Spectral Classification of Galaxies using the Principal Component Analysis: a Web Based Tool

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ABSTRACT

We have developed a web tool to perform Principal Component Analysis (PCA, Murtagh & Heck 1987; Kendall 1980) onto spectral data. The method is especially designed to perform spectral classification of galaxies from a sample of input spectra, giving the set of orthonormal vectors called Principal Components (PCs) and the corresponding projections. The first two projections of the galaxy spectra onto the PCs are known to correlate with the morphological type (Connolly et al. 1995) and, following Galaz & de Lapparent (1998), we use the parameters δ and θ which define a spectral classification sequence of typical galaxies from ellipticals to late spirals and star-forming galaxies. The program runs in the website http://azul.astro.puc.cl/PCA/ and can be used without downloading any binary files or building archives of any kind.

Subject headings: Spectral classification of galaxies: PCA — galaxies: spectral analysis

1. THE METHOD: BRIEF INTRODUCTION

In the context of Principal Component Analysis (PCA), each individual galaxy spectrum is treated as a single data point in a multi-dimensional space. The aim of the method is to find a set of orthonormal vectors that best describe the intrinsic relation between these data. These vectors are called Principal Components (PC’s) and satisfy the condition of minimal Euclidean distance from each data point to the axes defined by this new base. A detailed description of the PCA technique can be found in Murtagh & Heck (1987), and in Kendall (1980). Connolly et al. (1995) have shown using the spectra from Kinney et al. (1996), that the first 2 projections of the PCA define a sequence tightly correlated with the morphological type. Following Galaz & de Lapparent (1998), two parameters are used for the spectral classification of galaxies, due to its geometrical meaning. These parameters are δ and θ, and are defined as follows:

\[
\delta = \arctan \left( \frac{\alpha_2}{\alpha_1} \right) \quad (1)
\]

\[
\theta = \arcsin (\alpha_3) \quad (2)
\]

where \(\alpha_1, \alpha_2\) and \(\alpha_3\) are the projections of the corresponding spectrum onto the first, second and third Principal Component, respectively. The physical meaning of \(\delta\) is the relative contribution of the red (or early) and the blue (or late) stellar populations within a galaxy and \(\theta\) is related to the presence of significant emission lines in the spectrum.

It is worth mentioning that the definitions of \(\delta\) and \(\theta\) above, only makes sense if the first 3 projections carry most of the contribution to the total variance, that is: \(\sqrt{\alpha_1^2 + \alpha_2^2 + \alpha_3^2} \sim 1\) (see Galaz & de Lapparent 1998).

2. PROGRAM INPUT

The program input must be a gzipped tar file (tar.gz). The file must contain 1-D calibrated spectra (in the FITS format), both in flux and wavelength. It is assumed that the spectra are completely reduced (sky and cosmic ray-subtracted, no fringing, etc.) and corrected to the rest-frame wavelength. Each FITS spectrum must have a unique name (no more than 50 characters) and a maximum number of 50,000 spectra is allowed by the code. It is possible that the spectra may have different spectral coverage and resolution. The program can rebin the spectra automatically (using a cubic spline function) or by giving a proper wavelength step (in angstroms).

3. PROGRAM OUTPUT

The outputs of the analysis will be in a compressed tar file (tar.gz) and can be downloaded after the execution of the program. Some important results will be provided in the following files:

- DeltaTheta.txt: This file contains the values \(\delta\) and \(\theta\), calculated for each spectrum as defined above.

- Pcs.txt: Here the user can find the Principal Components listed in descending order, being VEC-1 the first PC, VEC-2 the second PC, VEC-3 the third PC and so on.

- Projections.txt: In this file are the projections of each spectrum onto the eigenvectors (PC’s), being PROJ-1 the projection onto the first PC, PROJ-2 the projection onto the second PC, PROJ-3 the projection onto the third PC, and so on.

- Log.info.txt: This file stores some relevant information about the PCA concerning the spectra cutting...
and rebinning, as well as the spectral range covered and the resolution.

Inside the tar.gz file there is a README with detailed information about each output. As a complementary result, after the analysis it is possible to see some plots of the first PC’s, and a series of interactive plots of the first three projections and the correlating parameters $\delta$ and $\theta$, in which the user can see each galaxy spectrum by clicking on the corresponding data point.

4. SPECIAL CONSIDERATIONS

- For the calculation of the parameters $\delta$ and $\theta$, it is assumed that $<\sqrt{\alpha_1^2 + \alpha_2^2 + \alpha_3^2}> \sim 1$ and only the first three projections are used, but depending on the quality of the spectra the user can look into the file Projections.txt to find the complete set of projections.

- The parameters $\delta$ and $\theta$ are calculated using the $\sqrt{\alpha_1^2 + \alpha_2^2 + \alpha_3^2} = 1$ normalization as defined in Galaz & de Lapparent (1998).

- The program can be used through the website [http://azul.astro.puc.cl/PCA/]. Please report problems, suggestions, and possible bugs to mor-tiz@astro.puc.cl or ggalaz@astro.puc.cl.

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