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MEASUREMENTS OF VELOCITY DISPERSIONS OF NEARBY GALAXIES

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Abstract. We discuss the dependence of the velocity dispersion measurements on different stellar libraries used as stellar templates. Apart from the well known blue part of the spectrum, we have also tested the red spectrum around the Ca+Fe feature at 6500 Å, following the prescription of Ho et al. (2009). We have measured the velocity dispersions of a sample of nearby galaxies of various Hubble types taken from the Sloan Digital Sky Survey (SDSS) and we discuss the obtained results.

1. INTRODUCTION

Reliable velocity dispersion measurements became very important, since velocity dispersion figures in many scaling relations with parameters fundamental to our better understanding of galaxies. All scaling relations that depend on velocity dispersion, particularly higher-order power laws σ-relations, revealed the significance of accurate velocity dispersion measurements. The well known Faber-Jackson relation (Faber and Jackson 1976), as well as the recently discovered tight correlation between stellar velocity dispersion and black hole mass (Ferrarese and Merritt 2000) *scale as the 4th order power law*, ($M_{BH} \propto \sigma^4$) suggesting that modest errors in velocity dispersion measurements produce large errors in these relations.

In §2 we present our sample of galaxies and discuss galaxy and stellar spectra preparation to make the entire wavelength range reliable for velocity dispersion measurements. Further, we have tested available stellar libraries to choose the most stable one to reduce the influence of stellar templates on our measurements. In §3 we briefly describe the fitting procedure. Finally, in §4 we present the results.

2. GALAXY SAMPLE

We have made a sample of 23 galaxies that are part of the Sloan Digital Sky Survey (SDSS) and also presented in Ho et al. (2009) (Ho09). This sample is chosen to be representative in a sense that it contains various morphological galaxy types. All the details are given in Lalovic 2010. We make a comparison of velocity dispersion measurements between different spectral regions used in Ho09. The data used in this work were taken from the SDSS DR7 WEB server[1] according to their equatorial coordinates obtained using HyperLeda[2] (Paturel et al. 2003) query form supplied with catalogue names taken from Ho09.

Minimal signal-to-noise ratio in this sample is 10.43 and the median is 43.50. We have only 2 galaxies with signal-to-noise ratio $s/n < 30$.

2. 1. PREPARATION OF GALAXY AND STELLAR SPECTRA

We have used three stellar library databases (DBs), chosen to spread over (almost) entire SDSS galaxy wavelength range. Basic description of the used libraries can be found in http://www-astro.physics.ox.ac.uk/ mxc//idl/, with links to each database listed. Due to the limits imposed by the range of SDSS spectra $(3800-7640)$Å, we have chosen Miles $(3525-7500)$Å, Valdes$(3460-9464)$Å and Elodie $(4100-6800)$Å stellar libraries. The decisive reason to use Elodie library is shown in Fig. 1, where Elodie and Valdes libraries have independent measurements of χ^2 value and velocity dispersion error as expected since velocity dispersion error is calculated using best-fitted template *after* the fitting procedure is done. The reason to choose Elodie over Valdes library are smaller χ^2 values for the majority of the objects (Fig. 1).

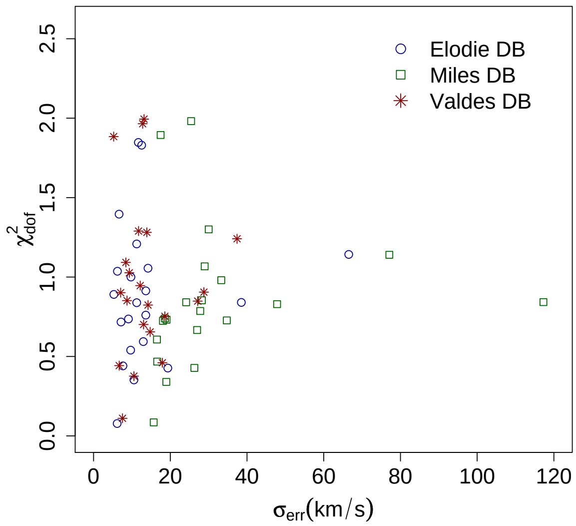

Figure 1: Measure of goodness of the fit (χ^2) vs. velocity dispersion error (σ_{err}) shows that only in the case of Elodie and Valdes libraries there is no correlation as is expected since these two parameters are calculated in different and independent processes.

Since the slope of stellar spectra influences χ^2 value as the measure of goodness of the fit and in order to avoid to manually normalize all stellar spectra, we have cut both

[1]http://www.sdss.org/dr7/access/index.html
[2]http://leda.univ-lyon1.fr/

galaxy and stellar spectra to smaller pieces. In the case of stellar spectra this enabled us to disregard remaining slopes. This preparation was done in MIDAS with simple procedures that can be found at http://wiki.ipb.ac.rs/index.php/SpectraPreparation. The first step of these procedures is to deredshift the galaxy and to divide spectrum in 4 wavelength ranges: (3800,4568)Å, (4568,5336)Å, (5336,6104)Å and (6104,6872)Å (the absence of any prominent absorption for λ >6872 Å made velocity dispersion measurements highly unreliable). Then, stellar library templates should also be divided in 4 regions somewhat larger than the galaxy (requirement of the code): (3700,4600)Å, (4450,5400)Å, (5200,6200)Å and (6000,6900)Å.

