

# S-PLUS: Emission line objects in the southern photometric local Universe survey

L. A. Gutiérrez-Soto,<sup>1</sup><sup>★</sup> Second Author,<sup>2</sup> Third Author<sup>2,3</sup> and Fourth Author<sup>3</sup>

<sup>1</sup>Departamento de Astronomia, IAG, Universidade de São Paulo, Rua do Matao, 1226, 05509-900, São Paulo, Brazil

<sup>2</sup>Department, Institution, Street Address, City Postal Code, Country

<sup>3</sup>Another Department, Different Institution, Street Address, City Postal Code, Country

Accepted XXX. Received YYY; in original form ZZZ

## ABSTRACT

The emission line objects are very important objects in astronomy because

**Key words:** keyword1 – keyword2 – keyword3

## 1 INTRODUCTION

The existence of an ionizing radiation field can lead to Balmer hydrogen emission lines. From the presence of the H Balmer lines in the optical spectra of some sources it is well known the possible presence of ionized gas. Many important astronomical objects involve the physics of photo-ionized gases and the interpretation of the emission-line spectra. Emission line objects as the H II regions allow us to study the star formation history of the far reaches of our Galaxy and of distant galaxies. Planetary nebulae let us to see the remaining envelope of dying stars. Star-burst galaxies and QSOs are one the most luminous objects and hence the most distant that can be observed. Their spectra can reveal details about of the first generation of star and the formation of heavy elements in the young universe. On the other hand, emission lines can also infer the presence or lack the accretion discs (Schwope et al. 2000; Ratti et al. 2012), the properties of single or double picked line can allow us to infer geometrical characteristics (Horne & Marsh 1986), the nature of donor stars in binary system (Steeghs & Casares 2002; van Spaandonk et al. 2010; Casares 2015) and the compact objects as black holes (Casares 2016).

Emission lines are also associated with stars in very early-type and/or very late evolutionary stage which are short phase. As already mentioned are also associated with binaries that experiencing mass transfer. These group of emission line stars includes young stellar (YSOs) and Herbig-Haro (HH) objects, post-asymptotic and some asymptotic giant branch (AGB), some red giant stars (RGB), Wolf-Rayet (WR) stars, supernova remnants, classical Be stars, active late-type dwarfs, interacting binary system like symbiotic stars (SySt) and cataclysmic variables (CV). Most of these class of object are in-homogeneous and some contains many few identified members, for instance at the moment around 323 symbiotic system have been identified from which 257 belong to the Galaxy and ~66 are extra-galactic objects (Akras et al. 019a). The same occurs with PNe from witch around 3500 of them are been cataloged (Parker et al. 2016), this current number of PNe represents only about 15-30% of the estimated total of Galactic PNe (Frew, 2008; Jacoby et al.,

2010) showing that a small fraction of the PNe have been cataloged. Many galaxies, in addition to harbor Planetary nebulae and H II regions, show characteristic nebular in their spectra. In most of these objects, the gas is photoionized by hot stars in the nucleus, which is thus much like giant H II region, or perhaps many H II regions. The galactic nucleus with very strongest emission lines of this type are often called blue compact galaxies, extragalactic H II regions, star forming or starburst galaxies (Osterbrock & Ferland 2006). There are also spiral galaxies that present emission lines.

In the past H surveys with modest spatial resolutions have been used to identified extended nebular emission to study supernova remnants, galaxy groups and star forming regions (Davies, Elliott Meaburn 1976). More recently, higher resolution surveys such as the INT Photometric H $\alpha$  survey (IPHAS; Drew et al. 2005; Barrentsen et al. 2014) have focused in the study of compact emission line sources on the Galactic plane, typically with objects in different stage of stellar evolution. The Anglo-Australian Observatory UKS chmidt Telescope Supercosmos H $\alpha$  Survey (Parker et al. 2005) is another H $\alpha$  survey of the Southern Galactic Plane and Magellanic Cloud which has covered to b ~ 10-13° (verificar esto). Currently ongoing is the VST Photometric H $\alpha$  Survey of the Southern Galactic Plane and Bulge (VPHAS+; Drew et al. 2014) that will cover the Galactic bulge and plane in five filters.

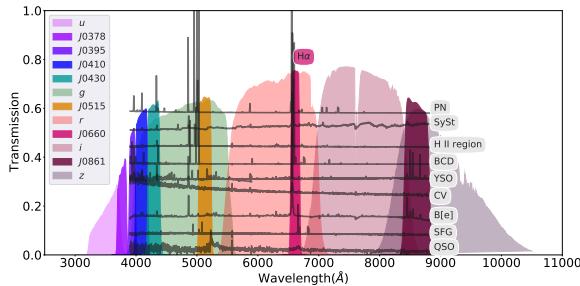
Like VPHAS+, others ongoing surveys that are used to study the population of emission line objects are the The Javalambre Photometric Local Universe Survey (J-PLUS<sup>1</sup>, Cenarro et al. 2018) and the Southern-Photometric Local Universe Survey (S-PLUS<sup>2</sup>, Mendes de Oliveira et al. 2019) are providing observations of the Galactic halo covering both northern and southern celestial hemispheres in a systematic way with twin telescopes using the same set of multi-band filters. In addition to the H $\alpha$  filter, which is already vastly applied to systematically searching for H $\alpha$  emitters the telescopes offer 11 more filters. And more ambitious yet the JPAS survey that will the same area of J-PLUS in 56 narrow-band filters.

