Kpc-scale properties of dust temperature in terms of dust mass and star formation activity

I-Da Chiang[1], Hiroyuki Hirashita[1,2], Jérémy Chastenet[3], Eric W. Koch[4], Adam K. Leroy[5], Erik Rosolowsky[6], Karin M. Sandstrom[7], Amy Sardone[5], Jiayi Sun[8,9], Thomas G. Williams[10,11]

[1]*ASIAA, Taiwan,* [2]*Osaka University, Japan,* [3]*Universiteit Gent, Belgium,* [4]*CfA | Harvard & Smithsonian, USA,* [5]*The Ohio State University, USA,* [6]*University of Alberta, Canada,* [7]*University of California San Diego, USA,* [8]*McMaster University, Canada,* [9]*CITA, Canada,* [10]*MPIA, Germany,* [11]*University of Oxford, UK*

We investigate the impact of local physical environment on dust temperature. In Hirashita and Chiang (2022), we built two analytical models for dust temperature and showed that the two most important quantities that set dust temperature are the star formation rate surface density ($\Sigma_{\rm SFR}$, tracing dust heating) and the dust-to-gas ratio (D/G, tracing dust shielding). In this work, we compile multi-wavelength observations in 46 nearby galaxies, measure their dust temperature and local physical quantities at 2 kpc resolution, and compare our measurements to the model predictions (Chiang and Hirashita et al. 2023).

We confirm that to first order, dust temperature scales with $\Sigma_{\rm SFR}$ with a correlation coefficient of 0.89, which is consistent with the model prediction. Meanwhile, there is no single quantity that traces the variation of dust temperature at fixed $\Sigma_{\rm SFR}$ throughout the entire sample space. Unlike the model prediction, we find that D/G only works as a secondary tracer of dust temperature at $\Sigma_{\rm SFR} \gtrsim 2 \times 10^{-3}$ M $\odot$ yr^{-1} kpc^{-2}. We also find that in the low-ΣSFR regime, the observed dust temperature is higher than the model predictions.

The discrepancy between the model and observations can be resolved if we modify the model to include the contribution of the old stellar population to dust heating. In our sample space, dust heating contributed by old stars becomes more important as we move to the low-$\Sigma_{\rm SFR}$ regime. This modification would improve the model prediction of dust temperature, especially in quiescent galaxies and non-starforming regions.

Finally, when comparing all the quantities implemented in the model with observations, we notice that at fixed gas surface density ($\Sigma_{\rm gas}$), the observed $\Sigma_{\rm SFR}$ tends to be higher than the model at larger D/G. This is mainly because we assumed the standard Kennicutt-Schmidt law (K-S law) in setting up the $\Sigma_{\rm SFR}$-$\Sigma_{\rm gas}$ relation in the model, which does not match the observation. We therefore propose an empirical correction to the K-S law with D/G and use it to improve the model prediction. The fundamental dependence of this D/G correction is likely based on the correlation between D/G, metallicity, and the H I/H_2 ratio.