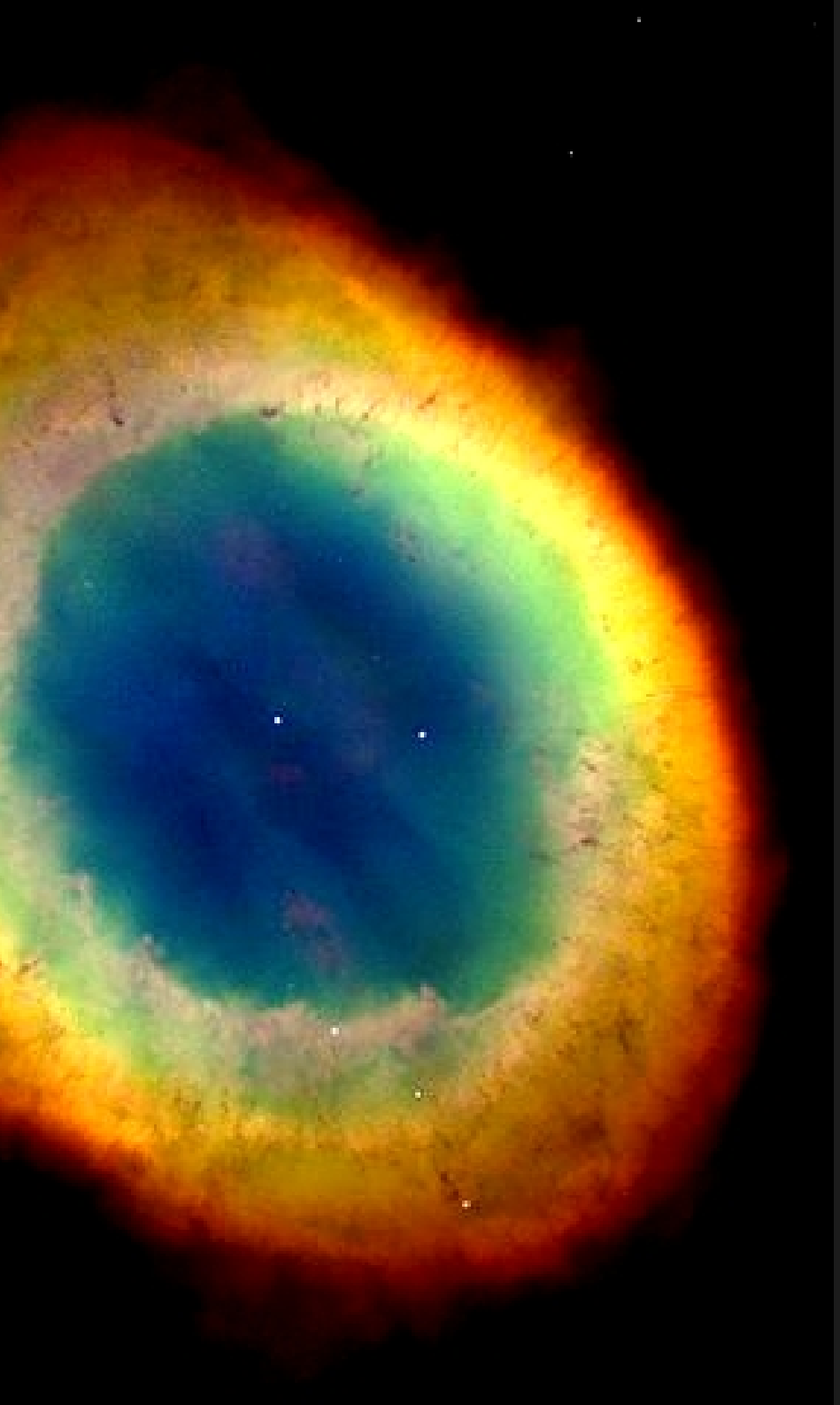

Exploring the PN population in S-PLUS

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Stavros Akras & S-PLUS collaboration

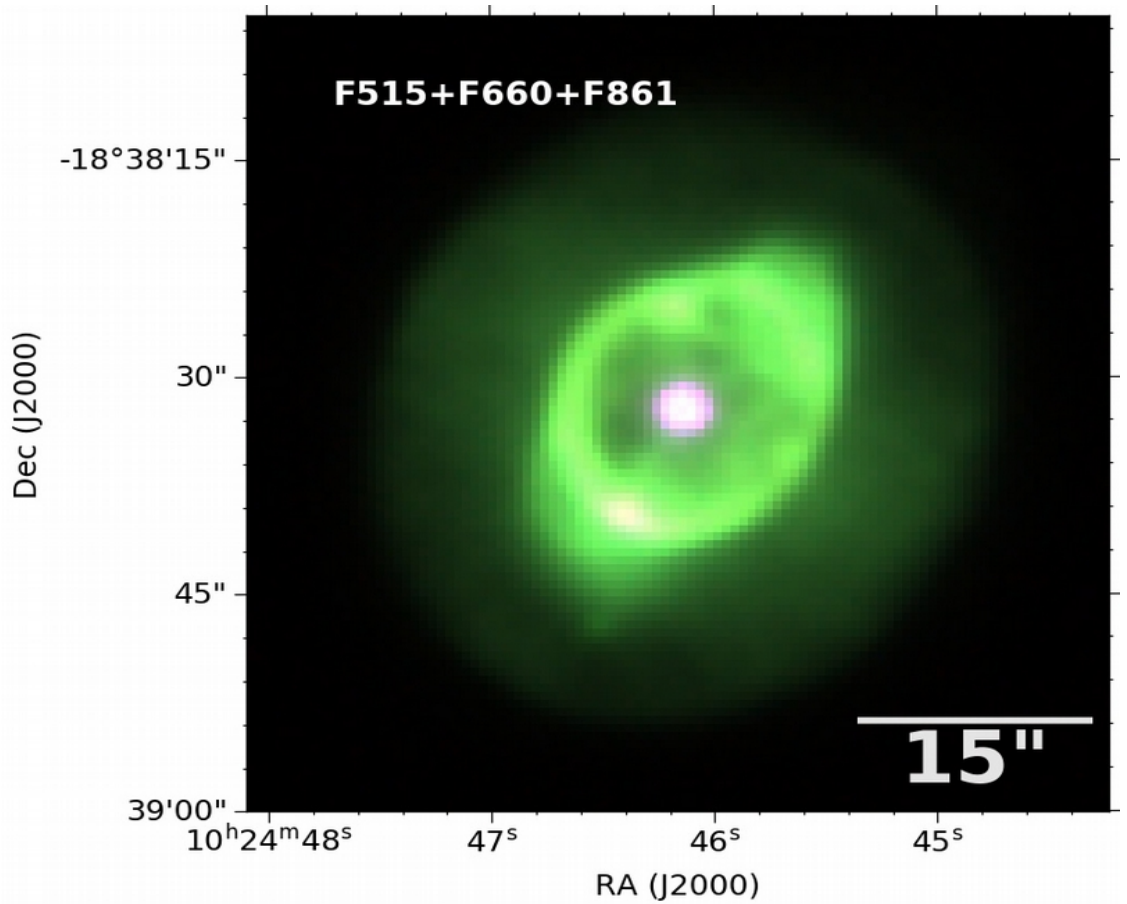
14th S-PLUS Collaboration Meeting
December, 2020

PLANETARY NEBULAE

Are composed by evolved stars

Planetary nebulae (PNe)

NGC 3242, **S-PLUS DR3,** composite image: **Blue: J0515, Green: J0660, Red: J0861**.