Traditionally, color-color diagrams based in H $\alpha$  filter are been used to identify H $\alpha$  emitters. The analysis the color-color diagram (r

\* E-mail: gsoto.angel@gmail.com

<sup>1</sup> <https://www.j-plus.es>

<sup>2</sup> <http://www.splus.iag.usp.br>



**Figure 1.** Transmission curves of the S-PLUS filters set. The narrow-band filter  $J0660$  detects the  $H\alpha$  emission line. Over-plotted are different classes of emission line objects, from upper to down PN, SySt ...

-  $H\alpha$ ) versus ( $r - i$ ) has resulted on the discovered of new emission line objects, for instance Witham et al. (2006, 2007) used the ( $r - H\alpha$ ) versus ( $r - i$ ) colour-colour diagram to find for new CV. On the other hand, Vink et al. (2008) reported the discovery of YSOs by using this same colour criteria. In this sense using this methodology a variety of classes of objects are been identified, which include symbiotic stars (Corradi et al. 2008; Corradi & Giammanco 2010; Corradi et al. 2011), early type emission line stars (Drew et al. 2008) and planetary nebulae (Viironen et al. 2009; Sabin et al. 2010). Recently, by using this same color diagram were also identified compact PN candidates in VPHAS+ catalog (Akras et al. 2019). And the same diagram in conjunction with new ones shows to be very efficient to find for PN candidates (Gutiérrez-Soto et al. 2020). In general terms, Witham et al. (2006) presented a methodology and first results in looking for emission line sources in narrow-band surveys.

In this work, we used S-PLUS observations of the southern hemisphere to search for objects with an excess of  $H\alpha$  using automatic methods based on the ( $r - H\alpha$ ) versus ( $r - i$ ) color-color diagram we also used color criteria based in ( $g - r$ ) and ( $z - g$ ) in conjunction to unsupervised machine learning techniques to split the final list in those with blue and red continuum. The paper is organized as follows...

## 2 OBSERVATIONS

Particularly, we are implemented data from S-PLUS DR3 (ref) to carried out our project. S-PLUS is 12-band optical photometric survey, which are formed by using seven narrow-band and five broad-band like SDSS filters. The narrow-band set include the filter  $J0660$  which detect the  $H\alpha$  emission line. Figure 1 shows the Javalambre filter system (Marín-Franch et al. 2012) overlapping are the optical spectra of several class emission line objects on which it is possible to see that the  $H\alpha$  line falls into the  $J0660$  filter, except for the QSOs.

The actual data release contains about 60 millions of objects, covering a total area of 8000 deg<sup>2</sup>, at high Galactic latitudes ( $\pm 30$ deg) using a dedicated 0.83m robotic telescope, the T80-South (T80S), located at Cerro Tololo, Chile. S-PLUS will cover an additional 1300 deg<sup>2</sup> of the Galactic plane and bulge to enable Galactic studies. In this work, we focus on the aspects that are of particular interest to the second data release of the S-PLUS main survey. Additional information about S-PLUS can be found in Mendes de Oliveira et al. (2019).

## 3 METHODOLOGY

Witham et al. (2008) presented a catalogue of point-sources  $H\alpha$  emission objects identified in IPHAS.

Applying the selection criteria to selecting  $H\alpha$  emitters. We used the same procedure in Wevers et al. (2017). The objects with  $H\alpha$  excess meet the condition:

$$(r - J0660)_{obs} - (r - J0660)_{fit} \geq C \times \sqrt{\sigma_s^2 - \sigma_{phot}^2}$$

where  $\sigma_s$  is the root mean squared value of the residuals around the fit and  $\sigma_{phot}$  is the error on the observed  $(r - J0660)$  colour

Firts see an approximation of the  $4\sigma$  cut away from the original fit.

