Baryonic Tully-Fisher relation and star formation rate

Masato I.N. Kobayashi (Nagoya University) and Tsutomu T. Takeuchi (Nagoya University)

In order to understand galaxy evolution, we first need to investigate physical properties of galaxies that we can observe. There is one good example for elliptical galaxies. We have already demonstrated “the fundamental plane” in three dimensions spanned by the surface brightness, velocity dispersion, and effective radius. Elliptical galaxies basically live on this plane. We, therefore, expect there is a counterpart for spiral galaxies: the fundamental plane that accommodates all spiral galaxies.

Many observations and discussions have been done on spiral galaxies and shown as scaling laws; Tully-Fisher relation (TFR), baryonic Tully-Fisher relation (BTFR), star formation main sequence (SFMS), Schmidt-Kennicutt law (KS-law), etc. They are well-established, tight, but empirical relations that are usually discussed separately. We predict the fundamental plane exists as a fundamental property underling those empirical scaling laws. Thus, we integrate those scaling laws to find the fundamental plane. In this work, we start with most important ones; BTFR and SFMS. The BTFR works not only as a powerful determinant of the distance but a tight connection between baryon and dark matter, because luminosity represents stars, while rotational velocity is related to gravitational potential of dark matter. SFMS connects current stellar mass and star formation rate, which represents the star formation history of each galaxy.

We first compiled data for 130 galaxies from Gurovich et al. (2010), Torres-Flores et al. (2011), Puech et al. (2010), Brosch et al. (2010), and McGaugh (2012). Here, for star formation rate, we employ both infrared and ultraviolet fluxes data on each galaxy to deal with the effect of dust extinction. Then, we use principal component analysis (PCA) to analyze these three dimensional data. PCA is one of the statistical procedures that works greatly on high dimensional data analysis. Lastly, we find a fundamental plane on which all of these sample spiral galaxies reside. This is the first step to determine which properties we need to concern primarily to establish a unified theory. The fundamental plane we disclose here would be one aspect of this unified theory in much higher dimensions.