Gas accretion and Ram Pressure Stripping of Haloes in Void Walls

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ABSTRACT
We conduct hydrodynamical cosmological zoom simulations of fourteen voids to study the ability of haloes to accrete gas at different locations throughout the voids at z = 0. Measuring the relative velocity of haloes with respect to their ambient gas, we find that a tenth of the haloes are expected to be unable to accrete external gas due to its fast flow passed them (so called 'fast flow haloes'). These are typically located near void walls. We determine that these haloes have recently crossed the void wall and are still moving away from it. Their motion counter to that of ambient gas falling towards the void wall results in fast flows that make external gas accretion very challenging, and often cause partial gas loss via the resultant ram pressures. Using an analytical approach, we model the impact of such ram pressures on the gas inside haloes of different masses. A halo's external gas accretion is typically cut off, with partial stripping of halo gas. For masses below a few times 10^9 $M_\odot$, their halo gas is heavily truncated but not completely stripped. We identify numerous examples of haloes with a clear jelly-fish like gas morphology, indicating their surrounding gas is being swept away, cutting them off from further external accretion. These results highlight how, even in the relatively low densities of void walls, a fraction of galaxies can interact with large-scale flows in a manner that has consequences for their gas content and ability to accrete gas.

Key words: galaxies: haloes – galaxies: kinematics and dynamics – cosmology: large-scale structure of the Universe – galaxies: formation – galaxies: evolution

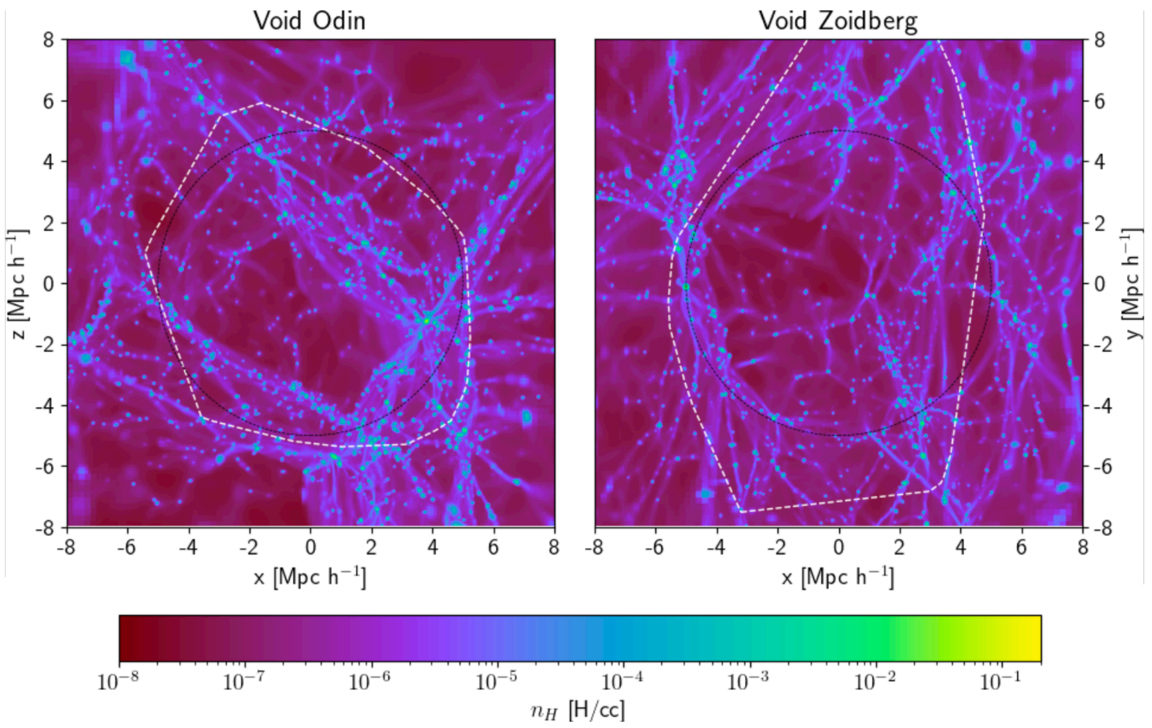

Figure 1. Two representative voids (*Odin* and *Zoidberg*, left and right panels, respectively). Both plots present the projected gas density within a cubic region of length 16 Mpc h^{-1}. The black circle represents $R_{\rm void}$ ~5 Mpc h^{-1}. The white dashed line encapsulates the dark matter particles associated with the void, as identified by VIDE, to trace out the void shape. Most haloes are located near the filaments and walls of the void, but a relatively fine network of dark matter filaments can be seen inside the void.

