Exploring the spectra of active galactic nuclei from the GAMA database

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Overview and Motivation

Motivated by coming vast photometric and spectroscopic surveys, we explore the possibilities of estimating the mass of the supermassive black hole (SMBH) in active galactic nuclei (AGN) using the empirical relations with the observed parameters of the AGN, i.e. the broad emission lines (e.g. *Bontà et al. 2020*) and of the host galaxy's bulge, i.e. the bulge Sérsic index (e.g. *Graham and Driver 2007*).

We select a sample of AGN from the Galaxy And Mass Assembly (*GAMA*) database with both broad emission lines in their spectra (see SpecLineSFR in GAMA, *Gordon et al. 2016*) and existing photometric decompositions of their host galaxies (see BDDecomp in GAMA, Casura et al., in prep). Since the GAMA survey was designed to study galaxies and only contains a fraction of AGN, this reduces our sample to 48 AGN with redshift $z < 0.08$.

Analysis

For the data extraction, we used two well-designed codes: one for the multi-component fitting of AGN spectra (FANTASY, Fully Automated Python Tool for AGN Spectral Analysis, *Ilić et al. 2020*, Rakic et al., in prep.) and the other for the galaxy two-dimensional surface profile fitting (ProFit, *Robotham et al. 2016*).

The FANTASY code is providing host-galaxy substraction with several host-model fittings, and here we used the eigenspectrum decomposition (Figure 1). The multicomponent fit is applied to the reconstructed AGN (Figure 2) in order to extract the broad line widths and the continuum flux at 5100 Å (Figure 4). To get the Sérsic index of the bulge, two dimensional ProFit 2-component surface brightness fit of the KiDS i-band is used (Figure 3).

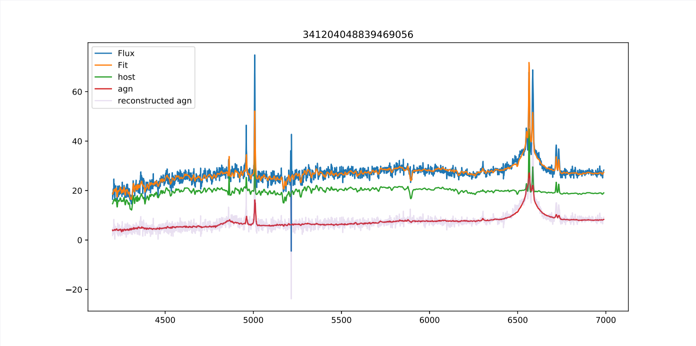

Figure 1: An example of the FANASY host-galaxy subtraction of the object CatID 47558, with the host (green), AGN (red), the reconstructed AGN (pink) and the model fit (orange).

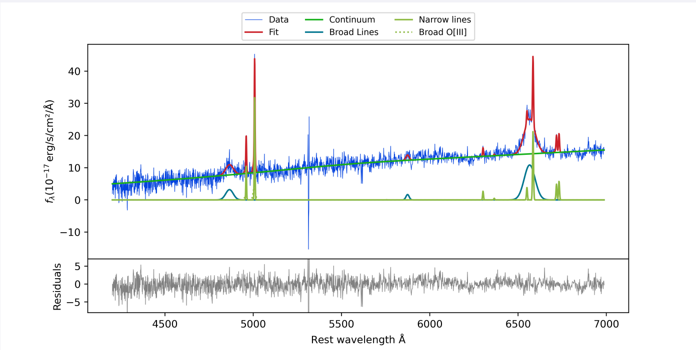

Figure 2: The FANTASY multicomponent fit of the reconstructed AGN of the object CatID 47558. Data (dark blue), fit (red), the AGN continuum (mint green), broad emission lines (turquoise), and narrow emission lines (light green).

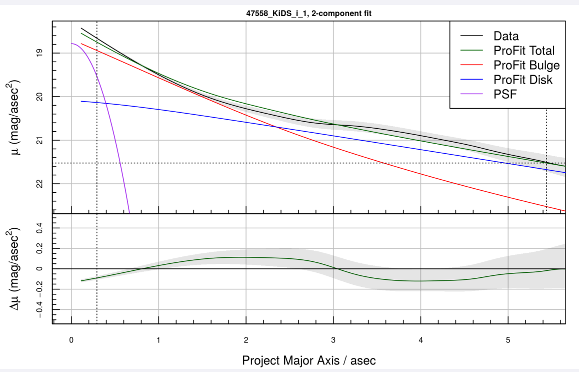

Figure 3: Two dimensional ProFit 2-component surface brightness fit of the object CatID 47558, taken from the GAMA BDDecomp catalogue results. The lines denote: the data (black), the ProFit model (green), the bulge component (red), the disk component (blue), and the point spread function (purple).

