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THE CONTRIBUTION OF STELLAR POPULATIONS TO AGN SPECTRA

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Abstract. We investigated the influence of the stellar population (SP) on the composite AGN spectra of Seyfert 2 (Sy2) galaxies, as well as characteristics of it's gaseous and stellar component. We have used the ULySS algorithm that we have modified and adjusted for simultaneous analysis of all component of AGN integrated spectra, that means to analyse the narrow emission lines in AGN spectra together with the AGN continuum and stellar population component from the host galaxy. In order to validate our method, we have simulated several thousands of line-of-sight integrated spectra of Sy2 galaxies. Spectra have different characteristics of featureless AGN continuum, signal-to-noise ratio, spectral range, and properties of emission lines. We fitted simulated spectra to evaluate our ability to recover characteristics of the model (age, metallicity, fraction and kinematical properties of stellar population, spectral index and fraction of AGN featureless continuum, and widths and intensities of emission lines). We succeed in determining the limits within which we can expect to achieve high accurate results with our method. We find that degeneracies between AGN and SP parameters increase with increasing AGN fraction. This shows that nebular continuum and SP spectra should be fitted at the same time. Analysis revealed that the method is not suitable to correctly recover SP properties when the SP contribution to the total observed spectrum is less then 25%.

We applied our method on 3D observations of Seyfert 2 galaxy Mrk 533. The gas kinematics show non-circular motions in the wide range of galactocentric distances from 500 pc up to 15 kpc, and the outflow corresponds to the position of the radio structure, which is assumed to be created in an approaching jet. We also found that the gas and stars show similar motion, but the velocity of the gas is around six times higher then the mean stellar velocity in the same region of the galaxy. Stellar populations represent a significant constituent in the optical continuum (between 47% and 95%). Metallicity map reveal a positive stellar metallicity gradient which may be expected if the central region is fueled from fresh gas, probable caused by merging or accretion.

1. INTRODUCTION

Line-of-sight integrated spectrum of Active Galactic Nuclei (AGN) consists of featureless continuum from an accretion disk, narrow emission lines from the Narrow Line Region (NLR), broad emission lines from the Broad Line Region (BLR) and underlying stellar population (SP) from the host galaxy. In order to study an AGN, it is very important to evaluate the repercussion of the host galaxy to the spectrum of the AGN and analyse if the influence depends on the type of the galaxy. Therefore, it is very important to determine as precisely as possible the stellar population in the AGN emission.

There are a number of methods for removing the starlight from an integrated AGN spectrum (see e.g. Storchi-Bergman 1993, Ho, Filippenko & Sargent 1997, Hao et al. 2005, Sarzi et al. 2005), but all these methods neglect the fact that the stellar population composition is highly affected by the presence of an AGN or heated dust in the case of infra-red band, in the case when they are not analysed in the same time (Moultaka 2005). In this paper we present a method for simultaneous analysis of all components of integrated spectra of Seyfert 2 galaxies, i.e. the analysis of narrow emission lines of AGN spectra together with the AGN continuum and stellar population from the host galaxy. This approach minimize the degeneracies between the host galaxy properties and the characteristics of an AGN itself.

2. THE MODEL OF INTEGRATED AGN SPECTRA

In order to analyse stellar populations in AGN spectra, we developed the method for the simultaneous fitting of all components of integrated light from an active galaxy. Following Barth et al. (2002), we made a model M(x) of integrated AGN spectra, consisted of a model for the AGN continuum C(x) (here assumed to be a single power law), stellar template spectrum T(x) convolved with a line-of-sight velocity broadening function G(x) and a sum of Gaussian S(x), that represent AGN emission lines:

$$M(x) = P(x)([T(x) \otimes G(x)] + C(x) + \sum S(x)). \tag{1}$$

Line-of-sight velocity broadening function G(x) can be represented by Gaussians or by Gauss-Hermit functions. Multiplicative polynomial is incorporated into the fit (P(x)) to remove large-scale shape differences between the observed stellar and galactic spectra, caused by the differences in instrumental throughput as a function of the wavelength (Kelson 2000). The polynomial represents a linear combination of Legendre polynomials. The proposed method consists in minimizing the χ^2 between an observed spectrum and a model.

