Supplement: Viruses such as SARS-CoV-2 can be partially shielded from UV radiation when in particles generated by sneezing or coughing: Numerical simulations

1. Effect of the number of virions per particle (N_v) dried respiratory fluid on R_i

This section explores how the number of virions affects the results, and how the number of virions compares with other work. As noted in section 2 of the paper, the measured concentrations of SARS-CoV-2 virions in saliva and nasopharyngeal fluids varied from 4×10^4 to 4×10^{10} copies/mL (Wyllie, 2020). The resulting average numbers of virions per particle (N_v), for 9-µm particles, range from approximately 0.001 to 3700 (see Section 2). The large majority of dried 9-µm particles from the persons studied by Wyllie et al. (2020) would have 10 or fewer virions, and the most common number of virions per particle overall would be zero. Other researchers have indicated lower numbers of virions per 9-µm dried particle, e.g. Vejerano and Marr (2018).

Figures 2 and 3 in the main paper illustrate that intensity of a virion within a dried droplet, relative to a naked virion on a surface (R_i) spans several orders of magnitude. Thus large number of virions, e.g., 10,000, are used to obtain a distribution of the R_i. For the simulations in the paper a total of 12000 virions were used for 9 µm particles. The number of virions was selected to use as many as possible while still being able to be run in a short amount of time <48 hours. We desire ensemble averages for many particles each containing randomly dispersed virions, where N_v is not so large that virions cause large variations in the R_i of other virions. Problems with attempting to calculate the R_i in a sphere containing 10,000 virions are that increasing the virions per particle increases the runtime and increases the probability of virions having a significant effects on the R_i of other virions. On the other hand, running the MSTM code for 2500 sets of four-virions each is possible but tedious to setup and run. Therefore, we investigated the effects of N_v per particle on interactions within particles and runtimes. We generated a set of 4000 virions, randomly positioned within a 9-um diameter spheres, and selected 10 of these virions for comparison. The R_i were then calculated for the sphere on a surface for N_v = 10, 25, 50, 100, 250, 500, 1000, 2000, 3000 and 4000. The differences between the R_i of only these 10 virions in a dried saliva droplet and these 10 virions in a dried saliva drop N_v higher than 10 are illustrated in Fig. S1. It is clear that even when N_v = 4000 virions, there is less than a 5% difference between the individual virions. When N_v = 100, this difference drops to <0.5%. Even with N_v = 4000, the virions still only comprise about 0.5% of the volume for this case, where the difference between the m_r of material of the virion and of dried particle is small. Thus, there is a relatively small effect. Similarly, for a 5 µm particle, the R_i were calculated for the sphere on a surface for N_v = 5,10, 25, 50, 100, 400, 800 (Figure S2). When N_v = 25, the maximum difference is also about 0.5%.

