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Separation of stars and quasars in multispectral images of J-PAS, J-PLUS, S-PLUS and ALHAMBRA

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Abstract. In order to classify stars and quasars from the data collected by J-PAS and other multi-band surveys, we elaborated a method that essentially consists in Principal Component Analysis (PCA), which was primarily applied on ALHAMBRA database. This database contains images in 20 different bands of a small area of the northern sky. We obtained some graphical results that show different regions of stars and quasars densities, allowing us to classify 79 quasar candidates in the studied area. A procedure to measure the redshift of each object is employed using thousands of known quasars by simulating the 20 bands of ALHAMBRA from the SDSS spectra of these quasars. We tested this procedure on the known QSOs of ALHAMBRA, and it returned 65.15% of the redshifts at the second decimal place. 16 out of the 79 QSO candidates had their redshift estimated within STD < 0.1.

Resumo. Para classificar estrelas e quasares de dados coletados pelo J-PAS e outros *surveys*, elaboramos um método baseado em Análise de Componentes Principais que foi aplicado, primordialmente, aos dados do ALHAMBRA. Estes dados referem-se a imagens em 20 dferentes bandas de uma pequena área do hemisfério norte. Obtivemos resultados gráficos que mostram diferentes regiões de densidade para estrelas e quasares, permitindo-nos classificar 79 candidatos a quasar. Para estimar o redshift destes candidatos, foi aplicado um método usando milhares de espectros de quasares conhecidos do SDSS, convoluídos nos filtros do ALHAMBRA. Testamos este método nos QSOs conhecidos do ALHAMBRA, retornando 65.15% dos redshifts na segunda casa decimal. Dos 79 candidatos a quasar, 16 tiveram seus redshifts estimados com STD < 0.1.

Keywords. quasars: general – methods: statistical

1. Introduction

Elaborating a method based only on multi-band photometry to separate point-like objects into stars or quasars (QSOs) allow us to possibly find QSOs not cataloged. Finding new QSOs and determining their redshifts is a crucial first step for understanding the physics of QSOs and their environments and for using them as tracers of large scale structure. In order to devise a method to accomplish such a goal, we applied Principal Component Analysis (PCA) on 8 ALHAMBRA fields (Moles et al., 2008), for which images in 20 optical and 3 NIR bands are available, covering 3 square degrees. We sampled stars from ALHAMBRA, i.e., point sources at a high confidence level (Molino et al., 2014), but some of them could be misclassified QSOs. In addition, we have 198 known QSOs identified in the ALHAMBRA fields (Matute et al., 2012). Both samples have objects with magnitudes 17 < F814W < 21. Our objective is to find new QSOs and determine their redshifts, by using approximately 90k sloan spectra convolved with the ALHAMBRA filters.

2. Principal Component Analysis

The PCA was applied on 10 parameters, which were chosen based on their contrasting behaviours for QSOs and stars. Those parameters are: standard deviation (STD), skewness and kurtosis of the residuals from linear regression applied on the SED, slope of that linear regression, Hα, Hβ, D4000, J – H, H – KS and J – F954W. Plotting two different principal components, one against the other, shows two different locus for QSOs and stars as seen in Figure 1. In order to disregard the real stars on our data, we selected the objects above the dashed line in top panel of Figure 1 and applied PCA again, obtaining the bottom panel of the same figure. Therefore, we estimated in Section 3 the redshift for all the objects in bottom panel of the Figure 1 to get the best QSO candidates.

3. Redshift estimation

Unlike QSOs, stars are not receding by the cosmological expansion, so their stellar spectra are not affected by redshift. Therefore estimating the redshifts of our QSO candidates allows us to confirm their classification. For redshift determination, we elaborated the method described for each QSO candidate:

1. Get the residuals from the linear regression to the 18-band SED of each known QSO from SDSS and of the QSO candidate from ALHAMBRA
2. Calculate the root mean square error to each QSO from SDSS:

$$RMSE = \sqrt{\frac{\sum (x_i - y_i)^2}{n}}, \quad (1)$$

   which x_i is the residual i from ALHAMBRA and y_i is the residual i from SDSS, $i = 1, ..., n$.
3. Estimate redshift by the median of the 10 spectroscopic redshifts with lowest RMSE

We only selected objects with estimated redshift higher than 0.1 to ensure that our list of QSO candidates is not contaminated by any stars.