### 3.1 Maths

### 3.2 Figures and tables

## 4 RESULTS

## 5 CONCLUSIONS

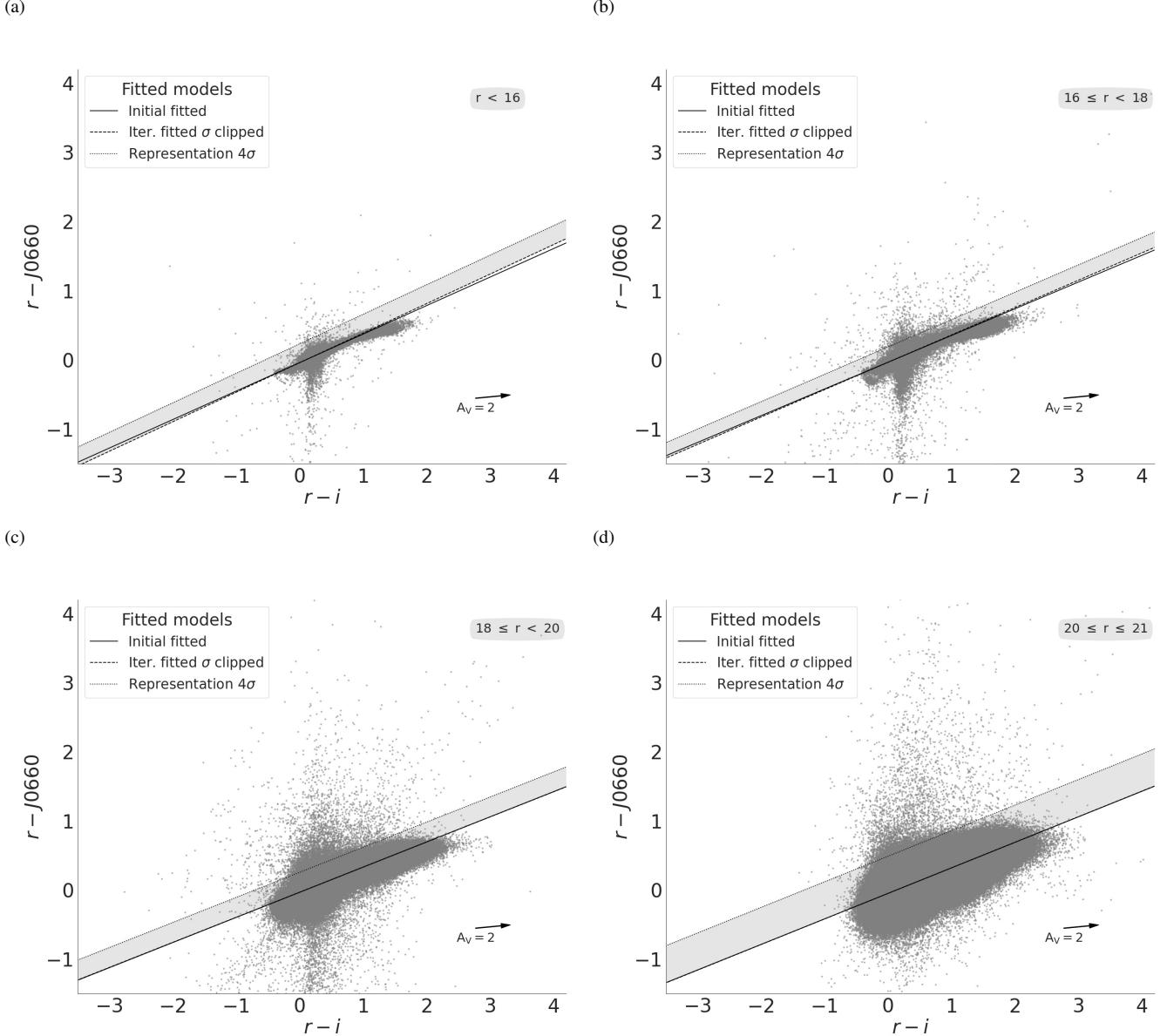
We have found a important sample of emission line objects.

## ACKNOWLEDGEMENTS

## DATA AVAILABILITY

## REFERENCES

- Akras S., Guzman-Ramirez L., Gonçalves D. R., 2019, *MNRAS*, **488**, 3238
- Akras S., Guzman-Ramirez L., Leal-Ferreira M., Ramos-Larios G., 2019a, *ApJS*, 240, 21
- Barentsen G., et al., 2014, *MNRAS*, **444**, 3230
- Casares J., 2015, *ApJ*, **808**, 80
- Casares J., 2016, *ApJ*, **822**, 99
- Cenarro A. J., et al., 2018, preprint, ([arXiv:1804.02667](https://arxiv.org/abs/1804.02667))
- Corradi R. L. M., Giammanco C., 2010, *A&A*, **520**, A99
- Corradi R. L. M., et al., 2008, *A&A*, **480**, 409
- Corradi R. L. M., Sabin L., Munari U., Cetrulo G., Englardo A., Angeloni R., Greimel R., Mampaso A., 2011, *A&A*, **529**, A56
- Drew J. E., et al., 2005, *MNRAS*, **362**, 753
- Drew J. E., Greimel R., Irwin M. J., Sale S. E., 2008, *MNRAS*, **386**, 1761
- Drew J. E., et al., 2014, *MNRAS*, **440**, 2036
- Gutiérrez-Soto L. A., et al., 2020, *A&A*, **633**, A123
- Horne K., Marsh T. R., 1986, *MNRAS*, **218**, 761
- Mendes de Oliveira C., et al., 2019, *MNRAS*, **489**, 241
- Osterbrock D. E., Ferland G. J., 2006, Astrophysics Of Gas Nebulae and Active Galactic Nuclei. Sausalito: University Science Books, <https://books.google.com.br/books?id=HgfrkDjBD98C>
- Parker Q. A., Bojićić I. S., Frew D. J., 2016, in Journal of Physics Conference Series. p. 032008 ([arXiv:1603.07042](https://arxiv.org/abs/1603.07042)), doi:10.1088/1742-6596/728/3/032008
- Ratti E. M., Steeghs D. T. H., Jonker P. G., Torres M. A. P., Bassa C. G., Verbunt F., 2012, *MNRAS*, **420**, 75
- Sabin L., Zijlstra A. A., Wareing C., Corradi R. L. M., Mampaso A., Viironen K., Wright N. J., Parker Q. A., 2010, *Publ. Astron. Soc. Australia*, **27**, 166
- Schwöpe A. D., Catalán M. S., Beuermann K., Metzner A., Smith R. C., Steeghs D., 2000, *MNRAS*, **313**, 533
- Steeghs D., Casares J., 2002, *ApJ*, **568**, 273
- Viironen K., et al., 2009, *A&A*, **502**, 113
- Vink J. S., Drew J. E., Steeghs D., Wright N. J., Martin E. L., Gänsicke B. T., Greimel R., Drake J., 2008, *MNRAS*, **387**, 308
- Witham A. R., et al., 2006, *MNRAS*, **369**, 581



