Homework 10

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Task 1

(a) The Schmidt Law attempts to describe the relationship between large-scale star formation rate and ISM (more specifically: the SFR per unit area and the surface density of the ISM)

(b) Measurements of Hα luminosities suffer from errors due to extinction variations and extrapolated initial mass functions. Errors in measurements of the gas density are largely due to variations in the CO/H conversion factor, combined with sometimes limited CO measurements. These influences are difficult to reduce, since many times one has to rely on estimates instead of accurate data.

(c) Figure 3 depicts density profiles of 21 galaxies, which were obtained by azimuthally averaging Σ_{SFR} and Σ_{gas} at different distances from the galactic centre. For high densities a Schmidt Law is fulfilled, while below a certain threshold the profiles steeply decrease. This is to illustrate deviations due to averaging over the whole galaxy, as it is done in that paper.

(d) The Σ_{SFR}-Σ_{H_1} relation is similar to the Σ_{SFR}-Σ_{total} relation, which is not surprising as H_1 makes up roughly half of the total gas density. Further, one could read from the correlation that the SFR regulates the H_1 density through photodissociation of molecular gas by (young) hot stars.

(e) The Σ_{SFR}-Σ_{H_2} correlation is much weaker, possibly as it is based on a CO/H_2 conversion factor which is valid for regions with near-solar metalicity, but thereby underestimating H_2-mass in metal-poor regions.

(f) In figure 6, filled circles represent global Hα measurements of normal spiral galaxies, which are found in regions of low densities, and filled squares represent FIR measurements of the central regions of starburst galaxies, which fill regions of higher densities.
While both types remarkably agree in their slope, they are separated by an empty gap. In order to show that a physical continuity exists between both domains, from 25 normal spiral galaxies Σ_{SFR} and Σ_{gas} were derived by averaging only their central regions. When this data is plotted (as open circles), it fills aforementioned gap.

(g) The Schmidt Law is rather a statistical description averaged over many galaxies, since some of them deviated substantially from the mean relation.
For concrete models, the size of star-forming regions is required on linear scales, which is straightforward for normal galaxies, but might be more challenging for starburst galaxies, since in some cases the relevant regions are only a few percent of the parent galaxy's radius.

(h) Although the Schmidt Law is an empirical law, it can be interpreted with simple models, which reproduce the prior discussed behaviour and in which star formation is due to self-gravitation of the ISM.
One way is relating ρ_{SFR} with the ratio of ρ_{gas} and the growth timescale of density perturbations $\tau_{\text{growth}} = (G\rho_{\text{gas}})^{-.5}$: $\rho_{\text{SFR}} \propto \frac{\rho_{\text{gas}}}{\tau_{\text{growth}}} \propto \rho_{\text{gas}}^{1.5}$.
Alternatively, one can find a kinematic description by looking at the ratio of Σ_{SFR} and the local dynamical timescale: $\Sigma_{\text{SFR}} \propto \frac{\Sigma_{\text{gas}}}{\tau_{\text{dyn}}} \propto \Sigma_{\text{gas}}\Omega_{\text{gas}}$, were Ω_{gas} is the angular velocity of the ISM.
The high SFR in starburst galaxies is in the first interpretation simply due to higher gas densities in those regions, while in the second one smaller physical scales and shorter timescales compared to normal galaxies are responsible.