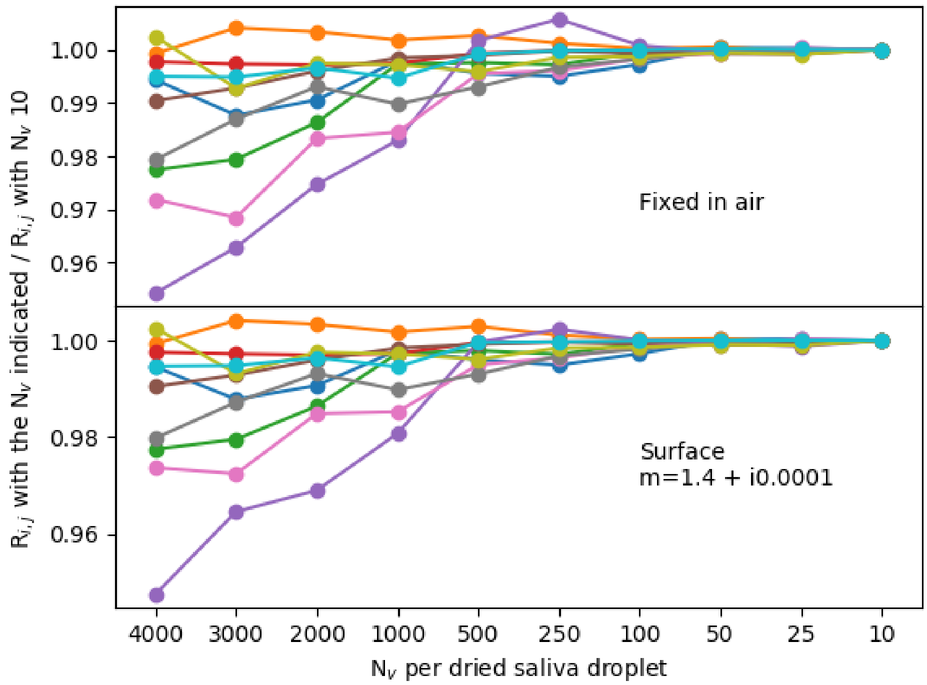

Figure S1: Ratios of $R_{i,j}$ (with the N_v shown) to the $R_{i,j}$ with N_v=10, for a 9-um saliva particle illuminated with 260-nm UV. The horizontal axis is of N_v. The position of each virion is the same in all runs. The first 10 virions in all cases have the same positions as the virions from the 10 virion case. Each dot shows the ratio of the jth virion in the particle with the N_v indicated, to the j^{th} virion of the particle with N_v = 10, where a different color is used for each j (same for both line and dot). (a) Ratio of $R_{i,j}$ with the N_v indicated to the $R_{i,j}$ with N_v=10 for particles fixed in air. (b)) Ratio of $R_{i,j}$ with the N_v indicated to the $R_{i,j}$ with Nv=10 for particles on a surface with the complex refractive index of 1.4 + i0.0001. Each colors is associated with a different one of the 10 virions compared.

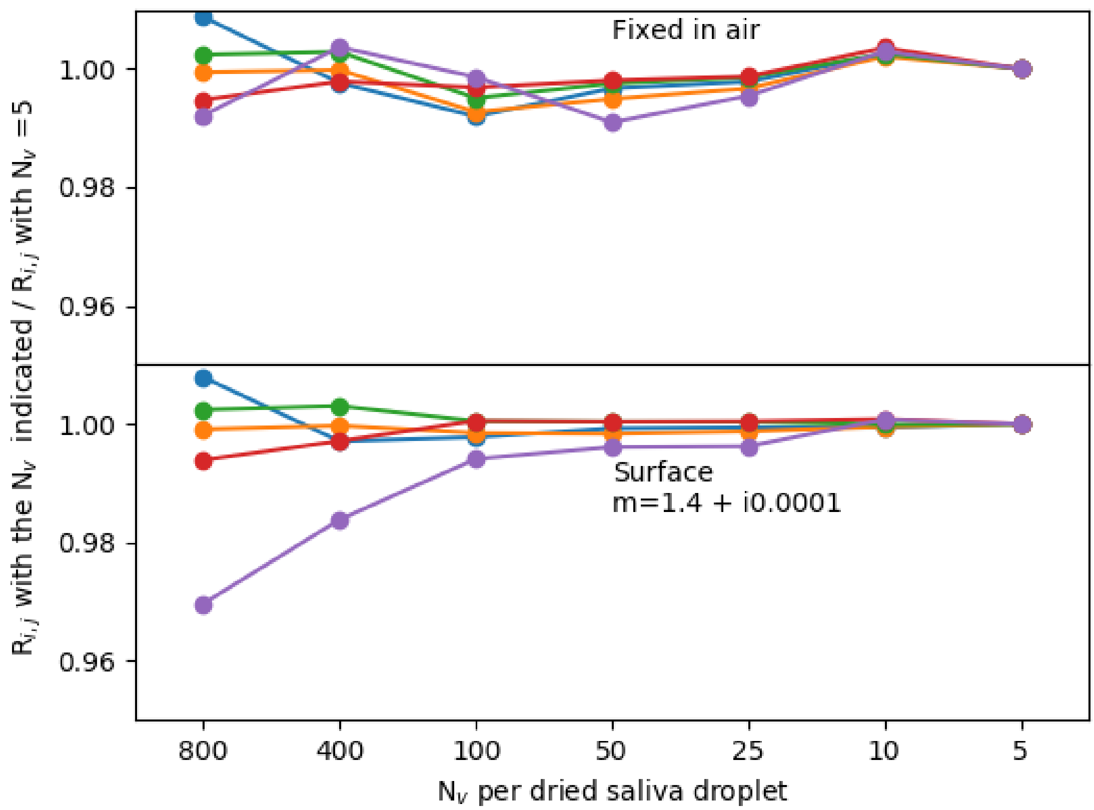

Figure S2: Ratios of $R_{i,j}$ (with the N_v shown) to the $R_{i,j}$ with N_v=5, for a 5-um saliva particle illuminated with 260-nm UV. The horizontal axis is of N_v. The position of each virion is the same in all runs. The first 5 virions in all cases have the same positions as the virions from the 5 virion case. Each dot shows the ratio of the jth virion in the particle with the N_v indicated, to the jth virion of the particle with N_v = 5, where a different color is used for each j (same for both line and dot). (a) Ratio of $R_{i,j}$ with the N_v indicated to the $R_{i,j}$ with N_v=5 for particles fixed in air. (b) Ratio of $R_{i,j}$ with the N_v indicated to the $R_{i,j}$ with N_v=5 for particles on a surface with the complex refractive index of 1.4 + i0.0001. Each colors is associated with a different one of the 5 virions compared.

