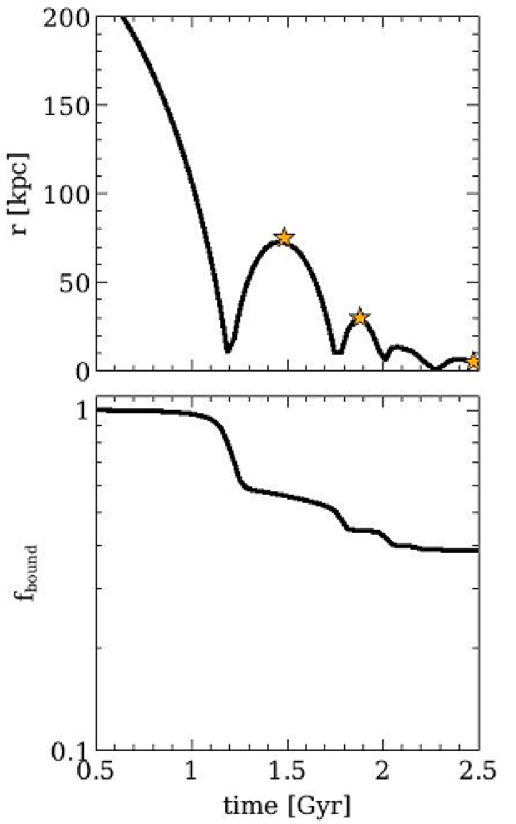

Figure 1. *Upper panel:* Distance between the centres of the two systems. Stars indicate the snapshots shown in Fig. 2. The satellite orbit decays in a few orbits due to dynamical friction. *Lower panel:* Bound mass evolution of the satellite. The tidal mass loss is almost halted after the third percentric passage ($t \gtrsim 2$ Gyr) and ~ 40 percent of the initial mass is still retained in the satellite, because the compacted satellite is resilient to the tidal force.

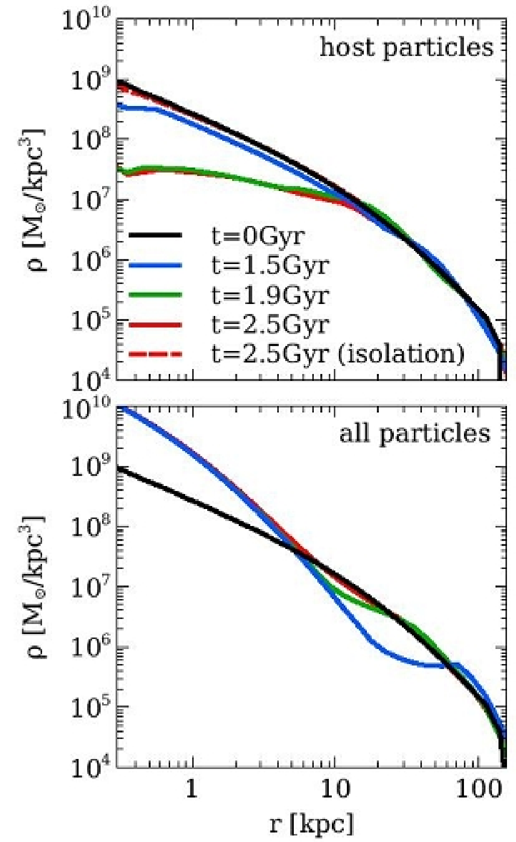

Figure 2. Density profiles obtained from the merger simulation. In the analysis of the upper (lower) panel, particles initially belonging to the host (all particles) are included. Lines with different colours present the different phases of the dynamical evolution, as presented in the legend. To test the stability of the N-body system, the density profile after evolution of 2.5 Gyr in isolation is shown in the upper panel (dashed red). The central density of the host is reduced by the energy and angular momentum transfer from the merging satellite and the central cusp gets shallower (*upper panel*). However, the total central density is in fact increased and the slope of the total density profile gets steeper at $r \lesssim 10$ kpc through the merger because the satellite

