Abstract

Dust Attenuation in Dusty Star-Forming Galaxies Using Spectral Energy Distribution

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Despite its low contribution to the total mass of the interstellar medium (ISM), dust plays a crucial role in the evolution of galaxies, and it has the biggest impact on the shape of their total spectral energy distribution (SED). Dust attenuates the stellar light by absorbing the short wavelength photons incoming from the newly-formed stars, and emits them thermally in the infrared (IR). The affluence of IR and radio detections of millions of galaxies, provided by powerful instruments such as Herschel and ALMA, has allowed us to study the cold dust in galaxies over a wide range of redshift.

To account for dust attenuation in models, one should assume a dust attenuation law which describes how stellar emission is absorbed by dust. Attenuation laws are representative of different distribution of dust relative to the stellar population, and they vary from simple screen models to more complex dust-stars geometries. These laws are represented by “curves” of attenuation, the slope of which dictates how much attenuation is dust causing on a specific wavelength range. Recent studies show a non-universality of dust attenuation curves when reconstructing galaxy SEDs. Moreover, assumed dust attenuation slopes can strongly alter the estimation of main physical properties of galaxies obtained by fitting the observed SED through theoretical models, such as the stellar masses. Therefore, dust attenuation slopes have a direct implication on our understanding of how galaxies build up their stellar masses through the cosmic times. Despite the growing knowledge in the field of extragalactic astronomy, key questions remain unanswered: What dust attenuation law one should use at high redshift? What are the physical conditions on which dust attenuation curves depend?

In this thesis, I aim at answering the aforementioned questions by analyzing the SEDs of galaxies and study the correlations between dust attenuation and various physical properties of these galaxies. First, I study a complex system of two galaxies around the cosmic noon (z ~ 2), one of these galaxies is a massive ultra dusty galaxy, detected by ALMA. I analyze the role of dust attenuation in these galaxies and most importantly, the importance of their morphology in determining their physical characteristics, such as their loci from the main sequence of star-forming galaxies. To generalize the peculiar aspect of morphological extension of dust emission in dusty star-forming galaxies, I study the effect of star-to-dust spatial extension on the preferred dust attenuation law in these galaxies. For this, I build one of the largest ALMA-detected sample

that is studied from the aspect of dust attenuation (122 galaxies in total), and derive the effective radii of these galaxies. With careful SED modeling of these galaxies, I derive key physical parameters that govern galaxy evolution and investigate the correlation between the relative compactness of stellar emission and dust emission on the one hand, and on the other hand the dust attenuation law preferred for these galaxies.

Lastly, I conduct a large study of dust attenuation relation at intermediate redshift, with a large sample of ~ 1 000 galaxies from VIMOS Public Extragalactic Redshift Survey (VIPERS) that do not possess ALMA detection, therefore their dust continuum is inaccessible. However, I study the effect of their stellar continuum spatial distribution with the dust attenuation (in the IRX-β plane, where β is the UV slope and IRX is the IR excess). I also investigate the role of gas phase metallicity, the inclination of galaxies, and most importantly the environments in which they reside.

The results of these works show that the morphological properties of galaxies at different redshift ranges are highly important, and they should be taken into account as a prior for SED fitting, to accurately estimate the stellar masses and other quantities. Moreover, important correlations were found between dust attenuation and other physical properties, such as the metallicity, galaxy compactness, and the relative spatial extension of star-to-dust continua. I found that galaxies with relatively compact stellar emission preferred a steeper attenuation law, while galaxies with larger stellar emission preferred a shallow attenuation curve. I found a strong dependence of the IRX-β dust attenuation relation on gas-phase metallicity, and also strong dependencies on stellar ages, stellar masses, specific star formation rates and the compactness of the sources characterized by the Sérsic indexes. Metallicity is one of the drivers of the dust attenuation scatter, this also results from the older stars and higher masses at higher β values. The correlation with specific dust mass is strong in shifting the galaxies away from the IRX-β relation towards lower β values. I find that more compact galaxies witness a larger amount of attenuation than less compact galaxies. There is a subtle variation in the dust attenuation scatter between edge-on and face-on galaxies, but the difference is not statistically significant. Galaxy environments do not significantly affect dust attenuation in star-forming galaxies at intermediate redshift.

These results are promising in the era of big surveys, with the James Webb Space Telescope (JWST) which is allowing us to expand our knowledge of high redshift galaxies, and the upcoming Legacy Survey of Space and Time (LSST) which will allow to detect a large number of galaxies with high resolution optical/UV maps. This will allow us to quantify compactness of millions of galaxies, and study their dust attenuation and emission.