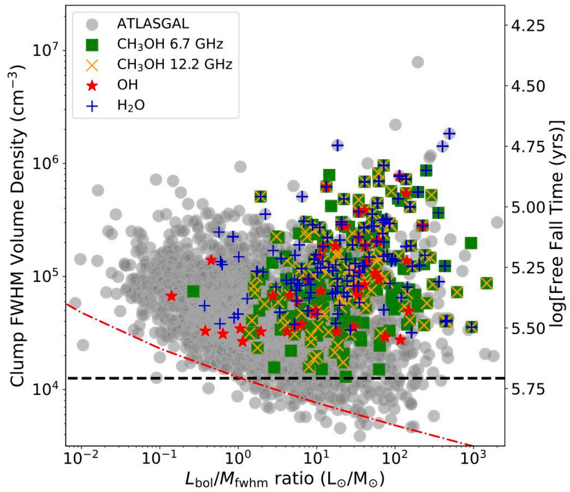

Figure 12. Distance-limited sample of volume density versus $L_{\rm bol}/M_{\rm fwhm}$ ratio for both the maser associated clumps and the full ATLASGAL sample. The entire ATLASGAL sample is shown in grey with the various maser species denoted by the legend in the upper left-hand corner of the plot. The sensitivity limits of the ATLASGAL survey is shown as the red dash-dotted line, determined for a distance of 2 kpc. The dotted black line at $y = 10^{4.1}$ cm^{-3} is the limit for 6.7-GHz maser emission to exist, as described in Billington et al. (2019).

$10^{4.1}$ cm^{-3}, and luminosities of above ∼500 L$_\odot$. This luminosity value corresponds to a protostellar mass of ∼6 M$_\odot$ assuming that $L \sim M^{3.5}$ (Kuiper 1938) and that the majority of a clump's luminosity arises from a single object. It also must be assumed that for this minimum mass to be accurate, any maser emission emanating from a clump must be associated with the most massive star. This scenario may not always be true, as it has been observed that water masers can arise from low-mass protostars. Naturally, these conditions are only required for masers present in star formation regions and may not hold true for the same maser species associated with other types of celestial objects.

5.2.2 *Statistical lifetimes*

Billington et al. (2019) presented the calculation of the statistical lifetime of the 6.7-GHz methanol maser by finding the ratio of maser associated clumps at specific volume density intervals and multiplying these by the free-fall times in these intervals. It was found that the mean statistical lifetime for this maser transition is ∼3.3 × 10^4 yr, which is in very good agreement with theoretical predictions (Van Der Walt 2005; 2.5−4.5 × 10^4 yr).

We have repeated this derivation for the maser species presented in this study. Free-fall times have been calculated for each clump within our sample that has a corresponding volume density measurement (as discussed in Section 4.2). These free fall times range from ∼20 000 to ∼750 000 yr. It is likely that any maser emission will only be present for a fraction of these time-scales and so by multiplying these times by the fraction of clumps associated with a particular kind of maser emission at specific volume density intervals, the statistical lifetime for maser emission can be found. Fig. 13 presents the clump ratios and statistical lifetimes for each maser species as a function of volume density. It can be seen from this Figure that the number of maser associated clumps increases with increased clump volume density. For the calculation of the statistical lifetimes, we only include clumps that have volume densities above our completeness limited for this

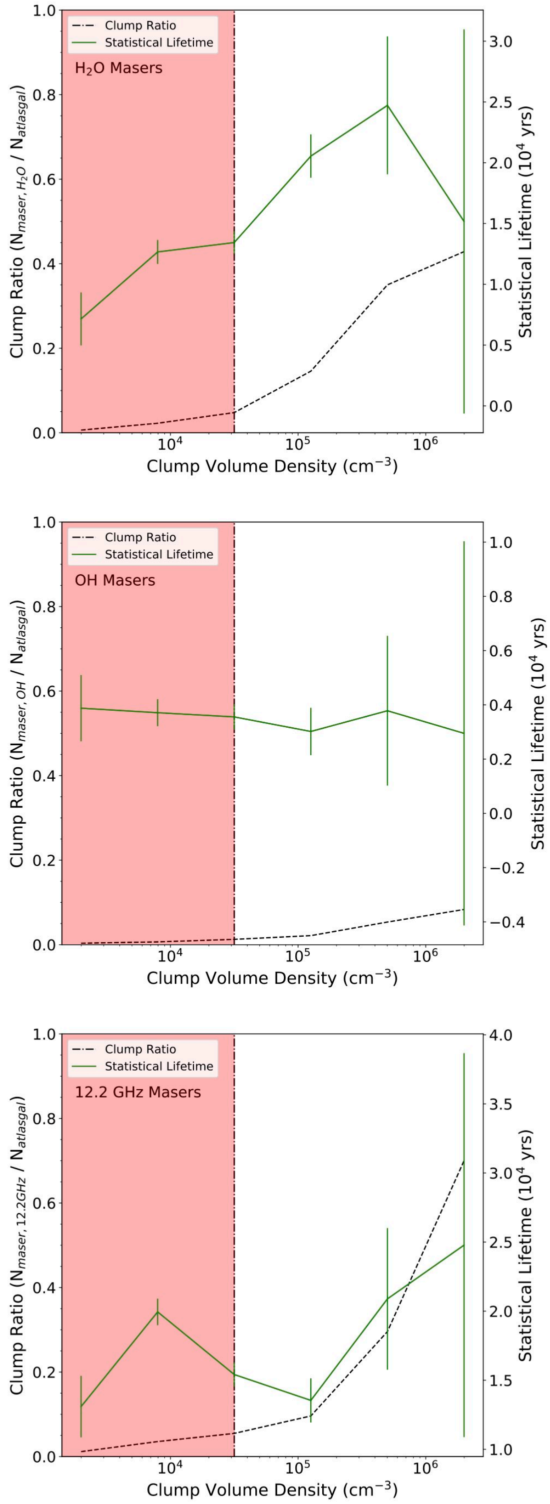

Figure 13. Plots presenting the clump ratios for each maser species and the statistical lifetimes as a function of clump FWHM volume density. The upper, middle, and lower panels present the lifetimes for the water, hydroxyl, and 12.2-GHz methanol masers, respectively. The black dotted lines shows the increasing number of maser associated clumps with respect to the volume density, whereas the solid green line presents the change in statistical lifetime for each volume density range. The shaded regions represents the parameter space where our sample is incomplete. Errors shown are derived from Poisson statistics.