Аккреция сгустков

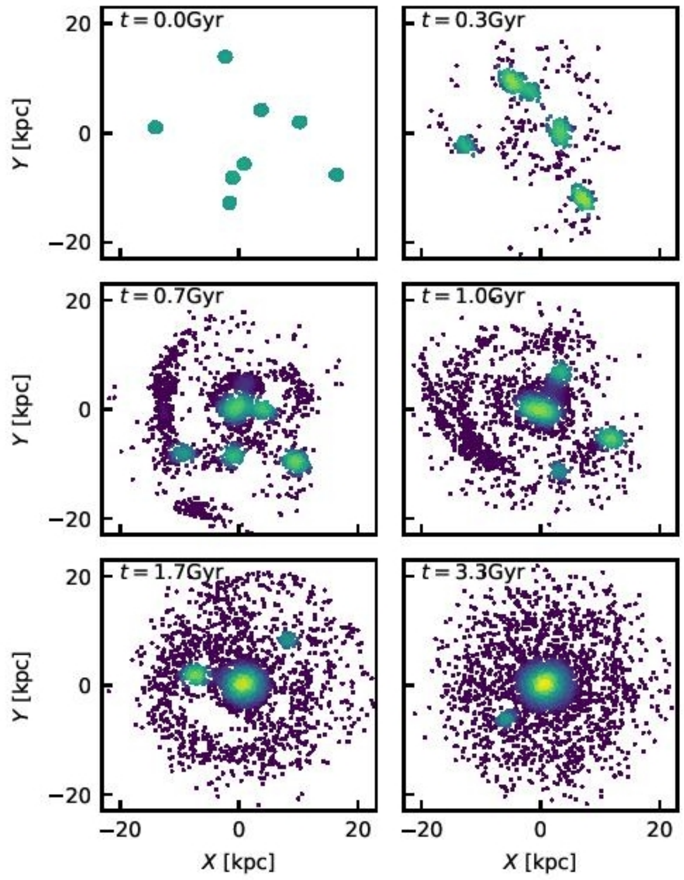

Figure 3. Distribution of clump particles obtained from the run-A. The time of snapshots is shown at the top left corner of each panel. Brighter (Darker) points indicate higher (lower) densities. Clumps are deformed by the tidal force of the host halo and interactions between clumps and sink to the centre

Помогает создать изотермическую сердцевину!

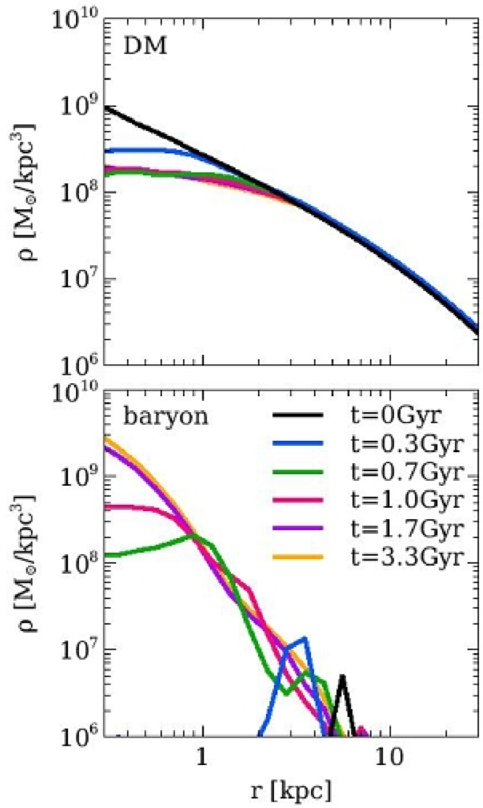

Figure 4. Density profiles obtained from the run-A. In the analysis of the upper and lower panels, particles initially belonging to the host halo and clump particles are included, respectively. The corresponding time of each snapshot is indicated in the legend. The DM central density is reduced and a core is formed at the centre in ~ 1 Gyr (*upper panel*), as a result of the dynamical heating by giant baryonic clumps. As a back-reaction, clumps sink to the centre and form a bulge-like structure (*lower panel*, see also Fig. 3).

