Measuring the $C^{18}O$ column density in hot cores

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High-mass stars are formed embedded within hot, dense, molecular gas reservoirs known as hot cores. Hot cores exist within cooler, larger scale structures known as molecular clumps. The column density of a species (particles per cm^2) is a fundamental observable quantity in astrophysics: it is the number density (particles per cm^3) integrated along the observational line of sight. Observations of low frequency carbon monoxide (CO) spectral lines are commonly employed to measure the column density of astronomical objects. This traditional technique is complicated by the high densities and temperatures found in hot cores. Observations of a rare isotope of carbon monoxide, $C^{18}O$, surmount density issues, while high temperatures, atypical of the cold cores associated with low-mass star formation, excite the $C^{18}O$ molecules into additional states. These additional excited states have corresponding spectral lines at higher frequencies. Both the low and high frequency lines are required in order to accurately determine the $C^{18}O$ column density in hot cores. The high frequency lines, which are blocked by the Earth's atmosphere, have been observed for the first time via the Herschel Space Observatory. The low frequency lines have been obtained via *collaborative* ground-based observations using the IRAM 30m telescope and the James Clerk Maxwell Telescope. Using both low and high frequency lines, we measure the $C^{18}O$ column density of the hot core and the surrounding molecular clump for 14 separate objects. Canonical abundance ratios scale the $C^{18}O$ column density to the total molecular gas column density, a quantity of key theoretical importance.