**Figure 2.** An illustration of the selection criteria used to identify strong emission-line objects via colour-colour plots. The data shown here are all from the S-PLUS DR3. The data are split up into four magnitude bins, as shown in the four panels. Objects with H $\alpha$  excess should be located near the top of the colour-colour plots. The thin red lines illustrate the original least-squares fit to all the data (grey points). The thin blue lines represent the final fits to the upper locus of points obtained by applying an iterative  $\sigma$ -clipping technique to the initial fit. The actual cuts used to select H emitters are shown by the thick dashed lines. If the cut was based on the initial (final) fit, it is shown in red (blue). Objects selected as H emitters must be located above the cut and are shown as large triangles. Note that the cut lines shown here are only approximate, as the actual selection criterion also considers the errors on each individual data point. This explains, for example, why an object in the bottom right-hand panel is not selected despite clearly lying above the cut line.

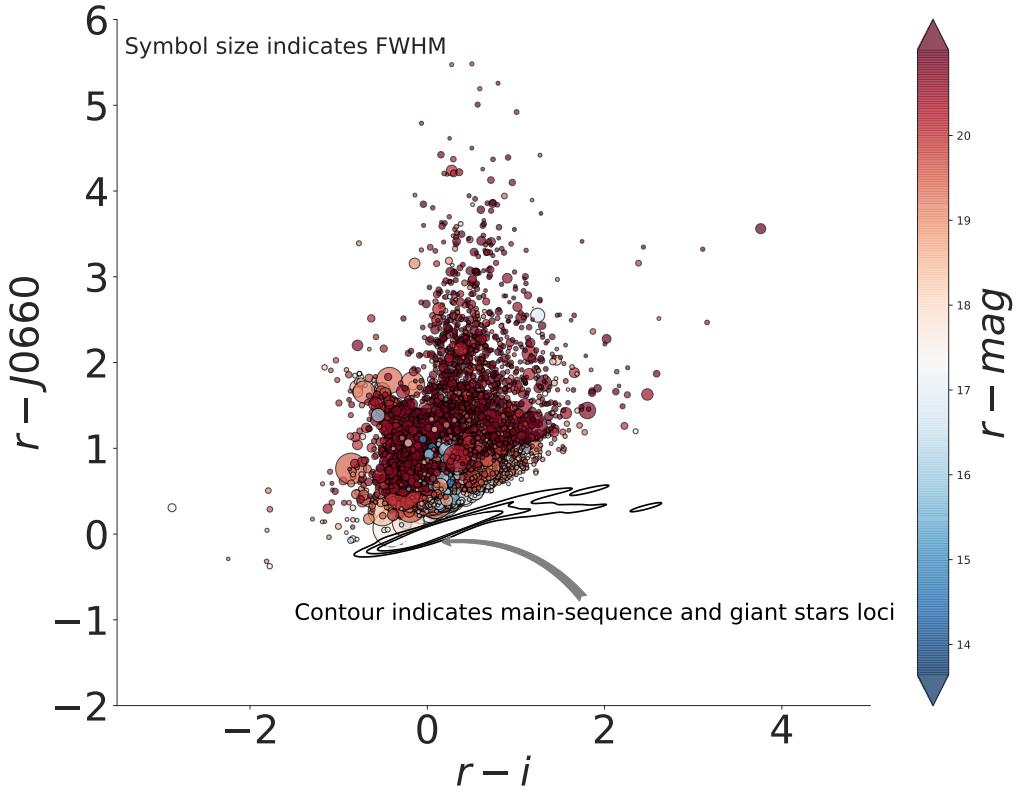
Witham A. R., et al., 2007, [MNRAS, 382, 1158](#)

Witham A. R., Knigge C., Drew J. E., Greimel R., Steeghs D., Gänsicke

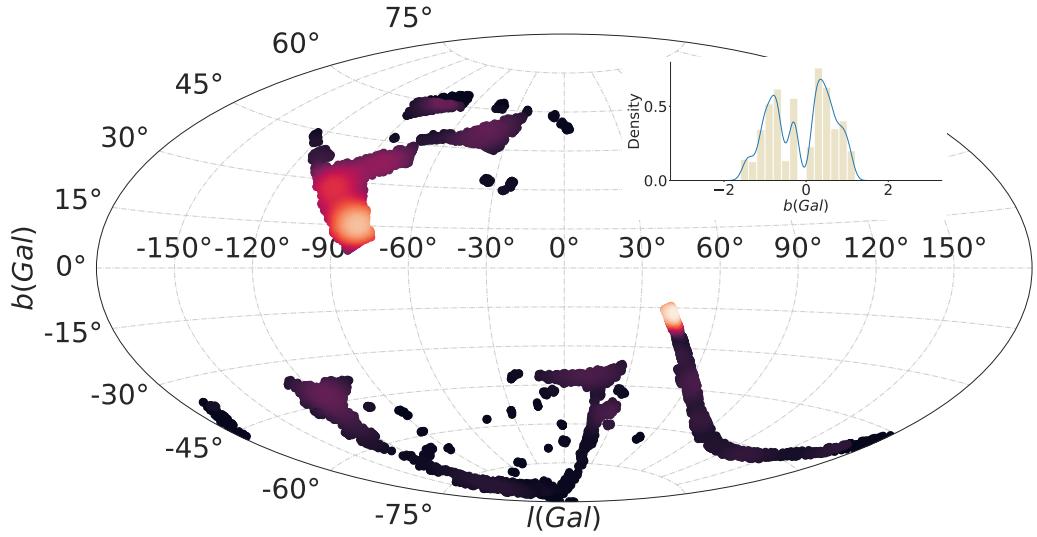
B. T., Groot P. J., Mampaso A., 2008, [MNRAS, 384, 1277](#)

van Spaandonk L., Steeghs D., Marsh T. R., Torres M. A. P., 2010, [MNRAS, 401, 1857](#)

