might imagine that for small chucking rates, where the density of solutes is low, the pulling force might tend to displace the chucker relative to its symmetric concentration gradient of solute, so that more solute would be behind it than in front, resulting in an osmotic enhancement of the mobility. This is what one would expect from an advection-diffusion equation with a source moving at a finite Peclet number (see e.g. Ref. [36]). However, for large chucking rates, the density of solutes near the chucker is higher, and one might imagine that the pulling force would lead to an increased collisions of the chucker with nearby solute particles, decreasing the mobility.

To test this hypothesis, we plot in Figure 12 the "volume fraction", as defined by $\phi \equiv (4/3)\pi R_2^3 c$, of solute particles within the conical volume supported by the angle $\theta = \pi/9$, in front of and behind the chucker (the cone is extended all the way to the edge of the box). We first note that there is a difference in the volume fraction of solute in front of and behind the chucker, for large enough chucking rate. These effects are more pronounced for the larger pulling force. For $F = 7.0 k_B T/R_1$, the solute concentration is larger behind than in front of the chucker, for chucking rates in the range $50 < k_c R_2^2/D_1 < 200$. We would expect this to cause an enhancement of mobility over diffusion; however, this range of k_c values is beyond the peak in $\Gamma k_B T/D_{\mathrm{eff}}$ (as shown by the green dashed line). For higher chucking rates, we would expect to see a larger volume fraction in front of the chucker, if the solute particles are inhibiting chucker motility. There is some indication that this happens for the highest chucking rates (not shown in Figure 12). It is possible that this crowding effect plays a more important role for the smaller value of the force $F = 3.0 k_B T/R_1$, where the pulling force is not strong enough to overcome the crowding; for the stronger pulling force $F = 7.0 k_B T/R_1$, we speculate that the pulling force is strong enough to overcome this effect. Further work will be needed to fully understand the data in Figure 11; it is clear, however, that the nontrivial relationship between mobility and diffusion in this system is caused by a complex interplay between crowding and osmotic effects.

D. A sedimenting chucker

We now consider the case of a chucker which experiences a constant force F perpendicular to a planar surface which either absorbs the solute particles or behaves as a hard wall. This models the gravity-driven sedimentation of a chucker onto a surface, in the case where