Только размеры ее маловаты – нужно больше сгустков (модель H)

Table 1. Summary of the simulation parameters. Column (1) Simulation ID. (2) Total clump mass. (3) Mass of individual clumps. (4) Clump size. (5) Disk scale length.

(1) ID	(2) $M_{\rm cl,tot}$ [10^9 $M_\odot$]	(3) $M_{\rm cl}$ [10^9 $M_\odot$]	(4) $r_{\rm cl}$ [kpc]	(5) $R_{\rm d}$ [kpc]
A	12	1.5	1	10
B	12	0.092	1	10
C	12	5.9	1	10
D	12	1.5	0.25	10
E	47	1.5	1	10
F	12	1.5	1	5
G	12	1.5	1	20
H	47	5.9	1	20

Все как Генцель прописал…

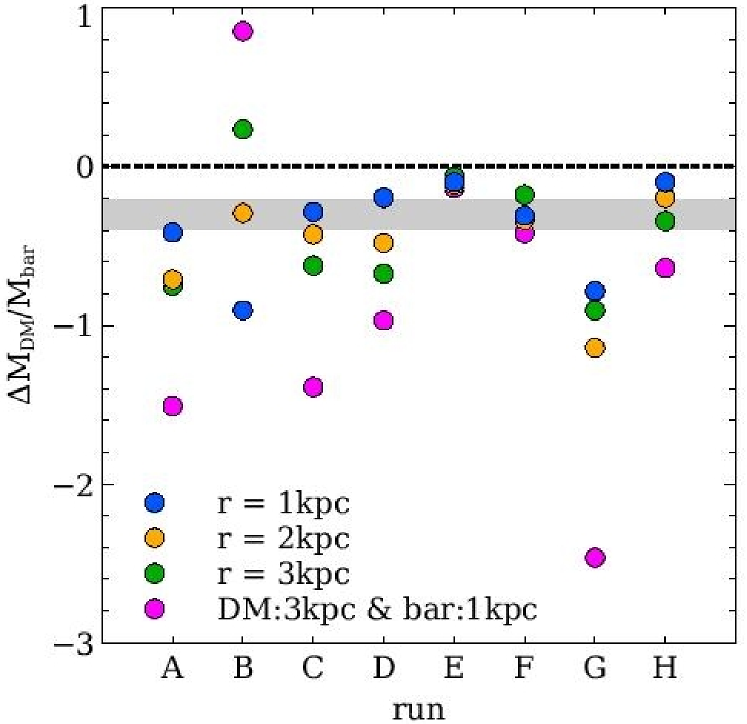

Figure 6. DM mass removal efficiency, $\Delta M_{\rm DM}(r)/M_{\rm bar}(r)$, measured at r = 1 (blue), 2 (orange) and 3 kpc (green), in each clump simulation. In the analysis of magenta circles, $\Delta M_{\rm DM}$ is measured at r = 3 kpc, while $M_{\rm bar}$ is measured at r = 1 kpc. Shaded band indicates the ratio of the difference between the observationally inferred and theoretically expected DM masses to the bulge mass of high-z star forming galaxies, obtained by Genzel et al. (2020). Horizontal dotted black line marks the DM mass removal efficiency of zero for reference. Most of points are below the horizontal dotted black line, indicating that the dynamical heating of giant clumps reduces the central DM mass, while the efficiency depends on the clump properties and the radius to measure it.