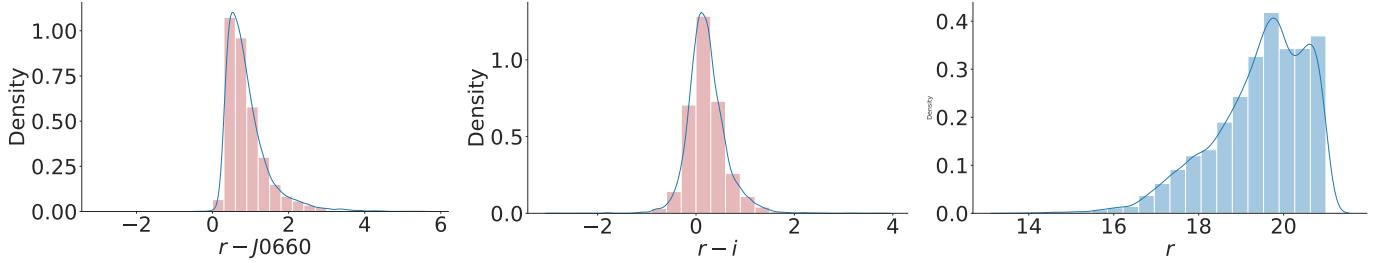
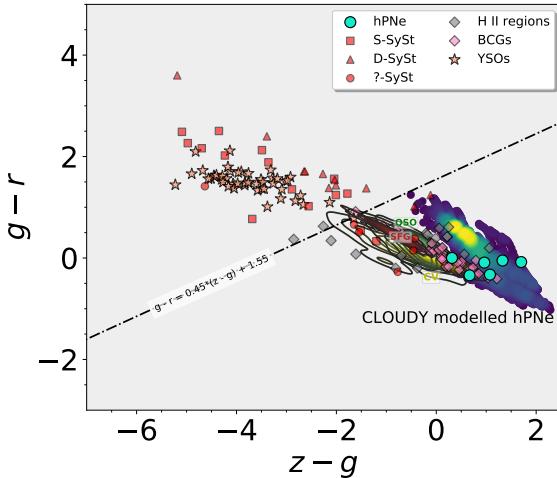
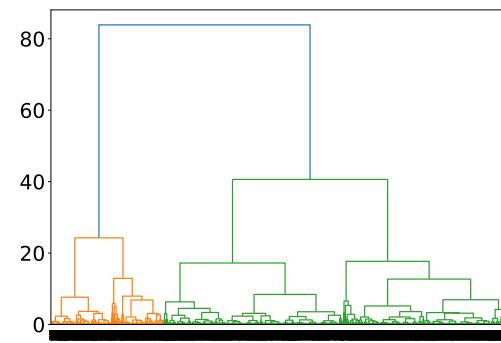
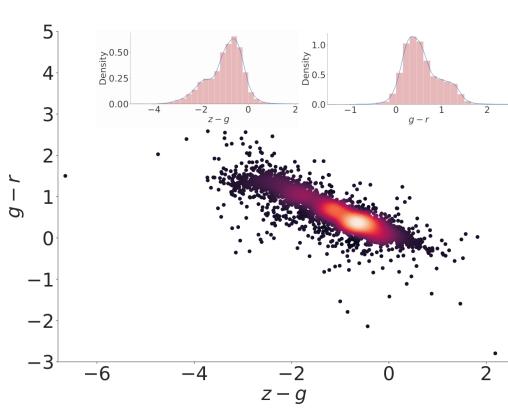
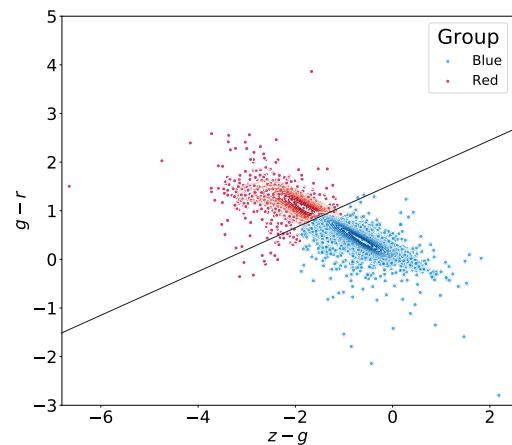
## APPENDIX A: SOME EXTRA MATERIAL