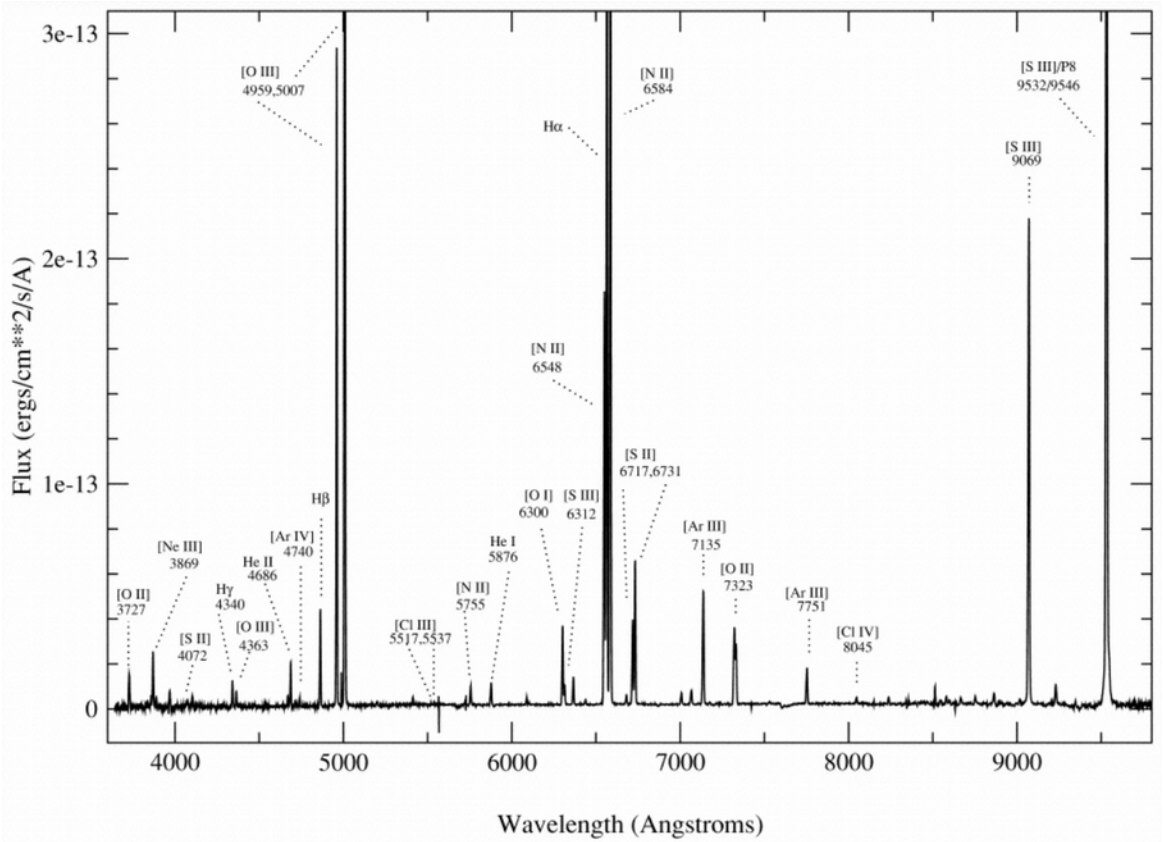


Material is ejected by low- and intermediate-mass stars at the end of their evolution, and then it is ionized by the radiation of this same star in a more evolved stage.

SPECTRA

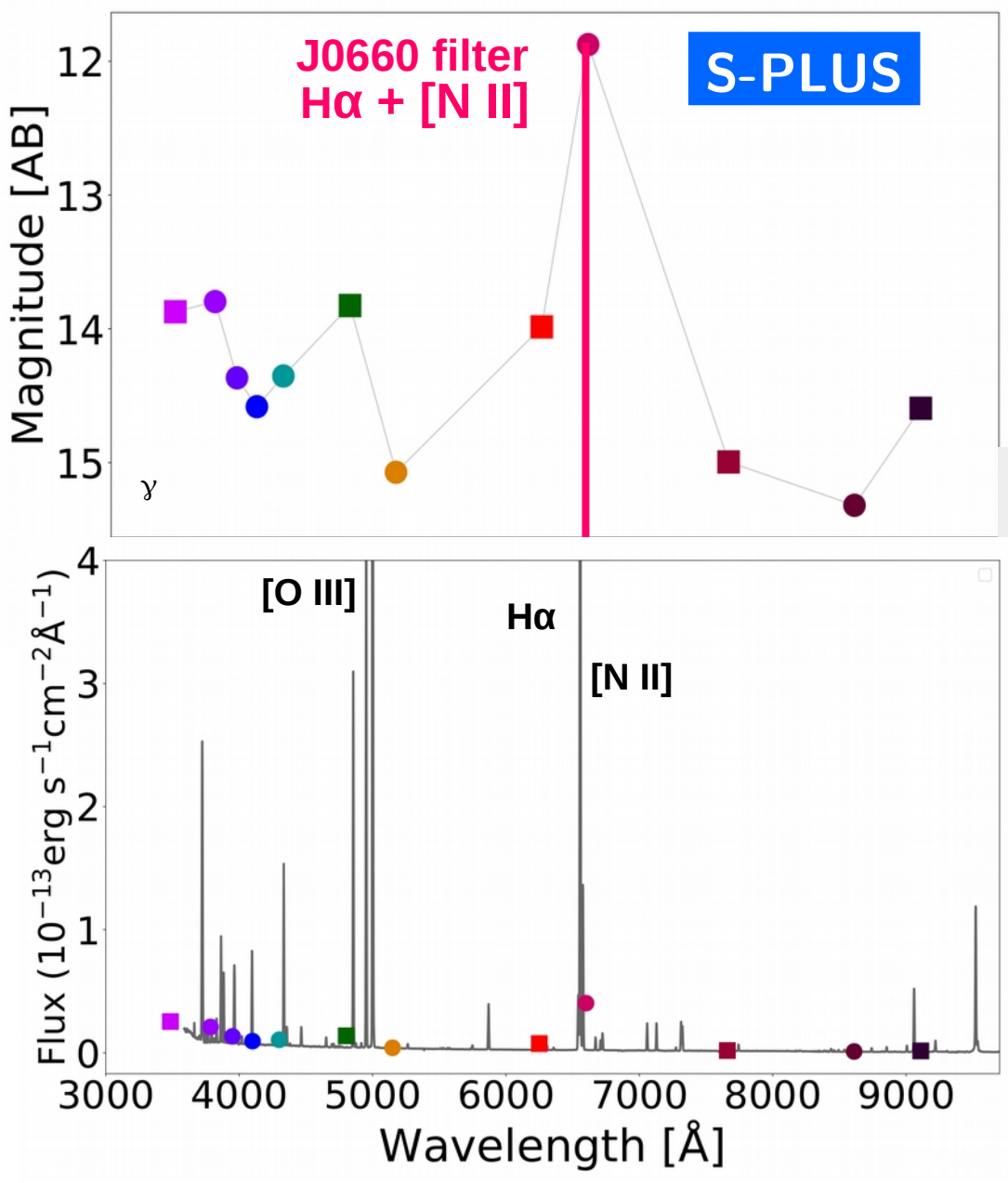
Planetary nebulae (PNe)

PN M1-57 (Kwitter & Henry 2001)



A hot stellar continuum with bright emission lines (recombination and forbidden)