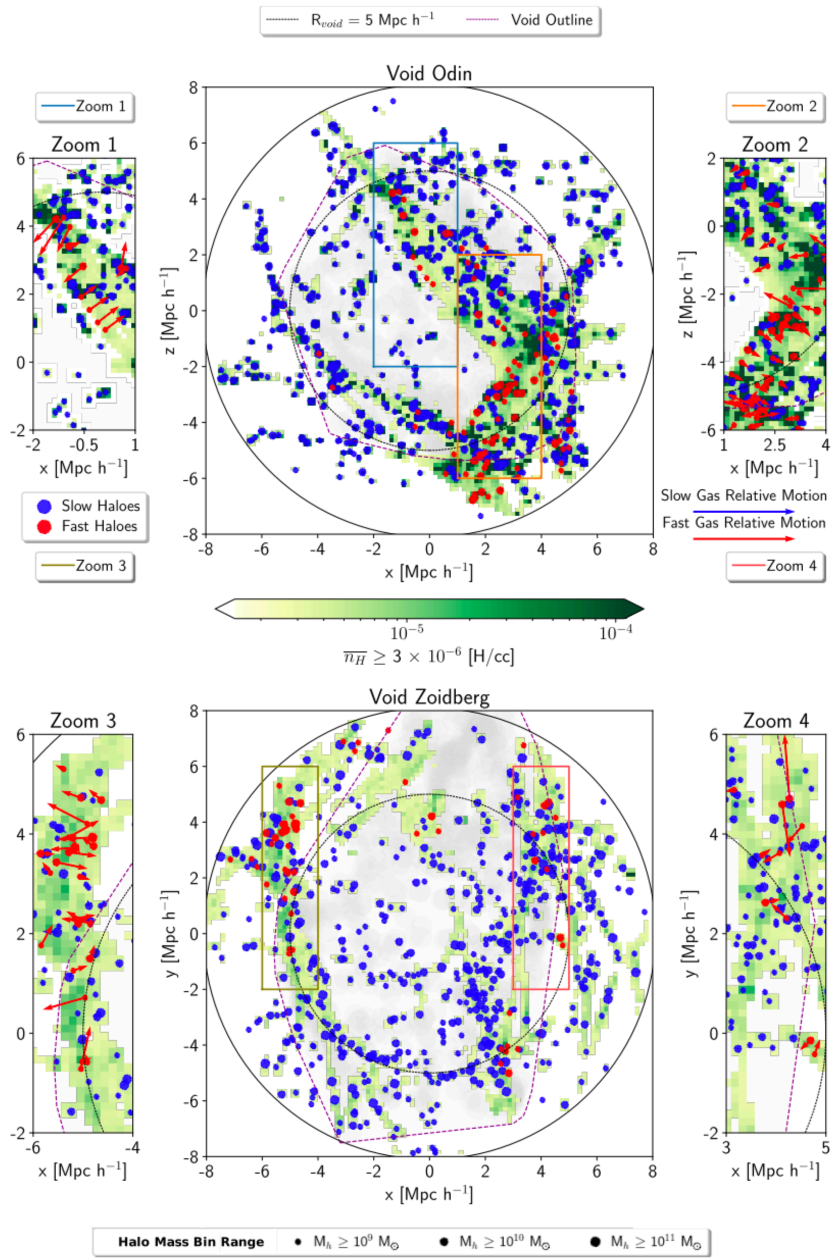

Figure 2. Plots of the two representative voids, *Odin* and *Zoidberg*. The central panels show the dark matter halo distribution with the radius of each circle scaled by the halo mass. The density of the ambient gas is indicated by the green colour-scale. The halo population is split into fast and slow flow haloes (red and blue filled circles respectively) as described by Equation (1). Fast flows are exclusively found near void walls and filaments. In the central panels, the dashed black line is a 5 Mpc h^{-1} sphere. The dashed purple line encapsulates the dark matter particles associated with the void, as identified by VIDE which traces the void shape. We show zoom-in views of four filament and wall regions on the left and right hand side of the central panel. In these zoom-in views, we include vector arrows indicating the direction of flow of the ambient gas with respect to the halo's velocity. The vector length indicates the relative flow speed. The fast flows tend to point towards the void walls, which ever side of the wall they are on.

Исследуют, где в войдах возможна аккреция, а где, наоборот, выметание газа.
Смотрят на скорости галактик относительно диффузного окружающего газа и выделяют две подвыборки – с высокими и низкими относительными скоростями.