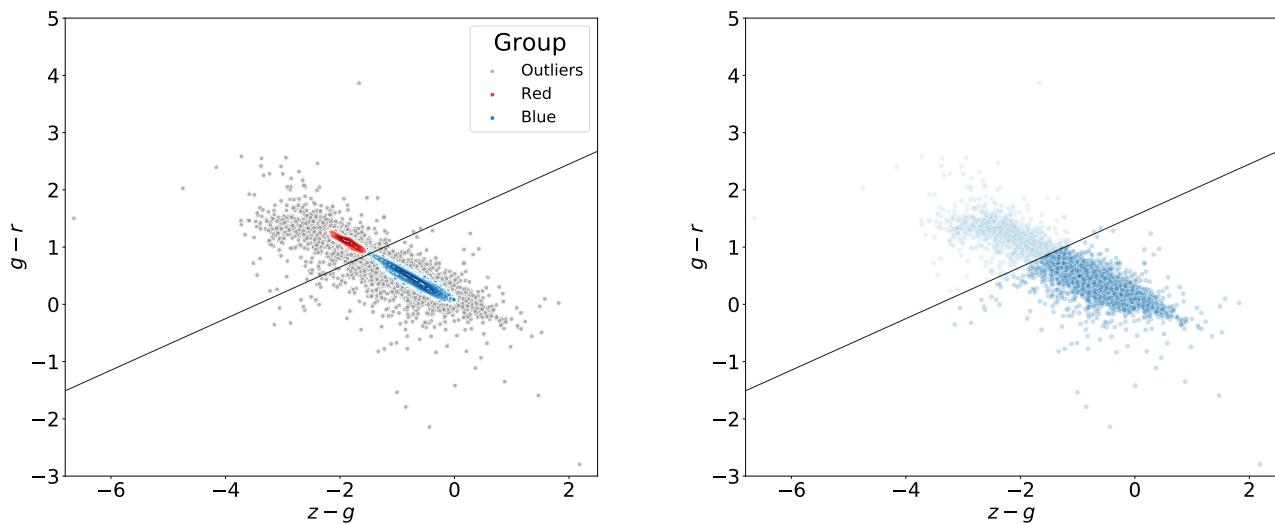


**Figure 3.** CCD of the three samples of outliers. Blue outliers are shown as blue circles, while emitter candidates are shown as grey triangles and absorption line candidates as green diamonds.

