1 Density unit

In convection, we used to measure ρ in units of $\rho_0 = \langle\rho\rangle$ and T in units of $[u]^2/c_{\rm p}$, but in the presence of radiation, we also have $\sigma_{\rm SB}$, and thus

$$\sigma_{\rm SB}\left([u]^2/c_{\rm p}\right)^4 = [\rho][u]^3, \tag{1}$$

i.e.,

$$[\rho] = \sigma_{\rm SB}[u]^5/c_{\rm p}^4. \tag{2}$$

Choosing $[u] = 1\,{\rm km\,s^{-1}}$, and with $c_{\rm p} = 3.46\times10^8$ (cgs) and $\sigma_{\rm SB} = 5.67\times10^{-5}$ (cgs), we have $[rho] = 3.9\times10^{-14}\,{\rm g\,cm^{-3}}$.

2 $\sigma_{\rm SB}$ as a free parameter

Fixing instead $[\rho]$, we have,

$$\sigma_{\rm SB}^{\rm art} = c_{\rm p}^4\,[\rho]/[u]^5. \tag{3}$$

Using now $[\rho] = 4\times10^{-4}\,{\rm g\,cm^{-3}}$ (BB14), we find

$$\sigma_{\rm SB}^{\rm art} = 5.76\times10^5\,({\rm cgs}). \tag{4}$$

which is 1.02×10^{10} times larger than the actual value.

3 KH time scale

$$\tau_{\rm KH} = \frac{E}{L} = \frac{[\rho]c_{\rm p}TR^3}{\sigma_{\rm SB}^{\rm art}T^4R^2} = \frac{[\rho]c_{\rm p}R}{\sigma_{\rm SB}^{\rm art}T^3}. \tag{5}$$

If we replace T by $gR/c_{\rm p}$ we have

$$\tau_{\rm KH} = \frac{[\rho]c_{\rm p}R}{\sigma_{\rm SB}^{\rm art}(gR/c_{\rm p})^3} = \frac{[\rho]c_{\rm p}^4}{\sigma_{\rm SB}^{\rm art}g^3R^2}. \tag{6}$$

Replace $R = [u]^2/g$, then

$$\tau_{\rm KH} = \frac{[\rho]c_{\rm p}^4}{\sigma_{\rm SB}^{\rm art}g[u]^4}. \tag{7}$$

Using $g = 274\times100\,{\rm cm\,s^{-2}}$, we have $\tau_{\rm KH} = 1200\,{\rm yr}$. Decreasing $\tau_{\rm KH}$ can be achieved by making larger than it is in reality, i.e., the same trend as found above.

References

Barekat, A., & Brandenburg, A., "Near-polytropic stellar simulations with a radiative surface," *Astron. Astrophys.* **571**, A68 (2014). (BB14)