The relation between active galactic nuclei and star formation in galaxies
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Introduction

Establishing the physical connection between star formation (SF) and active galactic nuclei (AGN) in galaxies remains one of the outstanding goals for studies of galaxy and black hole evolution. Standard methods of classifying objects as star-forming or AGN still rely on the long-established Baldwin, Phillips & Terlevich (BPT) diagrams. Fig. 1 shows the typical division of the log([OIII]/Hβ) vs. log([NII]/Hα) plane into objects classified as AGN or SF, using the demarcation lines of Kewley et al. (2001) and Kauffmann et al. (2003). A large number of objects are classified as “composite”, with a significant contribution from both AGN and SF, but the BPT diagram is unable to quantify how much of each is present in each object. Even in objects not classified as composite, there remains the possibility that low-level SF is present in an AGN-dominated galaxy, or vice versa. We have developed a technique based on mean field independent component analysis (MFICA) that allows us to separate the contributions from AGN and SF, based on generating component spectra that represent the different sources. In doing so we are able to quantify the contributions from each source, both in “composite” objects and those dominated by a single source.

Generating SF and AGN components

We have separated the AGN and SF contributions to observed emission-line spectra using mean field independent component analysis (MFICA). MFICA is a blind source separation technique, in which an input set of observed spectra is separated into a small number of component spectra, which can be linearly combined to reconstruct the observed spectra. The components are generated entirely based on the observed properties of the input sample, with no physical model specified. By setting priors on the flux values of the MFICA components we are able to specify that they must be positive everywhere, as would be expected for a physical emission source.

The components shown in Fig. 2 were generated from a sample of 730 emission-line galaxies with redshift, 0.10 < z < 0.12, selected from the SDSS to cover the BPT diagram evenly. The observed spectra were continuum subtracted using a modification of the MFICA technique, and the resulting emission-line spectra were corrected for intrinsic dust reddening (see below). Component 1 is a SF region, while component 2 shows low-ionisation emission that is also commonly associated with SF. Components 3 and 4 each show distinctive AGN signatures, with emission from a number of high-ionisation lines. Component 5, dominated by [OIII] emission, represents very high ionisation emission, typically the result of an AGN but occasionally associated with SF.

Taking the combined components 1 and 2 as representing star formation, and components 3, 4 and 5 as representing AGN, we are able to calculate the fractional contribution of each source to each of the 730 input spectra. The varying contributions are shown by the different coloured points in the BPT diagram in Fig. 3. Crucially, we are able to quantify the relative contributions for each spectrum individually, even within the “composite” region where the contributions can change greatly with little change to the line ratios.

Measuring the dust extinction curve

The MFICA assumes that the data can be described as a linear sum of components, but dust reddening and extinction has a wavelength-dependent multiplicative effect, so the quality of the derived components is improved by correcting the input spectra for dust reddening before processing. To generate the above components we measured the Balmer decrements after subtracting the continua, then corrected the emission-line spectra according to the A_H extinction curve found by Wild et al. (2010) to be an accurate parameterisation of the dust extinction in low-redshift emission-line galaxies.

On the other hand, the high signal-to-noise ratio of the MFICA components, compared to the input spectra, gives us the opportunity to indirectly measure the typical extinction curve that affects the emission line spectra. Component 2 in Fig. 2 shows a prominent Balmer series that can be measured as far as H_α at 3751Å. By comparing the Balmer series fluxes in this component to the Case B prediction we can measure the extinction curve, averaged over all input spectra, at the Balmer series wavelengths. By iteratively correcting the input spectra according to the measured extinction curve we will be able refine the measurement, allowing us to derive accurately the extinction curve down to a wavelength of 3751Å.

References

Wild V., et al., 2010, arXiv:1008.3160