Быстрые сидят близко к стенкам.

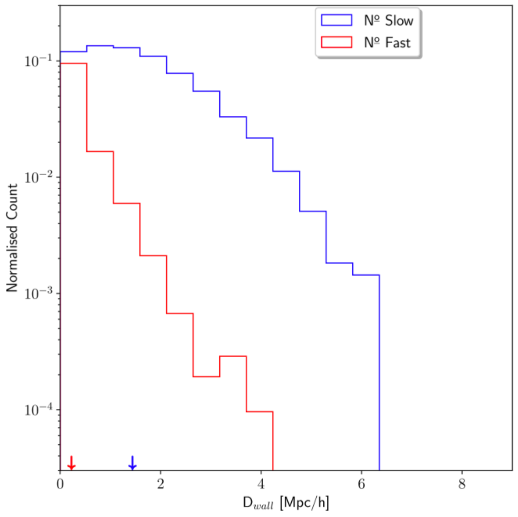

Figure 3. A 1D normalised distribution of haloes' closest distance to the void wall $D_{\rm wall}$. Normalisation is relative to the total number of haloes in the void sample. Fast flow haloes tend to be located within one or two Mpc h^{-1} of void walls where as slow flow haloes are distributed throughout the void. The median distances of fast and slow flow haloes are indicated by the arrows on the x-axis

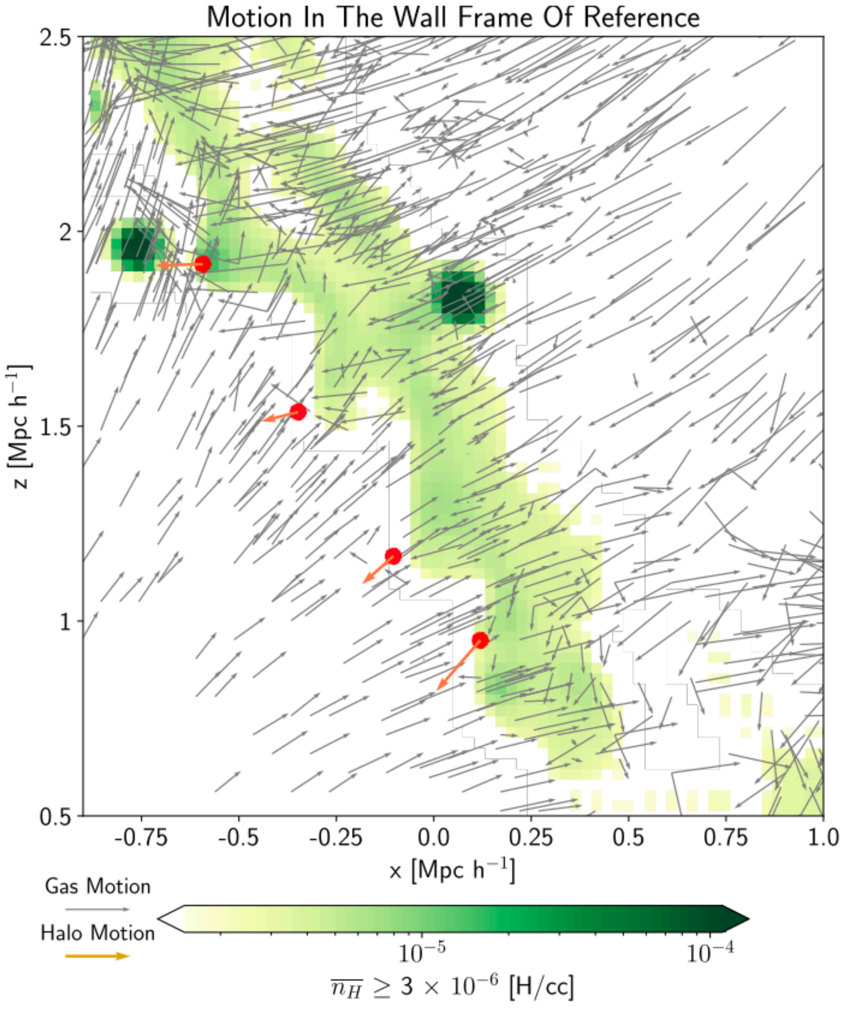

Figure 4. Four fast flow haloes (red filled symbols) are shown after having just crossed the void wall (shown in shaded green according to the gas density). Vector arrows show motion of the gas (grey vectors) and haloes (orange vectors) in the frame of reference of the void wall. In this frame of reference, gas flows towards the void wall from both sides as the voids on either side expand. Thus, haloes that approach the wall move with the gas motion, resulting in slow flow speeds. Meanwhile, haloes that recently crossed the wall encounter gas moving in the opposite direction from their motion, resulting in fast flows. The haloes and section of the void are extracted from Zoom region 1 in Figure 2.