The standard deviation of the 10 spectroscopic redshifts with lowest RMSE give us an idea of how well estimated is our redshift. Objects with STD much greater than zero have no reliable

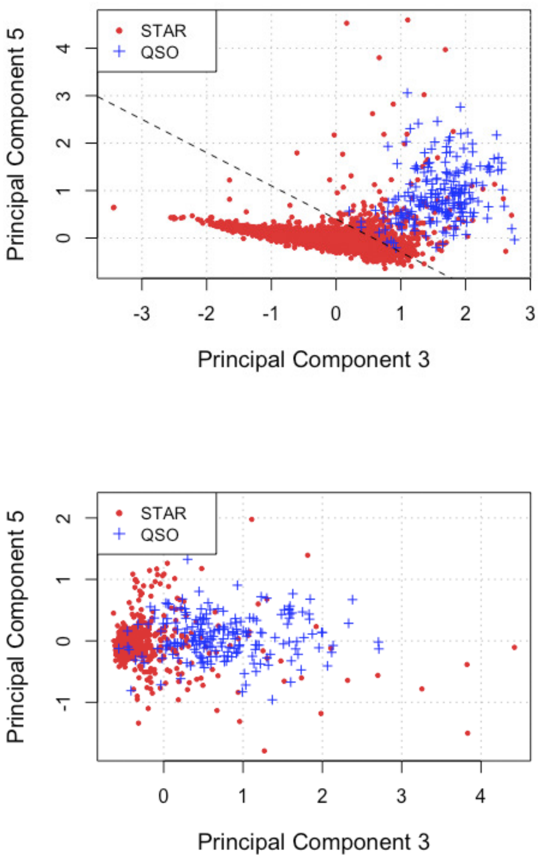

Figure 1. Principal Component 5 versus Principal Component 3, where blue crosses represents known QSOs and red filled circles represents stars. The top panel represents the first run of PCA, while the bottom panel represents the PCA applied only on the objects above the dashed line in top panel.

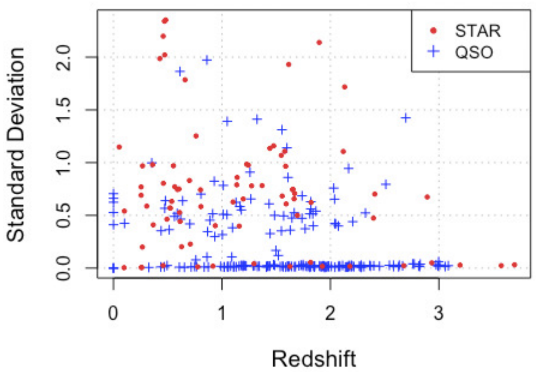

Figure 2. Standard deviation versus estimated redshift, where blue crosses represents known QSOs and red filled circles represents stars, or, actually, candidates of QSO.

estimation. We have 79 QSO candidates, which only 16 have STD ≈ 0 (Figure 2).

Figure 3 shows that most of the redshifts of known QSOs were estimated with low error. Precisely, 65.16% of those QSOs

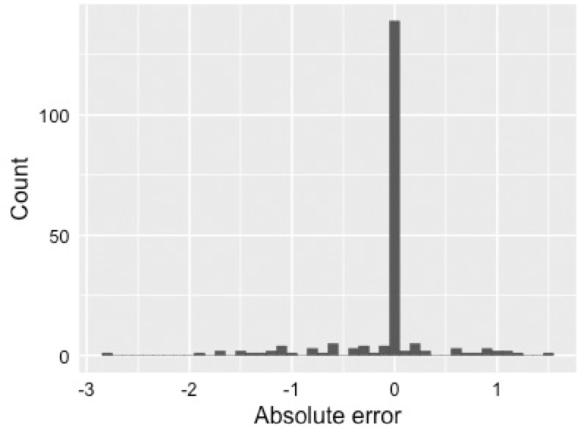

Figure 3. Distribution of the difference between estimated redshift and spectroscopic redshift for the known QSOs

had their redshift estimated at the second decimal place. It increases to 88.89% when considering those with STD ≈ 0.

4. Conclusions

We have found 79 QSO candidates by applying PCA on some defined parameters. Accordingly, the PCA seems a great tool to find new quasars among stars only using photometric data. Our method to estimate redshift returned 65.15% of known QSOs' spectroscopic redshift at the second decimal place, leading us to accept that this method can be useful. Finally, 16 of our QSO candidates had their redshift well determined (STD < 0.1). They are on fields 2, 3, 4, 6 and 7 with 15'x15' area from ALHAMBRA. We intend to observe the spectra of those objects to ensure that our results are correct.

References

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