SYNTHETIC PHOTOMETRY OR PHOTO-SPECTRA

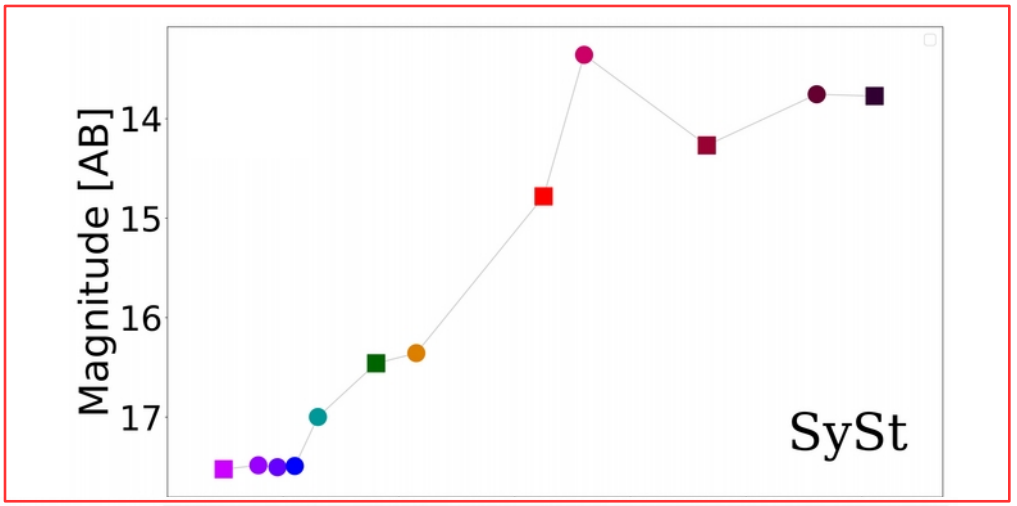


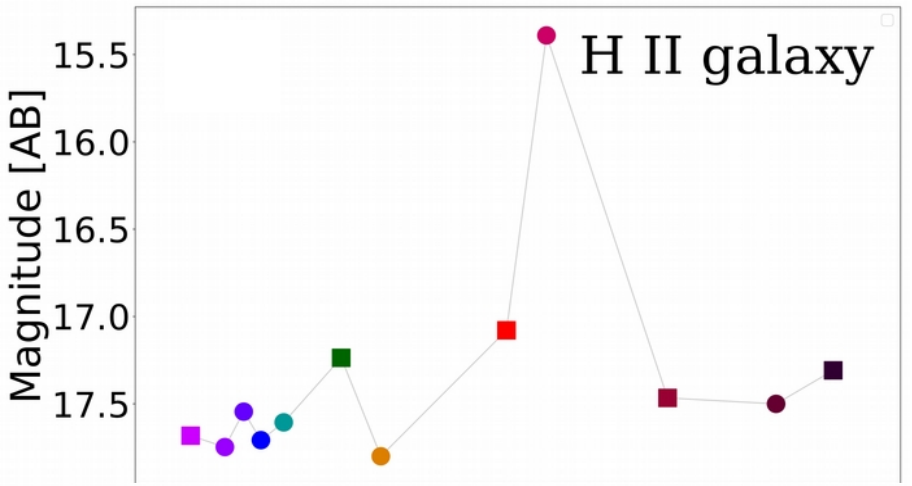
Halo planetary nebula: DdDm 1 (Kwitter et al. 1998)

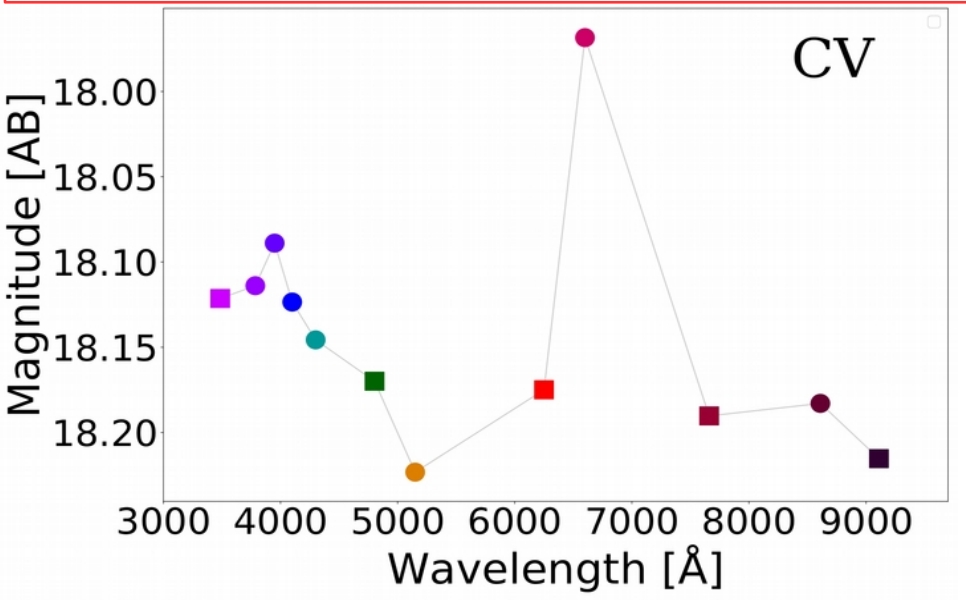
It shows Hα emission in S-PLUS. The narrow-band filter, J0660, detect the Hα + [N II] emission.

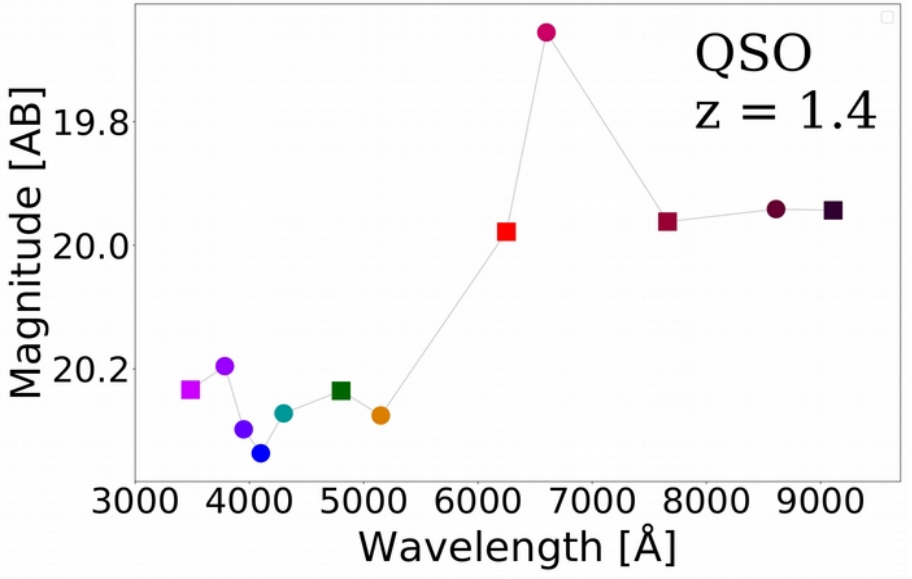
Contaminants S-PLUS photo-spectra

Symbiotic star (SySt), H II/compact galaxies (SDSS), CV (from SDSS); and QSO (SDSS).