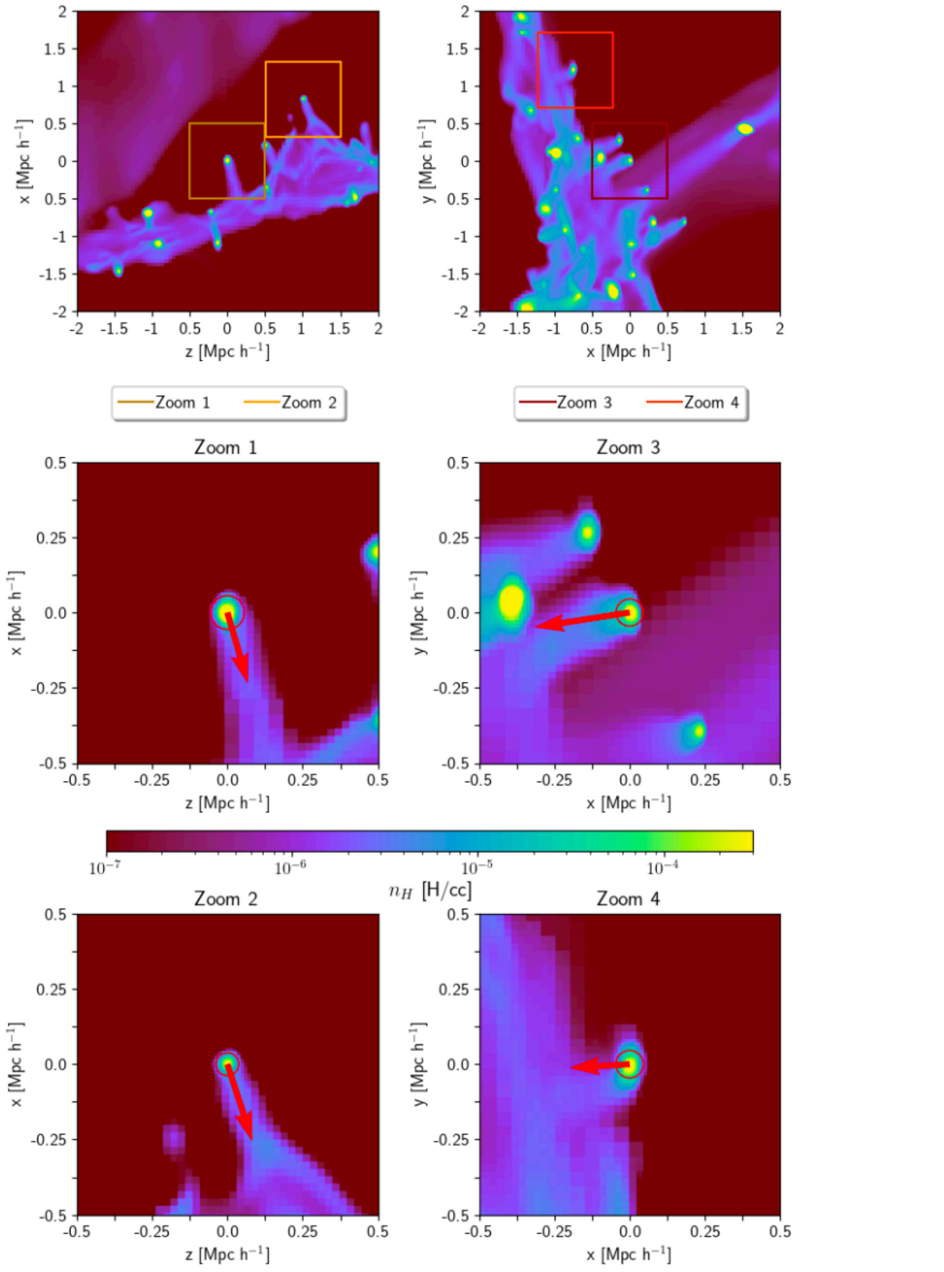

Figure 8. Four examples of the jellyfish-like morphologies (head and tail pointing in direction of flow) of fast flow haloes. The top two panels show a projected gas densityq of a small section of the outer filaments on the boundary of a void. These projections are of a cubic region with a length of 4 Mpc h^{-1}. Within these two example regions, we zoom in on four haloes. The viral radius of each halo is shown with the red circle and the vector arrows point in the direction of $V_{\rm flow}$ and the arrow length is relative to the magnitude of $V_{\rm flow}$. The jellyfish-like morphology is a well known indicator of ram pressure stripping in action. The mass of the halo highlighted in each zoom region is as follows; Zoom 1 = 4.09×10^{10} $M_\odot$, Zoom 2 = 1.26×10^{10} $M_\odot$, Zoom 3 = 2.15×10^{10} $M_\odot$ and Zoom 4 = 1.82×10^{10} $M_\odot$ and we find similar features in all of the fast flow haloes in our sample.

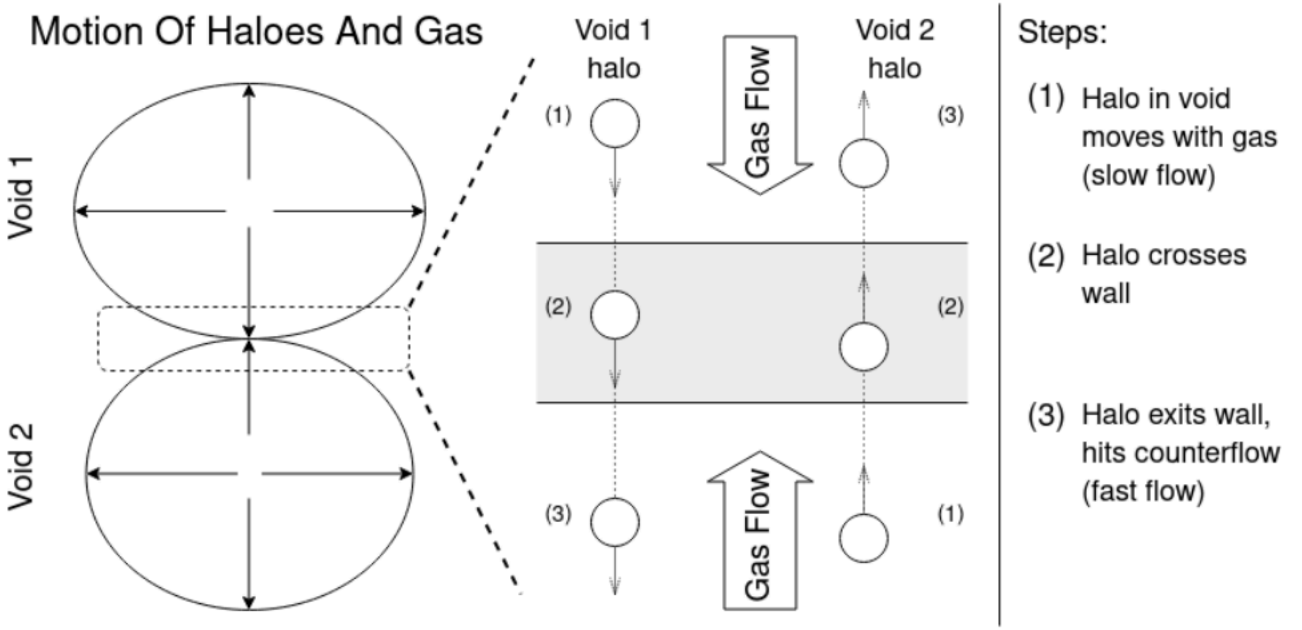

Figure 5. A schematic of our origin scenario for fast and slow flow haloes. *Left:* A zoom-out view of two neighbouring voids which expand outwards, causing a collision along one wall. *Centre:* Motion vectors are shown in the frame of reference of the void wall. Haloes moving out of their voids initially move with the gas flow from their void which results in slower relative velocities between the halo and its surrounding ambient gas. But, after crossing the void wall, the haloes continue to move away from the void wall, and encounter ambient gas flowing outwards from the other void, in the opposite direction from their motion. This results in higher relative velocities between the halo and its surrounding ambient gas, and the halo experiences a wind that blows back passed it in the direction of the wall. This origin scenario could explain why fast flow haloes are exclusively found near void walls but not embedded within them (as we will show in Section 3), and also explains why the fast flow halo's have vectors that tend to point towards the void walls.

Аккреция возможна в любом окружении в войдах (как ближе к центру, так и вблизи стенок/филаментов).
Но также возможно и выметание газа при прохождении галактик через стенки войдов или филаменты.