Integrated Brightness Temperature for MOLPOP-CEP
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For uniform conditions, the line brightness temperature at frequency shift $x = v/\Delta v$ from line center, where Δv is the thermal linewidth, is

$$T_{\text{br}}(x) = T_{\text{ex}}\left(1 - e^{-\tau(x)}\right) \tag{1}$$

where T_{ex} is the line excitation temperature. The optical depth $\tau(x)$ is

$$\tau(x) = \frac{\tau_0}{\mu}e^{-x^2} \tag{2}$$

where τ_0 is the optical depth at line center and μ the viewing angle from the slab normal. Therefore, the line-integrated brightness in $\text{K}\,\text{km}\,\text{s}^{-1}$ is

$$T_{\text{B}} \equiv \int T_{\text{br}}dv = T_{\text{ex}}\Delta v \int \left(1 - e^{-\tau(x)}\right) dx \tag{3}$$

Since MOLPOP produces the linewidth Δv in the quantity vt (it is internally converted to $\text{cm}\,\text{s}^{-1}$ and must be divided by 10^5) and all internal optical depths are at line-center, implementing this expression is straightforward. In CEP runs, the integration is performed zone by zone, then added up.