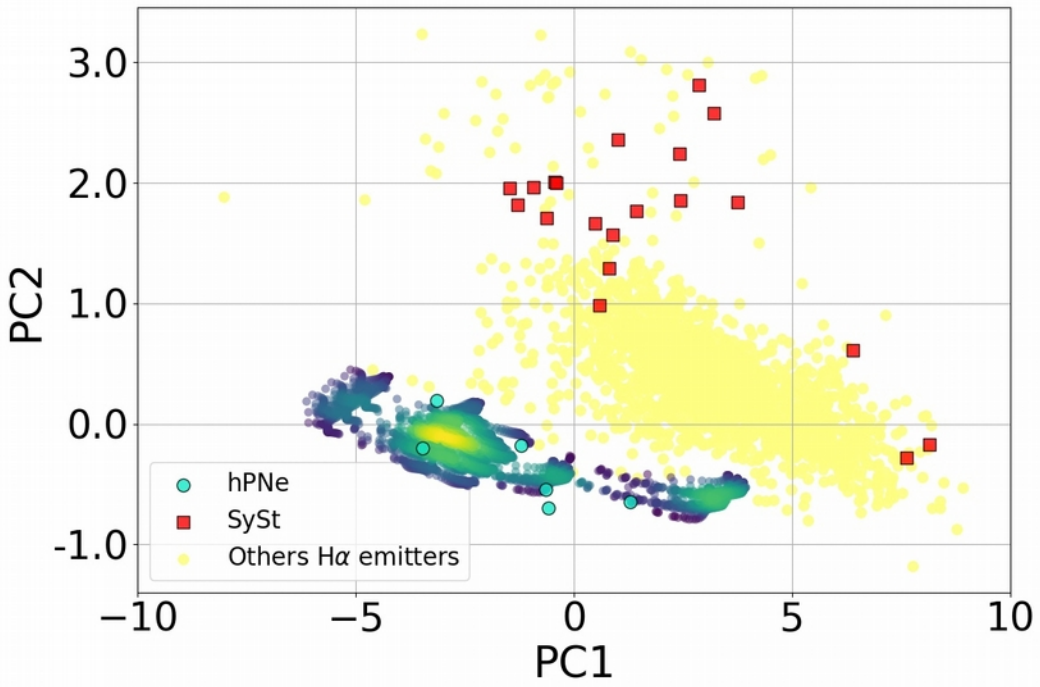


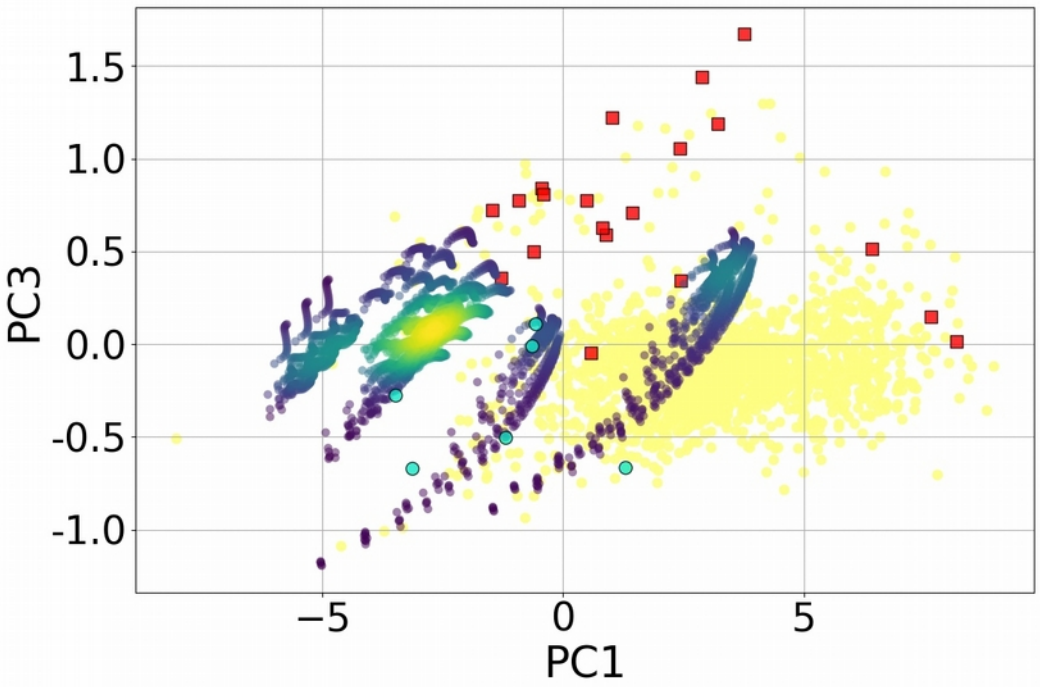


SEARCHING FOR PNe

Principal component analysis

PCA is applied to the S-PLUS synthetic photometry, thus reducing the dimensionality from 12 S-PLUS filters to 3. These 3 new variables explain 99.5% of the total variance of the sample.





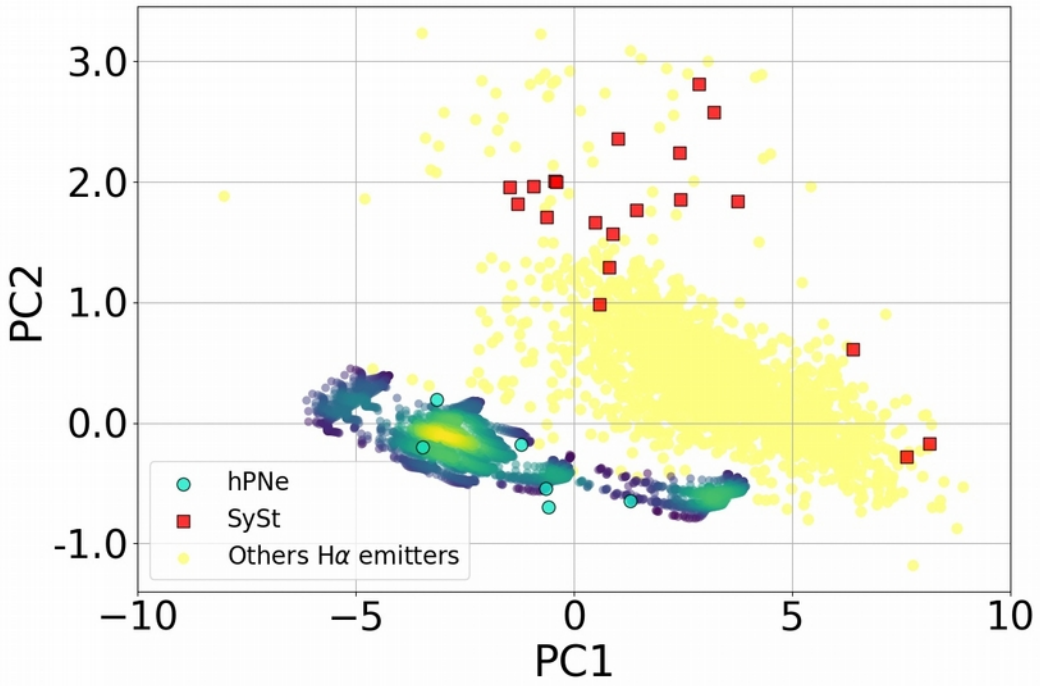
SEARCHING FOR PNe

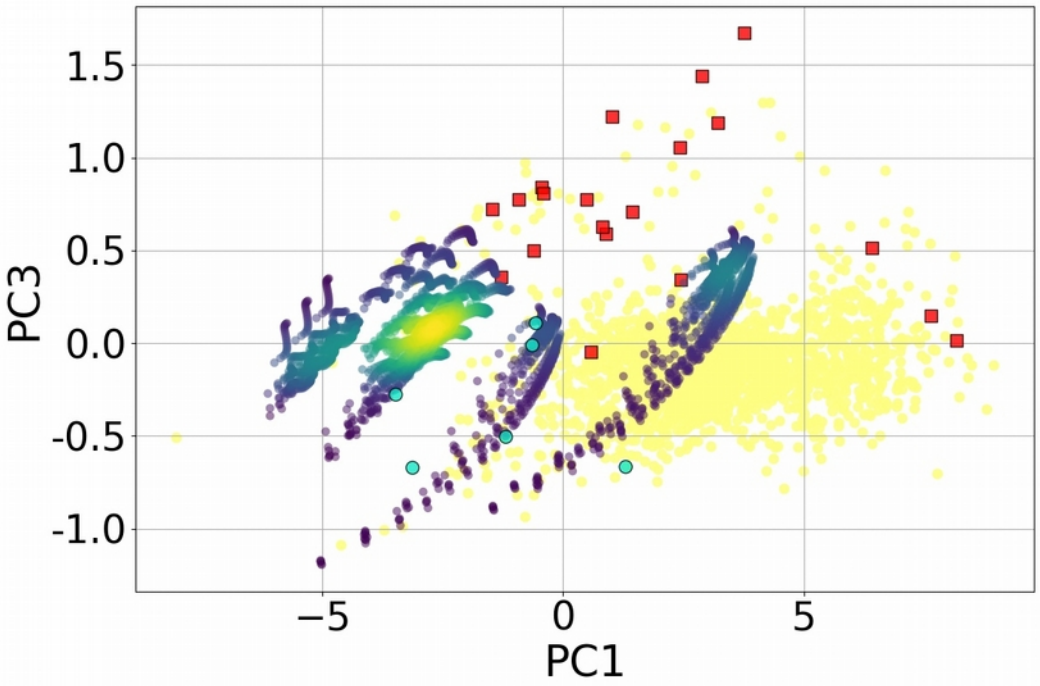
Principal component analysis and logistic regression

PCA is an algorithm to reduce the dimensionality of a sample and highlight the similarities and differences among the different class.

By using the **logistic regression** algorithm the probability of each object to belong to a given class is computed.