3. FITTING PROCEDURE

We have used Penalized Pixel-Fitting (ppxf) code that operates in the pixel space for velocity dispersion measurements (Cappellari and Emsellem, 2004). We will list some key points of this approach. In short, the best-fitting parameters of the line-of-sight velocity distribution (LOSVD) are determined by minimizing the χ^2 value, which measures the agreement between convolved stellar spectra with LOSVD parametric function and galaxy spectrum, over the set of good pixels. Further, for the reasons of comparison to the paper Ho09, we will approximate line-of-sight velocity distribution using a pure Gaussian function.

4. RESULTS

For each case we have separately calculated velocity dispersions using G+K stars and in Fig. 2 we compare the results when different stellar libraries were used.

To obtain the final value of the velocity dispersion, we have weighted both velocity dispersion and its error from *each region* with its corresponding χ^2:

$$\bar{\sigma} = \frac{\sigma_1/\chi_1^2+\sigma_2/\chi_2^2+\sigma_3/\chi_3^2+\sigma_4/\chi_4^2}{1/\chi_1^2+1/\chi_2^2+1/\chi_3^2+1/\chi_4^2} \qquad (1)$$

$$\bar{\sigma}_{err} = \frac{\sigma_{1,err}/\chi_1^2+\sigma_{2,err}/\chi_2^2+\sigma_{3,err}/\chi_3^2+\sigma_{4,err}/\chi_4^2}{1/\chi_1^2+1/\chi_2^2+1/\chi_3^2+1/\chi_4^2}, \qquad (2)$$

where $\bar{\sigma}$ is the average value of velocity dispersion σ_i $(i = 1, .., 4)$ from all 4 spectral regions, weighted with χ_i^2 $(i = 1, .., 4)$ value of each region and $\bar{\sigma}_{err}$ is the average value of the velocity dispersion error $\sigma_{1,err}$ $(i = 1, .., 4)$ weighted in the same way.

The resulting values will be closer to those with the smaller χ^2 values, i.e. better fitted regions. The largest error from all 4 regions is taken as the final error of the velocity dispersion. These errors are very similar to those given by Eqn. (2) as can be seen from Fig. 2 (grey error bars correspond to the largest errors), where they are compared to somewhat smaller χ^2-errors (black error bars). In Fig. 2 we compare our final results to the known measurements from Ho09, HyperLeda and SDSS databases.

5. CONCLUSIONS

We have selected a sample of 23 galaxies from Ho et al. 2009 (Ho09) that are part of the Sloan Digital Sky Survey (SDSS). For these galaxies we have calculated velocity dispersions using ppxf code (§2) and compared the results with SDSS measurements, Ho09 values and values found in Hyperleda database (§3).

We have very good agreement with SDSS DB measurements, reasonable agreement with Ho09 values and large discrepancies when we compare our results with the data

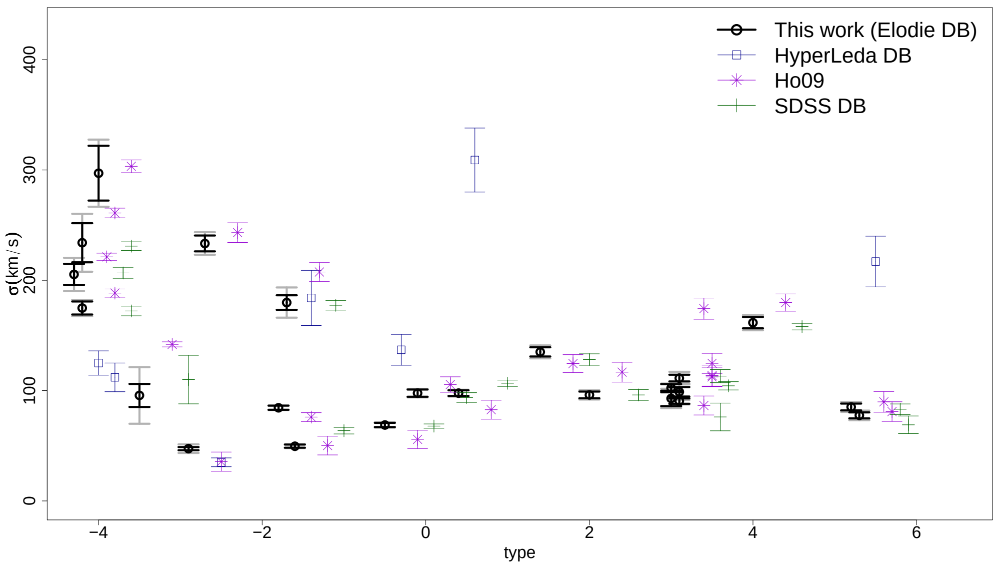

Figure 2: Calculated velocity dispersions with weighted χ^2 errors (black) and largest errors from all 4 regions (gray) compared to the existing measurements indicated in the upper right corner as a function of the Hubble type.

found in Hyperleda database. However, Hyperleda is a compilation of catalogues and the results found there are averaged values from several catalogs.

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