2. Distributions with 4000 particles in the same 9um particle

The previous section illustrated that the R_i values were slightly different when 4000 particles were used in a dried particle compared with a case with 100 virions, and showed that for 10 selected virions, the effect of increasing the number of virions was small, for the calculated test cases. However, the view in terms of 10 selected virions is incomplete because it only focuses on a few virions. To gain a more complete picture for 4000 virions, a histogram of the R_i values from a 4000 virion dried particle was compared to the histogram of 120x100 virions in 120 particles (Figure 3c in the main paper). These 4000 virions are located at the same locations in the particle as the first 4000 virions in the 120x100 virion cases described in the main paper.

Figure S3 illustrates, for 260 nm UV illumination, distributions the respective cases. Little difference is noted for both the particle fixed in air, and on a surface. Thus, the overall conclusions in this paper should be true regardless of the actual numbers of virions in a dried respiratory particle. A longer discussion of uncertainties is present in the main paper (section 4.2).

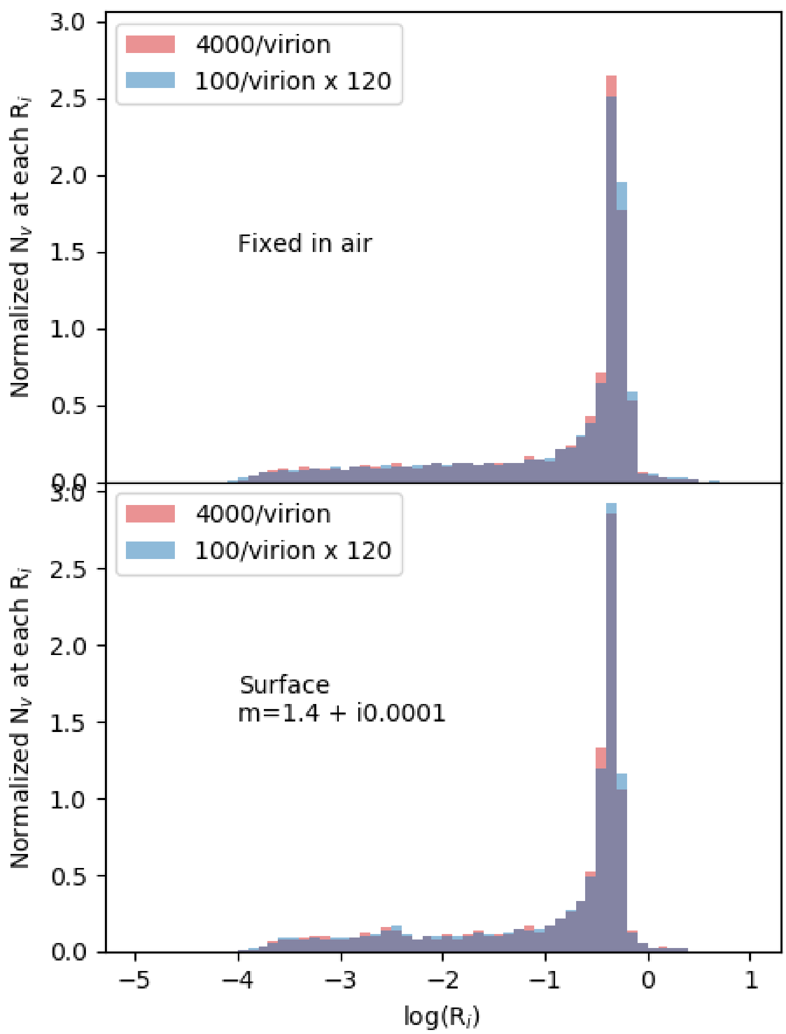

Figure S3: Relative numbers of virions in bins with the log(R$_i$) shown. The particles are 9-µm diameter and either fixed in air (upper panel) or resting on a surface with m= 1.4 +i 0.0001.

Reference:

Vejerano, E.P., Marr L.C. Physico-chemical characteristics of evaporating respiratory fluid droplets. J R Soc Interface 2018;15(139):20170939. Doi: 10.1098/rsif.2017.0939.

Wyllie A. L., Fournier J., Casanovas-Massana A., et al. Saliva or nasopharyngeal swab specimens for detection of SARS-CoV-2. *N. Engl. J. Med.* 2020; 383:1283-1286 https://doi.org/10.1056/NEJMc2016359.