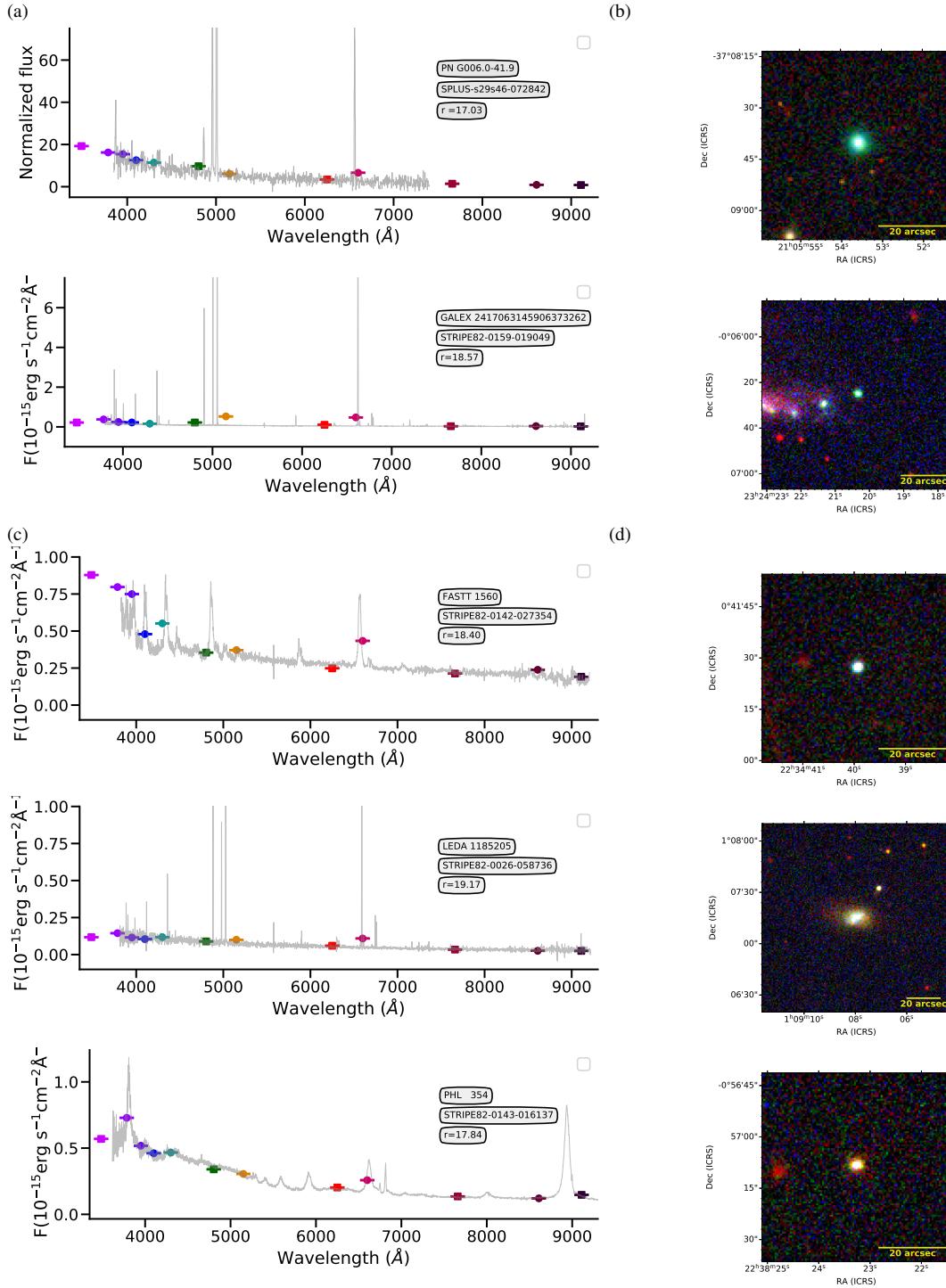


**Figure 4.** This is my embedded figure

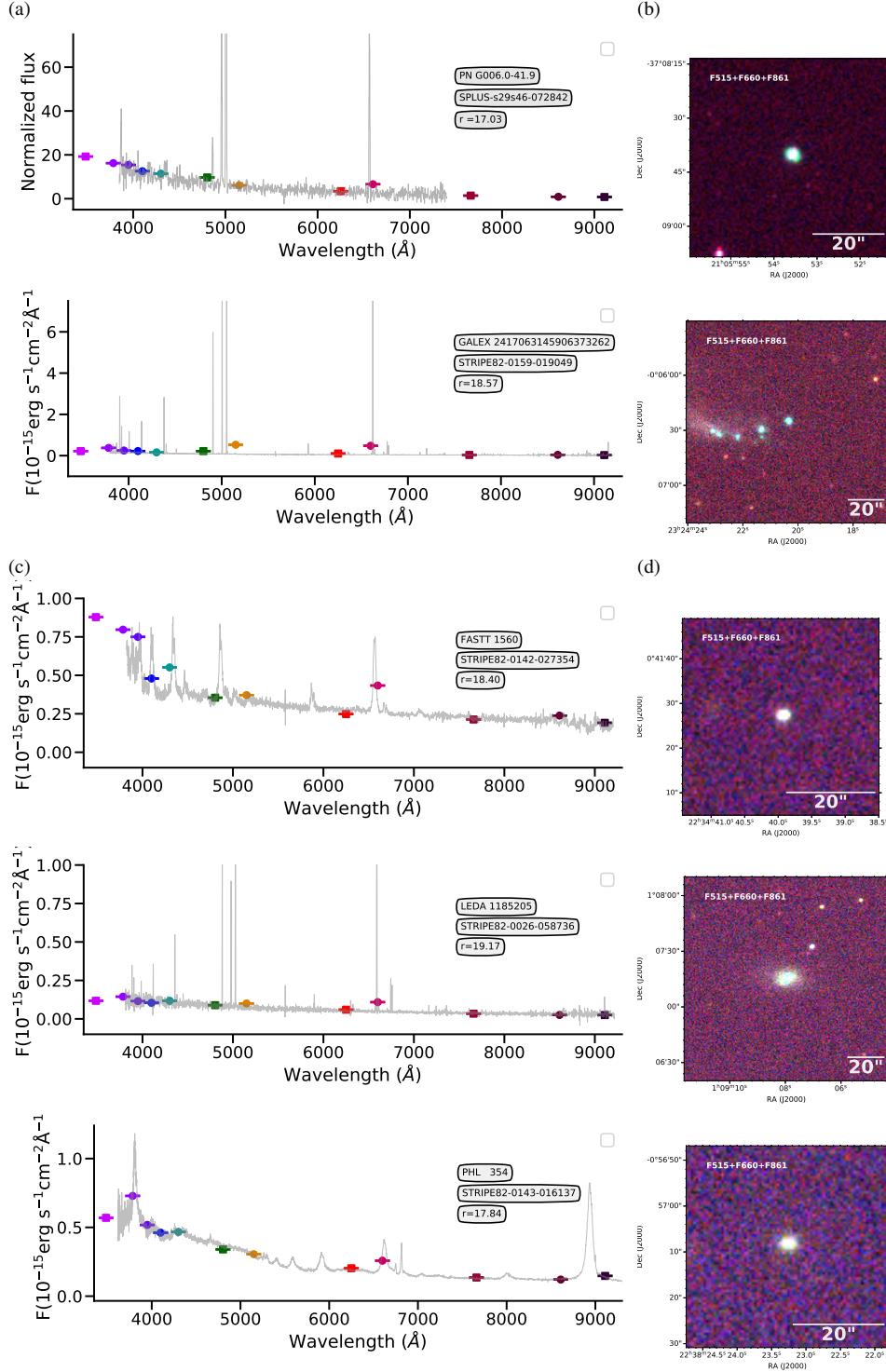
**Figure 5.** Emission lines selected...**Figure 6.** Classifying...**Figure 8.** Costomer dendrogram...**Figure 7.** Classifying...**Figure 9.** Costomer dendrogram...