For the fitting procedure we have used ULySS algorithm (Koleva et al. 2009) that we modified and adjusted for fitting of AGN integrated spectra. The program ULySS is developing on the Observatory of Lyon (Chilingarian et al. 2007, Koleva et al. 2009). It performs the Levenberg-Marquart minimization. Single stellar population (SSP)[1] models used by ULySS are spline interpolated over an age-metallicity grid of models, generated with PEGASE.HR (Le Borgne et al. 2004). The code is written in IDL/GDL. Therefore, fitting the AGN spectra of interest with ULySS, we reconstract the SSP-equivalent age and metallicity, SP kinematical properties and the contribution of SP to the intergated spectrum, the spectral index and the fraction of AGN, as well as characteristics of AGN emission lines.

[1] SSP is population with single age and metallicity.

3. SIMULATIONS OF AGN SPECTRA

In order to set the limitation of the method, we simulated line-of-sight integrated spectra of low luminous AGN. We assumed that it is composed of featureless AGN continuum from the accretion disk, narrow emission lines from the narrow line region and underlying stellar population (SP) from the host galaxy. We made a grid of 7200 spectra with Solar-type stellar population, combined with different fraction and slopes of featureless continuum, different intensities and widths of emission lines, various spectral ranges, signal-to-noise ratio and degrees of Legendre multiplicative polynomial. More details in Gavrilović et al. (in preparation).

In order to evaluate the ability of the method to restore characteristics of the gas and stars in the nucleus and in the host galaxy, we fitted simulated spectra with the described model of integrated AGN spectra.

The Figure 2. represents the restored SSP ages in a respons of SP contribution to the total spectrum (10%-90%) in the cases of SNR=20 (top pannel) and SNR=40 (bottom pannel). Analyzed spectral range was 4000-5600 Å. Figure 1. shows the best fit of simulated spectra with 70% of stellar population contribution.

At the wavelength range of 5100 Å on the Figure 1 one can read out the recovered light fraction of SP and AGN continuum.

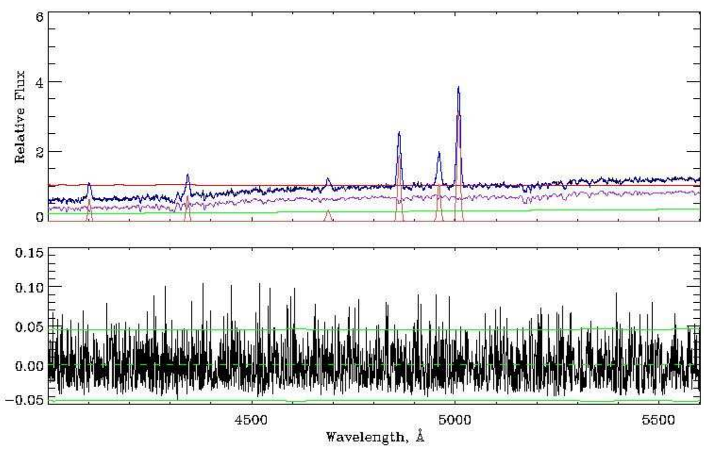

Figure 1: The fit of simulated spectra with α=1.5, 70% of stellar population contribution, intensity of [OIII]4959 equal to 1, width of 10 Å and SNR=20. The represented wavelength range is $\lambda\lambda = [4000-5600]$Å. In the upper panel the black line represents the input spectrum, the blue line represents the best fit model, and the red line the multiplicative polynomial, while the green, light red, and violet lines represent components of the best fit model: violet – stellar population, red– emission lines, and green – AGN continuum. The panel on the bottom of the figure represents residuals of the model (black line). The green line shows the level of the noise.