Precision = 70%





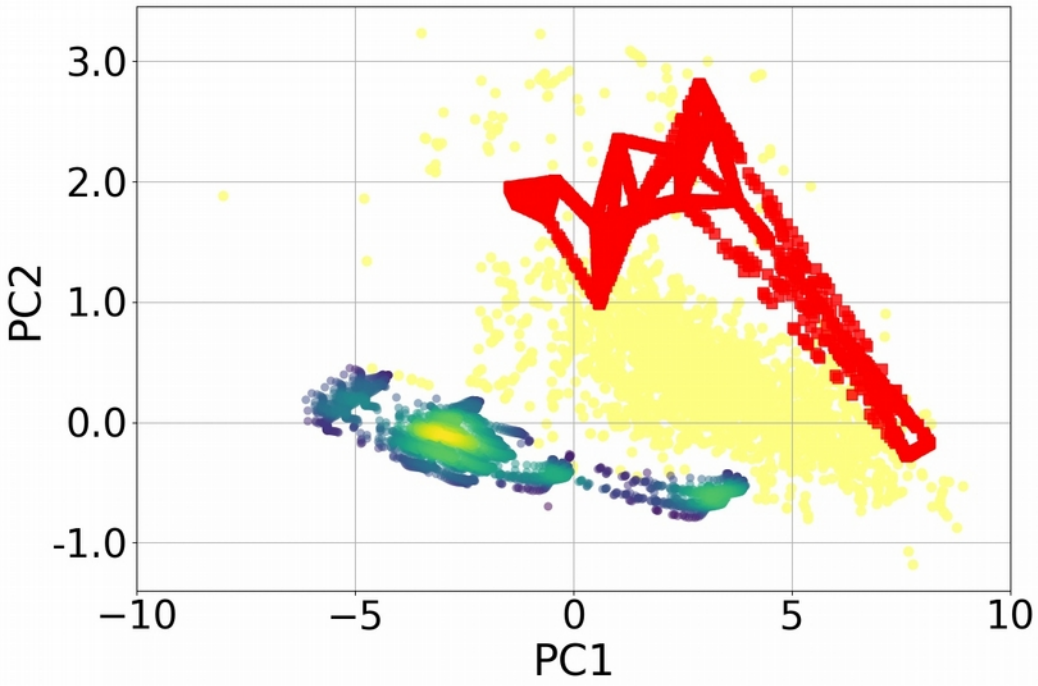
SEARCHING FOR PNe

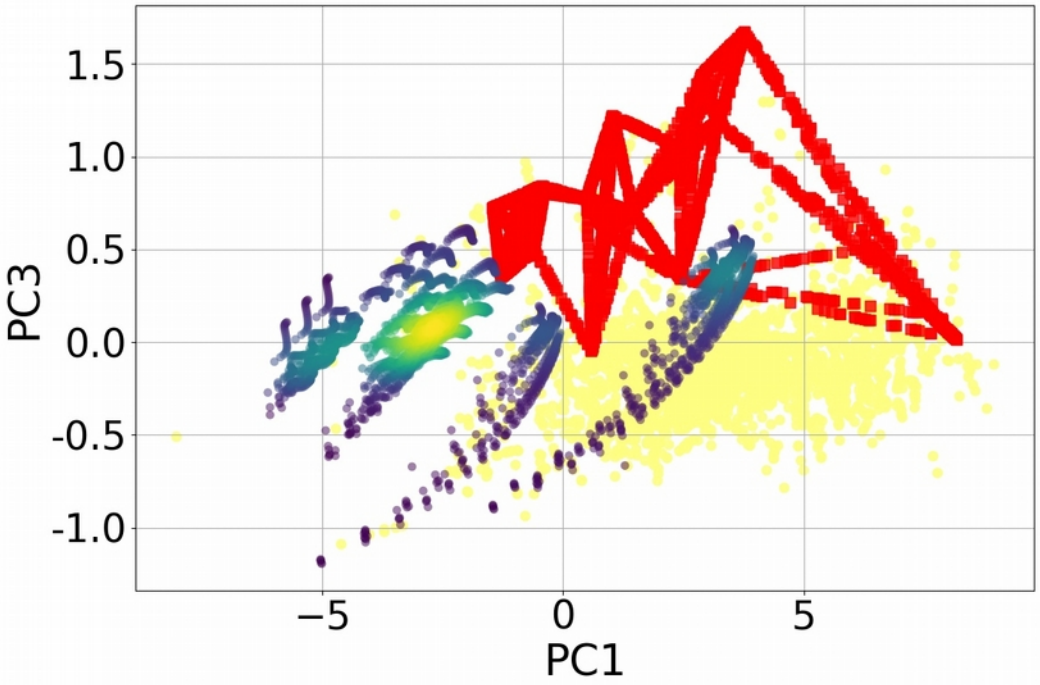
Approach to improve the classification

Data sets are highly imbalanced, 3,700 PNe, 25 SySt and 2400 other type of emission line objects.

Statistical techniques can handle imbalanced samples – A sampling method was used: synthetic minority oversampling technique (SMOTE, Chawla et al. 2002).

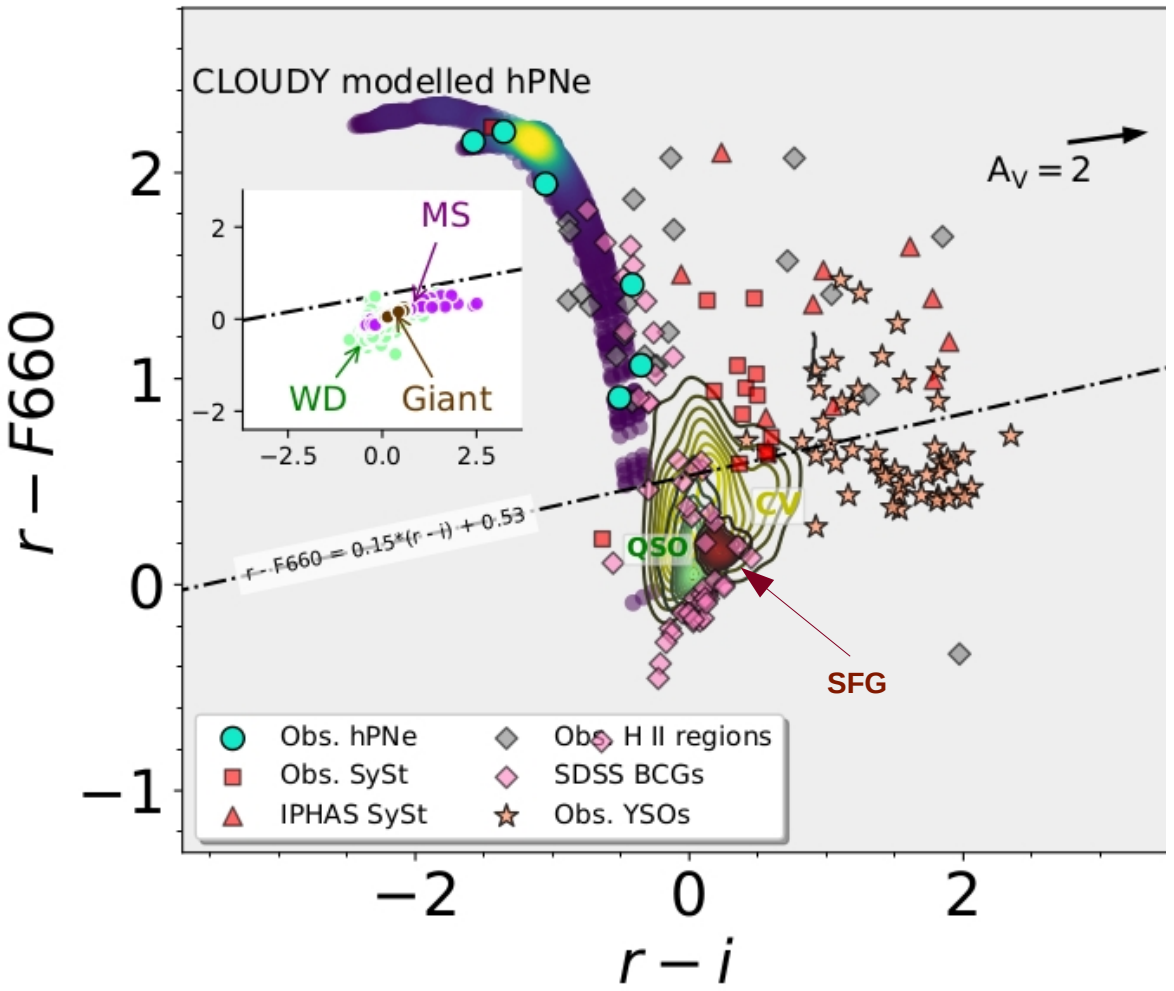
Precision = 95%





PN CANDIDATES

Preparing the sample: We first selected emission lines objects by using colour criteria to guarantee a better performance of the statistical techniques.