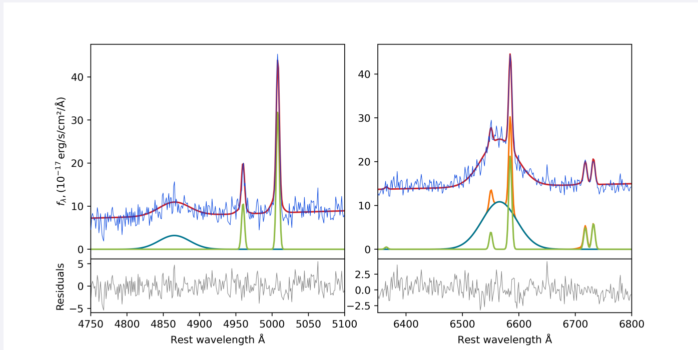

Figure 4: Zoom of the Hβ region left and Hα region on the right with the data (dark blue), the fit(red), the broad emission lines (turquoise), the narrow emission lines (light green) and the sum of broad and narrow component (yellow)

Estimate of the SMBH mass

We estimated the SMBH mass M_{BH} using two different methods. One is using the linear relation of the Sérsic index of the bulge s for the late type galaxies from *Sahu, Graham, and Davis 2020*:

$$log(M_{BH}) = 7.90 + 2.85 \cdot log\left(\frac{s}{3}\right)$$

The other method is based on the virial theorem, and uses the single-epoch spectrum to get the line widths of the Hβ line (FWHM$_{H\beta}$ - full width at half maximum of the broad Hβ component) and the continuum flux at 5100 Å, while the radius R$_{BLR}$ of the broad line region (BLR) is estimated from the R$_{BLR}$ - L relation (*Bontà et al. 2020*). To get the luminosity, we assume a flat ΛCDM cosmology.
Then the SMBH mass is obtained from:

$$M_{BH} = f\frac{R_{BLR}(FWHM_{H\beta})^2}{G}$$

where G is the gravitational constant, and the f-factor is dimensionless and accounts for the BLR geometry. We use $f = 1.12$ in agreement with *Li et al. 2021*.

Results and Discussion

Preliminary we applied this concept only to a small subset of objects with high quality spectra, for which reliable spectral parameters were extracted (Figure 4). For example, in the object CatID 47558 the virial method gives the mass of $(1.80 \pm 0.31) \times 10^7 M_\odot$, while the Sérsic-index relation gives the mass of $(5.33 \pm 0.86) \times 10^7 M_\odot$. For most of the objects, there is a large discrepancy in the SMBH masses obtained by using these two methods.

We believe this discrepancy in the different measurements at least partially to be due to over-resolved images in the brightness profile fits. And we want to emphasize that objects in our sample are all near-by and hence probably over-resolved, implying that more complex structures, such as bars and rings are also resolved. Like the clearly visible bar structure in Figure 5.

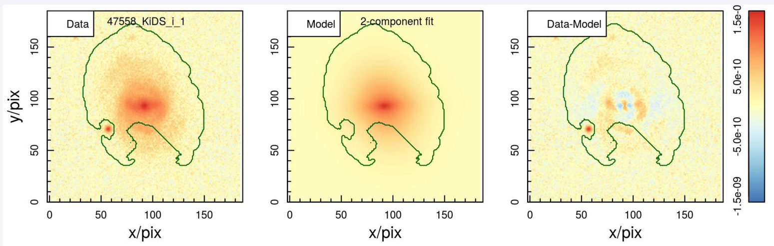

Figure 5: Left: CatID 47558 object with galaxy segment (green line) with a clearly visible bar component. Center: Fitted 2-component model of ProFit. Right: Residuals of the image data - model. The residuals show the presence of additional structures in the galaxy. Data taken from the BDDcomp results.

Therefore, having only two components in the galaxy modelling (see Figure 5) introduce unreliable Sérsic index with large error bars. To optimize the bulge Sérsic index results we need more complex galaxy models, which will be the subject of our future work. Moreover, with the careful and more complex galaxy modelling of a large sample of objects, one could get reliable Sérsic index and corresponding SMBH mass, and use these findings to constrain the f-factor, as suggested by *Sahu, Graham, and Davis 2019*.

References

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