The inspection of the obtained results showed that the ULySS code efficiently restores the information about the shape and light fraction of the AGN continuum, the kinematics, age, and metallicity of the underlying stellar population in AGN spectra,

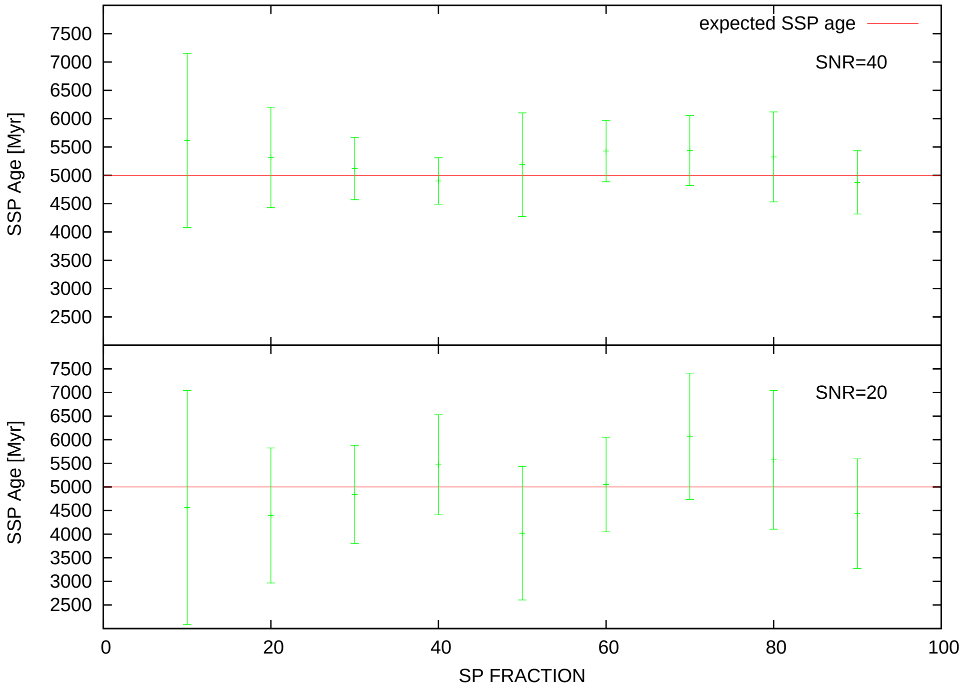

Figure 2: The restored SSP ages from the single best fit for different SP contribution to the total spectrum (10%-90%) in the cases of SNR=20 (top pannel) and SNR=40 (bottom pannel).

as well as characteristics of emission lines, if the SNR is higher that 15. The accuracy of the results obtained for stellar population properties decreases with increasing of the AGN component contribution to the spectrum and the level of the noise. This follows the conclusion of Moultaka (2005) and validates our conclusion that nebular continuum and SP spectra have to be analysed at the same time. Analysis revealed that the method is not suitable to restore accurately the SP kinematical characteristics in the case when the SP contribution to the total observed spectrum is less then 25%.

4. CHARACTERISTICS OF GASEOUS AND STELLAR COMPONENT OF SEYFERT 2 GALAXY Mrk533

Optical spectrum analysis of Seyfert 2 galaxy Mrk533 show unusually strong blue asymmetry of the forbidden lines, such as [OIII]$\lambda\lambda$ 4959,5007 and [NII]$\lambda\lambda$ 6548,6583 (Smirnova et al. 2007). In order to make detailed analysis and to explore possible reasons for the assimetry, the galaxy was observed with the integral-field spectrograph MPFS of the SAO RAS 6m telescope.

The inspection of gas kinematic maps reveal the the gas kinematics showed regular non-circular motions in the wide range of galactocentric distances from 500 pc up to 15 kpc. The maps of inward and outward radial motions of the ionized gas were constructed. The study showed that the narrow line region is composed of at least two (probably three) regions with different kinematical properties. The maximal outflow velocity comes from the nucleus and corresponds to the position of the observed radio structure, which is assumed to be created in an approaching jet. We suggest that these ionized gas outflows are triggered by the radio jet intrusion in an ambient medium (for more details see Smirnova et al. 2007).