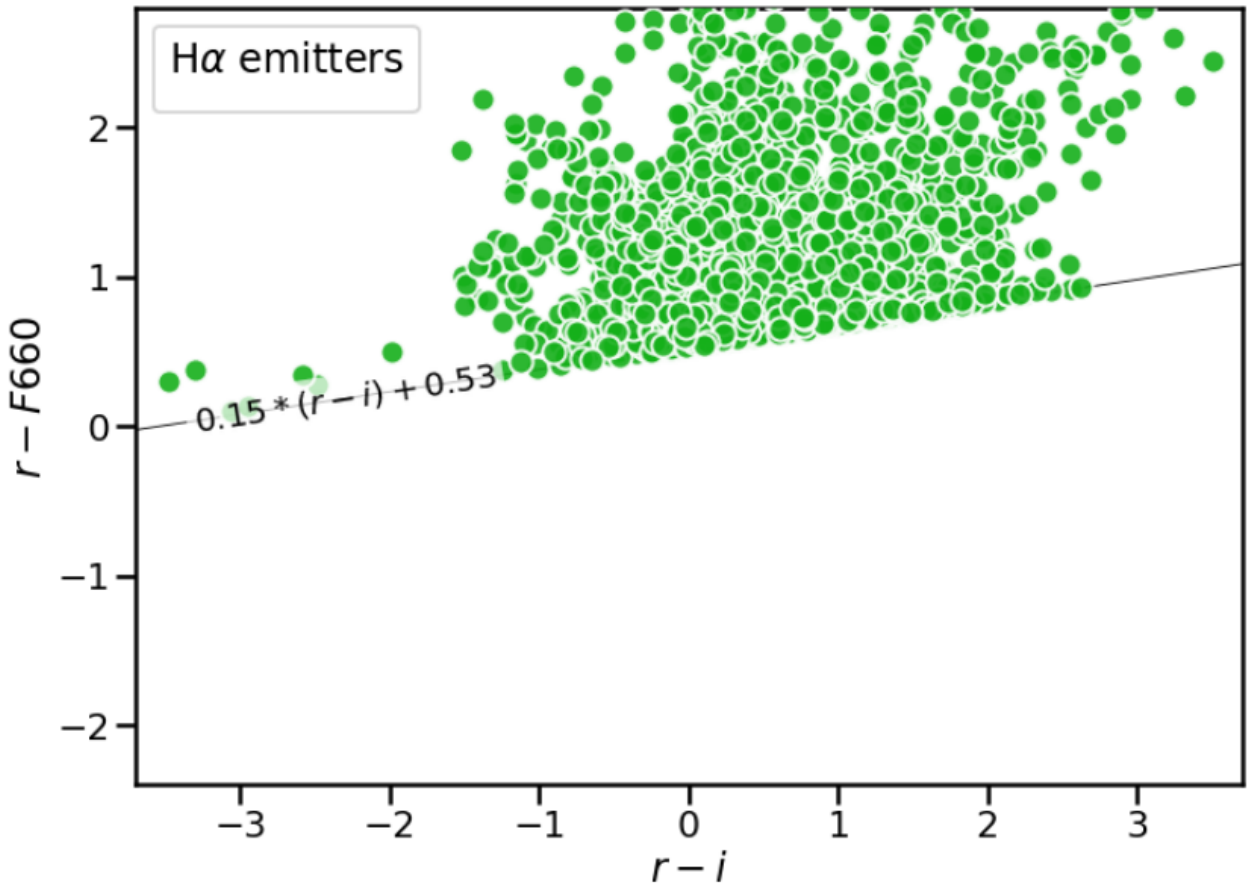


Corradi et al. 2008,
Viironen et al. 2009,
Gutiérrez-Soto et al. 2020

PN CANDIDATES

Preparing the sample: We first selected emission lines objects by using colour criteria to guarantee a better performance of the statistical techniques. Around 8,000 objects were selected with r $<$ 20.5 (mag).

Out[33]: Text(-2.3, 0.19, '$0.15*(r - i) + 0.53$')



PN CANDIDATES

PCA + Logistic regression algorithm

- **Logistic regression algorithm** was used to classify our list of DR3 Hα emitters. The **first three components (PCs)** were used as the training dataset.

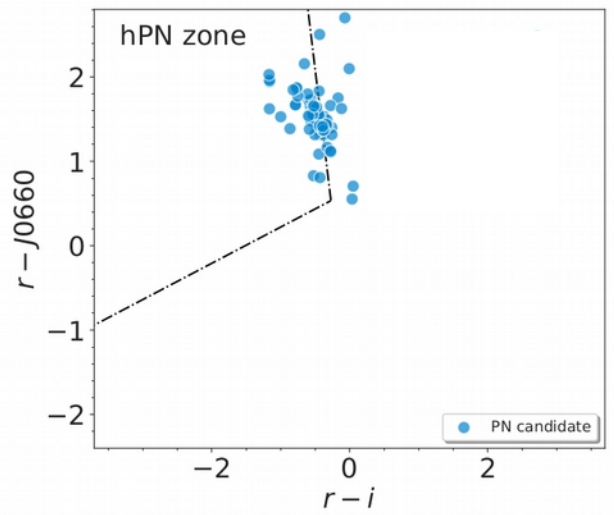
- 85 objects were classified as PNe.

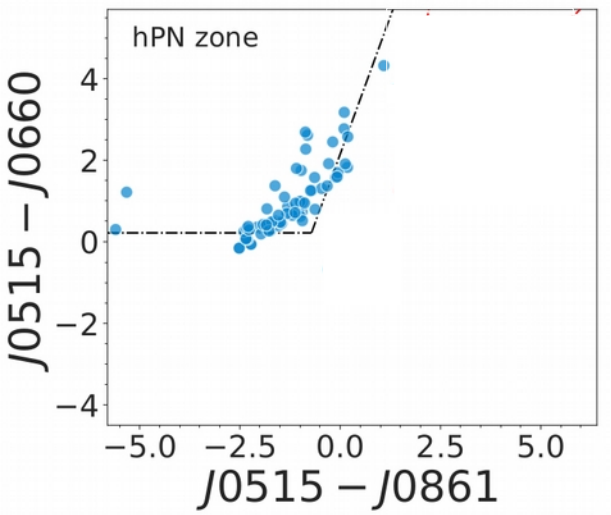
- There are 5 known in the S-PLUS area:
  - 3 known compact PNe were classified as PNe, with a probability ~100% of being a PN.
  - 2 known low-surface brightness PNe were not recovered.