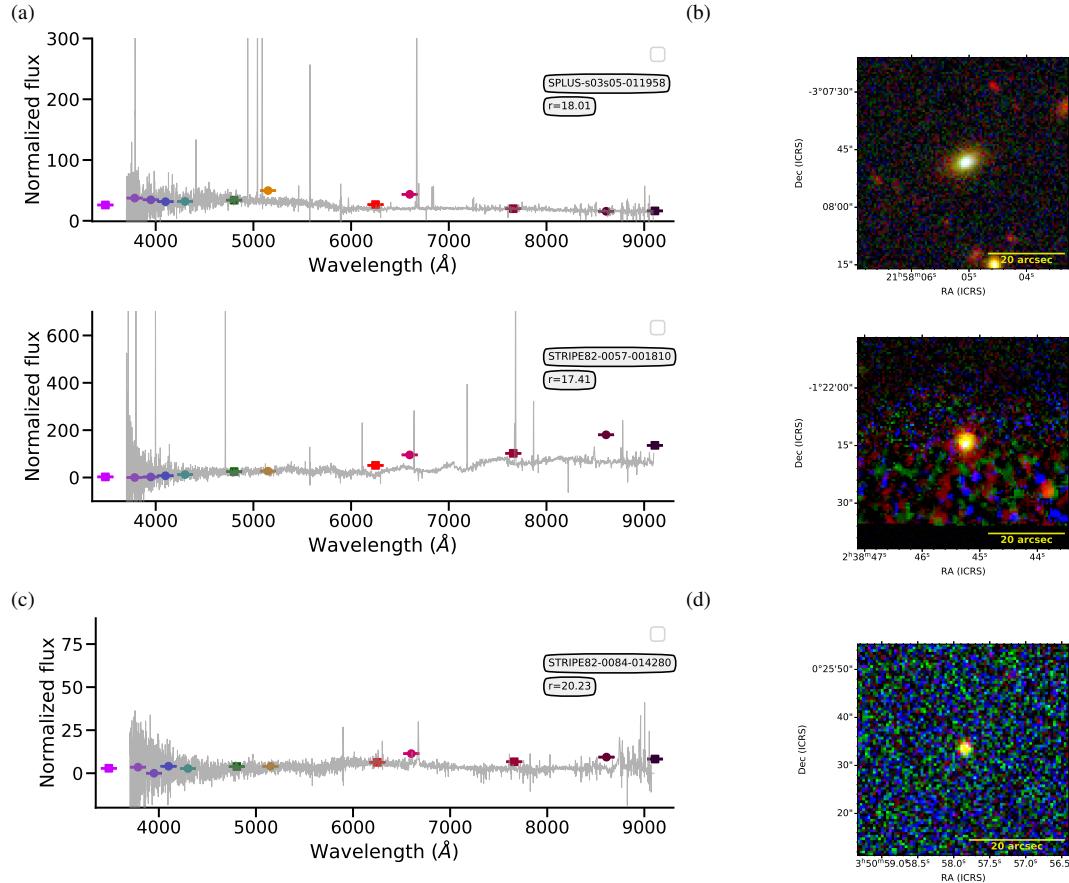


**Figure 10.** New color-color diagram to separate the blue objects from the red ones.

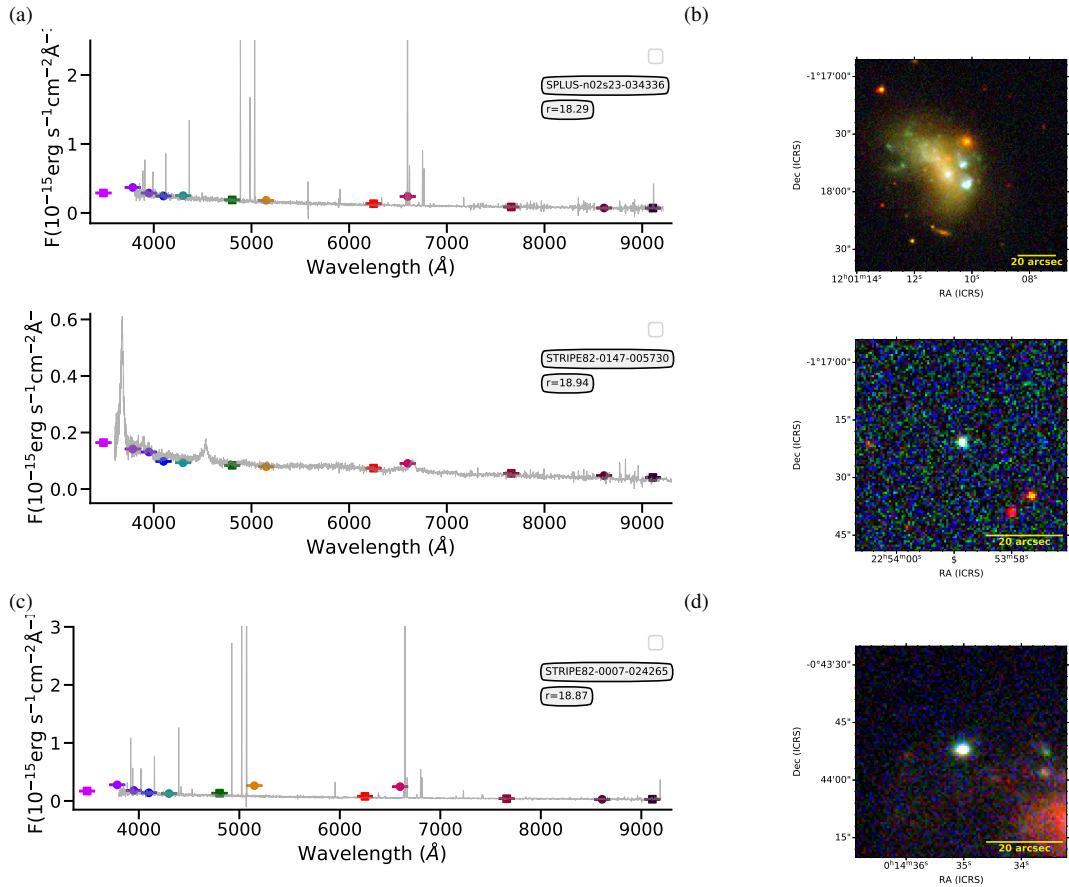


**Figure 11.** Spectra of the known objects select with our algorithm

**Figure 12.** Spectra of the known objects select with our algorithm



**Figure 13.** Spectra of the Lamost

**Figure 14.** Spectra of the SDSS