Subsequently we were interested in the stellar populations properties in nuclear region of the galaxy and possible connection between gaseous and stellar kinematics. We investigated the stellar underlying continuum and its contribution to the observed emission.

Therefore, we used ULySS package in order to analyse stellar populations in Mrk533. Since we already analyzed gaseous component in Smirnova et al. (2007), we masked prominent emission lines during the fitting procedure. The used model consisted of single stellar population and AGN continuum, represented by power low. We chose 30 central spaxels with signal-to-noise ration on the continuum level higher then 30, in order to have required conditions for stellar population analysis.

The Figure 3. shows stellar population contribution to the observed emission and the metallicity distribution. The SSP equivalent age is about 7 Gyr throughout the analyzed central region of the galaxy.

Our kinematic maps show that gas rotates faster than its stellar counterpart. This is not unexpected, since due to its dissipative nature, the gas is not slowed down by an asymmetric drift. Similar conclusion we can make if we compare maps of velocity dispersion of the gas and those of the stellar component. The gas and stars show similar motion, just the velocity of the gas is around six times faster then stellar population in the same region of the galaxy.

Eventhough it is expected that AGN continuum is mainly absorbed by a dusty torus that surrounds the center of a Seyfert 2 galaxy, we can noticed on the SSP fraction map that AGN continuum is giving small, but not negligible contribution to the observed spectrum. Stellar populations represent significant constituent in the observed optical continuum (between 47 and 95%) and, as expected, it is higher in the outer parts of the galaxy.

Metallicity distribution shows the gradient from subsolar metallicity in central region of the galaxy toward the solar metalicities in surrounding regions. This kind of metallicity distribution is opposite than we expected, and can be understand if the central region is fueled from fresh gas, caused by merging or accretion. This is the interesting topic for futur investigatons.

5. CONCLUSIONS

In order to analyse the properties of the starlight and its contribution to the spectra of AGN, we used ULySS, full spectrum fitting package. We upgraded the ULySS code with the intention of simultaneously analysing all components that contribute to the integrated AGN spectra along a line of sight: stellar population, AGN featureless continuum, and emission lines.

In order to assess the possibilities of restoring the properties of gaseous and stellar components in the spectrum of interest, we made numerical simulations. They show that the ULySS code efficiently restores the information about the shape and light fraction of the AGN continuum, emission lines, as well as the kinematics, age, and metallicity of the underlying stellar population in AGN spectra. The accuracy of the

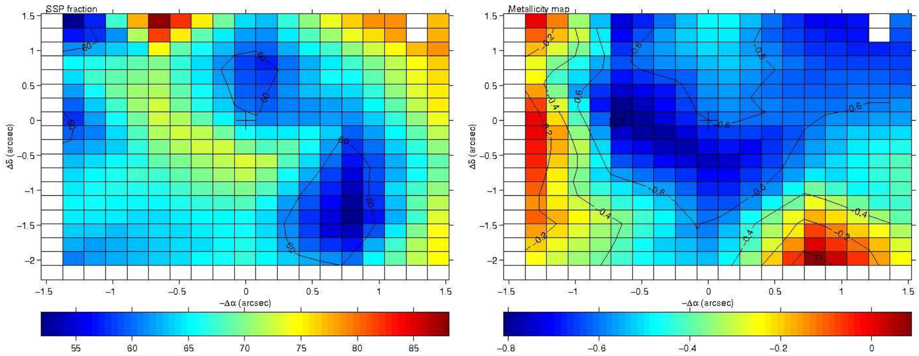

Figure 3: Maps of stellar population contribution to the observed emission (left panel) and the distribution of the mean metallicity of every spaxel (right panel).

results obtained for stellar population properties decrease with increasing AGN contribution to the spectrum. Results of Monte Carlo simulations confirm this statement: namely, we can noticed from the results of the MC simulations that degeneracies between AGN and SP parameters increase with increasing AGN fraction. This follows the conclusion of Moultaka (2005) and validates our conclusion that the nebular continuum and SP spectra have to be fit at the same time. Analysis revealed that the method is not suitable for the cases when the SP flux contribute with less then 25% to the total observed spectrum.

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