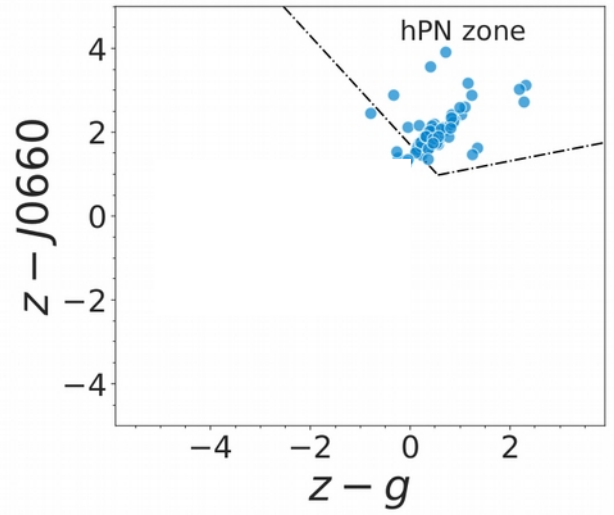
PN CANDIDATES

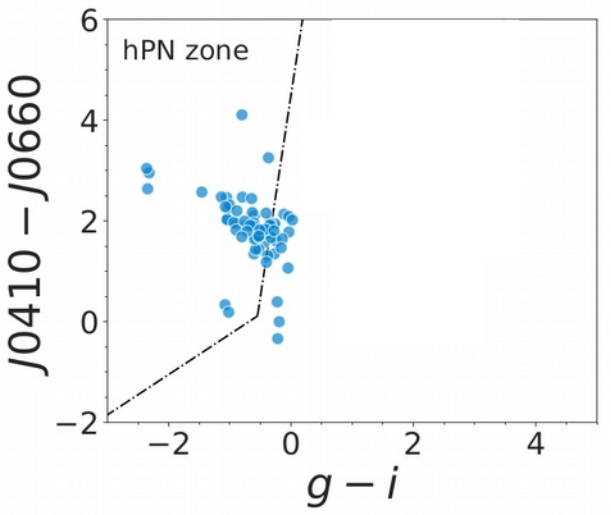
Selecting PN candidates

Colour-colour diagrams from Gutiérrez-Soto et al. 2020 with the **85 objects** selected by PCA and logistic regression.



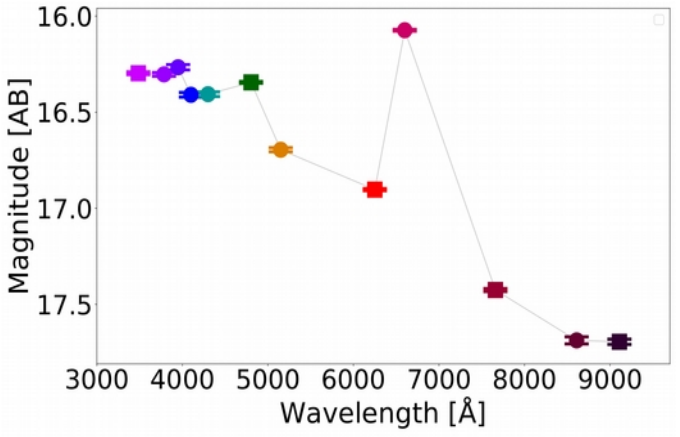


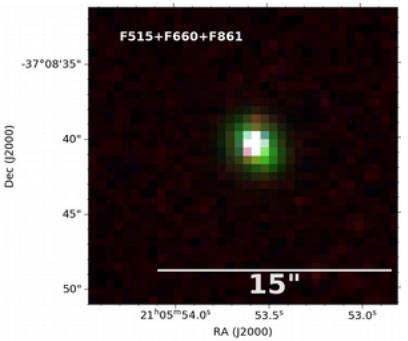




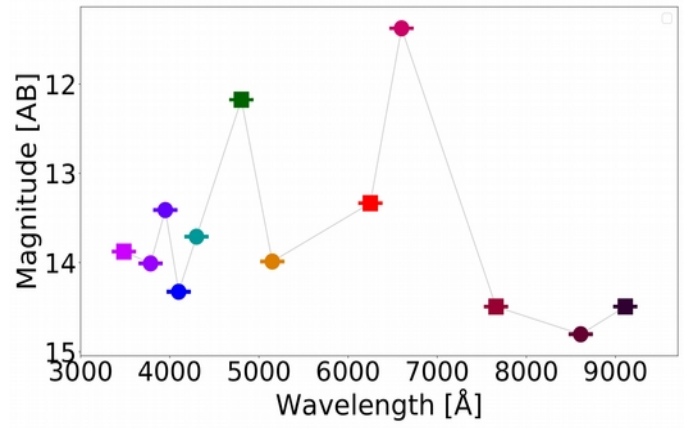
Known PNe

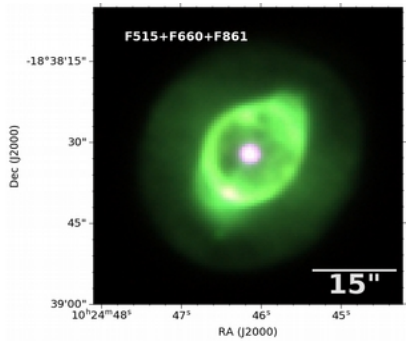
Example of two known PN selected





Halo PN G006.0-41.9:
One of the 14 PNe located in the Galactic halo.

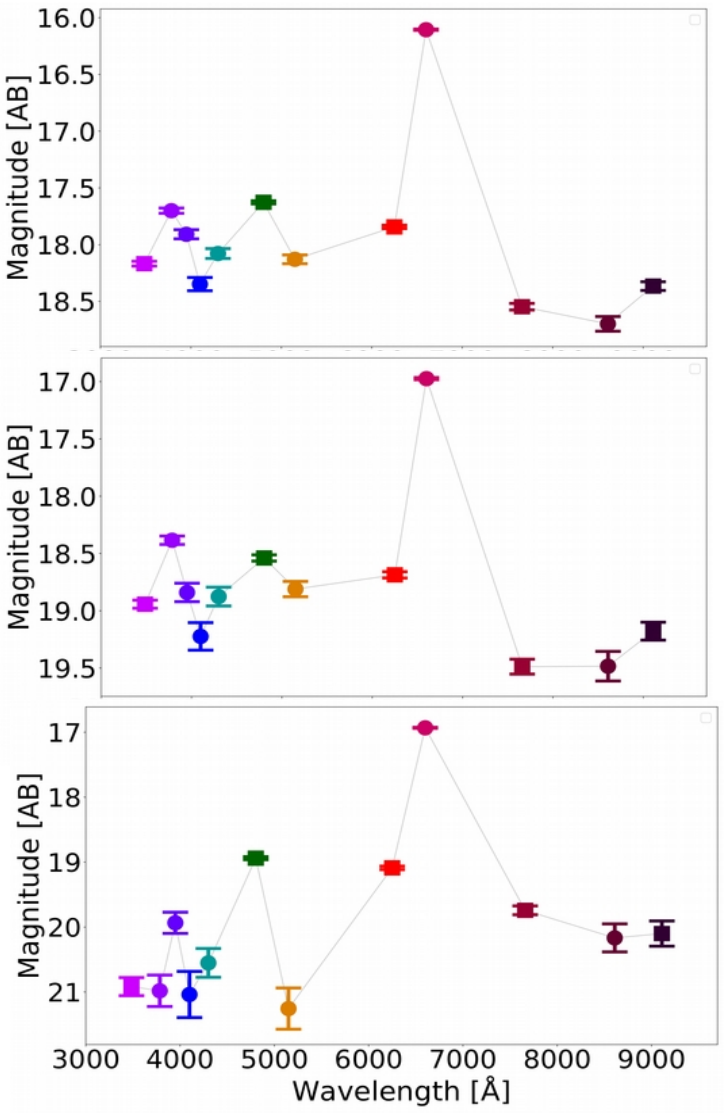


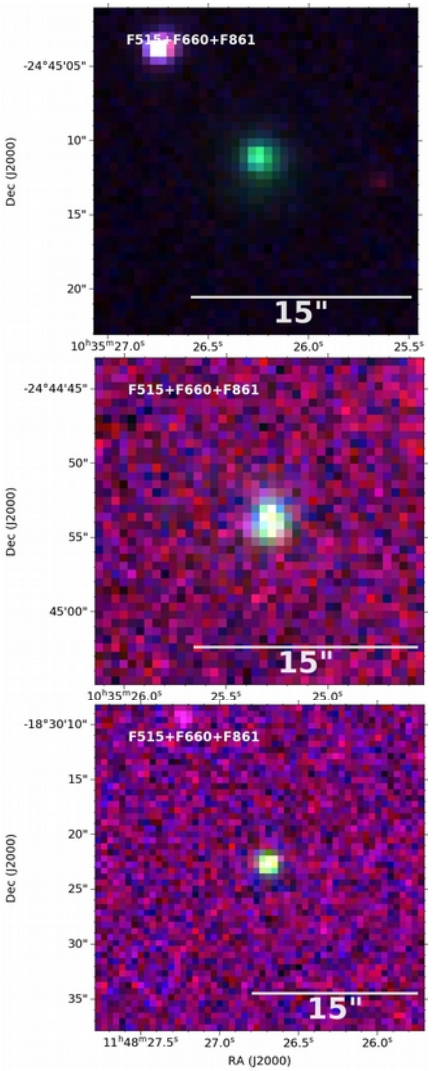


PN NGC 3242

PN candidates

Example of PN candidates.



