The Schmidt Law
Decoded and Explained

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Like the Bode-Titius Law before it, the Schmidt Law is not properly understood, given that it has never been reduced to, or predicted from first principles. Star formation is complicated. And, it is almost certainly a multi-scale process that has multiple immediate causes (quiescent, periodic and impulsive in their time dependence; local, global and cosmic/external in their origin) resulting in the same end product: stars. Philosophers of science would say that the theory of star formation is "massively underdetermined by the observations" of stars alone.

Schmidt (1959) plausibly suggested that the star formation rate (SFR) might scale as some power n of the gas density ρ. From dimensional arguments alone Madore (1977) first showed that an exponent of n = 1.5 would be predicted for gravitationally dominated systems. Sanduleak (1969) empirically tested Schmidt's hypothesis, for the first time in an extragalactic setting, spatially correlating OB stars and neutral hydrogen surface gas densties over the face of the SMC, and determined the power-law exponent to be $n = 1.84 \pm 0.14$. Einasto (1972) was so impressed by this determination that he declared Schmidt's hypothesis to be a law, *The Schmidt Law.* And the rest, as they say, is history.

We have returned to the SMC using larger (photometrically selected) samples of OB stars (Zaritsky 2002) and modern HI maps, but this time using a "process astrophysics" approach to the data. Two astrophysically distinct and observationally unambiguous phases in the star formation process are identified: (1) Regions of a given gas density where (recently-formed. hot, blue) OB stars are currently visible, and (2) those regions, of the same gas density, where no such stars have yet formed or have recently evolved to the red, away from the main sequence and died. The ratio of areas in these two states is directly proportional to the ratio of two independent timescales, τ_* and τ_{cc}. The former (a stellar, astrophysical) timescale is extremely well studied, calibrated and understood; the latter (a hydrodynamic/thermodynamic) timescale is controversial at best.

Expanding upon the mathematical formalism introduced in Madore (2010) where $SFR = M_*/\tau = (\epsilon M_g)/[\tau_* + \tau_{cc}] = (\epsilon_o \rho_g{}^{-\alpha}) \times (Vol. \times \rho_g)/[\tau_* + B\rho_g{}^{-\beta}]$ and then $SFR = (A\rho_g{}^{1-\alpha})/[\tau_* + B\rho_g{}^{-\beta}]$, we have determined for the SMC that the efficiency of star formation ϵ varies as $\rho^{-1/2}$ and the cloud-collapse timescale τ_{cc} scales as $\rho^{-5/2}$.

References

Einasto, J. 1972, *Ap. Lett.*, 11, 195
Madore, B. F. 1977, *MNRAS*, 178, 1
Madore, B. F. 2010, *ApJ*, 716, L131
Sanduleak, N. 1969, *AJ*, 74, 47
Schmidt, M. 1959, *ApJ*, 129, 243
Zaritsky, D., Harris, J., Grebel, E. K., & Massey, P. 2002, *ApJ*, 123, 855