Правда, только в центре, а надо до 10 кпк от центра

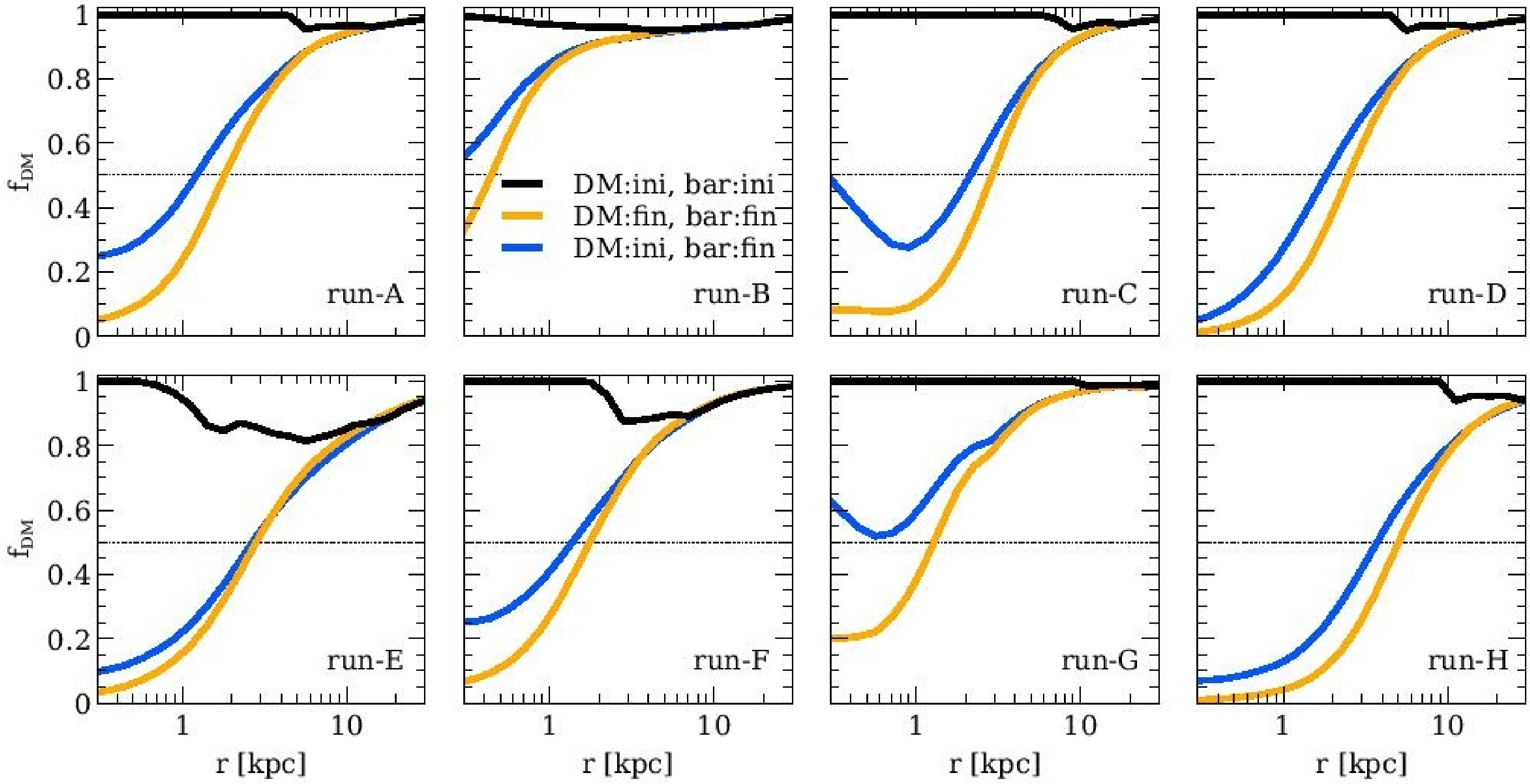

Figure 7. DM mass fraction as a function of r, $f_{DM}(r)$. In each panel, three combinations of the initial and final enclosed mass profiles are shown as indicated: black and orange lines depict the initial and final states, respectively. To disentangle the impact of the DM core formation from that of the baryon condensation, blue line adopts the initial DM profile having a central cusp. Horizontal black dotted line marks $f_{DM} = 0.5$ for reference. The baryon condensation reduces the central DM mass fraction (blue). The DM core formation further boosts the reduction of f_{DM} (orange).

Тем не менее, вывод:

- Аккреция массивных сгустков – многообещающий выход из противоречия между LCDM симуляциями и реальными дисковыми галактиками на $z=2$