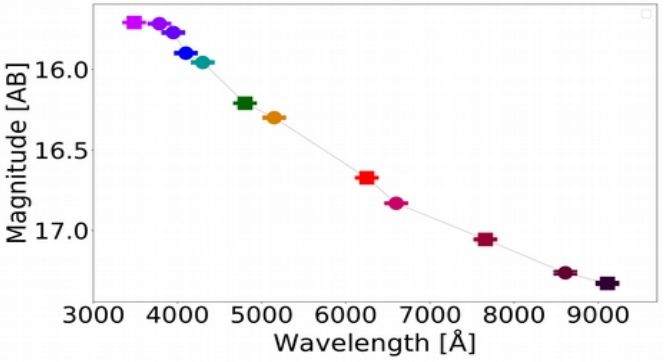


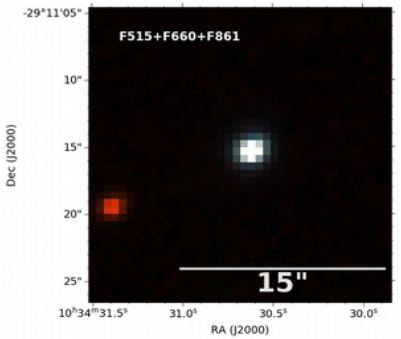
0026-052331

0026-050342

n15s20-042930

What about low-surface brightness PNe?



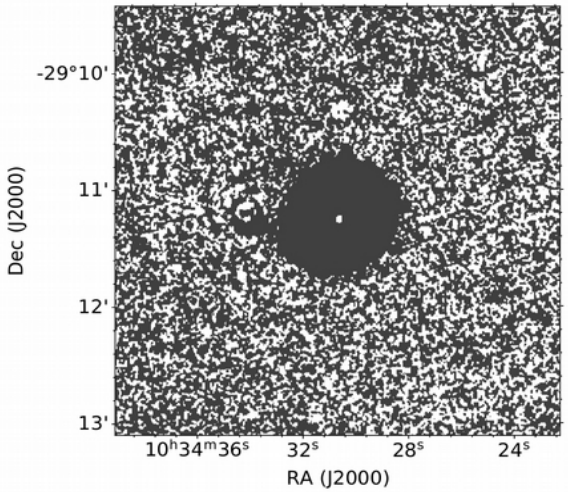


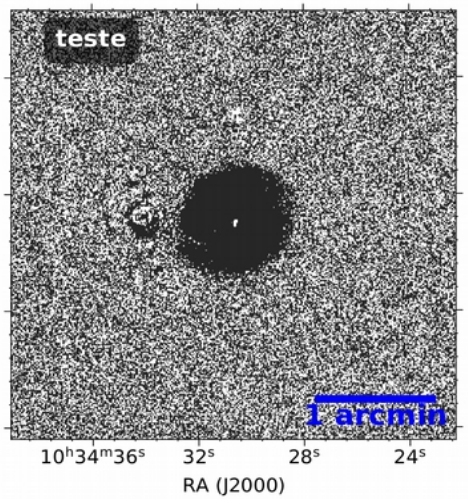
PN K 1-28

Recovering the weak Hα + [NII] emission of the nebula

$$F_{\mathrm{H}\alpha+[\mathrm{NII}]} = \frac{\left(\overline{F}_{r'} - \overline{F}_{i'}\right) - \left(\frac{\alpha_{r'} - \alpha_{i'}}{\alpha_{F660} - \alpha_{i'}}\right)\left(\overline{F}_{F660} - \overline{F}_{i'}\right)}{\beta_{F660}\left(\alpha_{i'} - \alpha_{r'}\right) - \beta_{r'}}$$

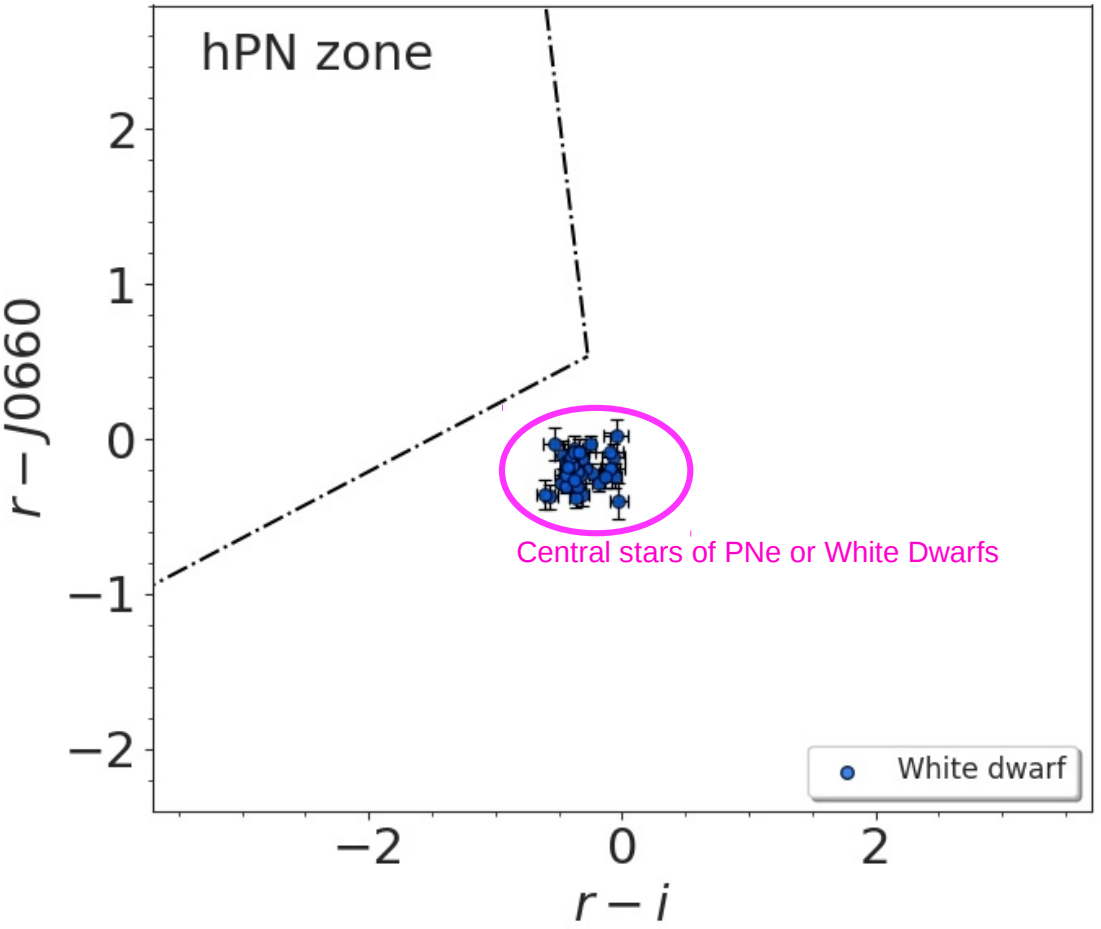
Vilella-Rojo et al. (2015)





What about low-surface brightness PNe?

Finding extended PNe by identifying young and blue WDs.



SUMMARY

- **We have combined a colour criterion, PCA and logistic regression to find PN candidates in S-PLUS.**

- **PCA have been used for feature extraction on which the 12 S-PLUS filters have been reduced only to three variables. We used the logistic regression to calculate the probability of one source of being a PN.**

- **We will investigate if these objects have already been previously cataloged in the literature. According to our experience it is possible that H II regions and blue compact galaxies end up within the selected PN candidates. As in Gutiérrez-Soto et al. (2020) these two types of objects are the main contaminants in this study.**

- **We are working in another machine learning technique -Random Forest- hopping to improve the selection.**